Kingdom of Cambodia
Electricite du Cambodge (EDC)

Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project

Final Report

November 2013

Japan International Cooperation Agency (JICA)

Tokyo Electric Power Co., Ltd.
Tokyo Electric Power Services Co., Ltd.
Nippon Koei Co., Ltd.

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Abbreviations

Abbreviations	Words
AC	Alternating Current
ADB	Asian Development Bank
ADSS	All-Dielectric Self-Supporting
AIS	Air Insulated Switchgear
ASEAN	Association of South-East Asian Nations
BIL	Basic Insulation Level
BOT	Build Operate &Transfer
CB	Circuit Breaker
CDC	Council for the Development of Cambodia
CEP	Cambodia Electricity Pte Co Ltd
CO_2	Carbon Dioxide
C/P	Counterpart
CPTL	Cambodia Power Transmission Line
CV	Cross-linked polyethylene insulated Vinyl sheathed
CVT	CV Triplex type
DAS	Distribution Automation System
DC	Direct Current
DEIA	Department of Environmental Impact Assessment
DF/R	Draft Final Report
DLMUPC	Department of Land Management, Urban Planning and Construction
DMD	Deputy Managing Director
DMS	Distribution Management System
DOE	Department of Environment
DPWT	Department of Public Work and Transportation; DPWT
DSM	Demand Side Management
EAC	Electricity Authority of Cambodia
EDC	Electricite du Cambodge
EENS	Expected Energy Not Supplied
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
EIRR	Economical Internal Rate of Return
EMS	Energy Management System
ERC	Energy Regulatory Commission of Thailand
EVN	Electricity of Vietnam
FIRR	Financial Internal Rate of Return
FR	Final Report
F/S	Feasibility Study
GD	General Department
GDP	Gross Domestic Product
GIS	Geographic Information System
GIS	Gas Insulated Switchgear
GMS	Greater Mekong Subregion
GREPTS	General Requirements of Electric Power Technical Standards
GS	Grid Substation
HQ	Headquarters
IcR	Inception Report
IEC	International Electrotechnical Commission
IEIA	Initial Environmental Impact Assessment
IMF	International Monetary Fund
IPP	Independent Power Producer

Abbreviations	Words
IRC	Inter-ministerial Resettlement Committee
ItR	Interim Report
ITU-T	International Telecommunications Union -Telecommunications
JICA	Japan International Cooperation Agency
KEP	Khmer Electrical Power Co Ltd
LA	A-Weighted Sound Pressure Level
LEPNRM	Law on Environmental Protection and Natural Resource Management
LIWV	Lightning Impulse Withstand Voltage
MEA	Metropolitan Electricity Authority
MEF	Ministry of Economic and Finance
MIME	Ministry Industry, Mines and Energy
MLMUPC	Ministry of Land management, Urban Planning and Construction
MOC	Ministry of Commerce
MOE	Ministry of Environment
MOU	Memorandum of Understanding
MPWT	Ministry of Public Works and Transport
NCC	National Control Center
NPP	North Phnom Penh
ODA	Official Development Assistance
OHL	Over Head Line
O&M	Operation and Maintenance
OPGW	Optical Ground Wire
PABX	Private Automatic Branch Exchange
PEO	Provincial Environment office
PLC	Power Line Communication
PMO	Project Management Office
PPSEZ	Phnom Penh Special Economic Zone
PPWSA	Phnom Penh Water Supply Authority
PSS/E	Power System Simulation for Engineering
PVC	Polyvinyl Chloride
RD	Resettlement Department
REE	Rural Electricity Enterprise
ROW	Right of Way
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SCS	Substation Control System
SDH	Synchronous Digital Hierarchy
SF6	Sulfur Hexafluoride
SHM	Stakeholder Meeting
SMT	Synchronous Transfer Mode
SPP	South Phnom Penh
SQMM	Square millimeter
SS	Substation
SWS	Switching Station
TSP	Total Suspended Particulate
UG	Underground
UGC	Underground Cable
UHF	Ultra-High Frequency
USD	United States Dollar
WB	World Bank

Abbreviations	Words
WHO	World Health Organization
XLPE	Cross linked Polyethylene

Chapter 1 Introduction

1.1 Background of the Survey

In the Kingdom of Cambodia, especially, in Phnom Penh and the surrounding areas, power demand has been increasing at an annual growth rate of 20% due to stable economic growth since 2002. According to the "Data Collection Survey on the Electric Power Sector in Cambodia" which was conducted by the Japan International Cooperation Agency (hereinafter referred to as "JICA") in 2012, power demand will increase at an annual growth rate of 8~25% until 2024. The state-owned power company, Electiricite Du Cambodge (hereinafter referred to as "EDC"), which has the responsibility to supply electric power to this area is expected to correspond to the progress of the construction of new transmission and distribution facilities and introduce an advanced control system for power supply.

This Preparatory Survey will review the necessity, feasibility, technical aspects of the construction of the transmission line and the distribution system in Phnom Penh which is to be proposed. It will analyze current conditions, the expansion of power plants and their transmission lines based on the load flow and short circuit study.

1.2 Purpose of the Survey and Scope of the Survey Works

1.2.1 Purpose of the Survey

The Phnom Penh Transmission Line and Distribution System Construction Project (hereinafter referred to as "the Project") aims to improve power supply by reinforcing transmission lines, substations and distribution lines in the Phnom Penh metropolitan area. The purpose of the Preparatory Survey for The Phnom Penh Transmission Line and Distribution System Construction Project (hereinafter referred to as "the Survey") is to investigate the required information, such as the objectives, outline, cost estimate, schedule, implementation, organizational structure, management, socio-environment, in order to evaluate power system reinforcement projects as a Yen-Loan project. The Survey will review the necessity, feasibility, and technical aspects of the construction of the transmission line and distribution system in Phnom Penh to be proposed. It will analyze the current conditions, expansion of the power plants and their transmission lines based on the load flow and short circuit study.

1.2.2 Survey Area

Phnom Penh city

1.2.3 Scope of the Survey Works

The Survey will be conducted mainly on the following items. This Survey will be conducted in accordance with the Minutes of Discussion (MD) signed between the organization of the partner country and the Japan International Cooperation Agency on August 30, 2012.

(1) Study of the current situation of the power sector (Review)

- to confirm the electricity industrial policy of Cambodia,
- to study the institutional and organizational structures of the power sector,
- to study the current situation of power supply and demand in Cambodia, especially in Phnom Penh city,
- to analyze the current situation of power supply and demand in Cambodia, especially in the Phnom Penh city transmission line in detail,
- to assess EDC's financial conditions, and

- to confirm the funds flow from donor agencies to EDC.

(2) Review of development plan of the transmission, transformation and distribution facilities in Phnom Penh city

- to review the "Feasibility Study of New Underground Cable in Phnom Penh" undertaken in 2008 and the "Data Collection Survey on Electric Power Sector in Cambodia" which was conducted by JICA in 2012, and update the Project scope and preliminary design (including a study of Japanese technology adoption), and
- to forecast future power demands, as well as energy data.

(3) Study of the current conditions of the existing transmission, transformation and distribution facilities in Phnom Penh city

- to confirm the design and specifications of the existing 115kV transmission line, 115kV/22kV Grid Substations, 22kV distribution line,
- to conduct a power flow analysis in consideration of forecasted future demands,
- to identify the bottle neck of the grid in Phnom Penh city
- to examine the countermeasures against the bottlenecks, and
- to confirm the priority of the above countermeasures.

(4) Environmental and social considerations

- to confirm the legal and institutional framework of environmental and social considerations including land issues,
- to conduct a study which complies with JICA Guidelines for Environmental and Social Considerations (April 2010), and
- to support EDC to obtain the necessary permit including IEIA, EIA and land issues.

(5) Feasibility study

- to confirm institutional and organizational structures for project implementation,
- to design the project outline,
- to conduct a geographical and topographical survey necessary for the basic design,
- to conduct a basic design of the planned and relevant facilities,
- to set up an implementation schedule,
- to estimate the project costs,
- to conduct an economic and financial analysis by calculating EIRR and FIRR,
- to analyze the project risk,
- to estimate GHG reduction by comparing it with the project and without it, and
- to recommend the appropriate indicators to assess the project output.

(6) Confirmation of Operations, Maintenance and Management

- to confirm the operational and management framework for the transmission and distribution lines,
- to confirm the technical and financial capacity of EDC,
- to propose the appropriate operations, management and maintenance system to enhance project output, and
- to confirm the need for technical assistance for operations, maintenance and management of transmission and distribution lines.

(7) Hold workshops during the Preparatory Survey and feedback for drafting reports

1.3 Project's Scope

Table 1. 1 shows the initial target construction work as the candidate of the project's scope.

Table 1. 1 Candidate of the Project's Scope at Initial Stage

115kV Underground Transmission Line	New GIS substation
GS1 — EDC Headquarters SS	EDC Headquarters Substation
GS2 — Hun-Sen Park Substation	Hun-Sen Park Substation
GS3 — Olympic Stadium Substation	Olympic Stadium Substation

Figure 1. 1 Geographic Image of the Initial Project Scope

During the first visit, EDC offered the removal of Hun-Sen park Substation and GS2 – Hun-sen Park Transmission line from the scope of the project, because of their urgent needs for building these facilities to catch up with the increasing load. As a result, these facilities were excluded from the Survey's objectives.

EDC plans to construct additional two 115/22kV substations (Chroy Changvar, Toul Kork) in the central area of Phnom Penh. This Project includes survey of above mentioned two substations as Phase 1 of the project.

1.4 Conducting Organizations

1.4.1 Counterparts of EDC sides

EDC organized the following organization for this project.

Table 1. 2 EDC Counterpart Staffs

Name	Position
1. Overall management	
• Dr. Chan Sodavath	Deputy Managing Director
• Dr. Praing Chulasa	Director, Department of Corporate Planning and Projects (DCPP)
• NouSokhon	Director, Department of Transmission (DT)
2. Coordinator	
• Chan Chetra	Deputy head office, DCPP
• NginKanida	Deputy head office, DCPP
3. Development Planning Team	
• Chun Piseth	Deputy Director, DCPP
• Hang Touch	Head office, Department of Business & Distribution (DBD)
• OukChetra	Head office, DBD
• RinSeihakiri	Deputy head office Planning, MIS and Tariff, DCPP
• ThourkMony	Deputy Office, DT
• ThachSovanReasy	Head office, DCPP
• LorsPuthy	Deputy head office, DT
• Try Soban	Staff, DT
• MuongVadhna	Staff, DT
• Touch La	Staff, DCPP
• SoamSopheak	Staff, DCPP
4. Facilities Design Team	
• PlongTitiaPhalkun	Deputy Director, DT
• Or Vadhna	Head office, Distribution Dispatching, DBD
• CheaSaemChantara	Deputy head office, DCPP
• KhySokhan	Head office, DT
• Hem Rattana	NCC/DT
• Vong Randy	NCC/DT
• HengSocheat	Staff, Telecommunication/SCADA
• Chon Virak	Staff, DCPP
• Prom Chan Nareth	Staff, DCPP
5. Environment	
• Mao Visal	Head of environment office, DCPP
• HeavChanvisal	Deputy head of environment office, DCPP

1.4.2 Organization of the Survey Team

The organization of the survey team is as follows:

Table 1. 3 Organization of the Survey Team

Expert (position)	Name
Project Leader/Power System Planning	Noboru SEKI
Power Demand Forecast	Yasuhiro YOKOSAWA
System Analysis	Atsushi YUIHARA
Economic and Financial Analysis	Takashi WAKABAYASHI
Environment and Social Consideration	Tomoe TAKEDA
Sub leader/ Project Designing	Masahiro OGAWA
Substation & Telecommunication Facilities	Masahiro IWABUCHI
Relay System	Masatoshi AKIMOTO
Civil	Yoshinori TAKAMORI
Underground Cable Designing	Yasutoshi WATANABE
GIS Substation Designing	Tomio ICHIKAWA
Distribution Facilities	Masaki IWAMA

Chapter 2 Power Sector in Cambodia

2.1 Cambodia's Economy

Given that JICA's precedent Study: Data Collection Survey on Electric Power Sector in Cambodia thoroughly examined Cambodia's economy in 2010, this section mainly refers to them and supplements the update of the economic indices.

2.1.1 Economic Growth

Cambodia's economy maintained high economic growth over 10% for 4 years from 2004 to 2007. The main factors were an increase in embroidery product exports, steady tourist industry, excellent agricultural production, briskness in the construction industry (especially residences, hotels, and factories), foreign investment, and rapid progress in loans from commercial banks. Subsequently, the worldwide economic crisis had a large impact and economic growth dropped down to 0.1%. However, the economy recovered in 2010 (ADB: 6.10%, MEF estimation: 5.0%) and MEF projects experienced similar growth at around a 6.5% rate in 2012 and thereafter.

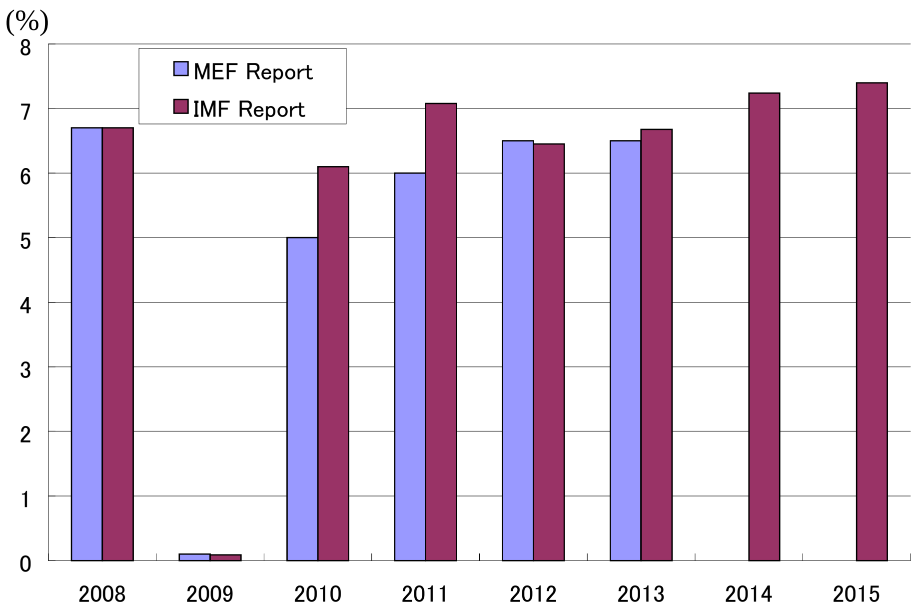
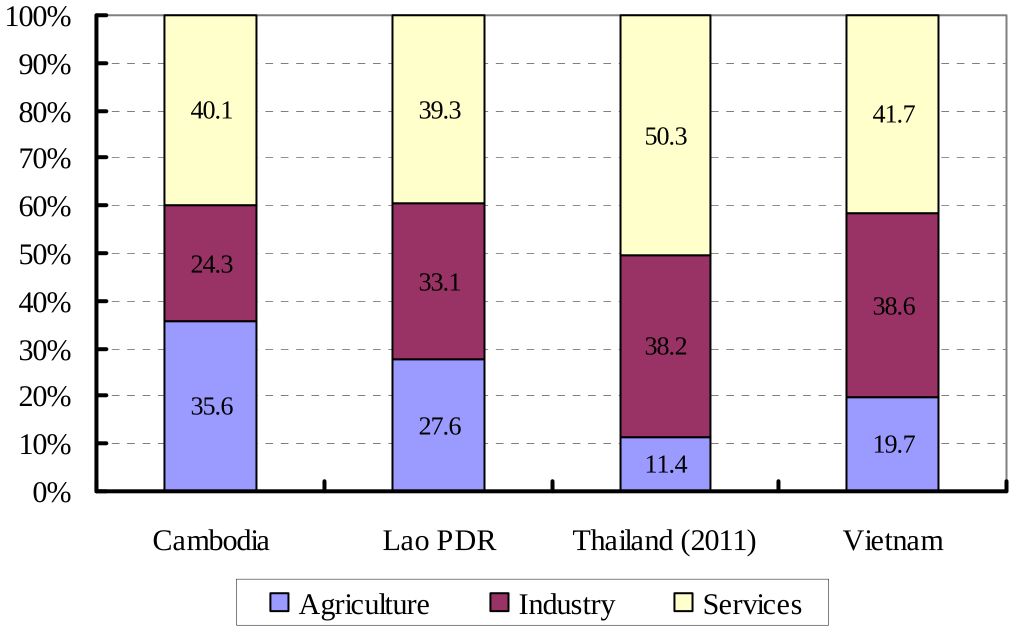


Figure 2. 1 Cambodia's GDP growth

Source: Cambodia MEF Microeconomic Framework 2010-2011 & World Bank's World Economic Database 2012 October

GDP component ratio (2012) of Cambodia and neighboring countries by industries are shown in Figure 2. 2.



Source: ADB, Key Indicators for Asia and the Pacific 2013 (July)

Figure 2. 2 GDP Component Ratio of Cambodia and Neighboring Countries (2012)

Compared to neighboring countries, the industrial structure of Cambodia indicates that it is at the initial stage of industrialization as with Laos.

2.1.2 Investment Trend

Investment projects that are prioritized through the Council for the Development of Cambodia (CDC) include Cambodian and foreign investments. In 1995, the year after the establishment of the Law on Investment, the allowable investment on fixed assets was $2.3 billion. As opposed to the annual average of 12 years from 1994 to 2005 (approximately $0.71 billion), that of 5 years from 2006 to 2010 was $5.3 billion, approximately a 7.5-fold increase. The cumulative allowable investment from 1994 to the end of 2010 was $35,060,000,000, the 75% of which was invested by China (top investor), Korea (2nd), and Malaysia (3rd) reflecting Cambodia's close economic relationship with these countries. The number of enterprises from Japan considerably increased since 2011. Following Minebea in 2010, the automobile parts industry, such as Sumitomo Wiring Systems and Yazaki Corporation, local offices of banks, such as Mitsui Sumitomo and Mitsubishi Tokyo UFJ, transportation industry, such as Nippon Express and Yusen Logistics were launched. The Japanese Business Association of Cambodia was increased on an annual basis, as 34 members in 2007, 35 members in 2008, 45 members in 2009, 50 members in 2010, and 83 members in 2011. Now, as of July 2013, it had a total of 143 members: 114 regular members, including trading companies, construction companies, manufacturers, financial/servicing companies; and 29 associate and special members, including enterprises and groups.

2.1.3 Miscellaneous Economic Indices

Miscellaneous economic index is shown in Table 2. 1.

Table 2. 1 Miscellaneous Economic Indices of Cambodia

Index	2006	2007	2008	2009	2010	2011	2012
Total population (million; as of 1 July)	13.5	13.7	13.9	14.1	14.3	14.5	14.8
GDP (US$ billion; at current market prices)	7.3	8.6	10.4	10.4	11.2	12.8	14.0
Agriculture (%)	31.7	31.9	34.9	35.7	36.0	36.7	35.6
Industry (%)	27.6	26.8	23.8	23.1	23.3	23.5	24.3
Services (%)	40.8	41.3	41.3	41.3	40.7	39.8	40.1
Per capita GDP (US$; at current market prices)	539	631	746	739	786	884	950
Export growth rate (%/yr)	27.0%	-12.0%	7.6%	-14.2%	29.7%	34.4%	15.3%
Import growth rate (%/yr)	21.8%	-5.3%	12.4%	-11.6%	21.7%	22.7%	18.7%
Inflation of Consumer price index (%/yr)	4.7	5.9	19.7	-0.7	4.0	5.4	2.9
Foreign direct investment (US$ million)	475	866	795	520	762	873	1,527
External indebtedness (US$ million; as of 31 Dec)	3,550	2,813	3,267	3,523	3,833	4,336	

Source: ADB, Key Indicators for Asia and the Pacific 2013 (July)

2.2 Basic Policy

2.2.1 National Development Policy

The Cambodian government has developed a third quadrilateral strategy in 2013. The quadrilateral strategy presents a comprehensive framework focused on four areas as the improvement of the agricultural sector, construction and reconstruction of infrastructure, developing the private sector and job creation, and human resource development and capacity building.

2.2.2 Energy Policy

The energy policy of the Cambodia government has set the following objectives which were formulated in 1994.

(1) Supply energy as an appropriate price
(2) Electricity Tariff setting to promote investment and economic development, and stable and reliable power supply
(3) To achieve energy supply commensurate with economic development, to promote development of energy sources as social and environmental friendly
(4) To promote efficient usage of energy, to minimize the environmental impact

2.2.3 Electric power sector policy

(1) Government policy

As a comprehensive national development plan, the “National Strategic Development Plan” was developed in 2010, the following as a policy priority in the power sector are mentioned in this.

(a) To secure the supply capacity
1) Power development of hydro power, natural gas and coal-fired power plant in utilizing domestic resources
2) Research nuclear and new technology power development
3) Improvement of energy security by securing reserve capacity and diversification of supply power sources
4) Promoting energy saving

(b) Electric Tariff reduction
Development power grid
1) Cooperation with bilateral or multilateral international transmission line development in the ASEAN, GMS
2) Promotion of rural electrification, including usage of renewable energy
3) Promotion of private investment
4) Balance between aspect of social and environmental and economic aspect in the development project

(c) Capacity building and strengthening of entities in the power sector
Improvement of management and electric power grid quality via capacity building and the reorganization of power sector

(2) Electrification rate target

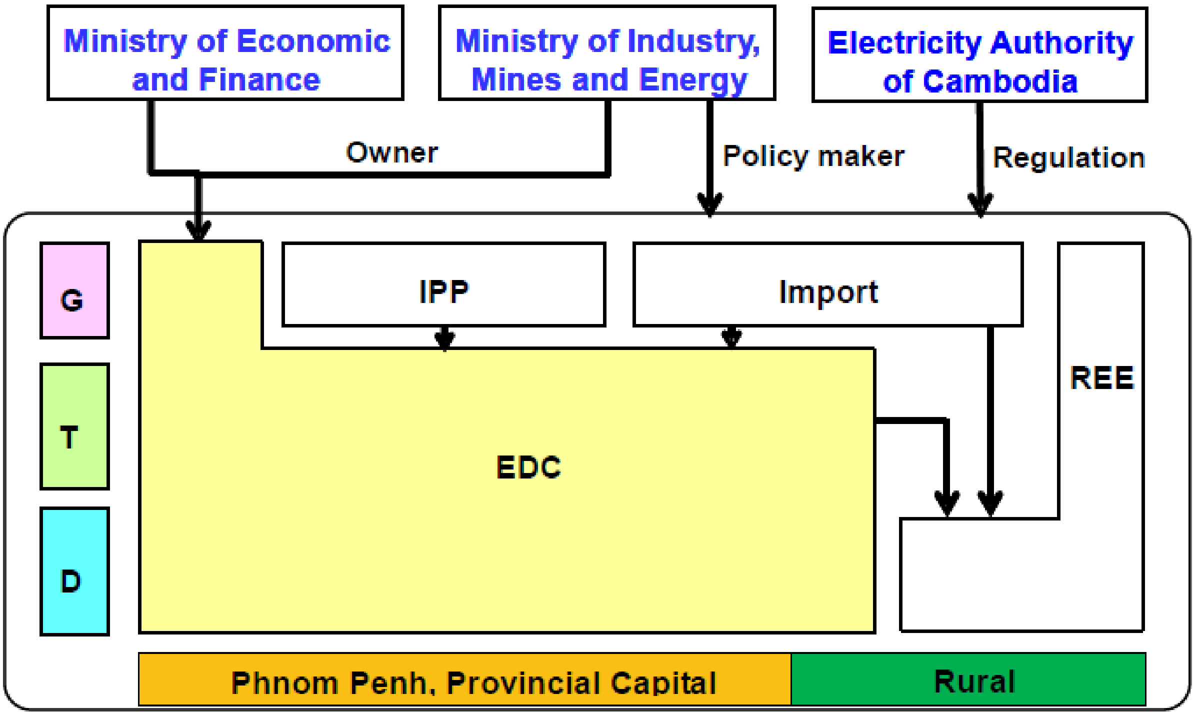
The following are set as the target electrification rate in the electric power sector.

(a) 100% electrification rate including battery lighting by 2020
(b) At least 70% of household electrification from the power grid by 2030

2.3 Organizations and their role in the electric power sector

According to the Electricity Industry Law (issued 2001), EAC has the authority to approve licenses and to regulate the electric power industry, MIME establishes power development policy, power development plans and operations and maintenance policy. EDC is the utility that conducts electric power business. EDC has been regulated by MIME and MEF.

In the Cambodian power sector, private investors have been introduced to not only Independent Power Producers (IPP), Distribution companies (REE), but also transmission businesses.

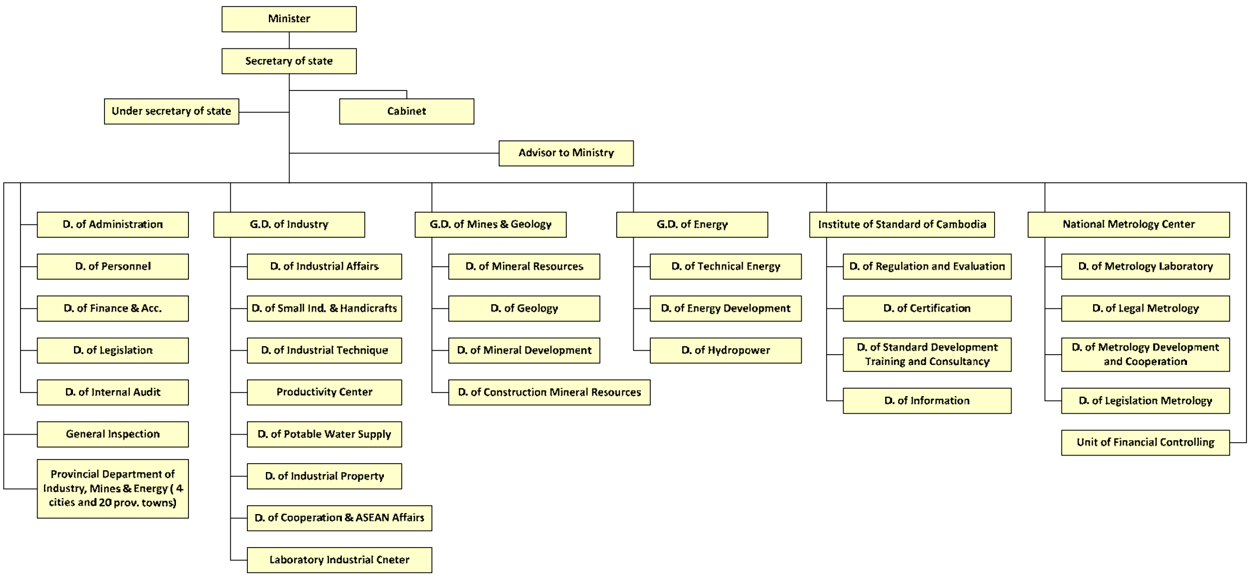


Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

Figure 2. 3 Relation on Power Sector

2.3.1 MIME

MIME conducts an administration of the power sector with EAC. MIME is responsible for coordinating policy in Cambodia of power development, policy establishment, the power development plan, the establishment of power technology, safety and environmental standards.
MIME is comprised of the General Department (G.D.) of Industry, G.D. of Mines & Geology, G.D. of Energy, Institute of Standard of Cambodia, National Metrology, and Center Provincial Department of Industry、 Mines and Energy which has jurisdiction in rural areas.

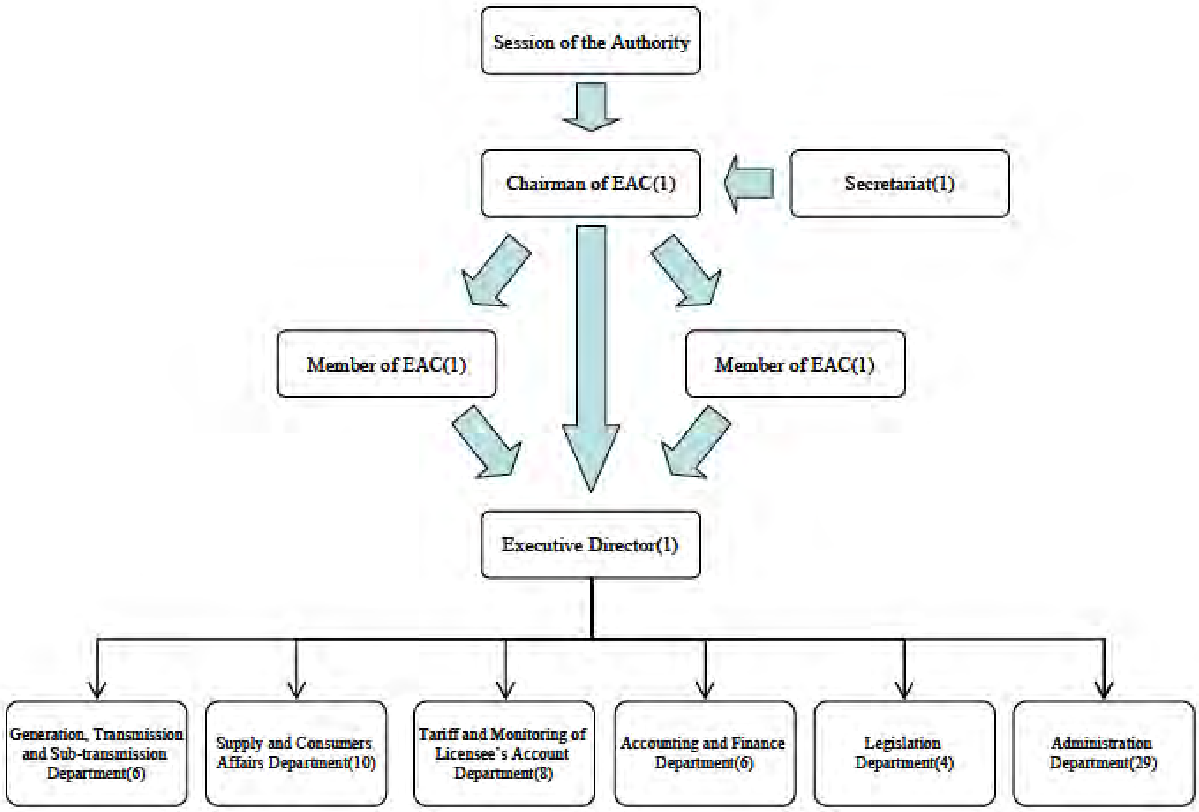


Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

Figure 2. 4 Organization Chart of MIME

2.3.2 EAC

EAC has regulations and guidance in the electricity industry in Cambodia. Operations have been carried out per the license fee from electric utilities, it is run on a financially independent basis.
As the main activities, issue and cancel the business license, authorization of electricity prices, the development of supply rules, audit of the electric power industry, and the electric power industry to collect relevant information.

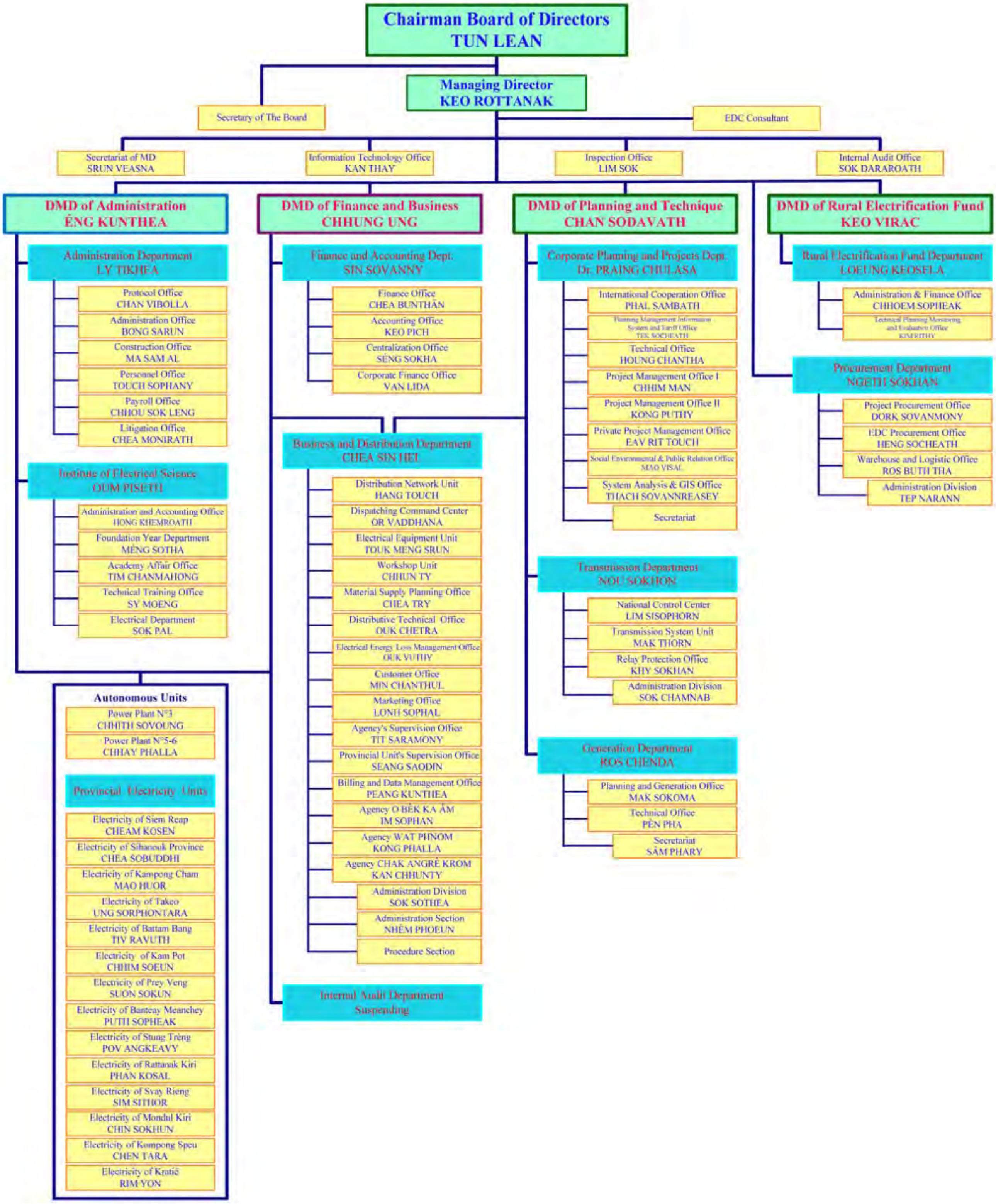


Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

Figure 2. 5 Organization Chart of EAC

2.3.3 EDC

EDC has been engaged in the business of electric power in Cambodia. The license of bulk power system operations is allowed only for EDC.



Source: EDC Annual Report 2012 Draft version

Figure 2. 6 Organization Chart of EDC

2.4 Balancing Supply and Demand situation

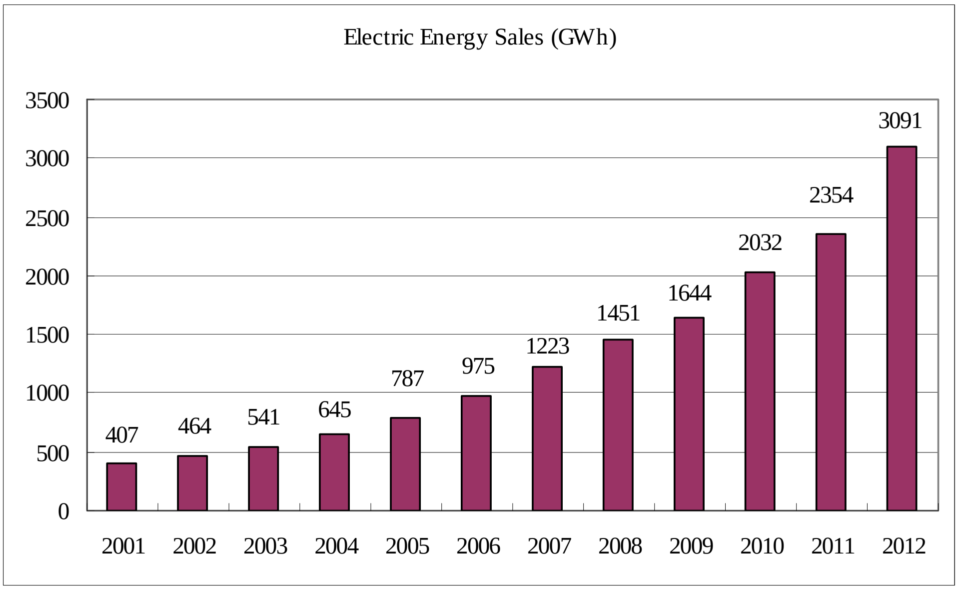
2.4.1 Electric Power Demand

(1) Electric energy sales records

(a) Trans of energy sales

The following figure shows the actual power demand nationwide sales of Cambodia from 2001 until 2012.

Energy sales increased from 407.3GWh in 2001 to 3091.1GWh in 2012, the average annual growth rate is 18.4%.

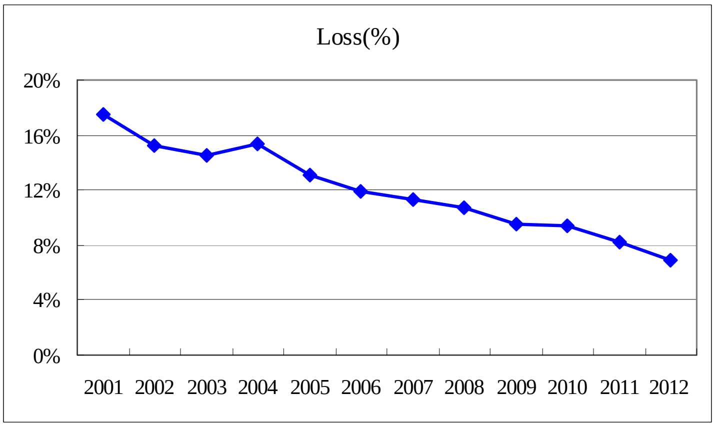


Source: EDC Annual report 2007, 2008, 2009, 2010, 2011, 2012 draft

Figure 2. 7 Actual Record of Electric Energy Sales, Whole Country

(b) Trend of system loss

Transmission and distribution losses were 17.5% in 2001. They decreased to 6.9% in 2012.

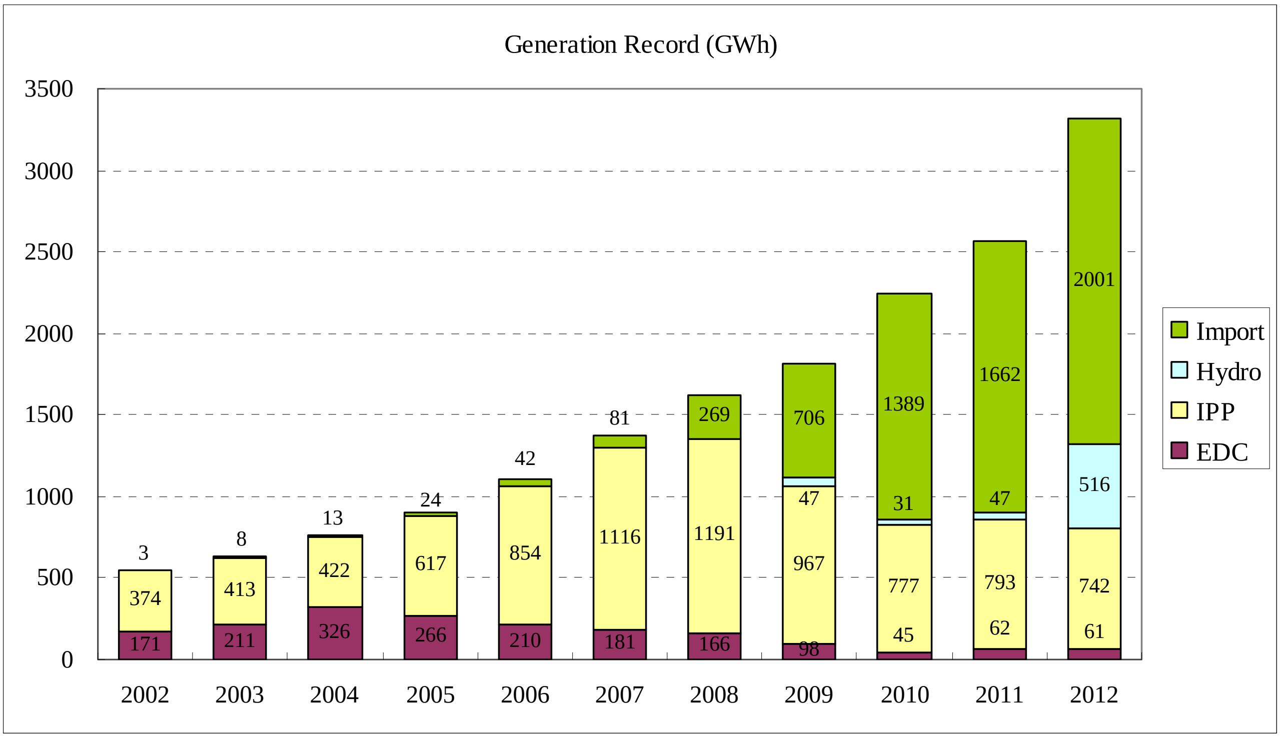


Source: EDC Annual report 2007, 2008, 2009, 2010, 2011, 2012 draft

Figure 2. 8 Trend of Transmission & Distribution Loss

(c) Trend of Generation record

The amount of power generation in 2001 was 493.4GWh. 3319.4GWh record in 2012, electricity imports from Thailand and Vietnam accounted for 60%. The average annual growth rate of electricity generation from 2001 to 2011 was 17.2%.



Source: EDC Annual report 2007, 2008, 2009, 2010, 2011, 2012 draft

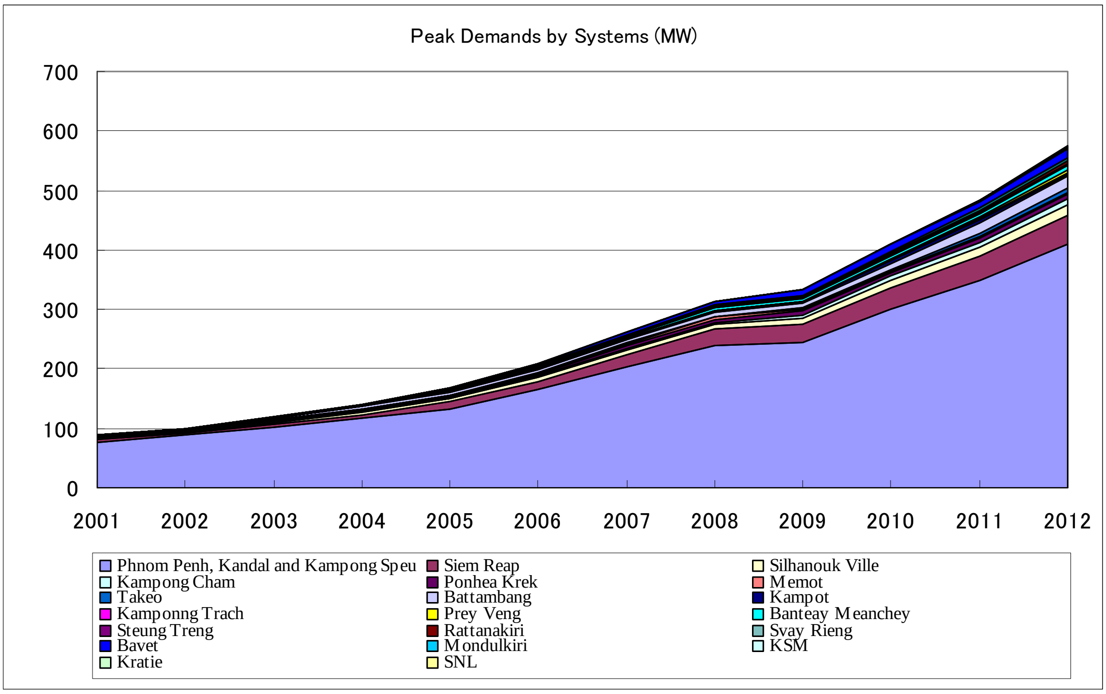
Figure 2. 9 Trend of Generation Record

(2) Peak demand record

(a) Trend of peak demand records

The peak demand of the whole country was 88.6MW in 2001, and 575.0MW in 2012, an average annual growth rate is 16.9%.

In the share of peak demand by regions, the Phnom Penh system accounted for 88% in 2001, 71% in 2012. Siem Reap peak demand share came to 8% in 2012. This is due to the results of promoting rural electrification. Siem Reap peak demand growth is high because the interconnection line with the Thai system has been commission and power imports can be implemented through the tie line.



Source: EDC Annual report 2007, 2008, 2009, 2010, 2011, 2012 draft

Figure 2. 10 Trend of Peak Demand

(b) Load factor rate record

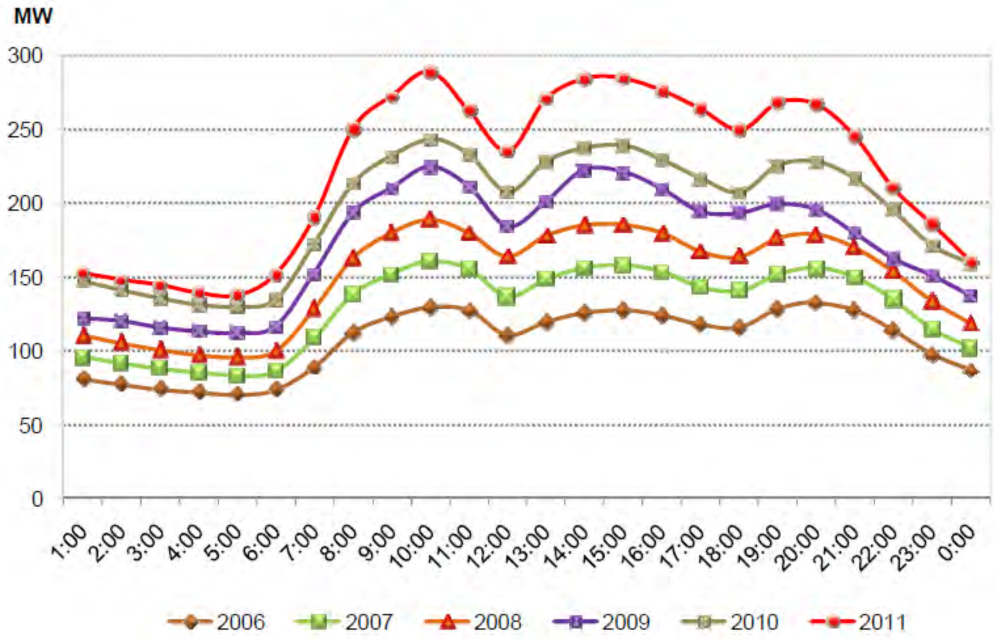
56% in 2001, and 61.2% in 2012, the load factor is 60.8% on average. EGAT of Thailand considered in the system is composed of about 70% and the load factor, load leveling and proceed with the progress of industrialization, there is room to consider measures such as load leveling DSM.

Source: EDC Annual report 2007, 2008, 2009, 2010, 2011, 2012 draft

Figure 2. 11 Trend of Load Factor

(c) Daily load curve

The changes in the daily load curve, there are three peaks similar to the Thai system. The morning peak has been showing a steep rise, the supply capacity that can follow such a steep rising demand becomes necessary. The current value of the load is not so large, it is able to supply by importing power from Vietnam.



Source: EDC Annual report 2011 draft

Figure 2. 12 Trend of Daily Load Curve

(3) Demand forecast

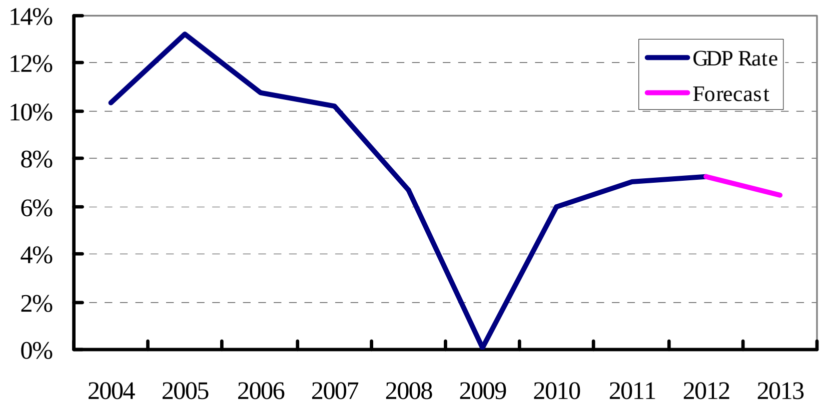
(a) Methodology of demand forecast

Energy sales are forecasted in consideration of the growth of the gross domestic product, population growth, electrification rate, and power development plan. Supply energy at the transmission end is estimated in the added transmission and distribution losses. The economic operation by the generator is calculated with the least cost load dispatching based on the supply energy at the transmission end. The generation energy is forecasted by the added station use energy by each generator. After that, the load factor is estimated in consideration of the progress of industrial structural reform and dissemination of air-condition equipment. The peak demand is forecasted by the load factor.

In Cambodia, the demand forecast of the development plan approved by the government, which adopted the demand forecast conducted by the WB. The demand forecast is considered a trend and forecast of GDP, growth of population, electrification of the rural area and the demand of households that were surveyed by MEMI.

(b) Trend and forecast of GDP

The Cambodian economy recorded a high growth rate per the global economic crisis of 2009, because of an increase in the export of products based on foreign investment. Between the years 2007 and 2004, the GDP recorded a growth rate of 10%. Affected by the global economic downturn in 2009, it fell to 0.1% but in 2010 achieved a recovery of 6%. The GDP growth rate was maintained at more than 7% in 2011 and 2012. Regarding MEF estimation, it can maintain a 6% growth rate in the future.



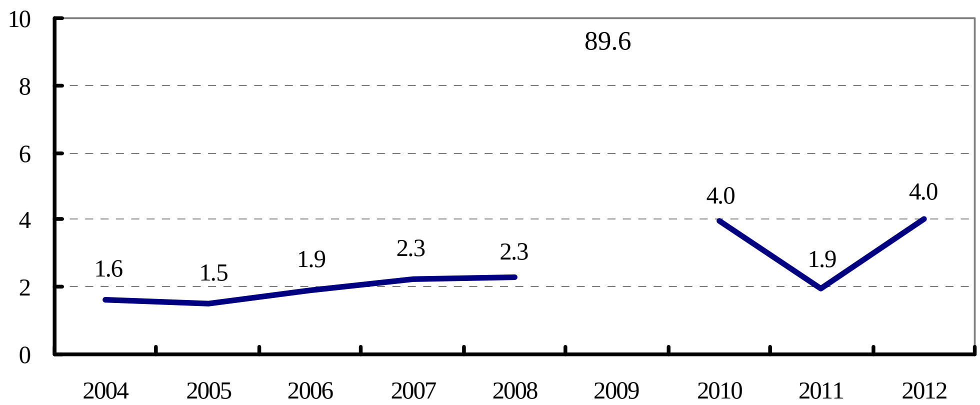
Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

Figure 2. 13 Trend of GDP Growth Rate

(c) Trend of GDP elasticity

Taking the value of elasticity from electricity demand and the growth rate of GDP, it has become a somewhat higher value for the year 2008, and from 2.3 to 1.5. Under the influence of the global economic crisis, the GDP did not grow, because demand for consumer and commercial demand did not decrease, so the value of the elasticity GDP became a large value in 2009 and 2010.

A large GDP elasticity value indicates that a large amount of input power is often to require the gross domestic product. In other words, it indicates that the power efficiency is not so good. It shows that energy saving measures could be high performance for lighting and air-conditioning.



Note: Because the growth rate of GDP in 2009 was very low with 0.1%, and the value of elasticity was too large, the point of year 2009 is excluded from the graph

Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

Figure 2. 14 Trend of GDP Elasticity

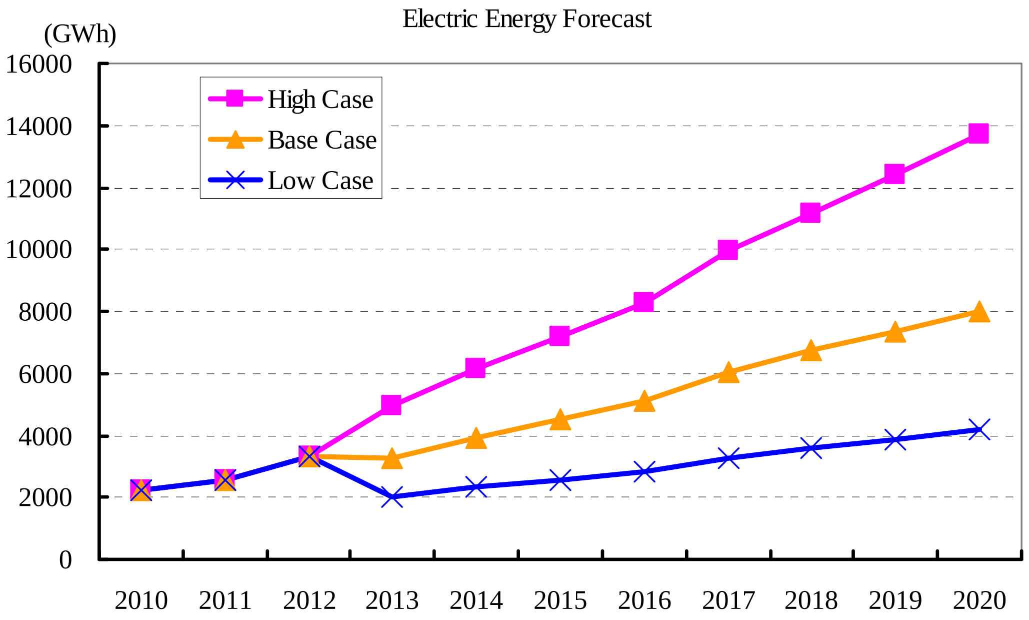
(d) The latest demand forecast in Cambodia

The latest demand forecast consists of the Base case, the High case which is an economic recovery scenario, and the Low case which is a weak economic scenario.

1) Generation energy forecast

Demand forecasts in 2020 are 8019GWh in the Base case, 13689GWh in the High case, and 4188GWh in the Low case. The average growth rates from 2012 are 17.0% in the High case, 10.3% in the Base case and 2.6% in the Low case

Furthermore, the GDP elasticity is 1.7 because the forecasted GDP growth rate is 6%.
The growth rate of the performance from the years 2001 to 2011 was 17.3%, so there not a significant departure from the actual growth rate of each case. Meanwhile, looking at the value of the elasticity the GDP, it is at the level before the economic crisis of 2009, it has followed a scenario that does not expect the effect of energy-saving measures.



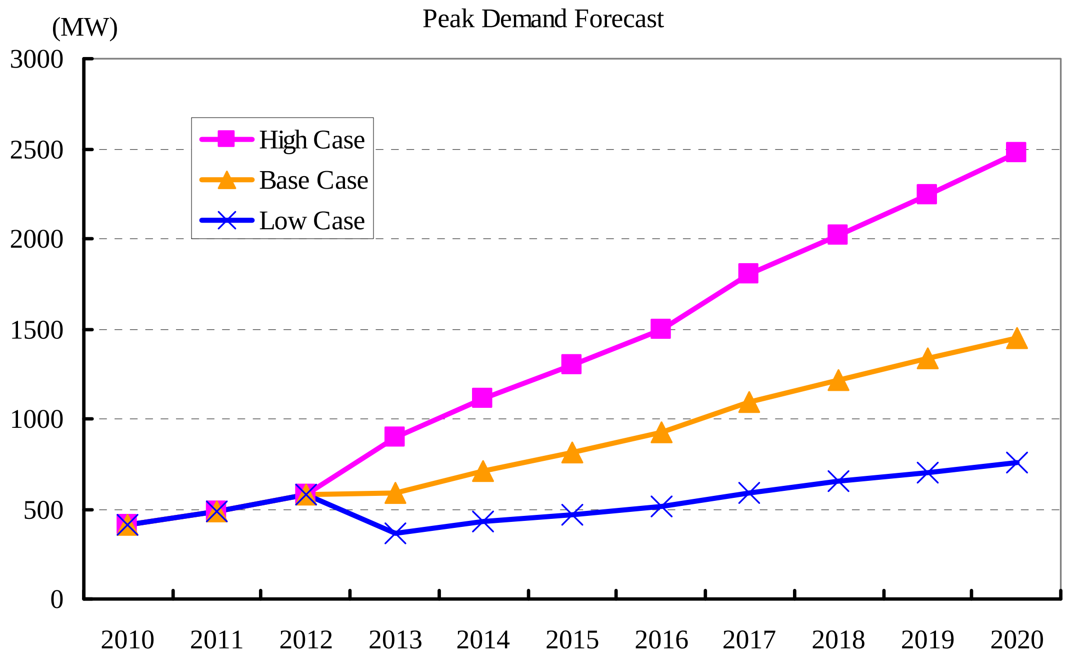
Source: EDC

Figure 2. 15 Electric Energy Forecasts

2) Peak demand forecast

Based on the electric energy forecasts, three cases are assumed. The load factor is estimated to be 63%, which is equivalent to the actual value. The effect of the further load leveling measures is not expected. The Thai system situation showed that the load factor would be reduced increasing demand. That is why the peak demand forecast is little bit of a high estimation.

The peak demand forecasts in 2020 are 2478MW in the High case, 1452MW in the Base case and 758MW in the Low case. The average growth rates from 2012 are 17.6%, 10.8% and 3.1% respectively. The system scales in 2020 are 4.3 times, 2.5 times and 1.3 times respectively in comparison with 575.0MW of the actual record in 2012.



Source: EDC

Figure 2. 16 Peak Demand Forecast

3) Evaluation of demand forecasts

From the point of view of past experience, there has been a reasonable assumption.

It is considered that the assumption value of the GDP elasticity is high and the load factor is slightly lower, which causes slightly high forecasts. For this reason, there are concerns that lead to excess capacity when considering the power development plan in assuming development delay risk.

However, given that not even the concept of load factor values and these GDP elasticity are significantly outside compared to the general trend, to adopt the current Base case it is appropriate.

2.4.2 Power Development Plan

The Power Development projects that start operations in the near future is shown below.

Table 2. 2 Power Development Projects Planned for the Next Few Years

No.	Project Name	Type	Capacity (MW)	Scheduled commencement progress	Company	Condition as of Dec. 2011	Connection Point to National grid
1	Kamchay	Hydro	194.1	Mar 2012	Sinohydro Kamchay Hydroelectric Project Co. Ltd. (China)	Under construction	230kV Kampot S/S (180MW) 22kV local (14.1 MW)
2	Kirirom III	Hydro	18	Apr 2012	CETIC Hydropower Development Co. Ltd. (China)	Under construction	115kV Kirirom I P/S
3	Stung Atay	Hydro	246	2012	C.H.D. (Cambodia) Hydropower Development Co. Ltd. (China)	Under construction	115kV O'soam S/S
4	Stung Tatay	Hydro	246	2013	Cambodian Tatay Hydropower Limited. (China)	Under construction	230kV O'soam S/S
5	Lower Stung Russei Churum	Hydro	338	2013	China Huadian Lower Russei Churum Hydroelectric Project (Cambodia) Co. Ltd.	Under construction	230kV O'soam S/S
6	100MW Project in the Preah Sihanouk Province	Coal	100	2013	Leader Universal Holding Berhad (Malaysia)	Under construction	230kV Sihanouk Province Terminal S/S
7	700MW Project in the Preah Sihanouk Province (Phase I)	Coal	135 135	2014 2015	Cambodia International Investment Development Group Co. Ltd.(China)	PPA singed with EDC	230kV Sihanouk Province Terminal S/S
8	100MW Project in the Preah Sihanouk Province	Coal	100	2016	Cambodia International Investment Development Group Co. Ltd. (China)	PPA singed with EDC	230kV Sihanouk Province Terminal S/S
9	700MW Project in the Preah Sihanouk Province (Phase II)	Coal	430	2017	Cambodia International Investment Development Group Co. Ltd. (China)	FS completed	230kV Sihanouk Province Terminal S/S

Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

2.4.3 Present Situation and Future Plan of Power Network

There had been only local power systems supplied with small diesel generators in Cambodia until the late 1990s. In 1999, the first 115 kV lines, approx. 23km, were constructed from GS1 to GS3 via GS2, and the long distance 115kV line, approx. 110km, was installed to connect Kirirom hydro power station and Phnom Penh in 2002.

At the end of 2007, the northwest Cambodia and Thailand systems were connected with 115kV interconnection line. In 2009, the southeast Cambodia and Vietnam systems were connected with the Cambodia's first 230kV transmission line of 97km and the line has connected Phnom Penh to the Vietnam system. This 230kV transmission line was expanded to southwest Cambodia from Takeo substation and Kampot substation, and Kamchy hydro power station were linked to this 230kV line in 2011. Cambodia has been importing power from both Vietnam and Thailand by using these interconnection lines.

In 2012, the new 230kV transmission line starts its operation, which connects Battambang – Pursat – Kampong Chang – NPP substations. The 230/115kV Battanbang substation has been connected to Thailand's' 115kV system and the Phnom Penh system can be linked to the Thailand system through this connection. There are several planned hydro power stations near the 230kV O'som substation and the power from these hydro power stations can be evacuated with this new 230kV transmission line between O'som and Pursat substations.

Four 115kV substations, GS1, GS2, GS3 and GS4, encompass and supply to the power to Phnom Penh metropolitan area. The power sources of these substations are mainly hydro power plants in Cambodia, power imports from Vietnam and Thailand via 230kV transmission lines. The power demand in Phnom Penh rapidly increases and the reinforcement of the Phnom Penh system is necessary to achieve stable power supply. EDC has been planning to install new 115kV substations inside the Phnom Penh metropolitan area and the 115kV underground cables to connect to these substations. This study investigates the installation methods and feasibility of these substations and cables.

Figure 2. 17 shows the existing and planned 230kV and 115kV transmission systems in Cambodia up to 2020. The solid lines are existing ones and the dotted lines are the planned ones in the figure. As can be seen from the figure, EDC plans to develop the country wide transmission systems with 230kV and 115kV and the Cambodian transmission system will be connected to Laos. Table 2. 3 shows the developments list.

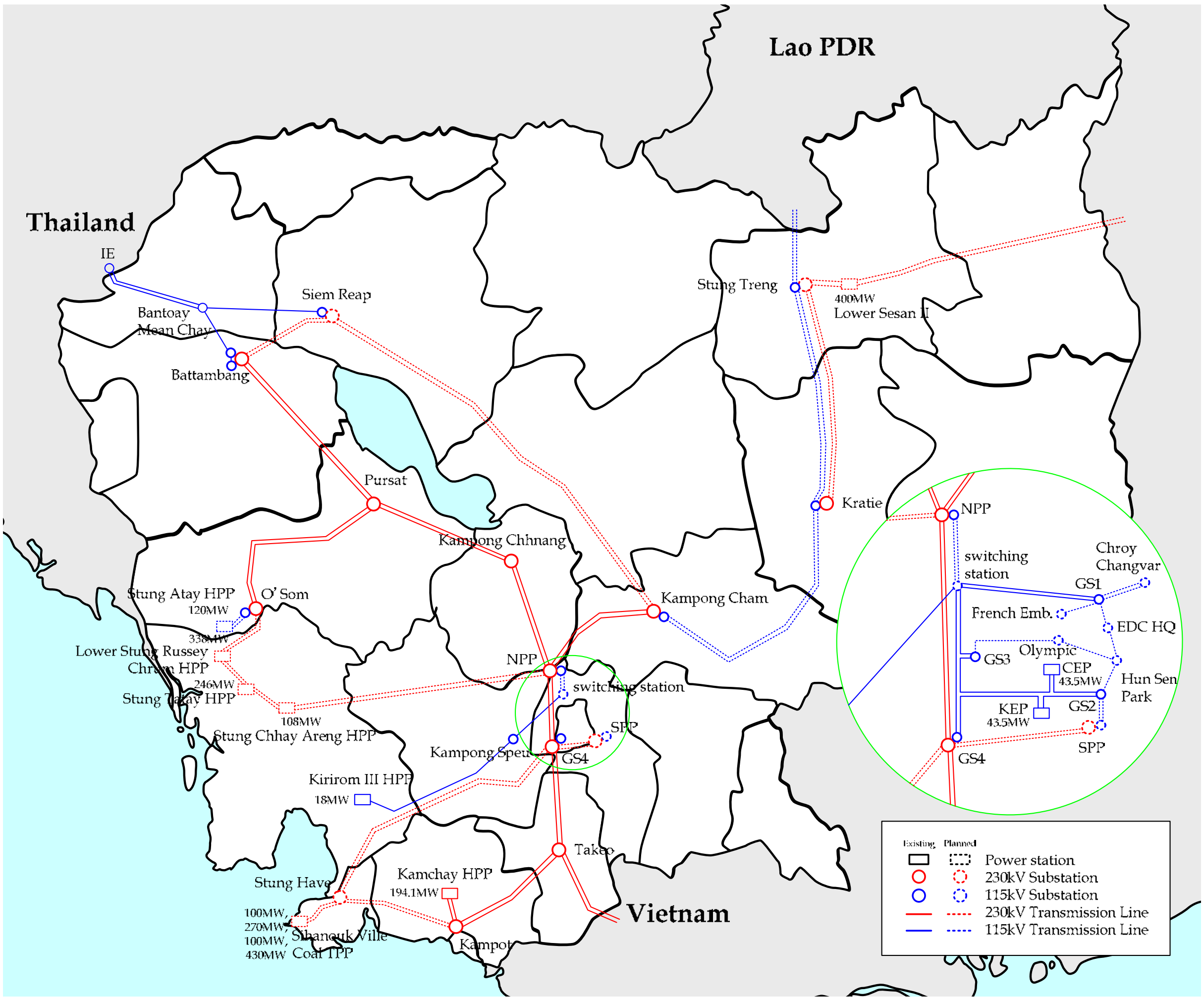


Figure 2. 17 Transmission system in Cambodia up to 2020

Table 2. 3 Transmission System Development up to 2020

Transmission lines	Circuit	km	COD
230kV from GS Kampot-GS Steung Hav (SHV)	2	88	2013
115kV from GS Steung Hav-GS Sihanouk Ville	2	11	2013
115kV loop line Phnom Penh	2	42	2013
230kV loop line Phnom Penh	2	48	2013
230kV line from Phnom Penh(NPP)-Kampong Cham	2	110	2013
115kV line from Atay Hydro-GS Osom	2	10	2013
230kV line Loa-Steung Treng	2	56	2014
230kV line Steung Treng-Kratie	2	126	2015
230kV line Kratie-Kampong Cham	2	110	2015
230kV line Osom-Upper Reussey Chrum Hydro power	2	32	2015
230kV line lower-Upper Reussey Chrum Hydro power	2	10	2015
230kV line Upper Reussey Chrum Hydro power-Tatay Hydro power	2	37	2015
230kV line Phnom Penh-Sihanouk ville (Along National Road No.4)	2	220	2016
230kV line Atay-Cheay Areng	2	32	2017
230kV line Cheay Areng-Phnom Penh (GS NPP)	2	145	2017
230kV line Phnom Penh-Neak Loeung-Svay Rieng	2	120	2018
230kV line Kampong Cham-Kampong Thom (GS KGT)- Siem Reap	2	250	2019

The following table shows the transformer capacity in Phnom Penh area at the end of 2012.

Table 2. 4 Transformer Capacity in Phnom Penh at the End 2012

Substations	115/22 kV	115/22/15 kV	230/115 kV
GS1	50 MVA×1	50 MVA×1	
GS2	50 MVA×1	50 MVA×1	
GS3		50 MVA×2	
GS4	50 MVA×2		200 MVA×2
NPP	50 MVA×2		200 MVA×2

<Interconnection line to Thailand>
The Power Cooperation Agreement (MOU) with Thailand was signed on 3rd February 2000. The PPA was signed in 2002 and amended in 2007. Cambodia has started importing power from Thailand with the 22kV distribution line since 2001, and from the Arranh Prathet substation in Thailand with the 115kV transmission line since 2007. For reference, the private company of the Cambodia Power Transmission Line (CPTL) owns the transmission lines from Arranh Prathet in Thailand to Battambang & Siem Reap substations.

<Interconnection line to Vietnam>
The Power Cooperation with Viet Nam was signed in 10th June 1999. Power imports from Vietnam started in 2002, and at the beginning of its operation, only southeast Cambodia was supplied by imported power, but in 2009, Phnom Penh has been receiving power from Vietnam via the 230kV transmission line since 2009.

<Interconnection line to Laos>
The Power Cooperation with Lao PDR was signed in 21st October 1999. The power import from Laos to Steung Treng in Cambodia started with the 22kV distribution line in 2010, and the World Bank has supported the 115kV transmission line between Ban Hat in Laos and Steung Treng under construction. The construction, however, has been suspended due to an environmental issue in the other Cambodian project.

2.5 Situations of Other Donors Activities

Situation of aid by donor countries, there is much support for power imports via the construction of power interconnection lines and aid to rural electrification, such as shown in the table below.

Table 2. 5 Support for Rural Electrification

Loan or Grant Name	Amount	Province	Scope
KfW (Grant)	22 MEuro	Kampot & Takeo	22kV grid extension, Transmission line project from Takeo to Kampot
JICA (Loan)	2,632MJPY	Sihanouk Ville, Kampot	Counterpart loan with ADB for Transmission from Kampot to Sihanoukville. 22 kV grid extension
Aus-Aid (Grant)	5 MUS$	Svay Rieng	22 kV grid extension
China Exim Bank (Loan)	53 MUS$	Kampong Cham, Prey Veng, Kampong Speu, Sihanouk Ville	22 kV grid extension
ADB (Loan)	45 MUS$	Siem Reap, Kampong Thom, and Surrounding area of Phnom Penh	22 kV grid extension
Royal Government of Cambodia (Loan)	80 MUS$	Pursat, Battambang, Banteay Meanchey, Svay Rieng, Kampong Chhnang, Paillin, Oddor Meanchey, Preah Vihear, Kratie, Steung Treng, Rattanakiri, Mondulkiri	22 kV grid extension

Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

2.5.1 World Bank

The World Bank has funded technical assistance and for performing power import from Vietnam, EVN to the Phnom Penh system. Concretely, financial support for the construction of an international interconnection line via co-financing with ADB, support for the reinforcement of the 115kV power transmission line in Phnom Penh city, support for the construction of the National Control Center (NCC), and expansion of the high tension distribution line (500km) in the local city were executed by the "Cambodia Rural Electrification and Transmission Project" that had been completed in January, 2012.
However, due to an alternate project in an other sector, there was a serious violation related to resettlement conditions, and it is in a state of suspended aid.

2.5.2 ADB

In addition to the above-mentioned support for the 230kV international interconnection line between Cambodia and Vietnam, ADB has been executing support for the expansion of the high tension distribution lines, the same as the World Bank. ADB is preparing the next Project that now supports rural electrification.

Chapter 3 Examination of Necessity and Appropriateness of the Project

3.1 Overview of Current Phnom Penh Network and Problems

3.1.1 Economy in Phnom Penh Metropolitan City and its Electricity Demand

Phnom Penh city is the capital of Cambodia with 1.35 million people living in its 678 km^2 of land. The labor price hikes that have occurred in Cambodia's neighboring countries: Thailand and Vietnam, and China accelerated the factory-shift of foreign companies to Phnom Penh city, which can supply abundant labor forces at a reasonable price. Among several industrial zones in Phnom Penh, Phnom Penh Special Economic Zone (PPEZ of 360 ha in its land), which was supported by the Japanese government, it has already invited 22 Japanese companies including Ajinomoto. The PPEZ provides their factories with good transportation: 15 minutes from the Airport and 45 minutes from the city center. Since PPEZ owns a well-maintained infrastructure, such as its own power station, and factory water system and the companies invested in PPEZ are entitled to tax reduction, Japanese manufacturers, seeking the distribution of their manufacturing stations after the Tohoku earthquake and floods in Thailand, are now quite interested in this area.

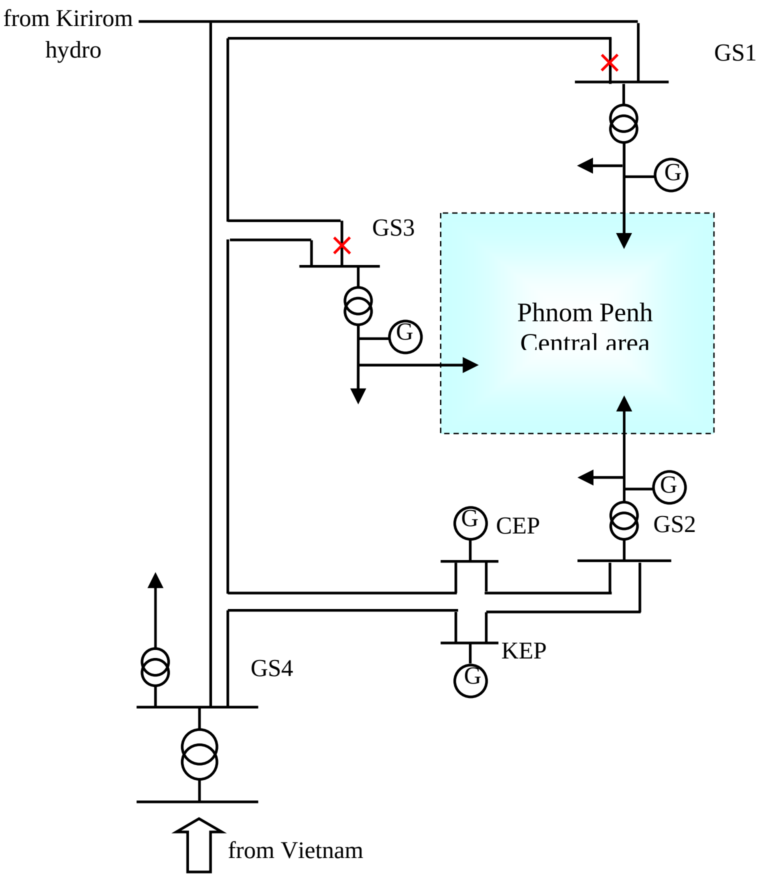
Also, the economic activities in Phnom Penh Metropolitan area, which is this project’s main target, is also brisk and lively. In particular, the Diamond Island Area could be the most prospective economically developing area, where the only Casino equipped hotel, NAGA, expands its building and the building plan of the tallest building (555m) in the Asian region is ongoing. One example of a Japanese company’s advancement in the Phnom Penh Metropolitan area is the AEON Mall. The president of AEON and the Prime Minister of Cambodia showed its opening ceremony of its big flagship mall (100,500m^2) located on the riverside land neighboring Diamond Island Area on December 10, 2012. Other developing areas in the Phnom Penh Metropolitan area are the Chroy Changvar and Boeungkak areas, where residential development is planned due to the recent high economic growth.

Figure 3. 1 Photo of AEON Mall Construction Site

3.1.2 Issues of the Phnom Penh Transmission System

(1) Immediate Issues

The following figure illustrates the present power system in Phnom Penh city and its neighboring areas. The area is interconnected with 115kV double-circuit transmission lines, but the Mekong River is located in the east of the area and it is difficult to supply power from the east side due to the river crossing.



(Source: Data Collection Survey on Electric Power Sector in Cambodia)

Figure 3. 2 Power System in Phnom Penh (Present)

The Data Collection Survey of the Electric Power Sector in Cambodia supported by JICA noted the following three issues.

(a) Planned outage due to a lack of transformer capacity

Continuous new substation developments and distribution reinforcements after 2014 are necessary in consideration of the demand increase of the yearly 100MW.

(b) Outage of half of Phnom Penh caused by a single 115kV failure

The transmission line between GS1 and GS3 was opened during actual operation due to a poor protection system, although the 115kV Phnom Penh system constitutes the ring network. Due to this disconnection, GS2 and GS3 will black out if the GS4-KEP line trips.

(c) Overloading of transformers

Relating to (a), the system faces a lack of transformer and distribution line capacities, and a single transformer failure causes power outages in some areas.

EDC has been planning to uprate the transformers in the GS1, GS2 and GS3 substations from 100MVA to 150MVA in order to solve the capacity shortage issues. The demand increase ratio of Phnom Penh is, however, 20%, which is quite high, and additional transformer capacities are required in a few years. The system, therefore, requires new substations.

(2) Future challenges

The following figure illustrates the future power system in Phnom Penh city and neighboring areas.

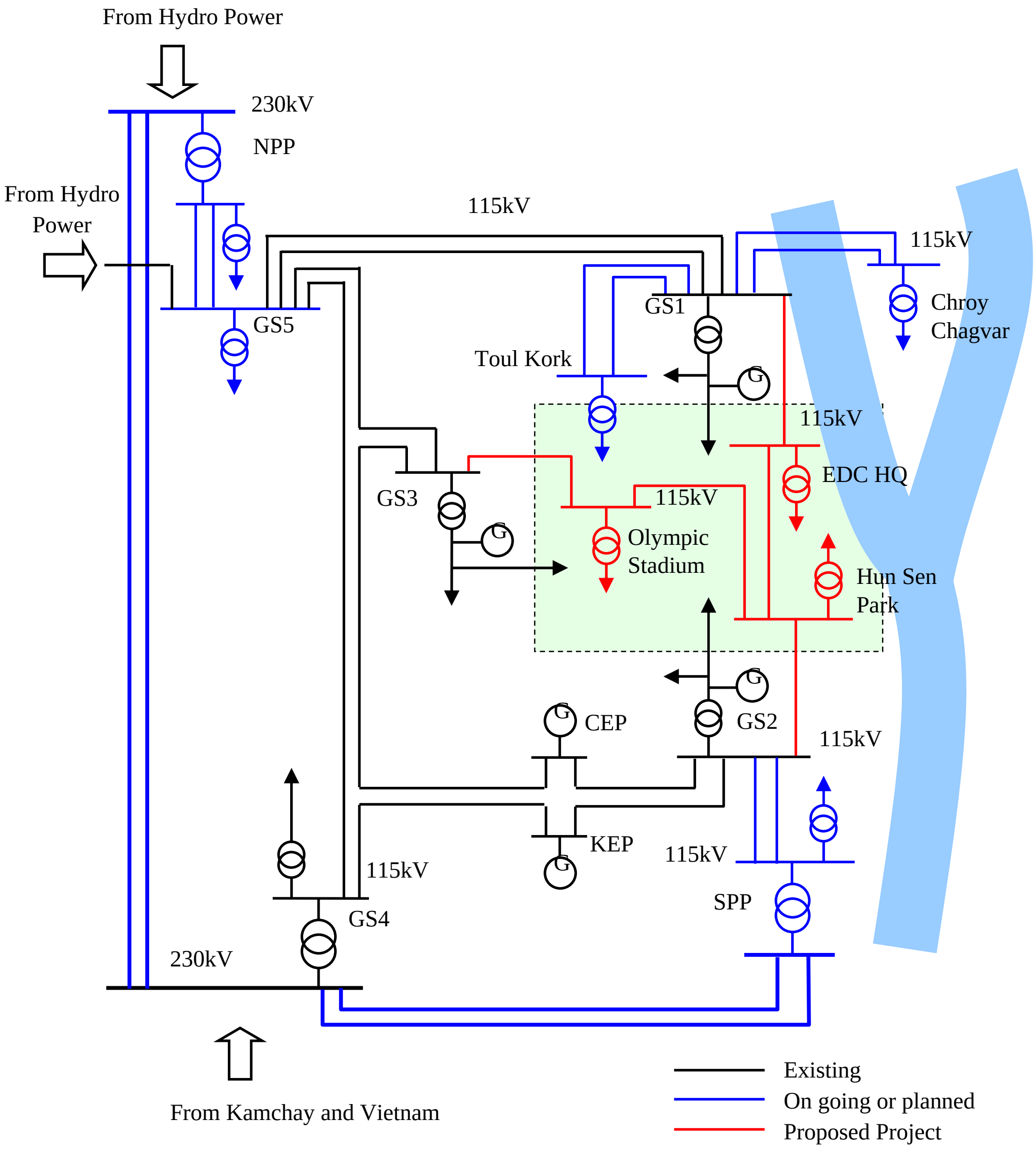


Figure 3. 3 Power System in Phnom Penh (Future)

(a) Mixture of Thai and Vietnam systems

The Phnom Penh area will have two power sources: the Thai system from the NPP substation and the Vietnam system from the GS4 substation, when the NPP substation in the north of Phnom Penh starts its operations. Both systems don't allow for synchronous operations; the systems must be decoupled at a point in Cambodia. There is the possibility that both systems are decoupled with distribution lines in Phnom Penh, i.e. the northern part is supplied with the Thai system and the southern part is supplied with the Vietnam system. In that case, it may be necessary to disconnect the distribution line from the system in order to switch loads during a failure, and the same is true when the system is turned back.

(b) Reinforcement of the North Phnom Penh system

The existing 115kV double circuits will supply power to GS1, EDC HQ, Chory Changvar and Toul Kork substations in the north. The maximum transmission capacity of the line is approx. 240MW per circuit and these have enough capacity to supply power to the north where the peak demand will be 140MW in 2013. The demand will, however, rapidly increase and the demand in the north area will exceed 240MW in 2016. As mentioned above, the transmission capacity of this double-circuit line is 240MW per circuit, and it faces overloading of another circuit under the N-1 conditions. If the system fails to shed loads within the setting time, the northern system can blackout due to overloading of the remaining circuit.

3.1.3 Present Condition and Subject of a Distribution Facilities

(1) The outline of the Cambodia Phnom Penh inner distribution facilities

The distribution facilities of the Phnom Penh central part is comprised of the MV distribution line control system (Supervisory Control AND Data Acquisition System: SCADA) installed in the EDC head office, The MV 22kV underground distribution line, the MV switching equipment and the MV distribution transformer which are installed in a substation building or a prefab type and the overhead LV distribution line.

a. EDC's SCADA

b. Building type substation

c. Substation type substation

d. MV switching equipment

e. transformer

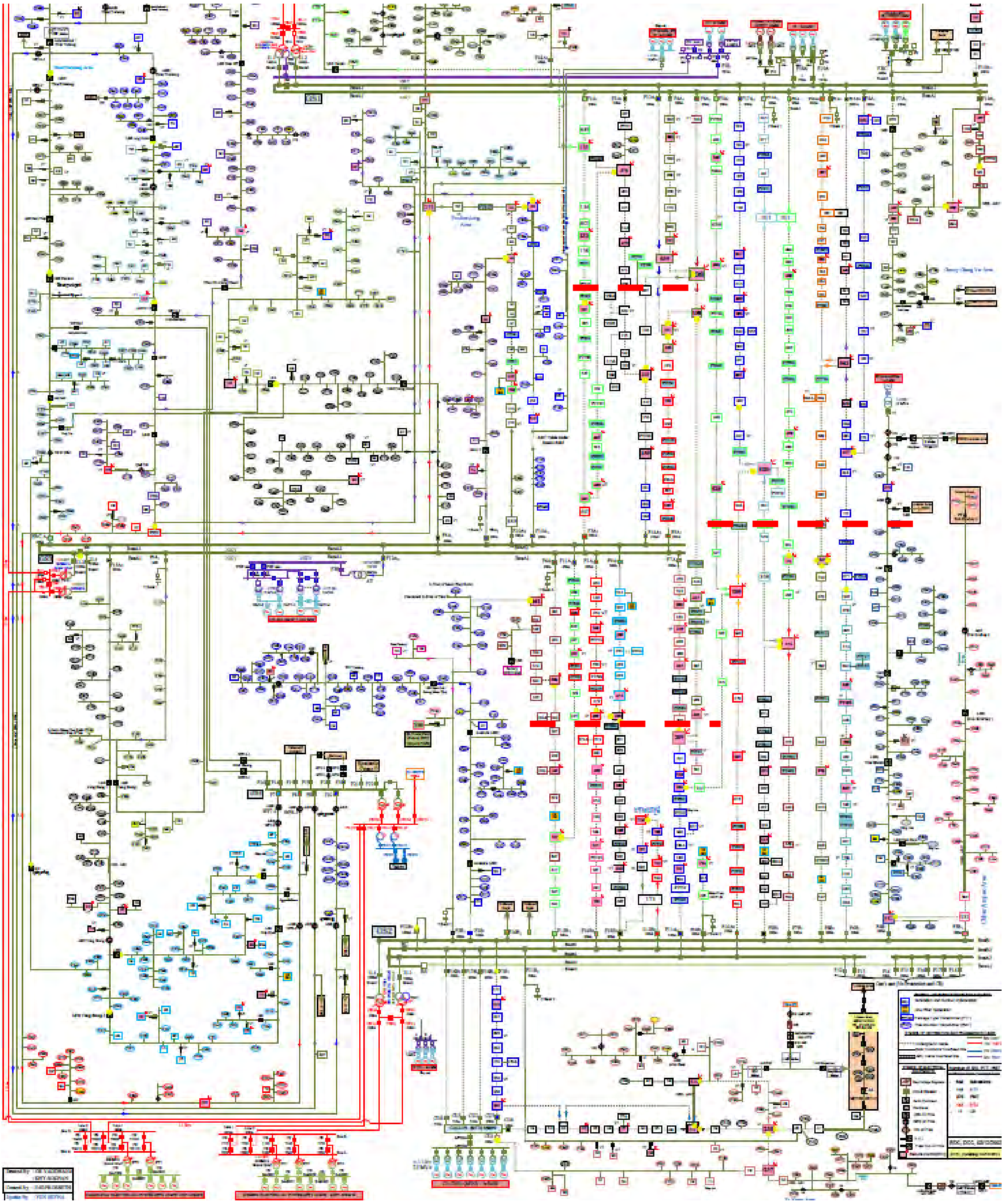
f. LV over head distribution line

Figure 3. 4 Underground Distribution Facilities in the Phnom Penh Inner Central Part

The MV distribution line of the city central part transmits electricity to and from the distribution substation (GS1, GS2, GS3) for the existing supply of electric power, and each distribution line connects through the switching equipment so that it becomes a regular opening established on the way between GS1 – GS2, GS2 – GS3, GS3 – GS1. In addition, it is connected to the circuit of other than the neighborhood by the linkage line, and the change circuit is enabled easily.

Hearing investigation, there is very little frequency of the MV distribution system fault Phnom Penh City center under the current situation and the main cause is when a fault occurred with the cable damage per the digging.

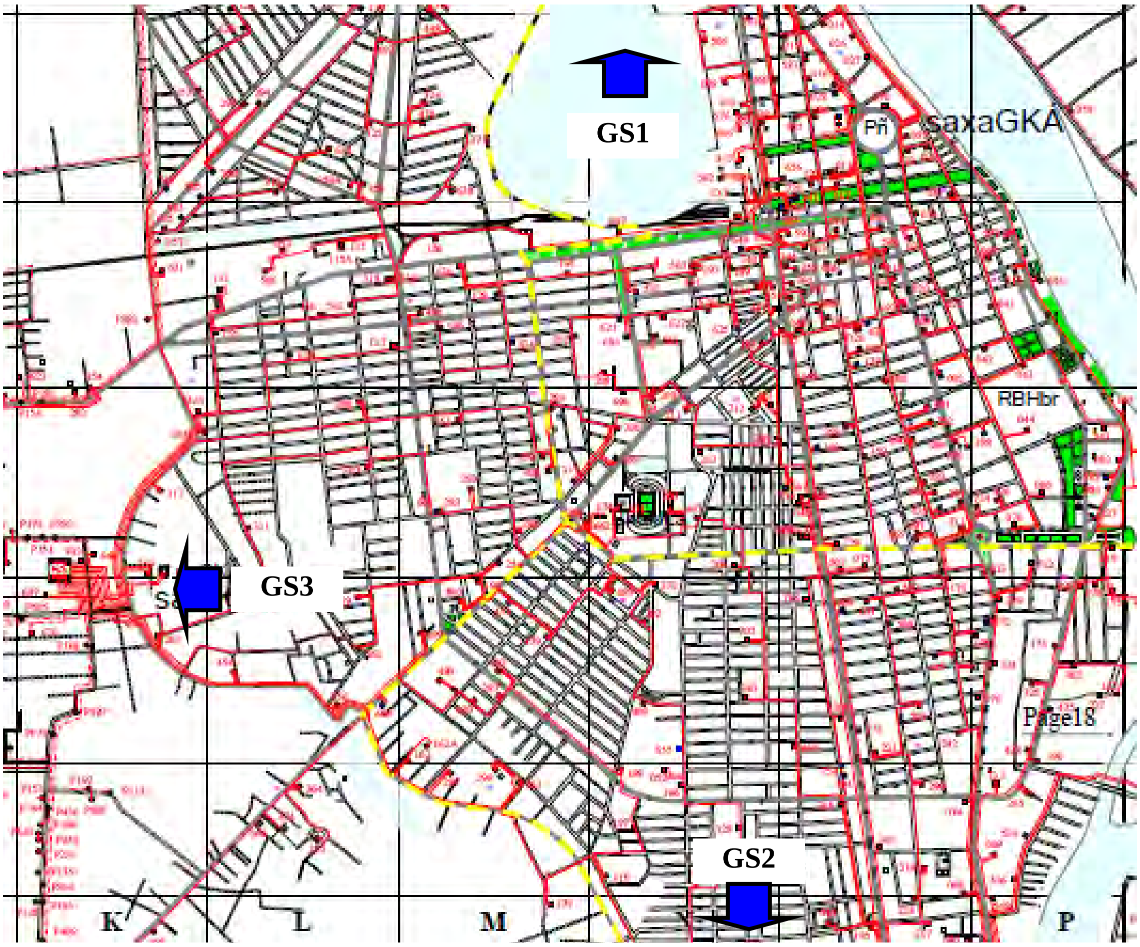
*In the first survey, the detailed data of the MV underground distribution line edited by GIS-software was shelved.



▬ ▬ ▬ ▬ ▬ : The switching equipment opened position outline that the Survey Team confirmed at the 1st survey

(Source : EDC data)

Figure 3. 5 MV Distribution Line System Diagram of Phnom Penh City



*The yellow line almost expresses the load of each distribution substation's load allotment border, each distribution substation for the supply of electricity.

(Source: EDC data)

Figure 3. 6 Existing MV Distribution Line of Phnom Penh City Center

(a) MV distribution line control system (SCSDA for MV distribution control)

The SCADA for the MV distribution control is established in the distribution control room of the EDC head office top floor. The UHF wireless communication system is adapted between SCADA for the MV distribution control of the present EDC (key station), and the control equipment (sub station) in the substation on the MV distribution line in which distant place control is possible. In the distribution SCADA system of the distribution control room of EDC, Information acquisition of the MV line feeding parts (the ON / OFF of CB, voltage, current, effective and reactive power, power-factor , etc.) of the distribution substation (GS1, GS2, GS3), the ON/OFF state information acquisition of the MV switching equipment installed in the inside of the substation on the MV distribution line equipped with the UHF radio, and the ON/OFF control are possible.


a. UHF antenna on EDC roof


b. UHF antenna on substation


c. signal convertor inner substation

Figure 3. 7 Communication Equipment for MV Distribution Control

(b) MV under-ground distribution line

The MV 22kV under-ground distribution cable based on the IEC60502 standard is used for the distribution line. Aluminum 240 mm^2 cables are used for the main MV distribution line, and the Copper 150 mm^2 cable is only used for the part which does not link for a main line at the branch line.

(Source: ERECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

(c) MV switching equipment

The MV under-ground switching equipment is installed in a substation on the MV distribution line for the supply of electric power, and there is the type where the distant place controllable and a type is only used for hand-operated operations, and adopts a SF6 gas insulation. The connecting part of it and cable terminal part shape is based on IEC standard together.

* There is not an automatic change function at the time of the MV underground distribution line fault.

(Source: ERECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

(2) The subject of the current distribution facilities

(a) SCADA

The UHF radio relatively has a high directivity, there have been the following problems.

- When tall buildings are founded between UHF radio antenna of the EDC head office roof and the sub-station antennas, repairs such as the supporting antenna setting is necessary.
- Given EDC's radio frequency and the radio frequency of the broadcasting station approaching it, due to radio interference, the sub-station may not react to the instructions from a supply of the electric power control room of EDC.

In addition, it is necessary to pinpoint the accident section per the order of the instruction from the distribution line control person in charge of EDC when a 22kV MV distribution line accident occurred in the existing SCADA.

(b) The MV distribution line

- As overload measures of the distribution substation (GS1, GS2, GS3) for the existing supply of electric power, EDC carries out periodical rolling planned blackouts and circuit changes.
- Only the feeding part of each MV distribution line on the distribution substation can acquire the demand situation of the distribution line.
- The present conditions, demand situation monitoring non-enforcement of every section of the 22kV MV distribution line.

(c) The substation on the MV distribution line

When connecting a new MV distribution line to an existing substation on the MV distribution line with a distribution substation new establishment for supply of electric power, there are the following problems. Therefore, at the time of the second survey, the survey team performs a detailed investigation of the candidate spot.

- Each substation building is different from the internal capacity and structure in every place.
- The manufacturer of the MV switching equipment and model installed in each substation building indoors are different.
- A transformer becomes the overload and the new establishment of a substation building is difficult and installs the prefab type structure substation called the pat mount on a pavement when a transformer increases capacity and the enlargement are difficult.

3.1.4 Present Status and Issues of Telecommunication System

(1) Outline of the Telecommunication System for the Power Sector in Cambodia

The primary function of the telecommunications system is to provide the necessary communication facilities required for Cambodian power networks, namely data, speech and teleprotection signaling. To meet these requirements, the telecommunications system shall be provided to facilitate:

- Fibre Optic Telecommunication (FOT) system (, and Power Line Carrier (PLC) system)
- Telephone communication via the new PABX (dial-up) and dispatch telephone set (hot line)
- Teleprotection signaling equipment

The present EDC telecommunication system was introduced to link the national control center (NCC) and nationwide power plants/substations. NCC was constructed in Phnom Penh in January 2012 under the Rural Electrification and Transmission Project financed by World Bank.

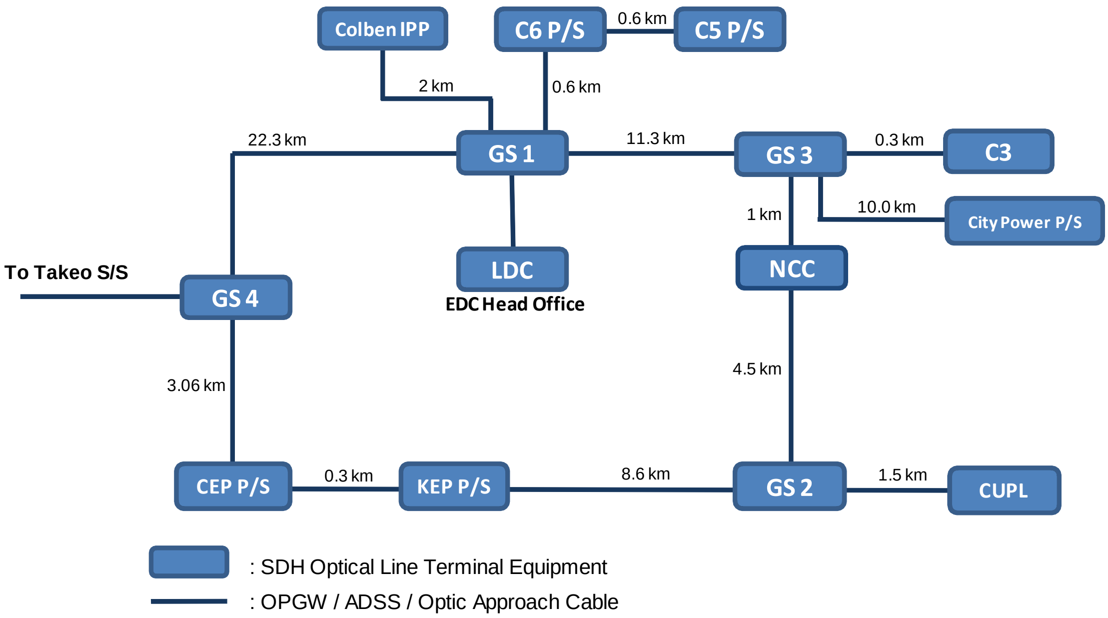
The day-to-day operations and supervision of the power network will be carried out from the NCC. The design philosophy of the telecommunications system is that the failure of any single component shall not cause the failure of a critical function, and the communication trunk network shall be capable of providing a fully resilient network in which all speech and data channels can be automatically re-routed in the event of a trunk failure and/or traffic congestion occurring anywhere on the network.

(2) Current Telecommunication Network in Phnom Penh

The current EDC telecommunication network in Phnom Penh is illustrated in Figure 3. 8.

The telecommunication network forms a loop circuit in GS1, GS1, GS2, GS3, GS4, NCC, CEP Power Station and KEP Power Station as a trunk line network, whereas small scale power stations (such as C5, C6, CUPL, City Power and Colben power stations) connect to GS1, GS2 or GS3 as a branch connection. This Phnom Penh telecommunication network interconnects with the southern system at GS4 (West Phnom Penh Substation), which finally links to the Vietnam system through the Chau Doc substation.

The power line carrier (PLC) system was used to communicate between the Kirirom hydropower station and the GS1 via Kampong Spue substation until 2008. However, this PLC system is currently not being utilized.



Source: Prepared by the Survey Team based on EDC's project documents

Figure 3. 8 EDC's Telecommunication Network Diagram in Phnom Penh

(3) Outline of Existing Telecommunication Equipment

The technical data of the telecommunication equipment used by EDC in Phnom Penh are mentioned below.

(a) Fiber Optic Telecommunication (FOT) System

EDC's fiber optic telecommunication (FOT) system is designed for digital transmission with a single mode optic fiber, confirmed with ITU Recommendations G.707 for the SDH digital bit rate hierarchy of 155.52 Mb/s (STM-1) up to 622.08 Mb/s (STM-4). The present system is used as the STM-1 bit rate.

The technical data for the major telecommunication equipment items are mentioned below.

Optical Ground Wire (for 115kV overhead transmission lines)

Actual sectional area	
-Steel:	64.34 mm^2
-Optical fiber unit:	13.55 mm^2
Ultimate tensile strength:	Not less than 78,000 N
Construction of OPGW:	8/3.2 mm
Number of cores for OPGW:	24
Diameter of individual wire:	St. 3.2mm/Al. 1/5.0 mm
Overall diameter :	11.4 mm
Resistance at 20°C:	0.774 ohm/km
Mode of OPGW:	Single
Concentricity error of OPGW:	not more than 1.0 μm
Cladding diameter of OPGW:	125 $\pm$ 3 micron
Self weight of conductor:	454 kg/km

1) Optical Fiber Cables

Three (3) kinds of optical fiber cable are used in EDC's telecommunication facilities in Phnom Penh, depending on the installation situation, i.e. (i) ADSS (All-Dielectric Self-Supporting) for overhead installation, (ii) outdoor use optical fiber cable, or (iii) indoor use optical fiber cable.

The technical characteristics of the above optical fibers have the following points in common :

Number of cores:	24
Mode of optical fibers:	Single
Mode field diameter:	9.3 μm±10%
Concentricity error:	not more than 1.0 μm
Cutoff wave length:	190≤ wave length c≤ 1330 nm (measured in 2 m fiber section)
Cladding diameter:	125 ± 3 micron

(b) SDH Optical Line Terminal Equipment (OLTE) and Multiplexer

The SDH optical line terminal equipment (OLTE) being currently used by EDC is '1662 SMC' manufactured by Alcatel-Lucent, and the multiplexer is 'P128M' by Shanghai Sunstar Telecom Technology Co., Ltd. The combination of this SDH OLTE (1662 SMC) and the multiplexer (P128M) is commonly used at all the outstations (power stations and substations) to link to EDC's FOT system as a standard.

(c) Telephone System

The EDC has its own telephone system by using their own telecommunication system. It has the following functions.

PABX administration telephone system,
1) Hot-line telephone system connecting NCC and each outstation monitored by NCC
2) Vice recording system

(d) SCADA System

EDC is currently installing SCADA equipment in the outstations (power stations and substations) to be monitored and controlled by NCC, as well as the telecommunication system. As of December 2012, GS1, GS2, GS3 and GS4 have been connected to NCC through SCADA and the telecommunication facilities set up by EDC.

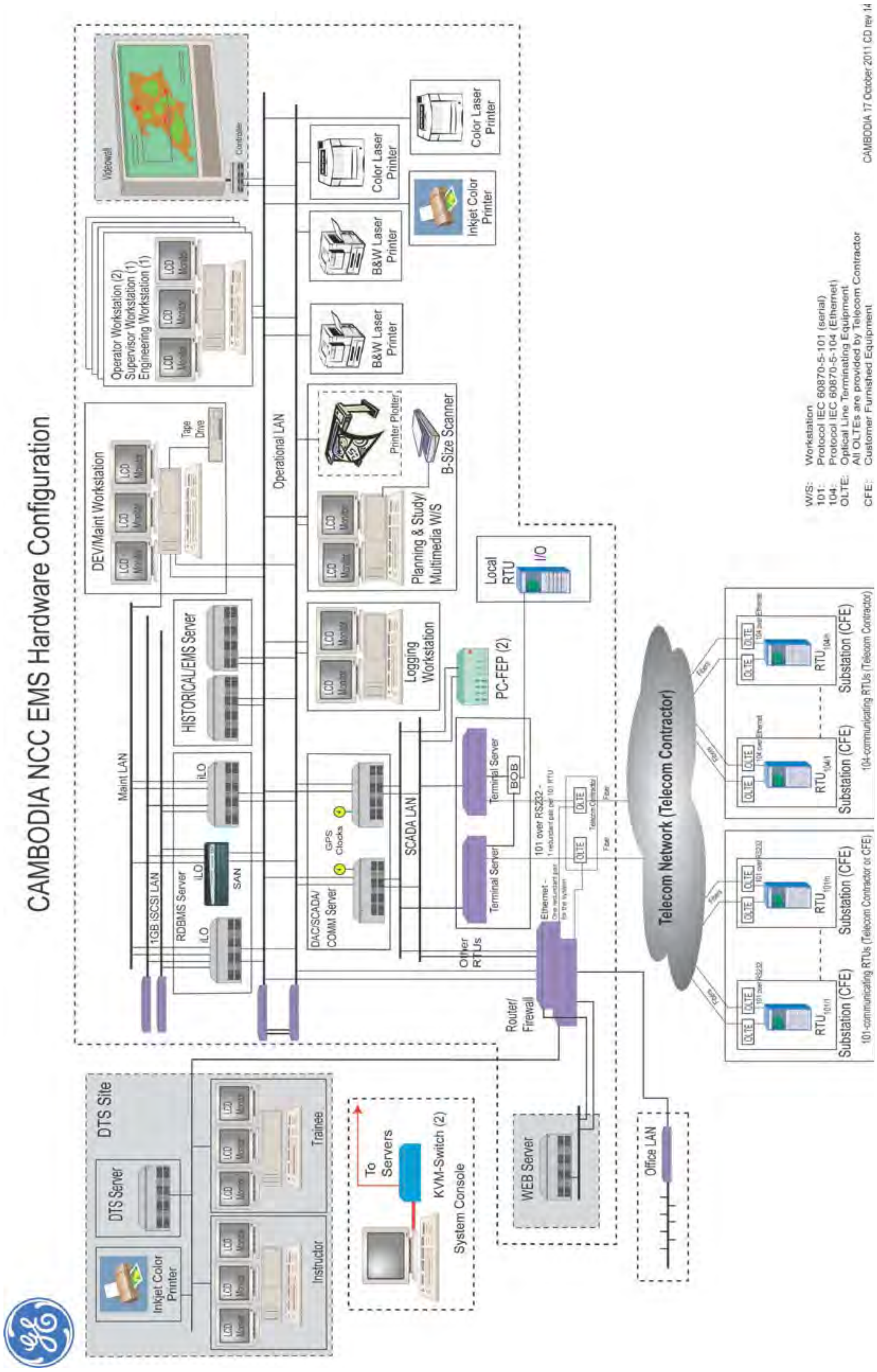
1) National Control Center

The system diagram of the SCADA/EMS master station in NCC is illustrated in Figure 3. 10.

NCC was established for the purpose of monitoring and controlling the power stations and 115kV and 230kV substations by SCADA system, and to optimize the power system operations by EMS. The distribution management system (DMS) which is to supervise and control the distribution line system in Phnom Penh city has not yet been installed in NCC.

Photo taken by the Survey Team in NCC in December 2012

Figure 3. 9 Control Room in NCC



Source: EDC’s project documents

Figure 3. 10 NCC Hardware System Configuration

2) Remote Terminal Unit

The Remote Terminal Units (RTU) used at outstations (power stations and substations) in Phnom Penh system and monitored and controlled by NCC are 'Callisto NT' which were made by Remsdaq in UK. The communication protocol for communicating with the master station in NCC is provided that complies with the IEC 870-5 T101 standard communications profile.

SDH OLTE and Multiplexer

RTU

Photo taken by the Survey Team in GS1 in December 2012

Figure 3. 11 SDH Optical Line Terminal and RTU in GS1

(4) Issues of the Existing Telecommunication System

The EDC telecommunication system in Phnom Penh is functioning properly in connection with the SDH optical fiber network at present.

However, by expanding its reach to the nationwide network, some telecommunication and SCADA systems locally developed have not occasionally worked in proper connection with EDC system, even EDC designated a communication protocol. In theory, when the communication protocol is properly defined, such communication devices should be connected to NCC and the existing system. However, it actually seems too difficult for different vendors to properly connect to the existing EDC system.

Under these circumstances, EDC is under way to unify the models of SDH OETL and the multiplexer to Alcatel-Lucent 1662 SM and Shanghai Sunstar P128M (which are currently used in the Phnom Penh system), as well as RTU to Remsdaq Callisto NT.

One fundamental issue is that EDC does not have a telecommunication specialist, and some contractors working in Cambodia may have no experience with such a fiber optic telecommunication system. Therefore, it may be the best option at the moment for EDC who is not familiar with such a fiber optic telecommunication and SCADA system, to unify the venders and model numbers of the major equipment, such as the OLTE equipment, multiplexer, and RTU. Second, EDC is encouraged to develop its own human resources for the telecommunication system and to manage more than one vendor to be involved in the same telecommunication system in the future.

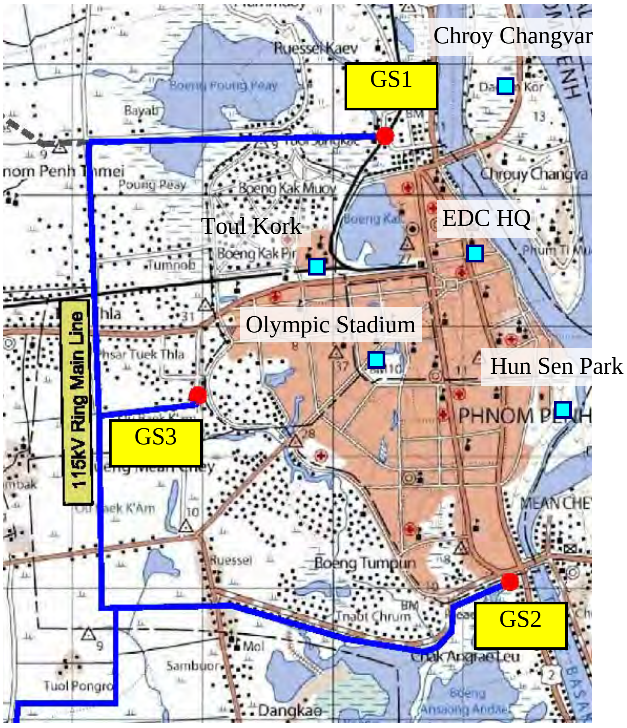
3.2 Reinforcement of Phnom Penh System

3.2.1 Power Supply to Phnom Penh and Surrounding Area

The figure below shows the existing 3 substations, GS1, GS2 and GS3 in the Phnom Penh area as of December 2012. During the peak demand time, some loads are shed due to a transformer capacity shortage. EDC, therefore, has been planning to uprate the capacity of these transformers from 100MVA to 150MVA. The demand increase ratio of Phnom Penh is, however, 20%, which is quite high, and additional transformer capacity is required in a few years. The system, therefore, requires new substations.

3.2.2 Planned Substations

There are five planned 115/22kV substations in the Phnom Penh area as shown below.



(Source: Data Collection Survey on Electric Power Sector in Cambodia)

Figure 3. 12 Substations in Phnom Penh

The following mentions the candidate sites for each substation as of December 2012.

(1) Hun Sen Park

The area has been experiencing slow development, although it is located in the center of Phnom Penh. In recent years, large development is under progress. There are large idled lands available, and it has huge potential in terms of rapid development. EDC planned to construct a 115kV underground cable between GS2 to the area and a 115/22kV substation, and began preparations for the land acquisition. EDC surely needs the substation by early 2014, and began arranging financing for the substation. The substation cannot be constructed by the time of its requirement as a Yen-Load project since it will take a long time to finalize the loan agreement. This project should not be covered by the Yen-Loan project considering its early requirements.

(2) Olympic Stadium

The west side of Phnom Penh receives power from the GS3 substation. The substation capacity is 100MVA (50MVA×2) at present. An additional 50MVA transformer is under construction and the total capacity will be 150MVA. The demand increase of this area is also high and the system needs the other substation to be located more close to the demand center. EDC plans to install a new 115/22kV substation connected with the underground cable. The candidate site of the substation is in the Olympic stadium, but the exact location has not been specified yet. (It was specified at the place of Option 2 of Figure 6.17 in October, 2013.)

(3) EDC HQ

The northern part of Phnom Penh receives power from the GS1 substation. The GS1 substation capacity is 100MVA (50MVA×2) at present. The replacement of the transformers is under progress to uprate the capacity to 150MVA (75MVA×2). In addition to this reinforcement, the system requires another substation located more closely to the demand center. There is the possibility of installing a new 115/22kV substation connected with the underground cable. The candidate site of the substation is the parking lot in EDC's headquarters.

(4) Chroy Changvar

Chory Changvar is located at the opposite side of the center of Phnom Penh across the Tonle Sap river. It is easily accessible from the center of Phnom Penh with the Japan-Cambodia Friendship Bridge and development of this area is expected. The northern part of this district is an uncultivated field like the following photographs now. However, the four-lane road has already been maintained, and there is a new city plan that develops the stadium and the housing complex, etc. on a large scale. In order to encourage the development of the area, an increment of the electric power receivable is necessary, but now there are only two 22kV distribution lines from the GS1 substation. (refer to 3.2.3 for a comparison of the supply measures of the Chroy Changvar area.)


Uncultivated field now


Four-lane road


New bridge

(5) Toul Kork

There are a lot of residential quarters in this area, and demand at present is not too large. However, this area is comparatively near the central area. So it is assumed that the expansion of demand in the future is large, and a substation will become necessary somewhere in this area. And 130ha (=1.3km^2) of land reclamation at the Boeung Kak lake located in this area is being carried out now. Large development is expected after the completion of the landfill work, but work has been delayed due to environmental issues.

3.2.3 Power Supply to Chroy Changvar area

(1) Future development plan in Chroy Changvar area

The following figure illustrates a future development plan in Chroy Changvar area.

(Source: Developer)

Figure 3. 13 Development Master Plan at Chroy Changvar Area

(2) Power Supply Methods to Chroy Changvar area

This study evaluates the following three methods supplying power to Chroy Changvar area.

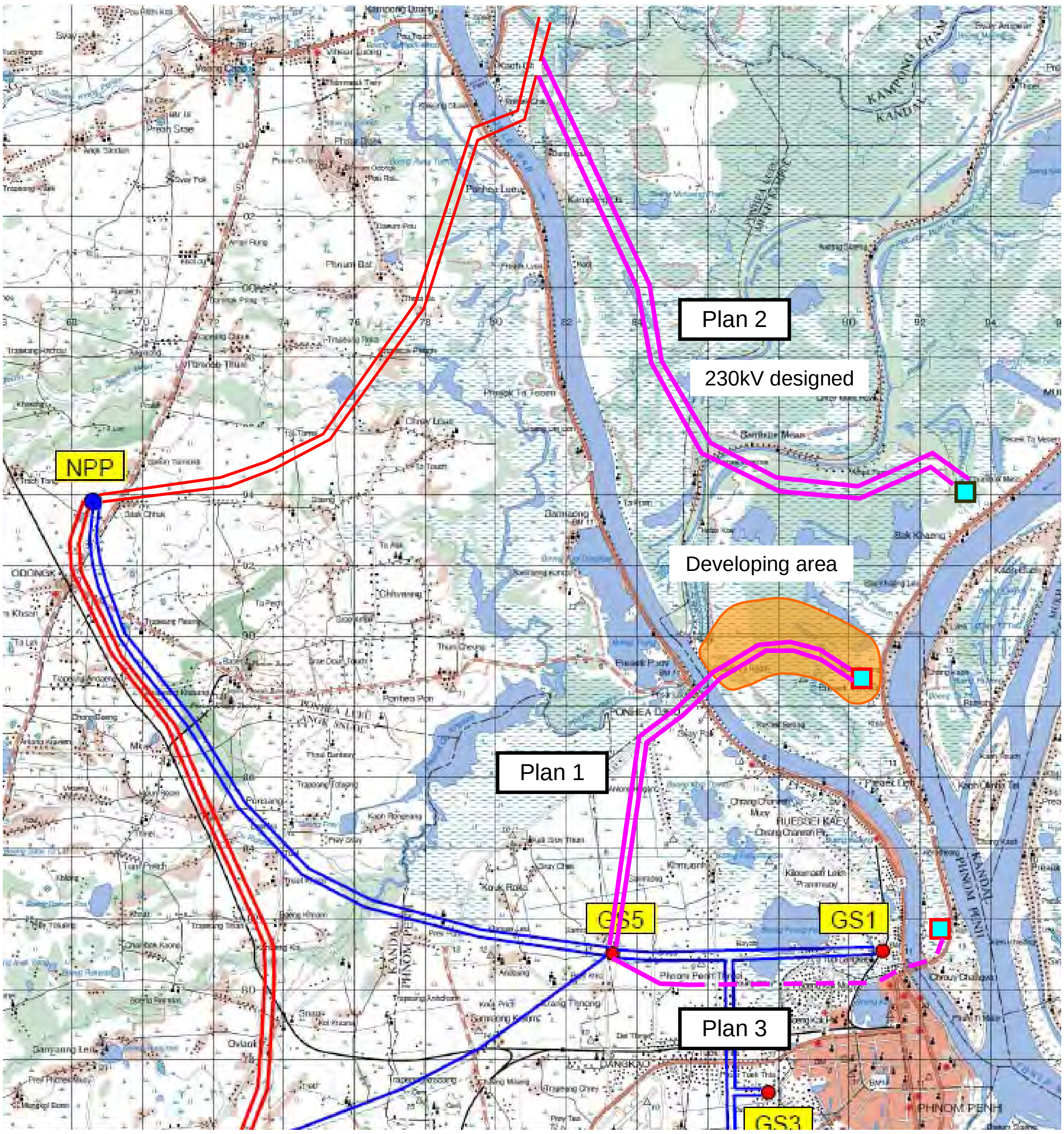
- Plan 1: Construction of a substation in north and to supply power from GS5 with 115kV overhead line
- Plan 2: Construction of a substation in further north and tap a transmission line from the 230kV NPP – Kampong Cham line (230kV designed line, but currently operated at 115kV)
- Plan 3: Construction of a substation near the Cambodia-Japan friendship bridge and supplying power from GS5 with 115kV overhead and underground mixed line

In Plan 3, the study assumes to supply power from GS5, but not GS1, which is the most economical option, since the line could become overloaded.

The main concern of power supply to Chroy Changvar area is how to pass the line over the Tonle Sap River. The followings show methods to pass over the river in each plan. Please be noted that the feasibility of each method is uncertain at the moment.

- Plan 1: There are continued houses along the National Road No. 5 near the new bridge, and no space for the line.
- Plan 2: Not required (Supply power from Chroy Changvar side)
- Plan 3: Cables are laid on the Cambodia Japan friendship bridge.

The following figure shows locations of each plan.



(Source: JICA Survey Team)

Figure 3. 14 Power Supply Methods to Chroy Changvar area

The table below shows the comparison results of each plan.

Table 3. 1 Comparison Results of Each Plan

	Plan 1	Plan 2	Plan 3
Feature	115kV OH line (from GS5)	115kV (230kV designed) OH line (from NPP)	115kV UG cable (from GS5)
Advantage	- Cheap - Easy to get S/S land	- Precedent construction of future Phnom Penh 230kV ring - Easy to get S/S land	- S/S site is near to demand center at this moment
Disadvantage	- Possibility of cable installation on the bridge - Few demand at S/S site at this moment	- Expensive - Few demand at S/S site at this moment	- Expensive

(Source: JICA Survey Team)

In Plan 1, it is assumed to construct the overhead line inside the large development area, and EDC may be requested to construct the underground cable instead. If a substation is constructed near the Tonle Sap River, the length of the underground cable can be reduced, but it leads to higher distribution loss due to long distribution line.

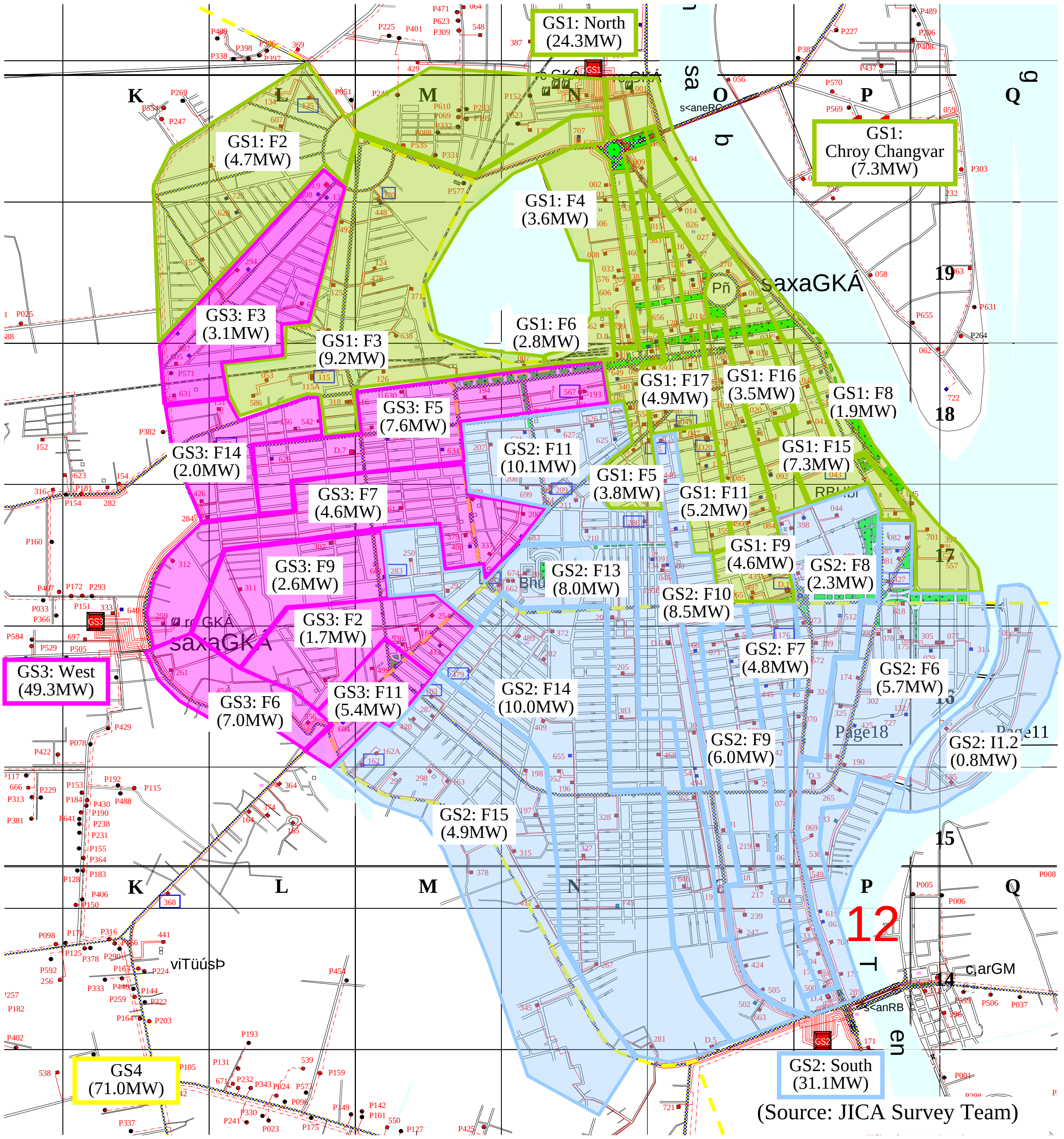
The construction cost of Plan 2 is 25 million US dollars and higher than the other plans, since it considers future requirements in the initial stage. In order to reduce the cost in the initial stage, it could be an option to install mobile transformers (25MVA X 2 units: 5 million US dollars), and reinforce the substation when the substation voltage is upgraded.

The JICA Study team believes that Plan 2 is better than the others considering required additional costs and future reinforcement.

3.2.4 Demand Forecast of Phnom Penh

(1) Area-wise electric power demand

The figure below shows the supply area and the electric power demand results of each distribution line at 11:00 September 7, 2012.



(Source: JICA Survey Team)

Note: The electric power demand is calculated based on the current value of each distribution line as the condition of 22kV voltage and 95% power factor.

Figure 3. 15 Electric Power Demand Results in Phnom Penh

If the electric power demand in each area for the five substations that EDC planned in the Phnom Penh City metropolitan area and existing substations (including substations under construction as of

March, 2013) is calculated based on the above-mentioned demand realities, the outline becomes as follows.
(refer to Figure 3. 16 as the supply area of each substation)

Table 3. 2 Results of Maximum Demand in each Substation Area

Status	Substation area	2012.09.07	Share
Existing	GS1	24.3 MW	7.4%
	GS2	31.8 MW	9.7%
	GS3	33.9 MW	10.3%
	GS4	35.5 MW	10.8%
Plan	EDC HQ	40.9 MW	12.4%
	Toul Kork	26.5 MW	8.1%
	Hun Sen Park	31.5 MW	9.6%
	Olympic Stadium	40.4 MW	12.3%
	Chroy Changvar	7.3 MW	2.2%
Under construction	NPP	9.9 MW	3.0%
	SPP	27.5 MW	8.4%
	GS5	19.7 MW	6.0%
	Total	329.3 MW	100.0%

(Source: JICA Survey Team)

(2) Total Demand in Phnom Penh

According to the Data Collection Survey on the Electric Power Sector in Cambodia supported by JICA, the peak demand forecast in Phnom Penh is as follows:

Table 3. 3 Peak Demand Forecast in Phnom Penh

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Maximum demand (MW)	439.9	541.1	649.3	753.2	858.7	961.7	1057.9	1161.5	1271.9
Annual Growth rate (%)	25.0%	23.0%	20.0%	16.0%	14.0%	12.0%	10.0%	9.8%	9.5%

(Source: Data Collection Survey on Electric Power Sector in Cambodia)

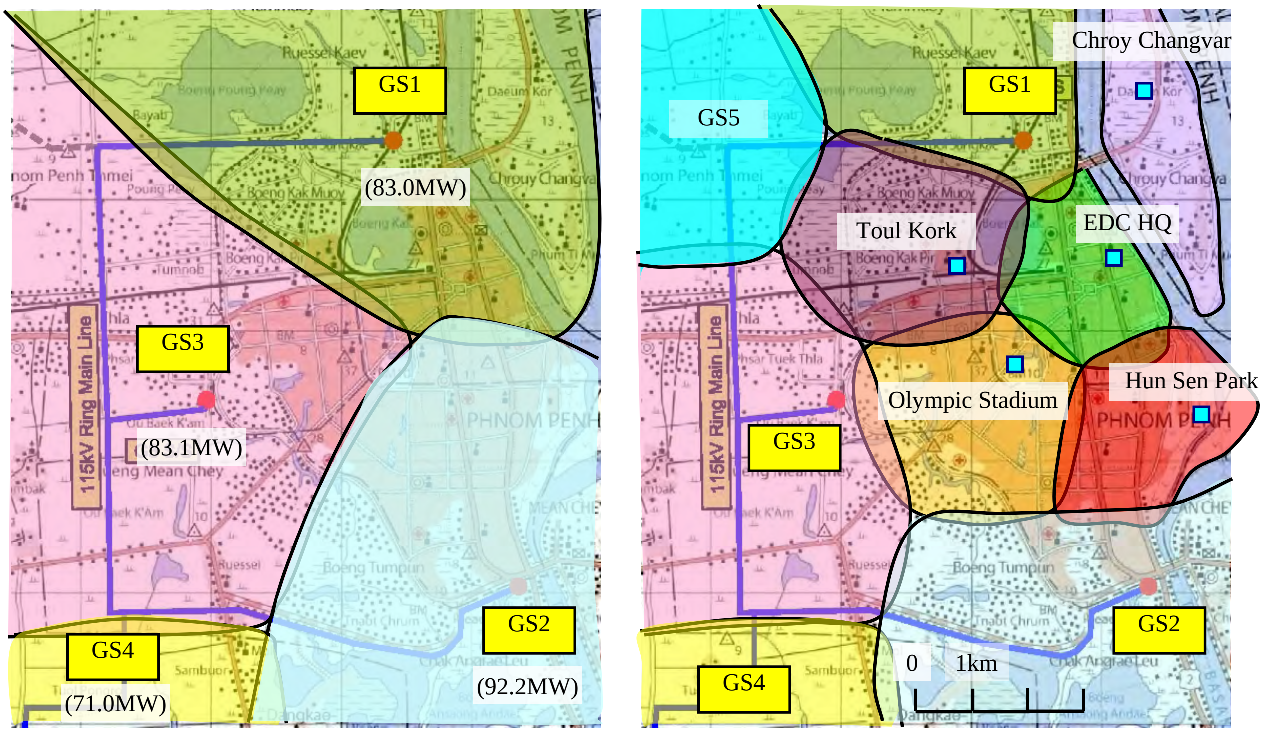
The demand in 2020 becomes 3 times higher than that in 2012. The average increase ratio for 8 years from 2012 to 2020 is 14.2%.

(3) Demands per area

As mentioned above, the demand increase of Phnom Penh is very high. The following shows the assumed reasons behind the high demand increase in the city:

- Large development of idled land in the city center
- Redevelopment in the existing city center
- Demand expansion in neighboring areas

The city center of Phnom Penh has been already developed. The large demand increase is expected in the idled land in the city center rather than redevelopment of the existing one. On the other hand, there are large development possibilities in the neighboring areas and a demand increase is also expected in these areas. There are 12 substations in the Phnom Penh area including the existing and planned ones. The following figure shows the catchment areas of these substations. The northern part of the GS1 substation is supplied with the NPP substation, the southern part of the GS2 substation is supplied with the SPP substation, and the western and southern parts of the GS3 substation is supplied with the GS4 substation.



Present
( ): Power demand at 11:00 September 7, 2012

Future
(including planed substation)

(Source: JICA Survey Team)

Figure 3. 16 Catchment Area of each Substation

The catchment area of the four substations is within the area of 2km from each substation in consideration of the location balance between the substations, and the area is at most 12km^2. These areas have been already developed to some extent and no large demand increase is expected unless large idled land is developed.

The demands in the city center will be supplied with the new substations and therefore existing GS1, GS2 and GS3 substations will have a surplus capacity to deliver power to the neighboring areas.

The following shows the assumptions to calculate the demand in each area:

- Areas in the center: EDC HQ, Olympic Stadium, Hun Sen Park, Toul Kork
  - Half of the existing three substations (GS1, GS2 and GS3) supplies power to the city center.
  - The demand increase of the idled land and redevelopment are expected, but it is relatively small compared to that of the neighboring area since it has been already urbanized.
  - The demand increase ratio experiences a sharp downturn when the demand exceeds 100MW after development due to the limited catchment area.
  - Given that urbanization is late at the Toul Kork area among the central area, the expansion in the future will be large. Moreover the demand increase after the landfill of the Boeuag Kak area becomes high compared to the average since it is located near the city center.
- Neighboring area: GS1, GS2, GS3, Chroy Changvar, GS5

  - ◆ Supplied loads from GS1, GS2, GS3 will be changed to the peri-urban area after the installation of three new substations in the city center. The demand increase is higher than the average after the load switching.
  - ◆ The demand increase ratio of the Chroy Changvar area is higher than average since it is relatively close to the city center.
  - ◆ The demand increase of the GS5 area is higher than average since it is in the city center.
- ■ Outside of the neighboring area: NPP, SPP, GS4
  - ◆ It is considered that a demand increase in this area is higher than the average, but lower than that of the neighboring area.

The table below shows the assumed maximum demand of each area in Phnom Penh in consideration of the above assumptions.

Table 3. 4 Maximum Demand Forecast of each Area in Phnom Penh

(Unit: MW, %/annum)

	2013	2015	2020	Growth rate
GS1	41.5	61.3	117.2	16.0%
GS2	54.3	80.2	153.4	16.0%
GS3	57.8	85.4	163.4	16.0%
GS4	58.3	81.1	144.0	13.8%
EDC HQ	63.4	79.2	98.9	6.6%
Toul Kork	43.6	61.5	114.7	14.8%
Hun Sen Park	52.7	74.6	105.3	10.4%
Olympic Stadium	65.2	84.1	106.4	7.2%
Chroy Changvar	12.2	18.8	43.6	19.9%
NPP	15.3	19.7	31.8	11.0%
SPP	44.4	60.7	107.7	13.5%
GS5	32.4	46.5	85.6	14.9%
Total	541.1	753.3	1272.0	13.0%

(Source: JICA Survey Team)

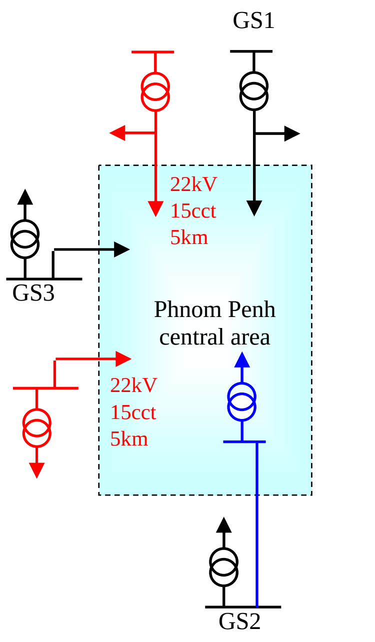
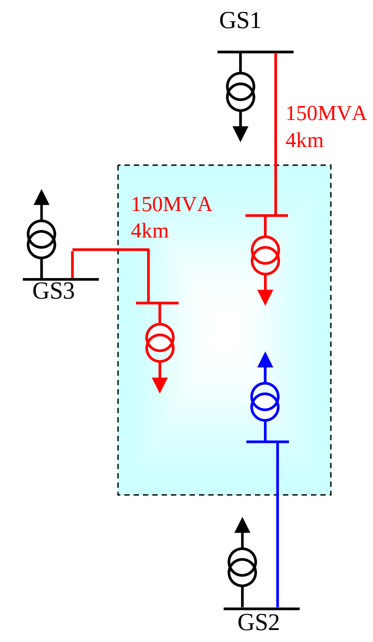
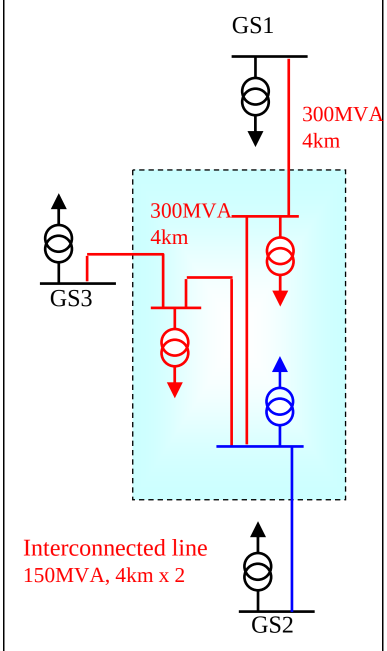
There are three substations, GS1, GS2 and GS3, in the city center in 2013, and the loads including the city center and the other areas are distributed from each substation which has a 150MVA capacity. The average loading ratio is 95% now and it is quite high. If the new substations are commissioned in 2015 and 2020, new substations will cover the surrounding areas near each substation. But, if the project is delayed, a neighboring substation will cover the demand in the delayed project area. When the demand scale of each area exceeds the transformer capacity, electricity is supplied from the near substations that have a reserve capacity by switching the distribution line.

3.3 Selection of the Optimum Plan

3.3.1 Plans to be Studied

The study selects the plan which installs two substations in the Phnom Penh metropolitan area as shown in the figure below, and analyses and validates this plan with alternative plans.

Table 3. 5 Plans to be Studied

Plan	Plan 1	Plan 2	Plan 3
Feature	Two additional substations in the peri-urban area without links in between	Two additional substations in the city center without links in between	Two additional substations in the city center with links in between
System			
Cost	Low	A little high	High
Reliability	Low	Same as Plan 1	High
Loss	Large	Small	Smaller than Plan 2

(Source: JICA Survey Team)

The study assumes a 150MVA capacity for each substation. In Plan 1, a substation connects 15 22kV distribution lines and supplies power directly to the distribution substation in the city center. The study assumes that the length of the distribution lines is 5km since the new substation can be constructed approx. 1km away from the existing ones considering the physical feasibility of the AIS substation construction. The study assumes that the underground cable capacity between the new substations is 150MVA. In Plan 2, the transmission capacity of the underground cable between the existing GS1 and GS3 substations are 150MVA. On the other hand, in Plan 3, it is 300MVA considering the loop power flow.

3.3.2 Evaluation of Alternative Options

(1) Evaluation of the transmission losses

Each plan has the same amount of transformer capacity and this is because the loading ratio is the same. This means that the transformer losses are the same in all plans; therefore, the study evaluates the losses with the transmission and distribution losses exclusive of the transformer losses.

Table 3. 6 System Losses (Transmission Capacity of 150MVA)

	Plan 1	Plan 2	Plan 3
Transmission voltage	22 kV	115 kV	115 kV
Resistance of transmission line	0.125 ohm/km	0.0782 ohm/km	0.0279 ohm/km
Number of circuit	15	2	2
Transmission current per circuit	276.2 A	396.4 A	396.4 A
Transmission Loss	2.15 MW	0.29 MW	0.11 MW
(Transmission Loss rate)	(1.51 %)	(0.21 %)	(0.07 %)

Assumed power factor: 95%

(Source: JICA Survey Team)

The above calculation assumes a power flow of 150MVA which is equivalent to the transformer capacity. The table below shows the annual system losses under the following conditions:

- Maximum load in each substation: 120MVA
- Annual average load in each substation: 84MVA (70% of the maximum load)
- Number of substations: 2
- Cost of losses: 0.16 USD/kWh

Table 3. 7 Cost of System Losses

Item	Plan 1	Plan 2	Plan 3
Transmission Loss at 120MVA	1.37 MW	0.19 MW	0.07 MW
Annual Transmission Loss	13,308MWh	1,828MWh	652MWh
Loss cost (million USD/annum)	2.13	0.29	0.10
[Difference]	Base	[- 1.84]	[- 2.03]

(Source: JICA Survey Team)

Box. Calculation of annual losses

$W = w\,G\,H$ [Wh]

w: Loss at maximum load

$G = a F + (1-a) F^2$ (G: Coefficient of Loss)

H: Time of a Period [hours], a year = 8,760 [hours]

F: Load Factor = (Average load) / (Maximum load)

a: Constant Value

$a = 0.3$, $F = 70\%$: $G = 0.553$

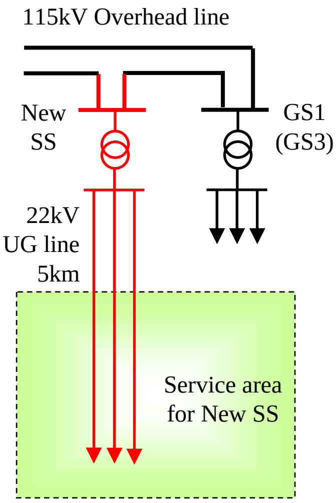
The construction costs of Plan 2 is a little higher than that of Plan 1, but the loss of Plan 2 is smaller than that of Plan 1. The loss cost difference between the two plans is 1.84 million USD per year. If the loss cost is considered in the evaluation, Plan 2 is more economical than Plan 1.

(2) Comparison of supply reliability

(a) Differences of the supply reliability of each plan

The figure below shows the supply reliability of each plan under abnormal conditions.

Table 3. 8 Plans to be Studied

<table>
<tr><th colspan="2">Plan</th><th>Plan 1</th><th>Plan 2</th><th>Plan 3</th></tr>
<tr><td colspan="2">System diagram</td>
<td>
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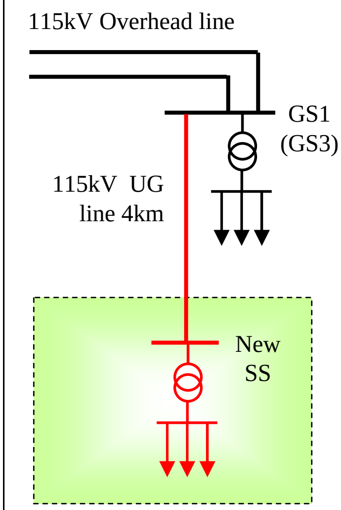
<td>
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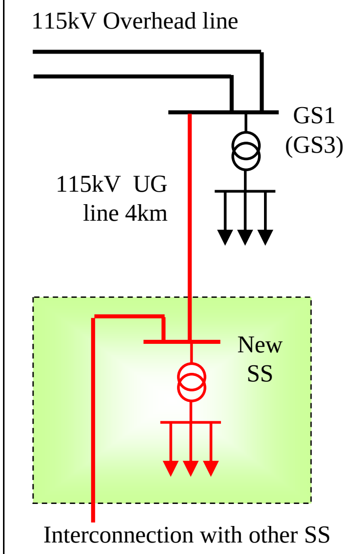
<td>
</td></tr>
<tr><td rowspan="3">Abnormal condition</td><td>115kV OH line</td><td>Outages of existing and new GSs</td><td>Outages of existing and new GSs</td><td>Outage of existing GSs and no outage of new GSs thanks to substation links (outage of existing substations can also be avoided depending on loading levels.)</td></tr>
<tr><td>115kV UG line</td><td>No</td><td>Outages of new substation</td><td>No outage thanks to substation links</td></tr>
<tr><td>22kV UG line</td><td>Outage in the area supplied with the tripped distribution line</td><td>No</td><td>No</td></tr>
</table>

(Source: JICA Survey Team)

The supply reliability of Plan 3 is higher than that of others, and the reliabilities of Plans 1 and 2 are almost equivalent.

(b) Failure ratio of transmission and distribution systems

It is very difficult to estimate the failure ratio and duration of the outage. The recent accident results of the 115kV transmission line are as follows.

Table 3. 9 Recent Accident Results of 115kV Transmission Line

Year	Date	Location	Cause
2011	21-Mar	GS1 – GS4	Construction building worker touching a conductor
	22-Apr	GS5 – GSKPS	Unknown
	07-May	GS1 – GS4	Construction building worker touching a conductor
	26-May	GS1 – GS4	Kite
	29-Jun	GS2 – KEP	To touch the conductor by telephone wire
	29-Aug	GS2 – CEP	Construction building worker touching a conductor
	10-Nov	GS1 – GS4	Construction building worker touching a conductor
2012	09-Feb	GS1 – GS4	Crane
	09-Mar	GS5 – GSKPS	A person climb up the tower
	20-Jun	GS1 – GS4	To touch the conductor by telecommunication wire
	01-Jul	GS1 – GS4	Construction building worker touching a conductor
	01-Aug	GS1 – GS4	Construction building worker touching a conductor
	26-Nov	GS1 – GS3	Crane
	12-Dec	GS1 – GS4	Construction building worker touching a conductor

(Source: EDC)

The 115kV transmission line accident occurred seven times each in 2011 and 2012. Almost all accidents are artificial ones caused by others, and the one that originates in the trouble of the natural damage and the equipment is not generated. In consideration of these realities, the Survey Team calculates the reliability in the following conditions.

The table below shows the Expected Energy Not Supplied (EENS) in a year under the following conditions:

- Failure of 115kV OHL: 5 times per year, 2 hours, loss of 80MW on average
- Failure of each 115kV UGC: once a century, 48 hours, loss of 80MW on average
- Failure of each 22kV UGC: once every 50 years, 48 hours, loss of 5MW on average

Table 3. 10 EENS of each Plan

Item	Plan 1	Plan 2	Plan 3
Failure of 115kV OHL	800 MWh	800 MWh	0 MWh
Failure of 115kV UGC	38 MWh	115 MWh	0 MWh
Failure of 22kV UGC	144 MWh	0 MWh	0 MWh
Total	982 MWh	915 MWh	0 MWh

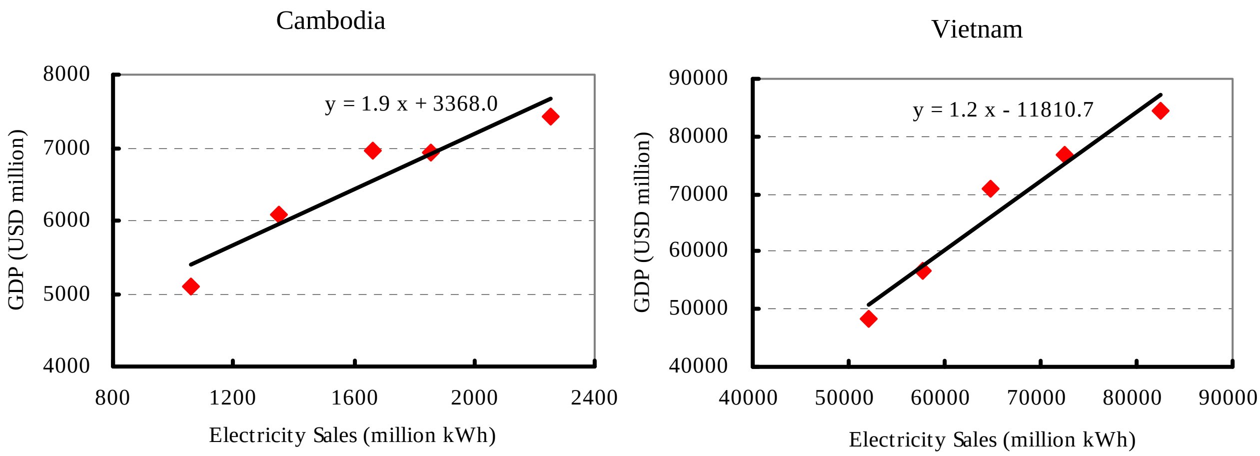
(Source: JICA Survey Team)

The difference of EENS between Plans 1 and 2 is small because both utilize an underground cable that has a small failure ratio although the supply voltages are different. On the other hand, Plan 3 can avoid outages of 915MWh per year since Plan 3 is configured with the 115kV loop system.

(c) Outage cost

EDC does not calculate the outage cost. The study estimates the outage cost by using the relationship between the GDP of Cambodia and power consumption (electricity sales).

The figure below illustrates the relationship between the GDP excluding the agricultural sector and electricity sales in Cambodia and Vietnam from 2006 to 2010.



(Source: JICA Survey Team)

Figure 3. 17 Relationship between GDP and Electricity Sales

GDP and electricity sales correlate with each other to some extent, and the outage has a negative impact on production, since most of the industries use electricity. For this reason, the study estimates that a national loss of 1.9 USD per kWh is caused by the outage as shown in the figure. The same calculation has been done for Vietnam and it is found that the loss is 1.2 USD per kWh.
The outage cost can not be evaluated with the relationship of GDP only, since the outage cost evaluates level of loss of customers caused by the outage. It depends on types of customers, but in general, damage for the customers who use more advanced technique is larger. This means that the outage cost in the well developed area tends to be higher than that of the other area. At present, the GDP per capita of Vietnam is approximately double against the same of Cambodia. It is considered that the development level and the outage cost of Vietnam are higher than those of Cambodia. It is reasonable to say that the outage cost of Cambodia is 1.0 USD per kWh.
However, this examination is the results for the whole of Cambodia. The influence is large if the power outage occurs in the Phnom Penh system. Therefore, the outage cost in Phnom Penh is assumed to be more than 1 USD per kWh.

(3) Comprehensive evaluation
The study evaluates each plan with the loss and supply reliability.

Table 3. 11 Comprehensive Evaluation

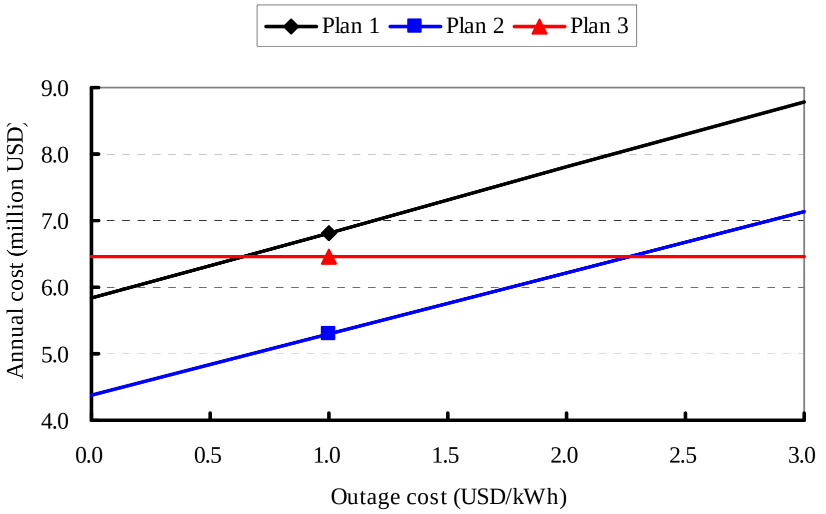
(million USD/annum)

	Plan 1	Plan 2	Plan 3
Annual capital cost	3.71	4.09	6.36
Loss cost	2.13	0.29	0.10
Outage cost	0.98	0.92	0
Total coat	6.82	5.30	6.46
[Difference]	Base	[- 1.52]	[- 0.36]

(Source: JICA Survey Team)

As can be seen from the table, the most economical option is Plan 2 and the second is Plan 3. The total cost of Plan 3 is 1.16 million USD per year higher than that of Plan 2. It depends, however, on the failure ratio, duration of failure and outage cost, and if there is the possibility that Plan 3 is the most economical option when these are considered.

The outage cost is set at 1 USD per kWh as a base case. However, it is assumed that the influence is large if a power outage occurs in the Phnom Penh system. The result of a sensitivity analysis by changing the outage cost is shown below.



(Source: JICA Survey Team)

Figure 3. 18 Sensitivity Analysis by changing Outage Cost

If the outage cost is more than 2.5 USD per kWh, Plan 3 becomes more economical than Plan 2.

In particular, the outage costs of Phnom Penh can be higher than 1.0 USD since it has important customers. In addition to that, the outage costs increase in the future with increased economic development. Plan 3 will become the most economical option in the future. The plan must be an expansive one for future development.

3.4 System Analysis in Phnom Penh

EDC plans to install a 230kV South Phnom Penh substation (SPP) in order to meet the rapid demand increase of Phnom Penh, and a 230kV North Phnom Penh substation (NPP) was already constructed in 2012. Three 230kV of electricity will supply power to the Phnom Penh metropolitan area by 2015. In the Phnom Penh area, 230kV electricity is transformed to 115kV at the substations and it will be supplied to each demand area via the 115/22kV substations and underground cables to be investigated in this study.

This study will consider the power demand increase of Phnom Penh up to 2020, and analyze the new five 115kV substations and these links of the 115kV underground cables. The study will use the PSSE Version 32 to analyze the system, which is used by EDC. The study includes the power flow and fault current analysis, and does not include the transient stability analysis, which evaluates the generators' stability due to a lack of data.

This study assumes that all new 115kV substations to be developed in Phnom Penh are commissioned by the peak period in 2020, and the study carries out simulations in 2020.

The appropriate transmission capacity must be selected to avoid the overloading of the transmission lines in consideration of future demand increases and generation development. This study assumes the current carrying capacity of 300MVA or 185MVA for the newly installed 115kV underground cables.

In general, the power system study is carried out under peak and off-peak demand conditions to analyze different power flow patterns in consideration of the different generation patterns and demands. There are CEP and KEP power stations inside the Phnom Penh area, but it uses uneconomical fuel, heavy oil, and they will be stopped when the economical power is available. This out-of-service assumption is severer for the system study. The peak demand conditions of the Phnom Penh area is the severest assumption for the transmission system study since the power demand of Phnom Penh is supplied through 230KV and/or 115kV transmission lines from the outside of Phnom Penh. This study, therefore, only analyzes the peak load conditions with zero power output from CEP and the KEP power station.

There are two options to supply power to Phnom Penh, one is from the south and another is from the north depending on the available power sources of the hydro power plants developed in Cambodia:

(a) From the south: Power imports from Vietnam or new coal-fired power plants are to be constructed in Sihanoukville
(b) From the north: Hydro power plants are to be developed in the middle west of Cambodia

The aforementioned power sources are connected to the GS4 substation in the south Phnom Penh and NPP substation in the north Phnom Penh, respectively. The study assumes the incremental power injection from the GS4 side in (a) and the incremental power injection from the NPP side in (b).

3.4.1 Power system planning criteria (Relaxed N-1 criteria)

Most of power utilities apply a N-1 (Normal minus one) criteria, which doesn't allow any overloading of transmission lines when a system has a single equipment failure. This study however applies a "Relaxed N-1" criteria which only considers the N-1 of overhead lines and allows short-term overloading of underground cables due to the following reasons:

- It is difficult to accommodate the N-1 criteria due to a rapid demand increase in Phnom Penh.
- Most of the new transmission lines in Phnom Penh are underground cables and their failure are less than that of overhead transmission lines.

The following are the Relaxed N-1 criteria to be used in this study:

- a failure of overhead transmission lines only
- allowance of short-term overloading of underground cables

The study defines the short-term overloading as the time required for switching operations by operator to resolve the overloading.

EDC defines to maintain the system voltages within ±10% against the rated voltage. As demands increase, the system voltages decrease in general, and the system needs to be compensated with reactive power sources to keep the voltages within the criteria. This study properly allocates the reactive power sources to maintain the system voltages.

It is better to install the reactive power sources of a smaller unit size for small step voltage control but the unit size should be decided in consideration of required switchgears cost for the small units and space. The following formula shows a voltage regulation ratio with the reactive power sources:

Voltage regulation ratio = reactive power injection (MVA) / short-circuit capacity (MVA)

It is preferred to be less than 2 % for power system operation.

EDC assumes a power factor of 90% for demands in Phnom Penh, and the reactive power demands in 2020 become 600 MVar (active power demand: 1,272 MW). In order to keep the voltage near the rated voltage, the system requires a reactive power injection almost equal to the reactive power demand of 600 MVar. The study assumes the allocation of the reactive power equipment at a primary and/or secondary side bus(es) of the 115kV substations in Phnom Penh.

There are two types of allowable current carrying capacity, continuous capacity for normal operation and short-term capacity for emergency conditions. When overhead lines are used under high temperature continuously to transfer large power flow, tension strength of the overhead lines is decreased. The allowable temperature limit of the overhead lines, therefore, depends on the lifetime of the conductor, while the same for the underground cables depends on the allowable temperature of the cable insulator covering a conductor. This leads to the high strength of the underground cables against the overloading. The allowable overloading duration of the overhead lines under 120 % overloading and above is only several tens of minutes, while the same of the underground cables is more than 10 hours. This study allows overloading of underground cables in order to reduce initial investment costs in consideration of the aforementioned characteristics.

3.4.2 115kV underground cable

As shown in Chapter 6, the study assumes the installation of 1,000mm^2 115kV underground cables as new transmission lines in Phnom Penh. The number of cables is one or two per phase depending on expected power flow. The current carrying capacities are 185 MVA for one cable per phase and 300 MVA for two cables per phase. The following table shows the transmission line parameters:

Table 3. 12 115kV Underground Cable Parameters

Cable	MVA	R1	R0	X1	X0	Charge
1000 mm^2×1	185	0.0261 [Ω/km]	0.1164 [Ω/km]	0.3429 [mH/km]	0.1597 [mH/km]	0.2844 [μF/km]
		0.000216 [pu/km]	0.000962 [pu/km]	0.000890 [pu/km]	0.000415 [pu/km]	0.0108 [pu/km]

Cable	MVA	R1	R0	X1	X0	Charge
1000 mm^2×2	300	0.01306 [Ω/km]	0.05821 [Ω/km]	0.17147 [mH/km]	0.07984 [mH/km]	0.56887 [μF/km]
		0.000108 [pu/km]	0.000481 [pu/km]	0.000445 [pu/km]	0.000207 [pu/km]	0.0216 [pu/km]

The figure below shows the short term current carrying capacity of the triplex type 115kV underground cable. The vertical axe is a short-term allowable current (A) and the horizontal axe is hours of overloading. The continuous current carrying capacity of the cable is 929 A. If the overloading duration is 1 hour or 2 hours, the short-term overloading capacity is 1900A or 1600A, respectively, which is more than two times higher than the continuous rating and large enough for the short-term capacity. The study expects that EDC’s operators will be able to reconfigure the system within this duration, and allows for the overloading of the underground cables under the N-1 contingencies.

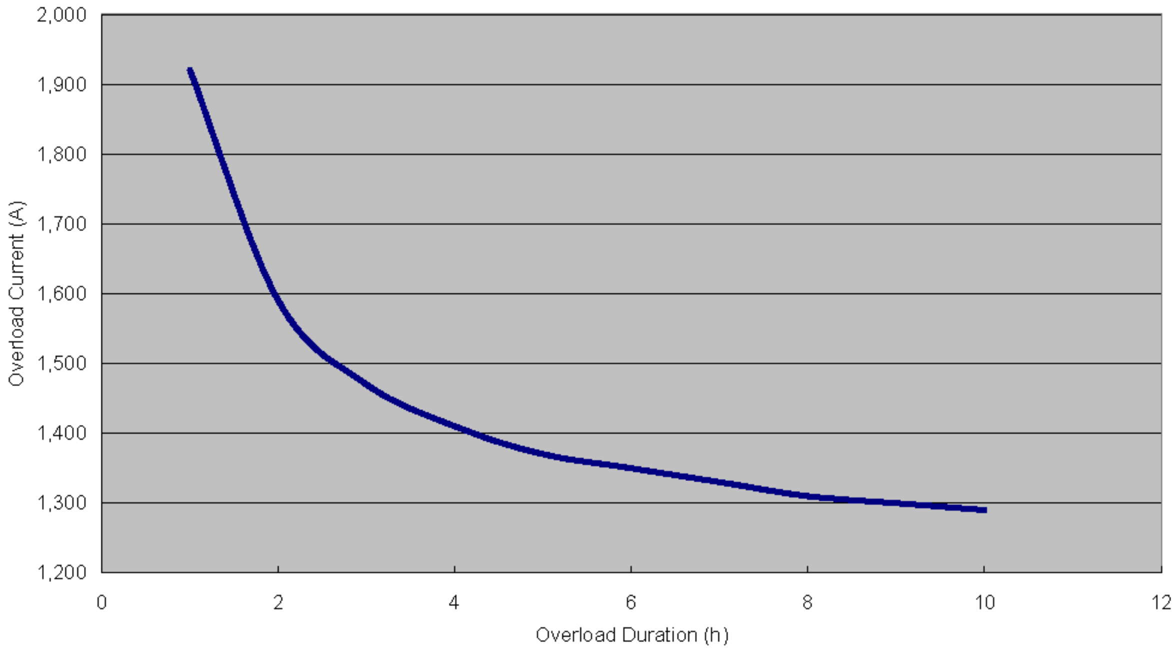
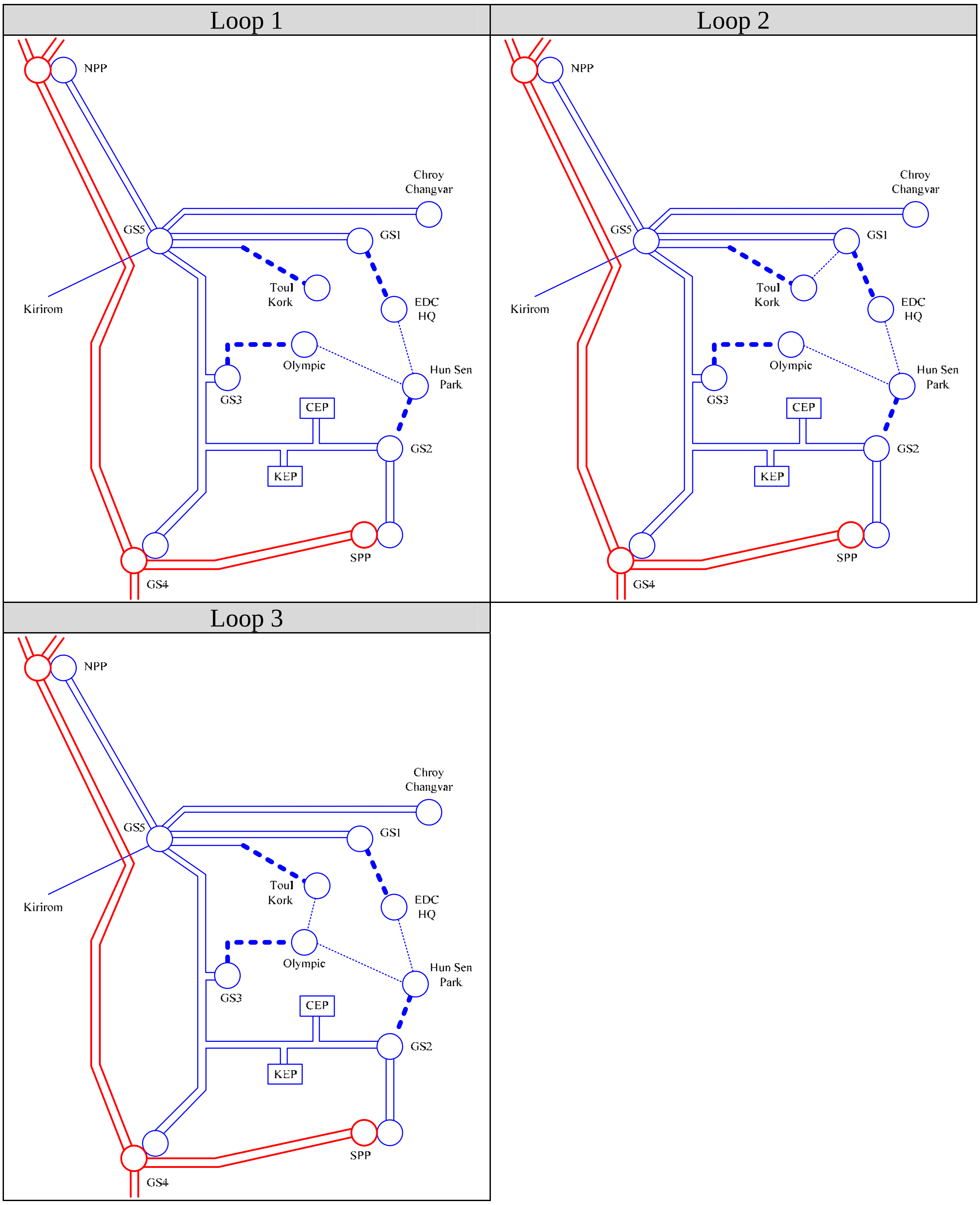


Figure 3. 19 Short Term Capacity of Triplex-type 115kV Underground Cable

3.4.3 Power system configuration study (loop system)

This section shows the results of the power system study in Phnom Penh in 2020. In consideration of the discussion with EDC, the study evaluates some transmission system patterns illustrated in Figure 3. 20. In order to secure and improve supply reliability, the system configures a loop system, and the first sections of the underground cable to the Phnom Penh metropolitan area are assumed to be the underground cable with a 300 MVA capacity, while the other cables (interconnections) have a 185MVA capacity. It should be noted that the 115kV GS2-Hun Sen Park underground cable is developed per the support of China and the capacity of the line is 250 MVA in the current plan. This study assumes the same in the simulation, and a new 115kV double-circuit overhead transmission line between GS5 and Chory Changvar according to the discussion with EDC. The 115kV Toul Kok substation is connected only to GS5 with a single circuit in Loop 1, and it has the potential risk of a substation outage in the N-1 contingency of this line.



230kV overhead line
115kV overhead line
115kV underground cable (250/300MVA)
115kV underground cable (185MVA)

Figure 3. 20 Transmission System Patterns in 2020

The following figures show the power flow diagrams of each pattern. As can be seen from the figures, 115kV GS2-Hun Sen Park line (continuous capacity: 250MVA) has approximately 350MW, and is overloaded under normal operating conditions in all cases. It needs a countermeasure to relieve this overloading, but the study assumes only one circuit of the same line, since the line is under a study in the different project.

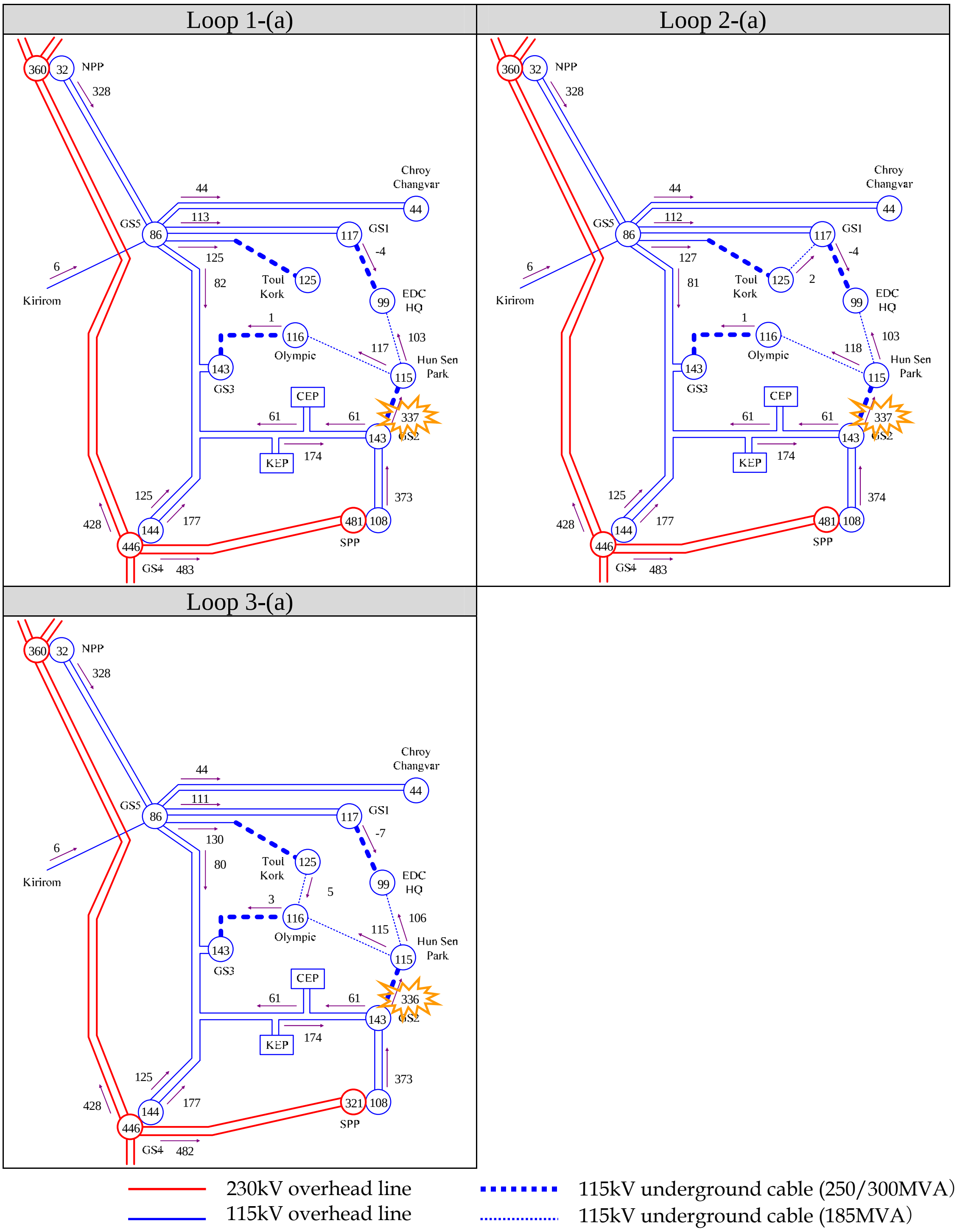


Figure 3. 21　Active Power Flow Diagram in 2020(a) (Power Import from Vietnam)

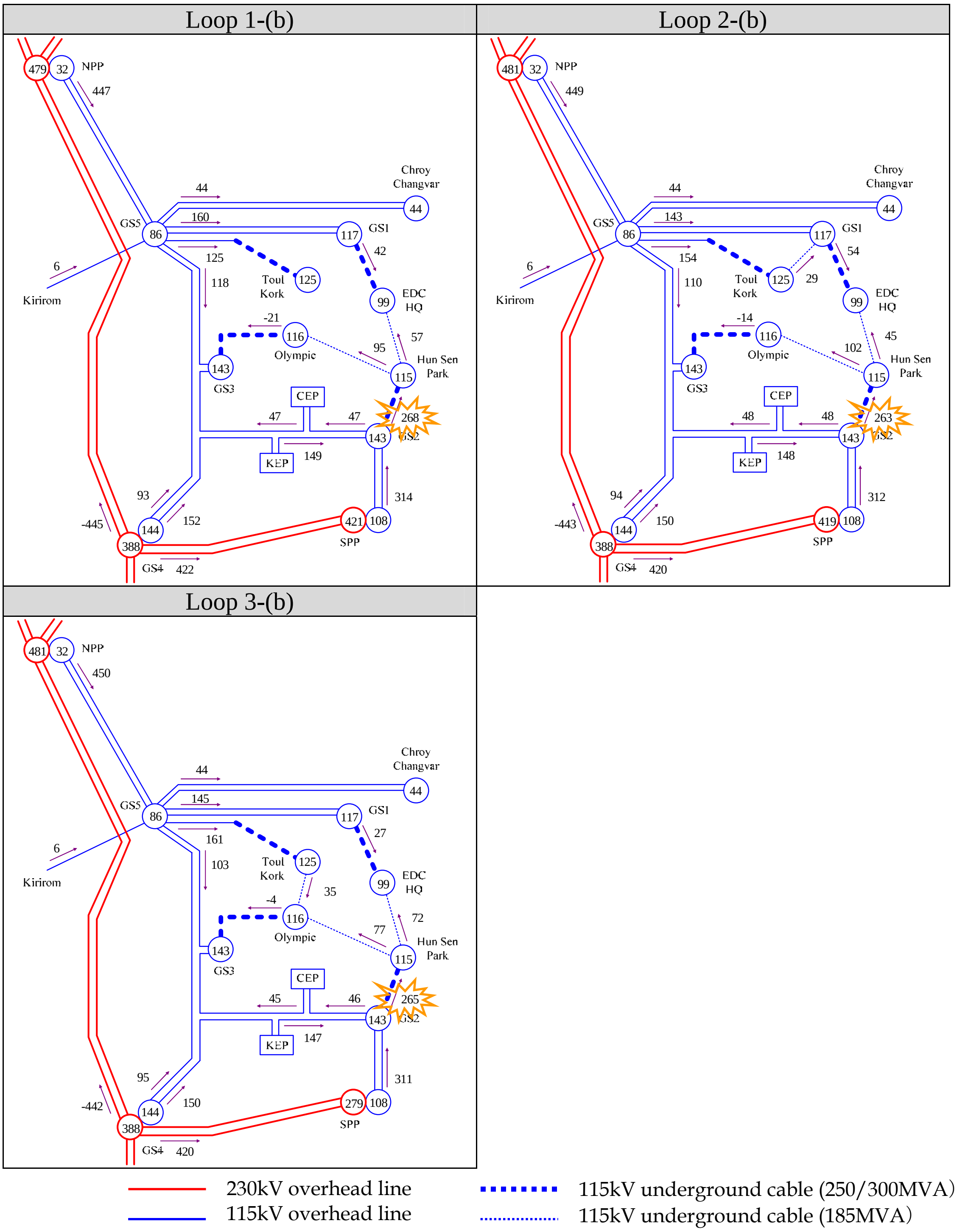


Figure 3. 22 Active Power Flow Diagram in 2020(b) (Hydro Power in Cambodia)

3.4.4 N-1 contingency analysis (loop system)

An N-1 contingency analysis is conducted under a loss of 230kV / 115kV overhead transmission line. The table below shows the results of the analysis. As mentioned above in this chapter, this study applies the Relaxed N-1 criteria, which allows for the short-term overloading of the underground cables, and the table also includes the maximum overloading of the underground cables for reference. There are several overloaded overhead transmission lines under the N-1 contingencies of the overhead transmission lines.

Table 3. 13 Maximum Overloading under N-1 of Overhead Lines in Loop 1

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS2-Hun Sen Park	UG	284.6	424.0	115kV GS4-GS5	yes
115kV GS2-SPP	OHL	284.6	353.1	115kV GS2-SPP	
115kV GS5-NPP	OHL	284.6	198.0	115kV GS5-NPP	
115kV Hun Sen Park-Olympic	UG	185.0	308.2	115kV GS3-GS5	

Table 3. 14 Maximum Overloading under N-1 of Overhead Lines in Loop 2

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS2-Hun Sen Park	UG	284.6	428.6	115kV GS4-GS5	Yes
115kV GS2-SPP	OHL	284.6	353.7	115kV GS2-SPP	
115kV GS5-NPP	OHL	284.6	199.4	115kV GS5-NPP	
115kV Hun Sen Park-Olympic	UG	185.0	353.7	115kV GS3-GS5	

Table 3. 15 Maximum Overloading under N-1 of Overhead Lines in Loop 3

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS2-Hun Sen Park	UG	284.6	426.8	115kV GS4-GS5	Yes
115kV GS2-SPP	OHL	284.6	353.9	115kV GS2-SPP	
115kV GS5-NPP	OHL	284.6	192.0	115kV GS5-NPP	
115kV Hun Sen Park-Olympic	UG	185.0	307.4	115kV GS5-TLKK	

3.4.5 Power system configuration study (radial system operation)

As mentioned above, 115kV GS2-Hun Sen Park line is overloaded under normal operating conditions. This section evaluates the radial operations of the Phnom Penh transmission system by opening some 115kV transmission lines. The analysis is conducted under the conditions that 115kV EDC HQ-Hun Sen Park and Hun Sen Park-Olympic Stadium lines are normally opened in consideration of power flow balance.

Power systems in Japan are mesh or loop systems, but they are operated as the mesh or loop system in the bulk network such as a 500kV only, while the networks below the 500kV system for local supply are operated as the radial system by opening a side of the lines. In general, the mesh or loop system has a larger adequacy compared to the radial system since the power flow is loaded on some or several transmission lines in a dispersed fashion, however, local areas are supplied with the radial system because of its advantages of simplicity of power flow and voltage controls and the restriction of the wide area blackout. The relay settings of the radial system are also easier than those for the mesh or loop system.

The simulation results under the N-1 contingencies of the overhead lines are shown in the table below. As can be seen from the results, there are some overloaded overhead transmission lines even under the radial system operation. Power flow diagrams under normal operating conditions are shown in Figure 3. 23.

Table 3. 16 Maximum Overloading under N-1 of Overhead Lines in Radial 1-(a)

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS2-CEP	OHL	284.6	293.4	115kV GS4-GS5	
115kV GS3-CEP	OHL	284.6	294.1	115kV GS4-GS5	
115kV GS5-NPP	OHL	284.6	304.6	115kV GS5-NPP	

Table 3. 17 Maximum Overloading under N-1 of Overhead Lines in Radial 2-(a)

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS2-CEP	OHL	284.6	303.0	115kV GS4-GS5	
115kV GS3-CEP	OHL	284.6	303.9	115kV GS4-GS5	
115kV GS5-NPP	OHL	284.6	300.9	115kV GS5-NPP	

Table 3. 18 Maximum Overloading under N-1 of Overhead Lines in Radial 3-(a)

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS3-GS4	OHL	284.6	305.5	115kV GS4-GS5	
115kV GS5-NPP	OHL	284.6	312.8	115kV GS5-NPP	

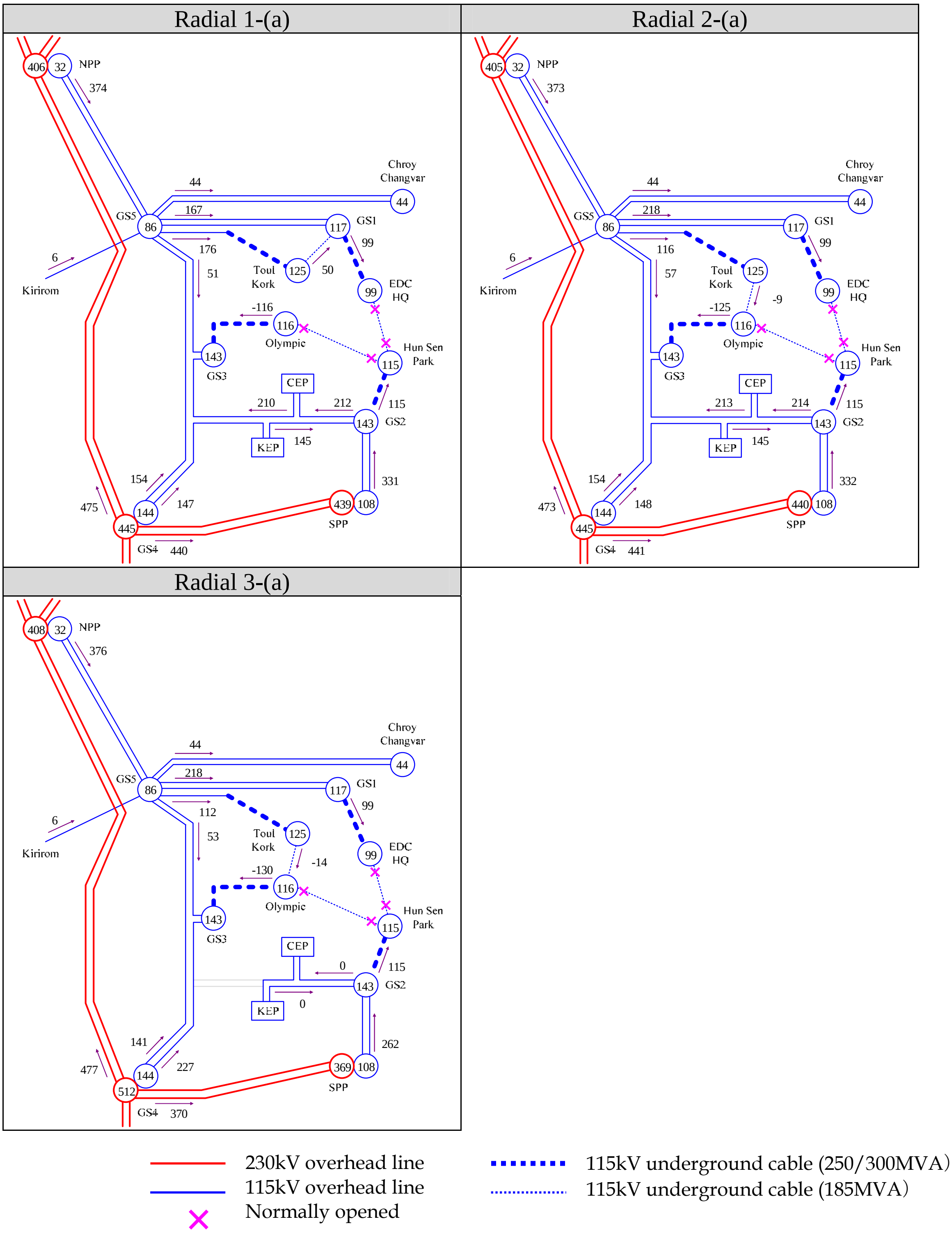


Figure 3. 23   Active Power Flow Diagram in Radial System Operation in 2020

3.4.6 Development of 230kV system in Phnom Penh metropolitan area

It has been observed that the Phnom Penh power system needs more transmission lines in order to satisfy the power system criteria applied in this study. It is an option to develop additional 115kV transmission lines, but the introduction of a 230kV system in the Phnom Penh metropolitan area is another good option because it has the higher capacity to accommodate a further demand increase after 2020.
According to the results of the site surveys, it seems that it is difficult to find enough land to construct a 230kV substation in the center of Phnom Penh. There is, however, enough land available for the 230kV substation next to the National Control Center (NCC) of EDC, and it is close to the city center. The study assumes that it is the candidate site for the new 230kV substation.
The following figures show the study cases. A 230kV NCC substation is tapped to a circuit of the 230kV GS4-NPP line under construction with double circuits. Some demands at the Olympic stadium and GS3 substations are shifted to the NCC substation.

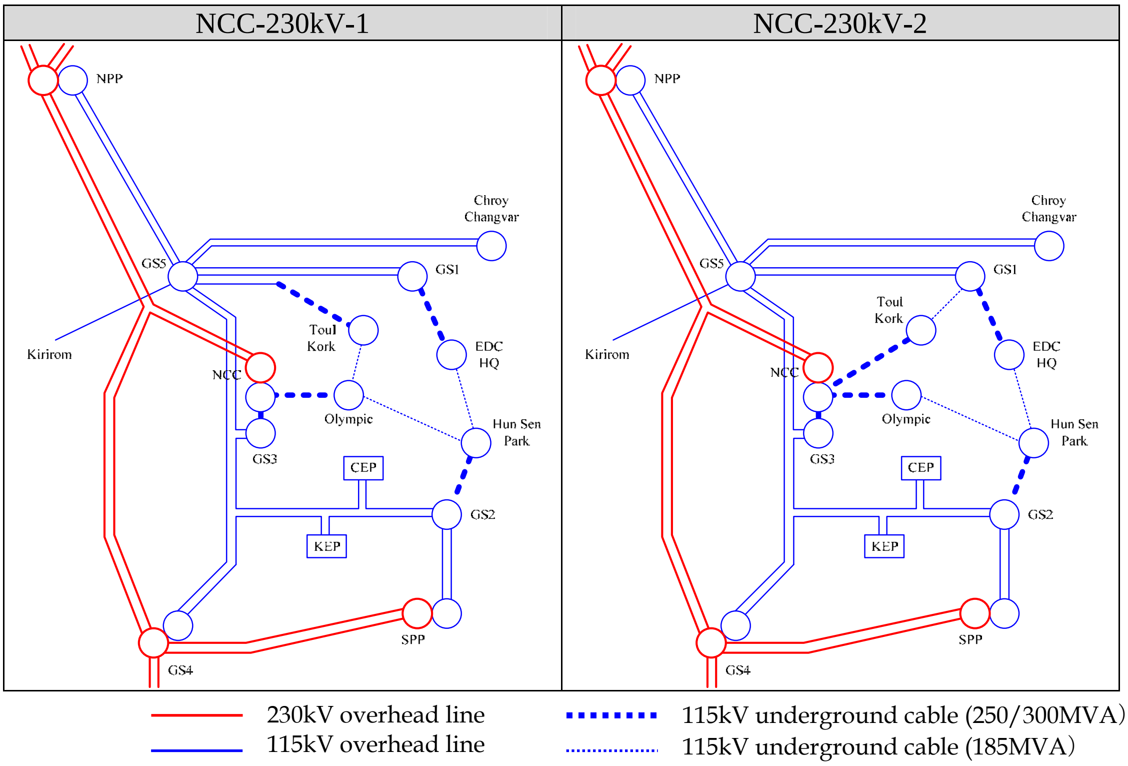


Figure 3. 24 Development of 230kV NCC Substation in 2020

The figures below show the active power flow diagrams. When the Phnom Penh system imports power from Vietnam, the loading level of 115kV GS2-Hun Sen Park line is still high, but the overloading is resolved. The systems don't have any overloaded lines under normal operating conditions, when it has a 230kV NCC substation.

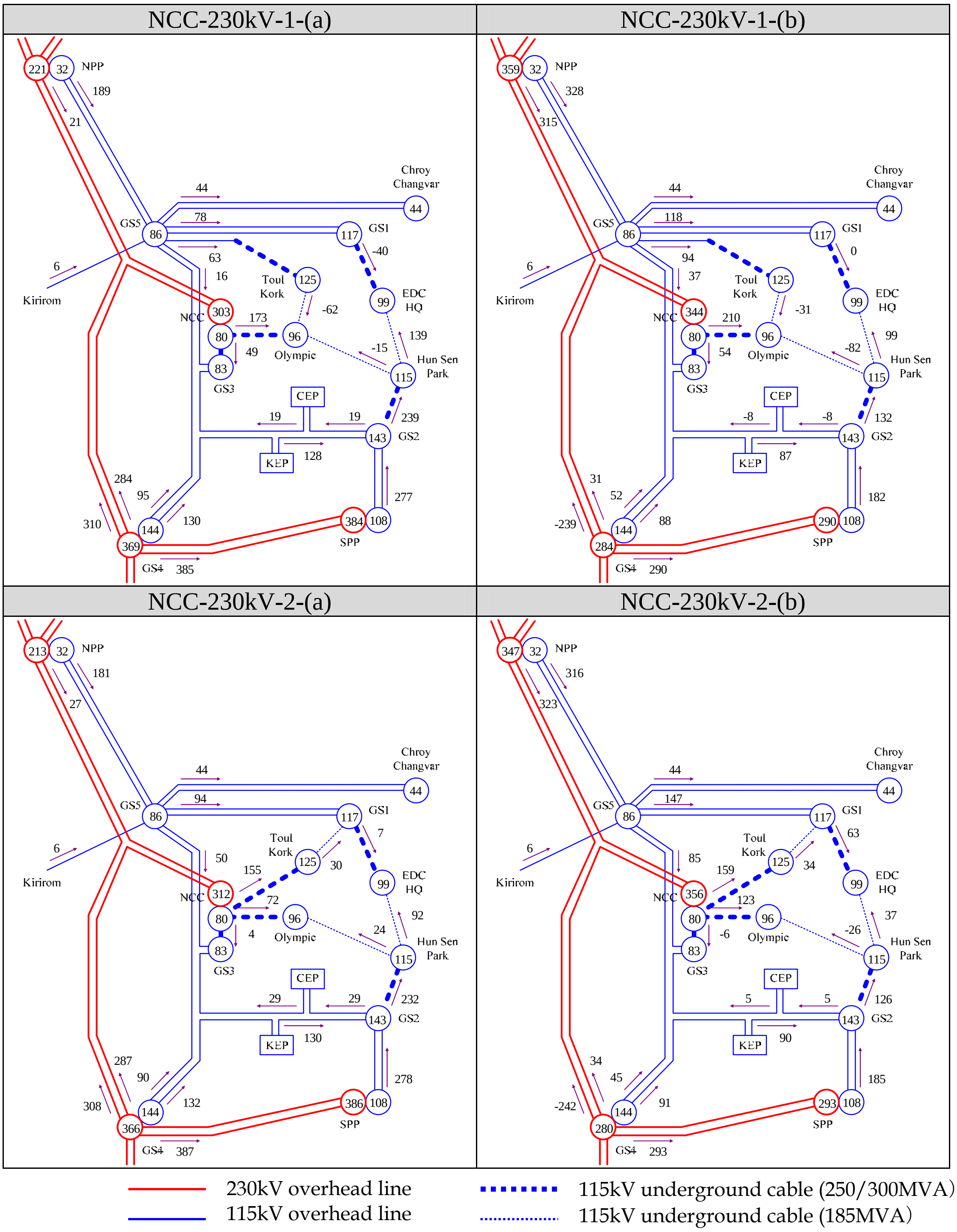


Figure 3. 25 Active Power Flow of the System with 230kV NCC Substation in 2020

The table below shows the results of the N-1 contingency analysis for the systems with the NCC substation in 2020. There is only one overloaded transmission line, 115kV GS2-Hun Sen Park, under the N-1 contingencies. Because this overloaded line is the underground cable, the system satisfied the Relaxed N-1 criteria applied as the system planning criteria in this study. As a result of the study, the JICA Study Team proposes 230kV-B as the best configuration since it doesn't have any overloaded lines.

Table 3. 19 Maximum Overloading under N-1 of Overhead Lines in 230kV-A

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
115kV GS2-Hun Sen Park	UG	284.6	341.2	115kV GS4-NPP	

Table 3. 20 Maximum Overloading under N-1 of Overhead Lines in 230kV-B

Overloaded transmission line	Type	Rating (MVA)	Maximum overloading (MVA)	Faulty line at maximum overloading	Overloading under normal condition
N/A					

3.4.7 Transmission System Voltage Control with Reactive Power Equipment

The system voltages decrease as the demands increase, and it needs to be compensated with reactive power equipment. In general, the shunt capacitor (SC) is used to raise the system voltage, while a shunt reactor is used to reduce the system voltage.
The proper allocation of SC improves the system voltage and the power factor of the transmission lines, and it leads to the reduction of MVA power flow on the transmission lines. The reactive power loss of the transmission line is high compared to the active power loss due to large reactance and small resistance of transmission lines, and it is preferred to install the reactive power equipment near demands in order to avoid the reactive power loss. Underground cables have approximately 10 times larger charging capacity, which raises the system voltage, than those of overhead lines. The charging capacities of 115kV underground cables proposed in this study are 1.1 MVar/km for 185MVA line and 2.2MVar/km for the 300MVA line.
This study analyzes the system voltages of the proposed NCC-230kV-2-(a) system with different amounts of SC in eight 115kV substations in Phnom Penh. In order to simplify the study, all reactive power equipment is disconnected from the system under the initial condition. The 230kV bus voltage at the GS4 substation is fixed at the rated voltage of the 230kV in the simulation.
The table below shows the 115kV bus voltages at the 115kV substations in Phnom Penh. As can be seen from the figure, the 115kV bus voltages are around 104kV without SCs, and it satisfies the system planning criteria of the voltage within ±10%. Most of the utilities in the world apply a ±5% voltage regulation criteria under the normal operating condition, and the system needs 40MVar SC at each substation and 320MVar in total in order to satisfy it. The voltage of the 230kV bus voltage of GS4, the source side, is fixed at 230kV of rated voltage, but it could become less than 230kV during actual operations. The amounts of SC must be determined taking this into account.
As a result, the system requires SCs of at least 300MVar in total in order to maintain the system voltages in Phnom Penh area in 2020. Since 115kV substations in Phnom Penh are located electrically close each other, actual installation amount can be adjusted in consideration of space available in each substation.
Figure 3. 26 shows the power flow diagrams without SC (0 MVar) and with 320 MVar SC in total (40 MVar at each substation)

Table 3. 21 115kV Bus Voltages in Phnom Penh

[kV]

Shunt capacitor at each substation (MVar)	0	20	40	60	80	100
Total (MVar)	0	160	320	480	640	800
GS1	103.8	106.9	110.0	113.2	116.6	120.1
GS2	104.7	107.5	110.4	113.4	116.4	119.7
GS3	104.2	107.2	110.2	113.4	116.6	120.0
GS5	105.3	108.0	110.8	113.6	116.6	119.6
EDC HQ	103.8	106.9	110.0	113.3	116.6	120.1
Hun Sen Park	104.1	107.1	110.2	113.3	116.6	120.0
Olympic	104.1	107.1	110.2	113.3	116.6	120.1
Toul Kok	104.0	107.0	110.1	113.3	116.6	120.1

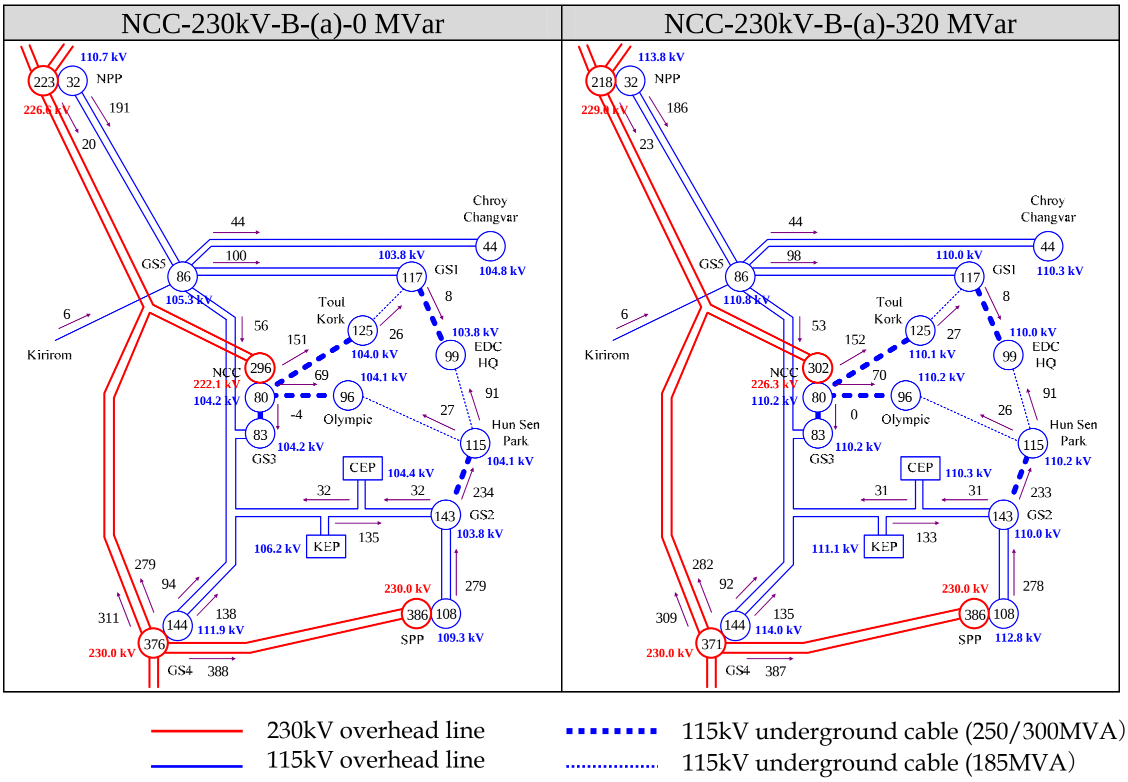


Figure 3. 26 Voltages of Phnom Penh in 2020 (SC: 0MVar / 320MVar)

Chapter 4 Results of Site Survey

4.1 Routes Survey

4.1.1 Substation

The sites of the existing substation and the candidate construction sites of the new substation are shown in Table 4. 1 and the substation map is shown in Figure 4. 1.
Pictures of their substation are shown in Appendix-4.1.

Table 4. 1 Existing Substation and New Substation

<table>
<tr><th>Existing/New</th><th>Substation</th><th>Required expansions/Facilities</th></tr>
<tr><td rowspan="5">Existing substation</td><td>GS-1</td><td rowspan="3">Installation of 115kV Feeder Bays for Underground cables.
Installation of relay panels and telecommunication facilities.
Expansion & of Substation Automation System</td></tr>
<tr><td>GS-2</td></tr>
<tr><td>GS-3</td></tr>
<tr><td>GS-4</td><td>Out of the scope of this project</td></tr>
<tr><td>GS-5</td><td>Under construction</td></tr>
<tr><td rowspan="3">New substations</td><td>EDC SS</td><td>115kV/22kV</td></tr>
<tr><td>Hunsen Park SS</td><td>115kV/22kV</td></tr>
<tr><td>Olympic Stadium SS</td><td>115kV/22kV</td></tr>
</table>

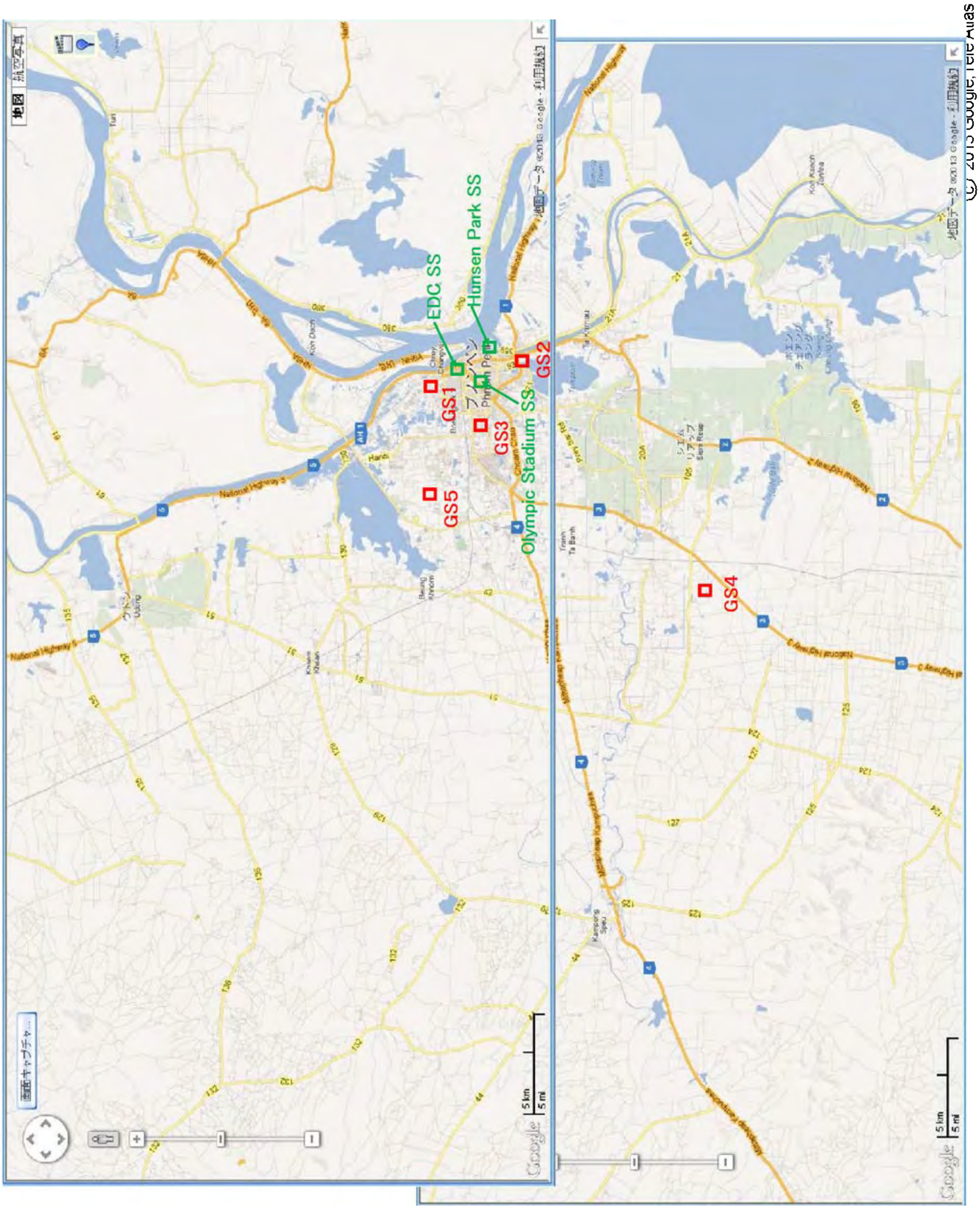


Figure 4. 1 Substation Map

4.1.2 Routes of the 115kV underground transmission lines

The JICA Team has surveyed the 115kV underground transmission lines, and selected the candidate transmission line routes as shown in Figure 4. 2 and the map of their routes is in Figure 4. 2.
The pictures of each new under transmission line are shown to the Appendix-4.1.
The transmission line of “UG-Route3” was decided in exclusion from the scope of work of this project after discussion between JICA and EDC.

Table 4. 2 Candidate Transmission Line Routes

Route	Location	Distance(m)
UG_Route1	[GS1～EDC SS]	2,330m
UG_Route2	[EDC SS～Hunsen Park SS]	3,330m
UG_Route3	[Hunsen Park SS～GS2]	(3,810m)
UG_Route4	[Olympic Stadium SS～Hunsen Park SS]	3,330m
UG_Route5	[GS3～OlympicStadium SS]	4,370m
Total distance		13,360m (17,170m)

( ) : UG_Route3 distance

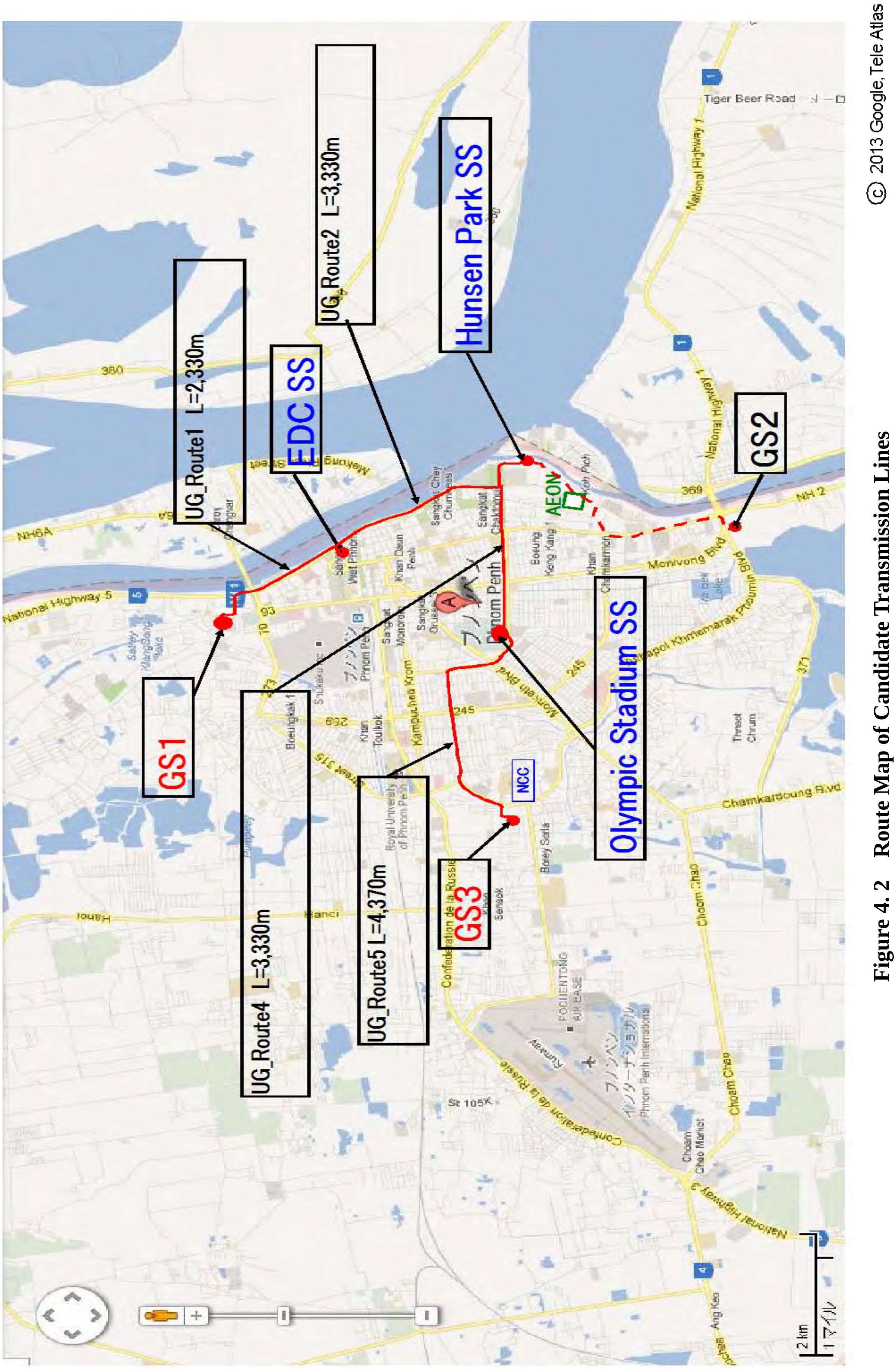


Figure 4. 2 Route Map of Candidate Transmission Lines

4.2 Findings in neighboring countries

4.2.1 Thailand

(1) Energy Regulation Committee Thailand（ERC）

(a) Interconnection with Cambodia

Interconnection between Cambodia has the power to the Battambang and Siem Reap transmission line by 115kV. The maximum power is 80MW.

Electricity exports to Cambodia, the Thai government supports the Cambodian government by cheaper price-based power. The system as well as in eastern Thailand, Ubon Ratchathani, there is less peripheral power, and the power system is a weak.

The interconnection capacity and the electricity sales price is determined by the (MOU) agreement between governments. The conditions and penalties for the power transaction, EDC and EGAT will work out the details for negotiation. It is expected that EGAT will report the detailed content of the agreement to the Thai Cabinet.

(b) Plan of interconnection with Cambodia

There is no plan of interconnection with Cambodia so far. The friendship price is not available for the next power export project to Cambodia, because the eastern Thai system has a lack of power and a weak system, and some investment for the Thai power system when there is a surplus in power export. It should be a market basis price.

(c) Power system situations in Eastern Thailand

The facility is becoming aged. EGAT will proceed with renovation plans in the next five years, the situation will be improved.

(d) Operation in the GMS region

The organization will be established to operate a transmission system in the GMS region supported by ADB. It has not been established yet. Some member countries would establish an entity to manage the bulk system in the GMS region. The Thai government, however, should operate their system themselves to secure frequency and voltage by their own responsibility.

(e) System operation in the Cambodia system

EDC should operate their system. EDC does not notify the details of the test operation in the system that is connected in the interconnection.

4.2.2 Vietnam

(1) EVN Southern Load Dispatch Center（SLDC）

(a) Present situation of Interconnection with Cambodia

There have been two forced-outages in the interconnection since it was commissioning. One was a failure of a line arrester (LA). Second, the operator had mistook the switch gears of the operation at Takeo substation. There is no root shat down and only one circuit failure. The operational error had occurred.   Therefore, the operating procedure table was sent by facsimile from the Vietnamese side. At this time, there are some instructors from the China manufacturer at the Takeo substation.

The power transmission capacity in a current PPA is 170MW increasing sequentially. Most recently, the EDC requested 200MW to the Vietnamese side. The capacity of the transmission line is 285MW. The conductor size is 797MCM of the single conductor on the Cambodian side. The conductor size is 450mm2 of the double bundle on the Vietnamese side. The allowable current is 880A from the heat capacity condition.

The system configuration of the interconnection between Cambodia and Vietnam is formed without synchronization with generators of the Cambodia system. The interconnection is connected with the loads only. The grid interconnection procedure is that first, the interconnection line is energized by the supply side, the Vietnamese substation, then the EDC connects their loads at the Takeo substation. The EDC should discuss with EVN, if the generator is connected to the Vietnamese system through the interconnection.

EDC and the Trading company of EVN holds a discussion on the PPA issues. The measurement of meter is carried out by the PTC4. The cross checking of the meter is performed by the PTC4, trading company of EVN and EDC.

(b) Frequency control and power flow control in the interconnection line

According to the EVN standard, the frequency is controlled within 50±0.2Hz. Under normal conditions, the frequency is controlled by the level 1 generator as the Dai Ninh hydropower plant and the Tri An hydropower plant. The frequency is controlled within ±0.5Hz at N-1. Under the N-1 incident, the level 2 operation is performed which are starting other generators. The UFR is performed to control the load shedding.

(c) Protection relay

Although the protection relay is designed to operate a difference relay, it has not been operating yet due to a delay of the commissioning of the OPGW communication system. The distance relay is protected in the range of 85%. Thus, there are the blind spots of the relay protection near the bus bar.

(2) EVN National Power Transmission Company（NPT）Power Transmission Company 4 (PTC4)

(a) Present situation of Interconnection with Cambodia

There were two incidents since March 2009, the interconnection between Cambodia and Vietnam had been operated. There was, however, only single circuit failure, no root down.

(b) Current status of the interconnection transmission line maintenance

The interconnection line is inspected one line each once a year. The date of the interconnection line maintenance is decided after discussion with EDC through the National Load Dispatching Center (NLDC) named A0. After notifying EDC from the SLDC on the determined day of maintenance, the PTC4 conducts maintenance on the Vietnamese side of the interconnection facilities. The No. 84 tower separates the interconnection facility between the Cambodian side and the Vietnamese side. The facilities on the Vietnamese side is made by the Alstom. The facility on the Cambodian side is made by a Chinese manufacturer. The PTC4 conducted training of maintenance for EDC in 2011. The EDC, however, has requested PTC4's support to mount accessories for every equipment failure.

The measurement of the energy meter is conducted by PTC4. The meter is cross checked by the tree parties as EDC, PTC4 and the Trading company. The trading company is a subsidiary company of EVN and it negotiates PPA with EDC.

(c) Interconnection facility design

The Vietnamese side facilities are designed based on the EVN design guideline and criteria. The design of Cambodian side facilities is different from the Vietnamese side, because they were designed by foreign consultants. Transmission capacities on both sides are almost same.

4.3 Soil Investigation

4.3.1 Summary of the geological survey

In the site of the EDC HeadQuarters where the construction of the substation is planned, The JICA Team carried out a geological survey for the purpose of obtaining geological feature data for the basic designs of the new substation.
A summary of the geological survey is shown below and a plan of a detailed geological survey is shown in Appendix-4.3.

(1) Investigation Date : 20/01/2013
(2) Location : EDC Head Quarter (Wat Phom ,Phnom Penh)
(3) Borehole : One bore hole/The diameter of 180 mm/End of SPT Test 19.5m Depth
(4) Laboratory test : 13 samples

4.3.2 Summary of the soil investigation results

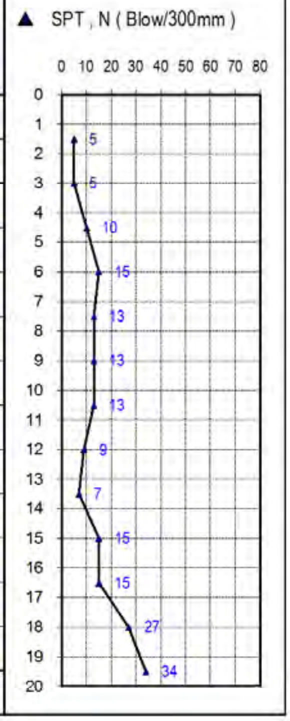
The bore hole log is shown in Figure 4. 3 and a summary of the laboratory test is in Table 4. 3.
Detailed soil investigation results are shown in Appendix-4.3.

BORE HOLE LOG BH.1

Sub-Contractor: Partner of Construction and Development Services Inc.	Method :Rotary Auger Casing Size : 180 mm Elevation: ....m	Date started : 20/1/2013 Date finished : 20/1/2013 Project : Sub Station Location : EDC (Wat Phnom, Phnom Penh)	

Depth to water flow: 4.00m
Depth to water Level: 4.00m

Sampling Depth, m From	To	Type of Sampling U / SPT	Strata (m)	Legend	Description of soil	N1=150mm	N2=300mm	N3=450mm	N=N2+N3
D1: 1.05 -	1.50	SPT	1.50		Loose brownish fine SAND	3	3	2	5
D2: 2.55 -	3.00	SPT	1.50		Firm brownish CLAY	2	2	3	5
D3: 4.05 -	4.50	SPT	1.50		Loose brownish fine SAND	4	6	4	10
D4: 5.55 -	6.00	SPT	9.00		Firm to stiff brownish, grayish, light gray fat CLAY	4	5	10	15
D5: 7.05 -	7.50	SPT				3	5	8	13
D6: 8.55 -	9.00	SPT				4	5	8	13
D7:10.05 -	10.50	SPT				4	5	8	13
D8:11.55 -	12.00	SPT				3	4	5	9
D9:13.05 -	13.50	SPT				3	3	4	7
D10:14.55 -	15.00	SPT	6.00		Medium dense to dense grayish, fine SAND	4	5	10	15
D11:16.05 -	16.50	SPT				4	8	7	15
D12:17.55 -	18.00	SPT				5	9	18	27
D13:19.05 -	19.50	SPT				6	14	20	34
					END of SPT Test19.50m Deth				



Consistency	Very soft	Soft	Firm	Stiff	Very Stiff	Hard
Blows 30Cm, Clay	Less 2	2 - 4	4 - 8	8 - 15	15 - 30	> 30
Relate. Density, Blows/300mm		Very Loose	Loose	Med. Dense	Dense	Very Dense
Fine		1 - 2	3 - 6	7 - 15	16 - 30	?
medium		2 - 3	4 - 7	8 - 20	21 - 40	> 40
coarse		3 - 6	5 - 9	10 - 25	26 - 45	> 45
Unit weight of granular soil base, γ_{sat} kN/m^3		11 - 16	14 - 18	17 - 20	17 - 22	20 - 23

LEGEND

- Stiff to hard sandy clay, lean Clay
- Firm to stiff silty clay/ lean Clay
- stiff to hard clay , fat Clay
- Clayey sand,Silty Sand
- V. Soft to soft clay, organic clay
- Fill/topsoil
- Gravelly Sand, Clean Sand
- Silty coarse sand with gravel
- Weather Rock
- Sandstone

Standard Penetration Test (SPT)
SPT
SPT - N Value

Figure 4. 3 Bore Hole Log

Table 4. 3 Summary of Laboratory Test

Soil Quality Analysis Office.

Project : Sub Station

Location : EDC (Wat Phnom, Phnom Penh)

DATE : 20/1/2013

TESTED BY : Mr. Chea Sery Vuth

Table.2

Boring No	Sample	Depth(m)		SPT - N Value, Every 150Cm Blows / 300mm				Soil description	Unified Clasification	NMC W (%)	Bulk density γ_w (g/cm^3)	Dry density γ_d (g/cm^3)	Atterberg limit			Grain size			Unconf. Strength q_u,kg/cm^2)	Shear Strength	
		From	To	N1	N2	N3	N						LL (%)	PL (%)	PI (%)	Clay and Silt %	Sand %	Gravel %		Cohesion Kpa	Friction Angle Degree (°)
BH.1	D1	1.05	1.50	3	3	2	5	Loose brownish fine SAND	SC	9.94	1.902	1.730	-	-	-	10.64	86.25	3.11	-	-	29
	D2	2.55	3.00	2	2	3	5	Firm brownish CLAY	CL	24.76	2.211	1.772	40.40	17.86	22.54	-	-	-	70.00	35.00	
	D3	4.05	4.50	4	6	4	10	Loose brownish fine SAND	SC	18.91	1.956	1.645	-	-	-	16.62	83.09	0.29			31
	D4	5.55	6.00	4	5	10	15	Firm to stiff brownish, grayish, light gray fat CLAY	CL	24.46	2.229	1.791	49.20	18.47	30.73	-	-	-	240.00	120.00	-
	D5	7.05	7.50	3	5	8	13			21.06	2.216	1.830	36.50	14.24	22.26	-	-	-	182.00	91.00	-
	D6	8.55	9.00	4	5	8	13		CH	27.42	2.220	1.742	71.60	18.01	53.59	-	-	-	234.00	117.00	-
	D7	10.05	10.50	4	5	8	13			25.78	2.221	1.766	67.20	21.05	46.15	-	-	-	234.00	117.00	-
	D8	11.55	12.00	3	4	5	9		CL	20.41	2.219	1.843	37.20	17.30	19.90	-	-	-	126.00	63.00	-
	D9	13.05	13.50	3	3	4	7			19.59	2.214	1.851	37.20	18.10	19.10	-	-	-	98.00	49.00	-
	D10	14.55	15.00	4	5	10	15	Medium dense to dense grayish, fine SAND	SC	21.76	2.115	1.737	-	-	-	23.48	76.52	0.00	-	-	32
	D11	16.05	16.50	4	8	7	15			24.32	2.127	1.711	-	-	-	17.32	82.68	0.00	-	-	32
	D12	17.55	18.00	5	9	18	27			18.19	2.150	1.819	-	-	-	16.14	83.86	0.00	-	-	37
	D13	19.05	19.50	6	14	20	34		SC-WG	18.84	2.179	1.834	-	-	-	17.35	71.74	10.91	-	-	39
								END OF SPT TEST 19.50m DEPTH													

4.4 Site Survey for Environmental and Social Considerations

The reconnaissance survey was implemented to investigate the current situation of the proposed site of the substations and the routes of the transmission/distribution line. The survey of the noise and traffic volume aimed to acquire the baseline data before the construction work.

4.4.1 Traffic Volume Survey

The traffic volume survey shown in this section and the noise survey shown in the next section were implemented via the subcontractor work at a point closed to the site where the construction noise might arise or traffic noise caused by a construction vehicle might be increased.

(1) Method

Two survey points were selected taking into account their long-term impact compared with the transmission line construction. One point is close to the proposed site of the SS in EDC HQ and another is close to the proposed site of SS near the Olympic Stadium. The details of the survey points are shown in Table 4. 4. The location map and picture are shown in Figure 4. 4.

The traffic was counted according to the classification shown in Table 4. 5. The measurement period was 24 hours and the measurement time was ten minutes per each hour. The survey period from the 2nd to the 4th January are weekdays in Cambodia.

Table 4. 4 Time Period and Point for the Survey of Traffic and Noise

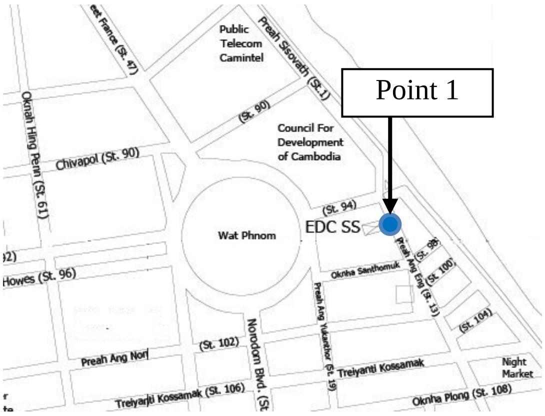
Survey Point		Latitude	Longitude	Site description	Survey period
Point 1	EDC SS	11º 34' 35''.0	104º 55' 31''.4	Prean Ang Eng Street(ROW:7.8m, 2 car lanes), 4.5 m far away from the road side at back gate of EDC HQ	6.00AM Jan 02 2013 - 6.00AM Jan 03 2013
Point 2	Olympic Stadium SS	11º 33' 25''.0	104º 54' 33''.2	Preah Sihanouk Street(ROW:16.8m, 6 car lanes), 2.6 m far away from the road side, near the Olympic Stadium	6.00 AM Jan 03 2013 - 6.00AM Jan 04 2013

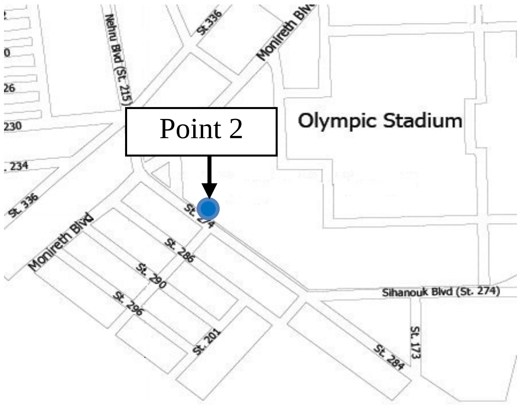
Source: JICA Survey Team

Table 4. 5 Vehicle Classification for the Survey

Classification	**Vehicle**
Type I	Motorbike / Motor tricycle, Motorbike trailer
Type II	Sedan, Wagon/Light Van, Pickup, Jeep/Light Truck
Type III	Short & Long Body Truck / Semi and Full Trailer Truck
Type IV	Short & Long Body Bus

Source: JICA Survey Team





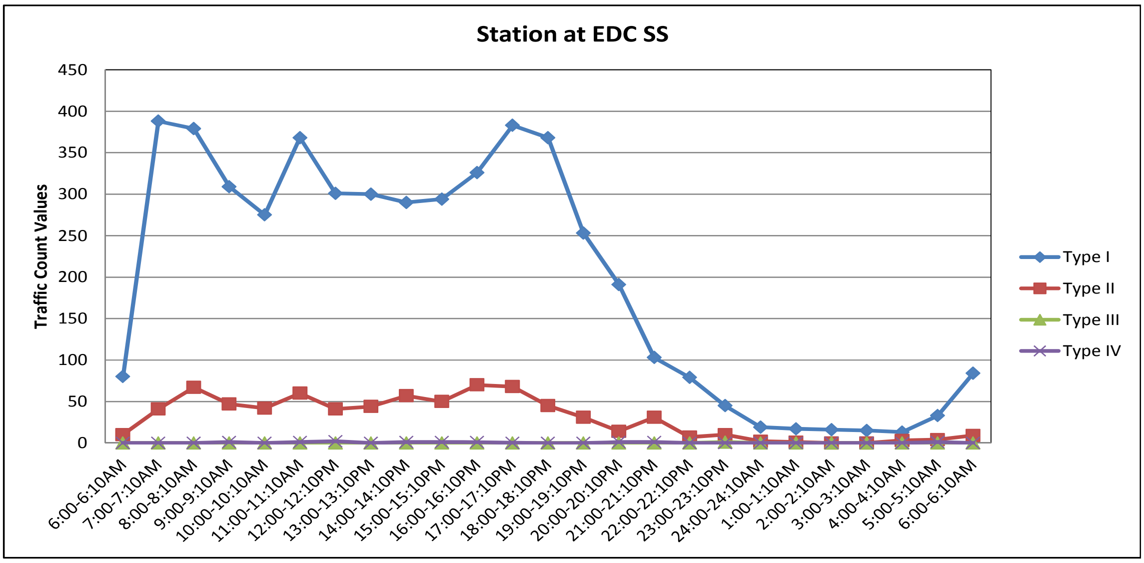
Point 1 (EDC HQ)	Point 2（Olympic Stadium）

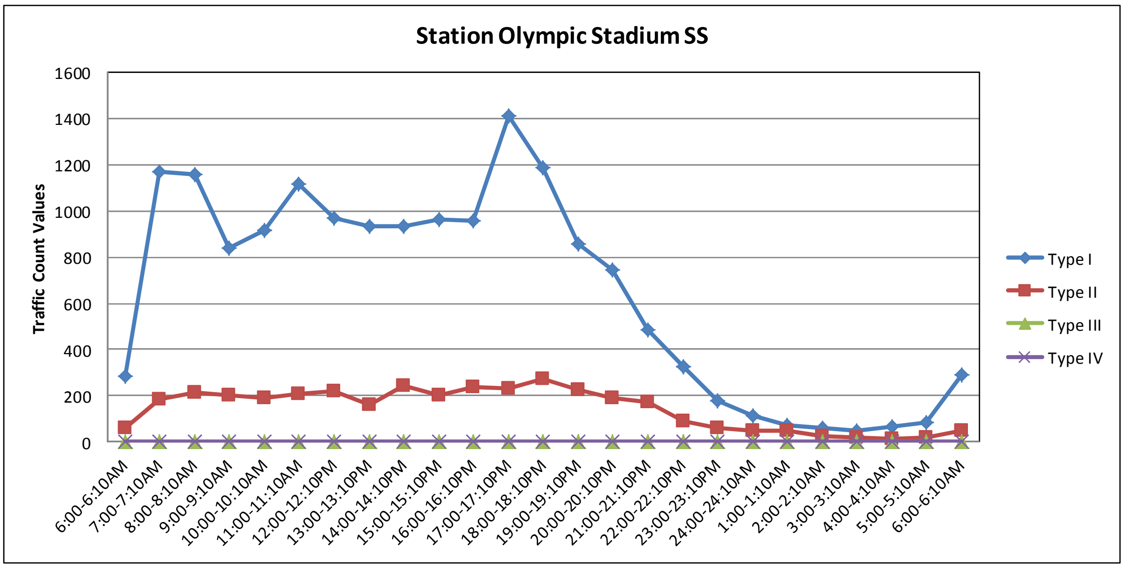
Source: JICA Survey Team

Figure 4. 4 Location Map and Picture for Traffic Count and Noise

(2) Results of the traffic count

The total traffic count of all lanes per each hour is shown in Figure 4. 5. The maximum volume at Point 1 near EDC HQ is approximately 2400 vehicles /hour and the maximum volume at Point 2 near the Olympic Stadium is approximately 8400 vehicles/hour. At both points, traffic peaks at the time periods from 7:00, 11:00 and 17:00, the commuter rush in the morning, rush hour during the lunch break and the commuter rush in the evening. Comparisons are based on the vehicle category. The Type I motorbikes etc had the most traffic volume for all of the time periods. Approximately 90 vehicles/hour at Point 1 at EDC HQ and approximately 290 vehicles/hour at Point 2 were counted even at the time period from 3:00. Although the total volume significantly decreased at midnight. Point 2 had much more traffic volume compared with Point 1 because the road in front of Point 2 is one of the main avenues in the City with a total of six lanes.





Source: JICA Survey Team

Figure 4. 5 Results of Traffic Volume

4.4.2 Noise Survey

A noise survey was implemented via the subcontractor work at the point closed to the site where construction noise might arise or traffic noise caused by a construction vehicle might be increased, as well as the traffic volume survey.

(1) Method

The Noise level was monitored by a noise level meter at the same site of the traffic volume survey. The details of the survey point were already shown in Table 4. 4. The location map and picture were also shown in Figure 4. 4. The measurement period is 24 hours and the measurement time is ten minutes per each hour.

(2) Result

The resulting noise level (LAeq) for each measurement time was shown in Table 4. 6 and Figure 4. 6. The noise level at the period from 6:00 to 18:00 was 67db which is a little lower than standard (70 dB). In the evening and midnight from 18:00 – 6:00, the noise level was not satisfied by their standards. It is presumed that heavy traffic volume was the main reason because Preah Sihanouk Street along Point 1 is one of the most crowded avenues in the City.

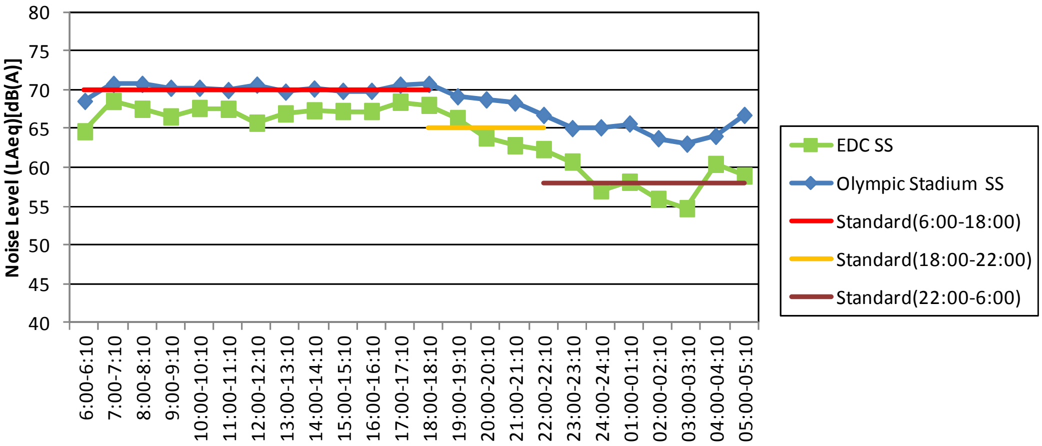
According to the surveyor's observation, it has been considered that this noise data was caused by traffic noise such as the sound of engines and fuming exhaust from motorbikes or other vehicles. Apparently the time trend of the noise decreasing between 18:00 and 22:00 at Point 1 at EDC HQ is correlated to one of the traffic volumes. At point 1 at EDC HQ, the noise level during the day time is less than the environmental standard. However, the noise level during the midnight hour exceeds the standard. The possible reason is that there is some traffic volume from the motorbikes etc during the midnight hour even though the midnight standard is 20dB stricter than the daytime hours. On the other hand, Point 2 near the Olympic Stadium has a higher noise level base line which is equal to or higher than the standard because there is much traffic throughout the day.

Table 4. 6 Result of the Noise Level

Survey Point		Surrounding Land use	Time Zone					
			6:00-18:00		18:00-22:00		22:00-6:00	
			Noise level (LAeq)[dB]	Standard in Cambodia [dB]	Noise level (LAeq)[dB]	Standard in Cambodia [dB]	Noise level (LAeq)[dB]	Standard in Cambodia [dB]
Point 1	EDC SS	Office, resident etc	67	70	65	65	58	50
Point 2	Olympic Stadium SS	Park, shops, resident etc	70	70	69	65	55	50

Note) The Noise Standards in the above table is MoE Standard, Maximum permitted noise level (dB(A)) in public and residential area for Commercial and service areas and mix, published by MOE.

Source: JICA Survey Team



Source: JICA Survey Tea m

Figure 4. 6 Results of Noise Level

4.4.3 Reconnaissance Survey for the Proposed Site

In the reconnaissance survey, the surrounding conditions and the land owner for the proposed site of the substations are confirmed as shown in Table 4. 7 and Table 4. 8. The sites of GS1, GS2 and GS3 that would be served for the expanded construction are owned and used by EDC. These sites do not require land acquisition and compensation. In the Olympic Stadium Park, some proposed sites whose land owner is the Ministry of Education were under consideration. EDC negotiated with the Ministry of Educations and confirmed the land of Option 2 can be ceded to EDC.

On the other hand, this project requires the other small type of substations which connect a 22kV distribution line. As of this Survey, new land acquisition is not necessary for these substations because the existing substations will be used.

Table 4. 7 State of the Proposed Site for Expanded SS

Item	GS	
	GS1	GS3
New/ Expansion of Substation	Expansion	Expansion
Installed/Expanded Facilities (To be updated)	- Installation of 115kV Feeder Bays - Expand the communication facilities and protection relay system - Modification of the Substation Automation System, etc	
Land Scale	To be designed	To be designed
Land owner	EDC	EDC
Background of land acquisition	Used for the existing substation	Used for the existing substation
Necessary permission and procedure for acquisition in this project	N/A	N/A
Natural Environment	Gravel, grass, concrete	Gravel, grass, concrete
Social Condition	The proposed space is located in the existing substation site. The only staff involved in EDC is able to enter. The surrounding area is the residence and shop areas. The primary school is located at approximately 150 m far away in the north from the gate of the substations.	The proposed space is located in the existing substation site. Only the staff involved in EDC is able to enter. The surrounding area is a residence and open area etc.

Source: JICA Survey Team

Table 4. 8 State of the Proposed Site for New SS

Item	SS				
	EDC HQ	Olympic Stadium			
		Option 1	Option 2	Option 3	Option 4
New/ Expansion of Substation	New	New	New	New	New
Installed/Expanded Facilities	115kV/22kV, 75MVA Tr (Q'ty: 2)	115kV/22kV, 75MVA Tr (Q'ty: 2)			
Land Scale (under consideration)	20 x 40 m^2	35 x 50 m^2	35 x 50 m^2	35 x 50 m^2	35 x 50 m^2
Land owner	EDC	Ministry of Education	Ministry of Education	Ministry of Education	Ministry of Education
Background of land acquisition	Used as the facilities or parking space of EDC	To be confirmed	Used as the soccer field	Used as the regulation pond	Used as the regulation pond
Necessary permission and procedure for acquisition in this project	N/A	EDC needs to negotiate with the Ministry of Education to use the site	EDC needs to negotiate with Ministry of Education to use the site	EDC needs to negotiate with Ministry of Education to use the site	EDC needs to negotiate with Ministry of Education to use the site
Natural Environment/ Land use	Parking	Open developed land	Soccer field	Pond, wetland (rainwater storage)	Wetland(rainwater storage)
Social Condition	- Only the staff involved in EDC is able to enter. - This space is currently used as a parking lot. An alternative parking space will be necessary. - The surroundings are office buildings and What Phnom and shops etc.	- There is a tentative house which construction workers seem to use.. It seems that the development plan of this site is going on.	If this site was selected, the succor field needs to be prepared at other locations.	This site has the drainage function and the pond works during floods. After the drainage work around the Olympic Stadium is finished, this site can be filled.	This site has the drainage function and the pond works during floods. After the drainage work around the Olympic Stadium is finished, this site can be filled.
Note	-	- The Survey Team proposed the sites. As the result of the discussion between EDC and the Ministry of education, Option site is chosen for the planed site which can be ceded (as of November, 2013)			

Source: JICA Survey Team

4.4.4 Route Survey of Transmission line

Regarding the under transmission line, a total of four routes are under consideration which links to each other substation. Some information on the feature of each route is shown in Table 4. 9. The route will be finalized in consideration of the road conditions, underground facilities, land use, the socio-environmental impact and so on. The current plan indicates that the underground cable will be buried under the public car lane and for now includes no private land such as farm lands etc.

Table 4. 9 Proposed Route of the Transmission Line

Item	Transmission line			
	Route1	Route2	Route4	Route5
Route	GS1 - EDC SS	EDC SS - Hunsen Park SS	Olympic Stadium SS – Hunsen Park SS	GS3 - OlympicStadium SS
Length (approximately)	2,330 m	3,330 m	3,730m	3,970m
Supervisor of road	National Road NO.5: MPWT City road: PPM(Phnom Penh Municipality)	City road: PPM	City road: PPM	City road: PPM
Surrounding condition	The area around GS1 is very crowded with residents and shops. National road No.5 along the river is busy and there are many restaurants and hotels etc.	The Sisowath Quay Str. along the river has many restaurants, shops and commercial building. This area is the tourist spot so that the considerate construction work is required especially for the area in front of Royal Palace.	SihanoukAvenue has six car lanes and there are many restaurants, shops and offices along the street.	This route passes the cross road between Sihanouk street which is a busy road near the Olympic Stadium and Monireth Street. After turning left from Jawaharlal Nehru Street, Route 182 is surrounded with small shops.

Note) Route3(Hunsen Park SS～GS2) is not applicable in this Survey.

Source: JICA Survey Team

4.4.5 Route Survey of Distribution line

The planned distribution line route is located around the EDC HQ and Olympic Stadium. The route will be finalized with the consideration of surrounding traffic conditions, underground facilities, land use and the socio-environmental impact as well as the T/L. As for the distribution line, the construction area will directly profit from the project. And the scale of the construction work will be smaller than one of T/L. Thus, the comprehensive impact is expected to be minor. In the current plan, the distribution line will be buried below the public car road or pathway.

However, the route around the Olympic Stadium goes through the Olympic Market in order to connect to the distribution board in the Market. The road shown in Figure 4. 7 is managed by the business center of the Olympic Stadium and the existing distribution line is already buried. In the current plan, the construction work will be implemented during the night time when the market is closed and the road will be recovered during the daytime. Though it will not affect commercial activities of the market shop Therefore, consultation with the business center and getting advance construction approval will be necessary. Environmental and social considerations will be undertaken again after the distribution route is finalized at the detailed design phase.

Source: JICA Survey Team

Figure 4. 7 Road in the Olympic Stadium

Chapter 5 Environmental and Social Considerations

5.1 Project Component

This project involves the construction of two new substations, 115kV transmission lines and a 22kV distribution line and the modification of existing substations. The scope of the survey on environmental and social considerations is described in Table 5. 1 based on the feasibility design of the substations and the transmission /distribution line route.

Table 5. 1 Scope of the Survey on Environmental and Social Considerations

Item	Point/Route
New GIS substation	EDC Headquarters Substation
	Olympic Stadium Substation
Modification of substation	GS1
	GS3
115kV Underground Transmission Line	GS1 － EDC Headquarters SS
	EDC SS – HunSen Park SS
	Olympic Stadium SS - Hunsen Park SS
	GS3 - OlympicStadium SS
22kV Distribution Line	Area near the EDC Head Office
	Area near the Olympic Stadium

Source: JICA Survey Team

5.2 Related Regulations and Organization

This chapter describes the legal framework in Cambodia with regards to the Environmental Impact Assessment (EIA), land acquisition, resettlement and compensation. The Survey Team implements the gap analysis between the requirements by Cambodian law and the JICA Guidelines for Environmental and Social Considerations (Apr. 2010) (herein after "the new JICA Guidelines") in order to confirm the regulations and procedures this project should follow. In addition, relevant organizations are shown to be used for the preparation of the environmental management plan and the environmental monitoring plan.

5.2.1 Organization in charge of Environmental and Social Considerations

(1) Environmental department of EDC

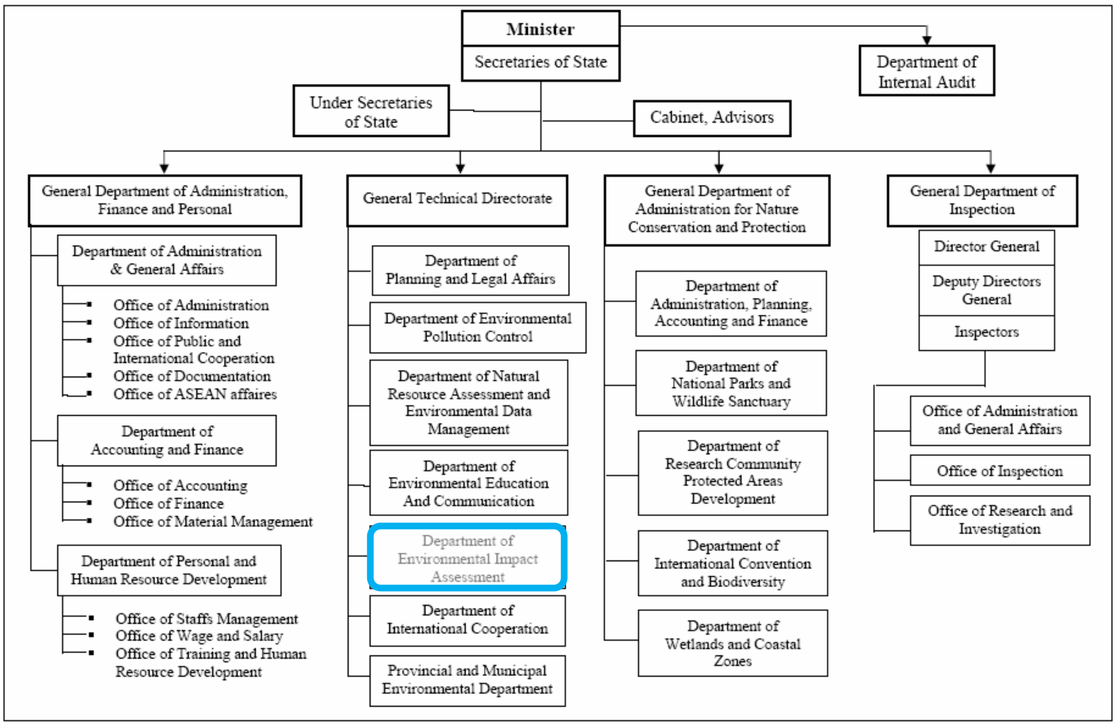
The Social, Environmental & Public Relations Office under the Corporate Planning & Project Department in EDC was founded on the 7th, July 2003 and began to operate practically from the 9th, May 2004 because no staff was assigned at first. They are in charge of Environmental and Social Considerations including IEIA (Initial Environmental Impact Assessment; equal to IEE) / EIA, land acquisition, resettlement and waste management etc. regarding the EDC project. One of their outputs is the IEE report for the Kampot Sihanoukville Transmission Line (Dec. 2005) founded by ADB. The Social, Environmental & Public Relations Office will cooperate with the Procurement Division of the Corporate Planning & Project Dept. in EDC, and DPWT and DLMUPC etc of the Phnom Penh Municipality when the project faces the issue of resettlement or land acquisition.

This department had eight staff in total as of 2012, though two of them were assigned for overseas training. They plan to recruit an additional two staff in 2013.

(2) MOE

The Ministry of Environment (MoE) is empowered by law to protect and enhance the nation's environmental resources and implement sub-decrees related to environmental impact assessment (EIA), air and water pollution control, and solid waste management that aim to mitigate environmentally damaging activities. The Sub-decree on the EIA Process in article 3 stated that MoE has the duties to examine and evaluate the EIA report in collaboration with other line-ministries, and to conduct monitoring during the project construction, operations, and closure for assuring that the project activities in compliance with the guideline/standards of Cambodia and EMP in the approved IEIA/EIA report.

The DEIA (Department of the Environmental Impact Assessment) is funded under the General Technical Department of MOE in 1994 and in charge of checking EIA/IEIA and the monitoring of the environmental management plan for the public and private project. An organizational chart is shown in Figure 5. 1.



Source: Department of Environmental Impact Assessment, Ministry of Environment

Figure 5. 1 Organization Chart of MOE

(3) Related Organization in the National Government

(a) Ministry of Economics and Finance(MEF)

The Resettlement Department (RD) is in charge of the administration of legislation and policy related to involuntary resettlement and land acquisition. RD, moreover, serves as a secretariat to the Inter-Ministerial Resettlement Committee (IRC) on Resettlement, which is a kind of construction body for the projects involved with involuntary resettlement and land acquisition.

(b) Ministry of Public Works and Transport(MPWT)

The Ministry of Public Works and Transport has three general directorates (General Directorate of Administrative Service, General Directorate of Transports and General Directorate of Public Works), Department of General Inspection, and Department of Finance Audit Control as the government ministry and twenty four Public Work Divisions per region. The MPWT is involved in the preparation of the Sub-Decree regarding the national roads and the railway road and supervises the national road with one digit and two digits and the provincial road.

(c) Department of Public Work and Transportation (DPWT)

The DPWT is the outpost agency of MPWT in the provinces. DPWT in Phnom Penh Municipality is responsible for the construction and maintenance of transportation infrastructures such as roads or bridges in Phnom Penh City

(d) Ministry of Industry, Mines and Energy(MIME)

MIME controls the administration of law and regulation, planning of strategy and technical standards in the power sector.

(e) Ministry of Land management, Urban Planning and Construction (MLMUPC)

MLMUPC provides the land law and the declaration against illegal construction in the national public land in the urban area.

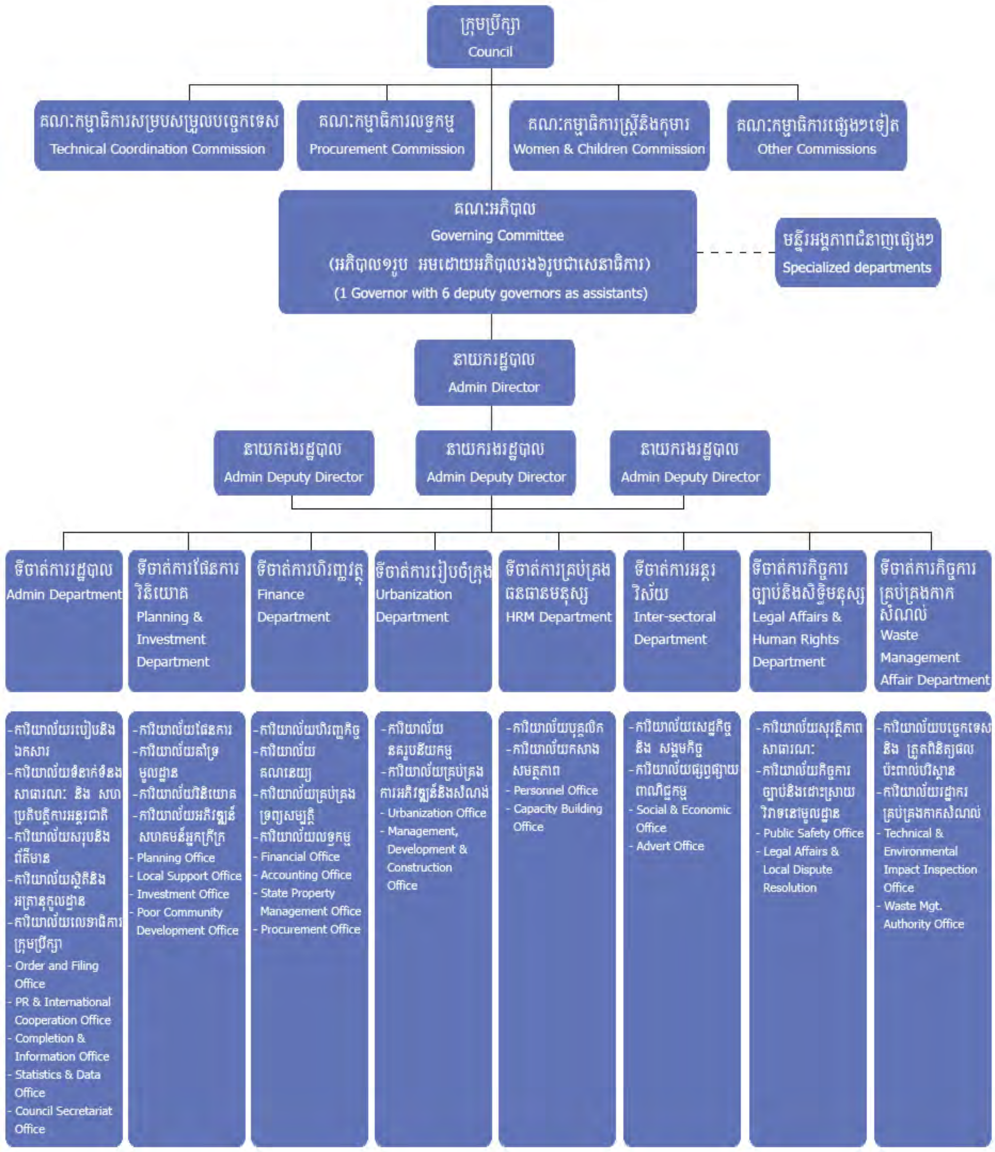
(f) Department of Land management, Urban Planning and Construction (DLMUPC)

DLMUPC is the local agency in Phnom Penh Municipality of MLMUPC.

(4) Related Organization in the Phnom Penh Municipality and under the local government

(a) EIA/IEIA department in the Phnom Penh Municipality

Technical & Environmental Impact Inspection office under the Waste Management Affair Department is supposed to take care of EIA for the municipal project. They work for the waste management mainly. The organizational chart in the Phnom Penh Municipality is shown in Figure 5. 2.



Source: http://www.phnompenh.gov.kh/org_chart.php(Website of Phnom Penh Municipality, confirmed on 19th , Jan. 2013)

Figure 5. 2 Organization Chart of Phnom Penh Municipality

(b) The Police and Transport Police in the Phnom Penh Municipality

The Phnom Penh Municipality Police and the Office of Traffic Police are responsible for traffic control, nabbing traffic offenders and investigating traffic accidents etc. in accordance with the Law on Land.

5.2.2 Law and Regulations

(1) Environmental/Related Law and Regulations in Cambodia

(a) Environmental legal framework

The Law on Environmental Protection and Natural Resource Management enacted in 1996 is the fundamental environmental law in Cambodia. Article 6 in Chapter 3 specified that EIA should be conducted for every public and private project and submitted to the Royal Government of Cambodia (RGC) after approval by MOE. The Sub-Decree on the Environmental Impact Assessment Process defines EIA and the target project of IEIA/ EIA whose Annex shows the list of categories and the scale of the project which needs to implement IEIA/EIA. The procedures of the preparation and the approval of IEIA/IEE follow “Prakas (Declaration) on the General Guideline for Conducting Initial and Full Environmental Impact Assessment Reports”. The other related laws and their summary are shown in Table 5. 2.

Table 5. 2 Related Laws, Sub-Decrees and Regulation

No.	Title	Enacted Year	Summary
Basic law			
1	Law on Environmental Protection and Natural Resource Management (LEPNRM)	1996	It is Environmental Basic Law in Cambodia in which chapter III stipulates EIA shall be conducted on every private or public project and activity, and shall be approved by the MOE before being submitted to the Royal Government of Cambodia (RGC) for decision. Article 7 provides the operative provision of IEIA. This law includes the other provisions about the natural resource management, environmental protection, monitoring, inspection, public participation, access to information. Environmental fund and penalties.
EIA			
2	Sub-Decree on Environmental Impact Assessment Process	1999	This Sub-Decree specifies the definition of “EIA”, target project types, public participation and others. In case that project has an adverse effect on the socio-environment, the project owner is required to submit an EIA report to MOE, and MOE reviews the EIA report and monitors the project. The Annex stipulates the criterion of the necessity of EIA in Cambodia as a type of project and their size and capacity.
3	Prakas (Declaration) on Guideline for Conducting Environmental Impact Assessment Reports	2000	This Declaration stipulated first that the Department of Environmental Impact Assessment (DEIA) in MOE is the unit in charge of EIA.
4	Prakas (Declaration) on General Guideline for Conducting Initial and Full Environmental Impact Assessment Reports	2009	This Declaration stipulates the approval procedures of IEIA/EIA of the project each on a national level and the municipality/provincial level and detailed instructions of the application form and documents which should be attached. Also the Declaration allows the project owner to hire a consultant company, which must be registered in the Ministry of Commerce (MOC) and be recognized by MOE beforehand, to prepare an IEIA/EIA report.
Natural Environment			
5	Royal Decree on Creation and Designation of Protected Areas	1993	National protected areas, which are managed and supervised for the development and protection of natural areas by the Secretariat of Environment, are classified into four categories; (1) National parks, (2) Wildlife sanctuaries, (3) Protected landscapes, and (4) Multiple use areas.
Pollution Control/Urban Environment			
6	Sub-Decree on Water Pollution Control	1999	This Sub-Decree stipulates the water quality standard of discharged water. MOE is responsible for the monitoring of the pollution source and pollution situation.
7	Sub-Decree on Air Pollution and Noise Disturbance	2000	The standard of the maximum allowable level of noise and the maximum quality of hazardous substances permitted in the air are specified in this Sub-Decree.
8	Sub-Decree on Solid Waste Management	1999	This Sub-Decree specified the concrete regulations and procedures for the management of general waste and hazardous waste.
Others			
9	Electricity Law of The Kingdom of Cambodia	2001	Each power company must comply with all conditions set forth in its License, the rules and regulations adopted by the Authority, and the laws of the Kingdom of Cambodia, including laws regarding environmental protection, safety, health, taxes, and electric system performance, protection and standards.

Source: JICA Survey Team

(b) Law and regulations related to land acquisition and resettlement

The system of land management, land expropriation and resettlement in Cambodia is based on the Cambodian Constitution (1993), Land Law (2001) and Expropriation Law (2010). The right to own land property is stipulated in the Cambodian Constitution. On the other hand, newly de facto land ownership provided by continuous use is not allowed after the Land Law enacted in 2001.

Regarding the expropriation of private property, the Cambodian Constitution and Land law allows the government to expropriate the land for only the purpose of public benefit via appropriate procedures provided by the law and after just and fair compensation which should be fair and just in advance. The Expropriation Law prescribes the principals and procedures for the legal expropriation of property including land. The ROW are stipulated by “Sechkdey Prakas No.6: Measures to Crack Down on Anarchic Land Grabbing and Encroachment” (1999) and “Regarding the Implementation of Right of way policy on National Roads, Provincial Roads, Railways in Cambodia”(2000) which mentions that any private properties existing in the ROW are not officially compensated. Nonetheless, the handling of private property in the ROW should be sensitive because the application of those regulations is on a case-by-case basis and complicated.

The policy of resettlement in Cambodia is applied only by “expropriation for the public interest” and the Expropriation Law and has not been systematized yet. Though ADB had supported the preparation of the draft of the Sub-Decree for the resettlement policy which is called the “Sub-Decree on Addressing Socio-Economic impacts caused by development `projects (DRAFT)”, it has not been enacted. The key laws and regulations related to land acquisition and resettlement are shown in Table 5. 3.

Table 5. 3 Law and Regulations Related to Land Acquisition and Resettlement

Category	Title	Enacted Year	Summary
Basic Law	Cambodian Constitution	1993	Constitution stipulates the property of land for Cambodian, expropriation of land for public benefit and state property.
Land	Land Law	2001	The Land Law is applied with the fair and equitable compensation in advance based on the law.
Land Expropriation	Expropriation Law	2010	This Law prescribes the principals, mechanisms and procedures etc. of expropriation, including fair and equitable expropriation, compensation in advance, expropriation for the public project of infrastructure construction This law is applied to the legal expropriation of lands from owners.
Land Concession	Sub-Decree on Social Land Concessions	2003	This is the Sub-Decree enacted by the management of MLMUPC. The procedures and mechanisms for land concessions for poverty-stricken groups or individuals who have to resettle due to infrastructure development construction etc.
	Sub-Decree on Economic Land Concessions	2003	This Sub-Decree is prepared by the Ministry of Agriculture, Forestry and. Fisheries and provides the article of concession for the purpose of economic development.
Illegal Occupation	Sechkdey Prakas No.6: Measures to Crack Down on Anarchic Land Grabbing and Encroachment	1999	This Prakas stipulates an ROW for the illegal occupation of roads and railway roads, though it was updated by the other Sub-Decree in 2009. Nonetheless this ROW is not applied to densely-populated areas.
	Circular on Settlement of the illegal construction on the state land in cities and urban areas	2010	This Circular describes the investigation of the illegal occupation of property, its countermeasures, and stakeholder participation etc. in order to resolve illegal occupations in urban areas.
ROW	Regarding the Implementation of Right of way policy on National Roads, Provincial Roads, Railways in Cambodia	2000	This was published by MEF for submission to the Phnom Penh Municipality and local government. These provisions indicate the appropriate management and utilization of ROW. This specifies that private property in ROW is not compensated officially.
	Sub-Decree on Right of way of National road and Railroads of the Kingdom of Cambodia	2009	This Sub-Decree stipulates national roads with one digit and two digit and railway road that are managed by MPWT, indicating each ROW

Source: JICA Survey Team

(c) Labor law

Labor law(1997) states the basic provisions related to the wage, working hours, overtime working, paid holidays, health care, labor health service and accident etc.

(2) Environmental Standard

(a) Air Quality Standards

The Air Quality Standard specified by the “Sub Decree on Air and Noise Pollution Control”(1999) is shown in Table 5. 4 and Table 5. 5.

Table 5. 4 Ambient Air Quality Standard in Cambodia

No.	Parameter	Hourly Average mg/m^3	Eight hourly Average mg/m^3	Daily Average mg/m^3	Yearly Average mg/m^3
1	Carbon monoxide(CO)	40	20	-	-
2	Nitrogen dioxide(NO2)	0.3	-	0.1	-
3	Sulfur dioxide(SO2)	0.5	-	0.3	0.1
4	O zone(O_3)	0.2	-	-	-
5	Lead (Pb)	-	-	0.005	-
6	Total Suspended Particulate (TSP)	-	-	0.33	0.1

Source: Sub Decree on Air and Noise Pollution Control (1999), Annex 1

Table 5. 5 Maximum Allowance Concentration of Hazardous Substance in Ambient Air

No.	Parameter	Formula	Maximum Allowance Level (mg/m3)
1	Aniline	C6H5NH2	0.03
2	Ammonia	NH3	0.2
3	Acetic Acid	CH3COOH	0.2
4	Sulfuric Acid	H2SO4	0.3
5	Nitric Acid	HNO3	0.4
6	Ben Zene	C6H6	1
7	Ben Zidine	NH2C6H4C6H4NH2	
8	Carbondisulfide	CS2	0.02
9	Chloroform	CH3Cl3	0.01
10	Carbontetracjloride	CCl4	3
11	Particle containing Asnestos	-	
12	DDT	C8H11Cl4	0.5
13	Formaldehyde	HCOH	0.012
14	Hydrogen Arsenic	AsH3	0.002
15	Hydrogen Cyanide	HCN	0.01
16	Hydrogen Fluoride	HF	0.002
17	Hydrogen Sulfide	H2S	0.001
18	Phenol	C6H5OH	0.01
19	Styrene	C6H5CHCH2	0.003
20	Tetra Chloroethylene	C2Cl4	0.1
21	Tetraethyle Lead	Pb'C2H5)4	0.005
22	Tri Chloroethylene	ClCHCCl2	0.2
23	Toluene	C6H5CH3	0.4
24	Vinyl Chloride	ClCHCH2	0.05
25	Arsenic (Compound organic)	As	0.00001
26	Cadmium (Compound & Oxide)	Cd	0.003
27	Chromiun (Compound & Metal)	Cr	0.0015
28	Nickel (Compound & Metal)	Ni	0.0002
29	Mercury (Compound & Metal)	Hg	0.0001
30	Petrol		5

Source: Sub Decree on Air and Noise Pollution Control (1999), Annex 1

(b) Standard of Noise

Noise standard (Table 5. 6) is specified in the “Sub Decree on Air and Noise Pollution Control” (1999).

Table 5. 6 Maximum Permitted Noise Level in Public and Residential Area

Unit : dB(A)

No.	Area	Time Zone		
		6:00 - 18:00	18:00- 22:00	22:00 - 6:00
1	Quiet areas - Hospitals - Libraries - School - Kindergarten	45	40	35
2	Residential area: - Hotels - Administration offices - House	60	50	45
3	Commercial and service area and mix	70	65	50
4	Small industrial factories intermingling in residential areas	75	70	50

Remark: This standard is applied to control of noise level of any source of activity that emitted noise into the public and residential area.

Source: Sub Decree on Air and Noise Pollution Control (1999), Annex 13

(c) Standard of Water Quality

Water Quality Standard (Table 5. 7) is specified in “Sub-Decree on Water Pollution Control”.

Table 5. 7 Water Quality Standard

No.	Parameter	Unit	Water Quality Standard of MoE		
			River(*)	lake and reservoir(*)	Allowable limits for pollutant substance discharging to public water areas or sewer(**)
1	Temperature	℃	-	-	<45
2	pH	-	6.5 – 8.5	6.5 – 8.5	5-9
3	Total Suspended Solid (TSS)	mg/l	25-100	1-15	<120
4	Dissolved Oxygen (DO)	mg/l	2.0-7.5	2.0-7.5	>1
5	Biological Oxygen Demand (BOD5)	mg/l	1-10	-	<80
6	Chemical Oxygen Demand (COD)	mg/l	-	1-8	<100
7	Total Nitrogen	mg/l	-	0.1-0.6	-
8	Total Phosphorus	mg/l	-	0.005-0.05	-
9	Total Coliform	MPN/100ml	< 5000	< 1000	-

Source: (*) Extraction from Annex 4 of the Sub-Decree on Water Pollution Control
(**) Extraction from Annex 2 of the Sub-Decree on Water Pollution Control

5.2.3 Procedure on Environmental Clearance System

(1) Environmental Categorization by JICA

It is anticipated that this project will have a certain degree of tentative impact on the surrounding environment and society mainly due to noise/vibration and traffic jams during the construction of substations and under the cable transmission line, but this impact will be limited. This project is classified as Category B.

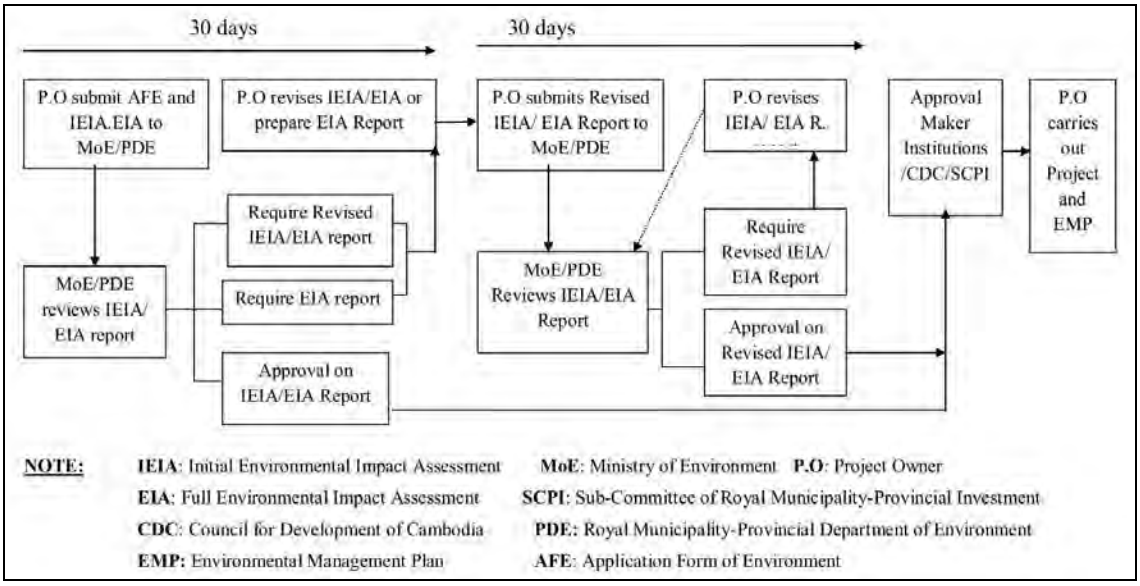
(2) IEIA/EIA procedure in Cambodia

(a) Criteria required EIA/IEE in Cambodia

The Annex of the “Sub-Decree on Environmental Impact Assessment Process” (No.72 ANRK.BK, 1999)” shows the projects which require an IEIA/EIA. In the power sector, a power plant whose scale exceeds 5MW and the hydropower plant whose scale is more than 1MW meet the criteria. Though the list of the Annex in this Sub-Decree does not include the transmission line project, the new Declaration (United Declaration for public service contribution of MoE, No. 999, 28 December 2012) issued on the 28th, specifies that the transmission line whose scale is 115 kV and more requires IEIA approval.

(b) Procedures of IEIA/EIA

Based on Article 6 of the Law on Environmental Protection and Natural Resource Management of the Royal Government of Cambodia (dated 24 December 1996) and Article 2 of the Sub-decree on Environmental Impact Assessment Process (dated 11 August 1999), all the projects and activities of the private or public sector are required to submit the EIA to the MoE for approval before submitting to the Royal Government of Cambodia (RGC) for a final decision. The Sub-decree on the Environmental Impact Assessment Process contains a requirement that an IEIA/EIA report shall be submitted along with the feasibility study of the project to the Ministry of Environment for review and approval. The approval procedure is shown in Figure 5. 3.



Source: PRAKAS on General Guideline for Conducting Initial and Full Environmental Impact Assessment Report, 02 September, 2009

Figure 5. 3 Approval Procedure in Cambodia

(c) Contents of EIA report

The Guidelines for Conducting an EIA Report defines the contents of an EIA report as follows.

Chapter 1: Introduction
Chapter 2: Legal frameworks
Chapter 3: Project Description
Chapter 4: Description of Environmental Resources
    4.1Natural Environmental Resources
    4.1.1 Physical Resources
    4.1.2 Biological Resources
    4.2 Socio-economic Resources
Chapter 5: Public participation
Chapter 6: Environmental Impacts and Mitigation Measures
Chapter 7: Environmental Management Plan
Chapter 8: Economic Analysis and Environmental Value
Chapter 9: Conclusion and Recommendations

References
Annexes

(3) Public Consultation

Public consultation will be done through community leaders in the commune and village. The participants are the village chief/vice chief, commune council members or policemen, and people from the village. This will be done during the IEIA study period.

(4) Resettlement and land acquisition

The policy framework of the resettlement has not been systematized yet in Cambodia. A practical and political measure of resettlement follows the Cambodian Constitution (1993), Land Law (2001) and Expropriation Law (2010). The Resettlement Department of MEF is in charge of the political measures of the resettlement for public works managed by the national government. The policy of resettlement and land expropriation for each project are discussed in the Inter-ministerial Resettlement Committee (IRC) whom RD serves as a secretariat. IRC is composed of MEF, MPWT, MLMUPC and related province/city organizations. MEF heads up IRC.

On the other hand, the government document issued on 28th, Dec. 2012 stipulates that EDC is responsible for the resettlement and land expropriation for projects that EDC is involved in. In the case of this Project, therefore, EDC will take care of those issues coordinated with DPWT, MLMUPC and other related organizations if this project requires land expropriation and resettlement. In the event that any project requires them, EDC shall implement a survey on a social economic reconnaissance and estimation of the land acquisition after IEIA or as a part of the IEE report. Based on the survey result, EDC negotiates a compensation or resettlement plan with the affected people or land owner, consulting with other related organizations as needed.

5.2.4 Gap Analysis

There is a slight gap between the theory of Cambodian regulations and the new JICA Guidelines (2010) with regards to the resettlement, land expropriation and compensation. The Land Law (2001) does not allow those who occupy ROW or common land to have the right to receive compensation or social support even though they are the vulnerable groups. In addition, Cambodian regulations do not provide political measures and the means for the people who suffer an adverse impact to recover their lost livelihood. On the other hand, the new JICA Guidelines (2010) initially require a project proponent etc. to take effective consensual measures to avoid involuntary resettlement and loss of livelihood, and to minimize the adverse impact and compensate the lost in cases where the impact is inescapable. Furthermore, the new JICA Guidelines(2010) requires support and compensation by the project proponents etc. for the people to improve or at least restore their living standard, income opportunities and production levels to a level comparable to their pre-project level. The comparison between Cambodian regulations and the new JICA Guidelines(2010) is shown in Table 5. 8. This project will propose the appropriate considerations required by the new JICA Guidelines(2010) to the project owner, if the adverse impact of resettlement or loss of livelihood occurs.

Table 5. 8 Comparison and Verification between Cambodian System and the New JICA Guidelines

	Item	New JICA Guidelines Policy	Regulation in Cambodia (officially promulgated)	Dissipating the dissociation between the Cambodian System and the New JICA guidelines
1	Establishment of support system for socially vulnerable groups	Socially vulnerable groups tend to be exposed to environmental and social impacts. In addition, they have limited access to the decision making process. Thus, it is necessary to give appropriate consideration to them.	The Constitution (1993) and the Land Law (2001) do not address socially vulnerable groups.	The project will comply with the New JICA guidelines policy. Socially vulnerable groups will be paid appropriate compensation by the Project.
2	Provide assistance to restore and improve living standards	Living standards and income opportunities, and production levels of project AP (affected people) should be improved or at least restored to their pre-project levels.	The government has no clear policy or procedure to restore the livelihood of AP.	This Project will propose assistance to restore and improve living standard of APs, if necessary.
3	Enhancement of public participation in planning and implementation of resettlement plans	Appropriate participation by the AP and their communities should be promoted in the planning, implementation and monitoring of involuntary resettlement plans and measures taken against the loss of their means of livelihood.	It is clearly declared in the Sub-decree on the Social Land Concession that there shall be participation from the area residents and others in initiating a national social land concession plan.	To follow both the Policy and the Regulation
4	Compensation for land acquisition with replacement costs	Prior compensation, at full replacement cost, must be provided as much as possible.	Compensation should be fair and just in advance. For legal ownership, However, “No person shall be deprived of their ownership unless this action is for the public interest consistent with formalities and procedures provided by the law and after just and fair compensation”. Therefore, compensation is not provided for other types of losses.	The project will comply with the new JICA guidelines policy if there is any need for compensation or land acquisition.
5	Providing support for illegal occupants	People to be resettled involuntarily and people whose means of livelihood will be hindered or lost should be sufficiently compensated and supported by project proponents at the appropriate time.	Those who have occupied the ROW or public properties are not entitled to any compensation or social support, regardless of them being an AP or coming from a vulnerable group.	The project will comply with the new JICA guidelines policy.
6	Grievance redress system	A grievance redress system must be formulated and it should function appropriately.	The grievance redress system is stipulated in the Law on Expropriation (2011).	To follow both the Policy and the Regulation

Source: JICA Survey Team

5.3 Environmental and Social Baseline

This chapter describes the basic and current information on environmental and social conditions that are necessary to analyze the alternatives and consider the environmental and social impact of this project.

5.3.1 Environmental Pollution

(1) Air pollution

Air pollution in Cambodia is caused by in-house power generations and automobiles. A higher concentration of particle matters is observed in some areas near the unpaved roads. The NO_2 and CO concentrations, which is equal to or higher than the standard of WHO are reported in Phnom Penh City[1].

(2) Noise

The periodical monitoring data of noise in Phnom Penh City has not been reported. The noise survey described in Chapter 4.4 was implemented to get the baseline data in the project area.

(3) Waste Management

The waste in Phnom Penh City is mainly collected by a private company which is outsourced by a Municipality. Domestic waste is disposed of to the landfill in Beung Chheung Ek by CINTRI (Canadian and Cambodian Join-Venture) company. Industrial waste is collected by SAROM TRADING company and transferred to their own landfill.

5.3.2 Natural Environment

(1) Geography and geology

Phnom Penh is located in the south-central region of Cambodia, at the confluence of the Tonle Sap, Mekong, and Bassac rivers. Though the inner –city is located on the natural levee, the surrounding area is a kind of swale site represented by some lakes such as Tompun lake and Trabek lake.

(2) Meteorology

The project area has a monsoon-dominant climate. The dry season lasts from December to May and the rainy season lasts from June to November. The air temperature varies from 18 degrees to 38 degrees. After the northeast monsoon brings drier and cooler air from early November to March, the heat wave comes in April and early May.

(3) Natural protected area

There are some protected areas designated by the MOE and Ministry of Agriculture and Forestry in Cambodia. This Survey area of Phnom Penh City does not include the natural and environmental protected area.

(4) Urban Ecosystem/Animals and Plants

This Survey area is located in developed urban areas. Significant precious species or endangered species that should be protected are not reported.

(5) Hydrology

Tonle Sap river coming from Tonle Sap lake and Mekong river meet each other at the east of Phnom Penh city and forks to the Mekong river and Bassac river downstream. Mekong River causes flooding because of the heavy rain during the rainy season. The monitoring point in Phnom Penh measures the river water level which is more than EL. +7m in the months from August to November and less than EL.+2m from March to July. There is a big difference in the river water level between

[1] Effective approach to development subject—Air pollution— (JICA, 2005)

the rainy season and the dry season. When the water level of Mekong River exceeds the level of Tonle Sap river, the river water flows upward.

(6) Aesthetic landscape and cultural heritage
The survey area does not include the aesthetic landscape specified by law. However, Phnom Penh Municipality takes into consideration the landscape for the Tonle Sap river side area because it is a tourist spot. On the other hand, Palace and Wat Phnom are famous cultural heritages in Phnom Penh, though this project has no physical impact on these heritages

5.3.3 Social Environment

(1) Population
The data in Table 5. 9 published by Phnom Penh Municipality shows that the population in the city has recorded approximately 1.5 million. In Phnom Penh, by 2011, civil servants were comprised of 24%, staff and workers 26%, service providers 36% and farmers 14%.

Table 5. 9 Basic Data on Phnom Penh City

Area	Population	Women	No. of Households	Density	Khan	Sangkat	Village
678.46 Km2, 0.37% of country's total area	1,501,725 people	792,926 people	295,358	2,213 people/Km^2	9	96	897

Source: http://www.phnompenh.gov.kh/phnom-penh-city-facts-99.html(Website of Phnom Penh Municipality, confirmed on 19th , Jan. 2013)

(2) Administrative district
Phnom Penh City is composed of nine Khans and each Khan has some smaller regions which is called Sangkat (Table 5. 10, Figure 5. 4). The proposed SS and Transmission Line of the underground cable cover six Khans (Table 5. 11).

Table 5. 10 Administrative Section n Phnom Penh City

Khan	Population	Area(m^2)	Density(people/ Km^2)
7 Makara	91,895	2,228,027	44,395
Chamka Mon	182,004	10,788,213	17,468
Dangkao	69,319	11,775,8500	589
Doun Penh	126,550	7,412,767	17,479
Mean Chey	327,801	44,000,448	2,951
PoSenChey	183,826	230,384,385	798
Russey Keo	196,684	63,948,255	1,827
Sensok	147,967	40,021,647	1,606
Toul Kork	171,200	8,432,543	21,977

Source: http://www.phnompenh.gov.kh/phnom-penh-city-facts-99.html(Website of Phnom Penh Municipality, confirmed on 19th , Jan. 2013)

Source: Website of Phnom Penh Municipality, confirmed on 19th , Jan. 2013

Figure 5. 4 Administrative District in Phnom Penh City

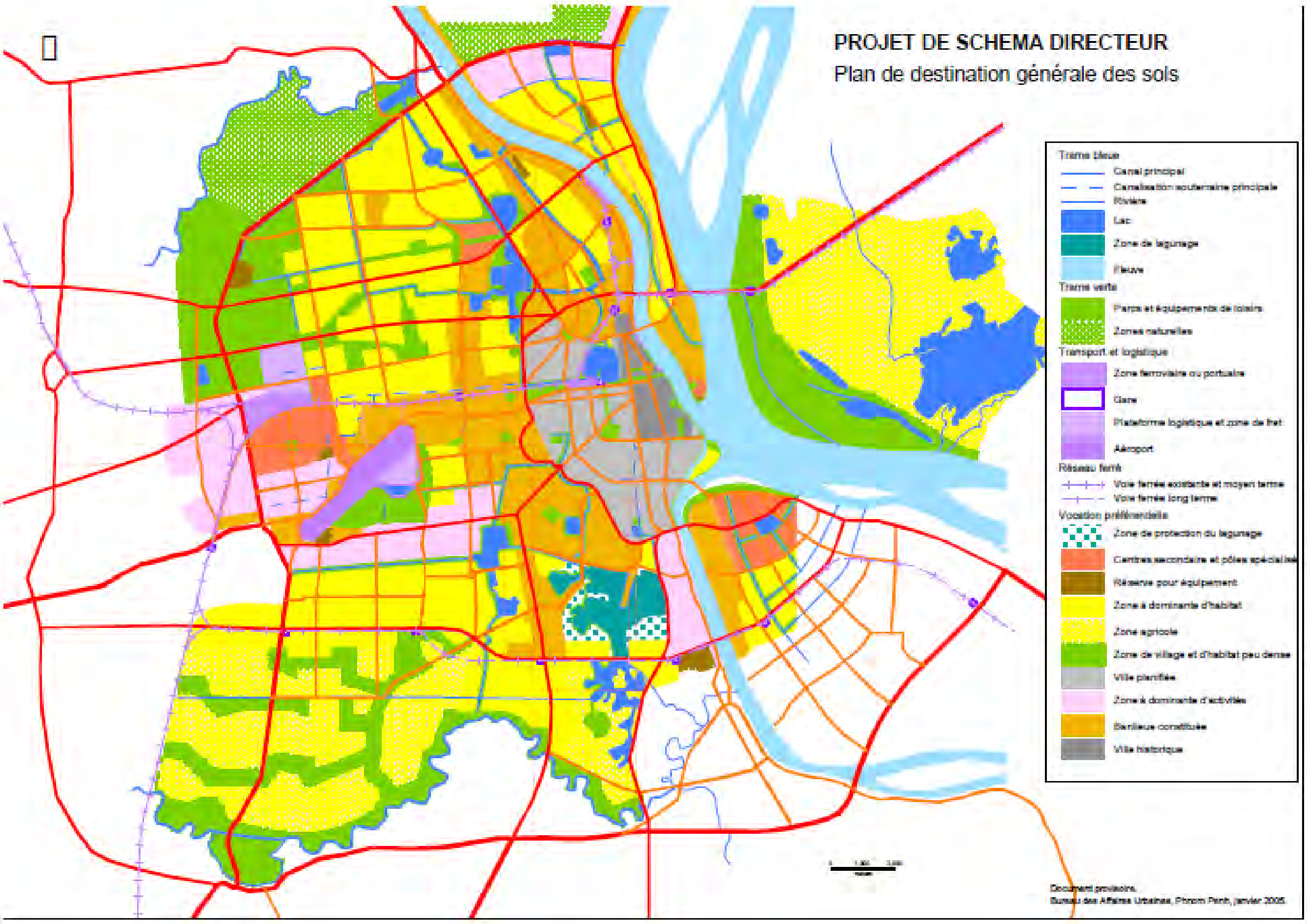
Table 5. 11 Local Administrative Section in Project Area

Item	Name of SS/Route		Khan(District)
SS	GS1		Russey Keo
	GS3		Saen Sockh
	SS in EDC		Doun Penh
	SS in Olympic Stadium		7Makara
Transmission Line	Route1	GS1～EDC SS	Russey Keo, Doun Penh
	Route2	EDC SS～Hunsen Park SS	Doun Penh, Cham Mon
	Route4	Olympic Stadium SS～Hunsen Park SS	Chamka Mon, 7Makara
	Route5	GS3～OlympicStadium SS	7Makara, Tuol Kouk, Saen Sockh

Source: JICA Survey Team

(3) Land use

The Survey area is a mixed zone of residential areas and commercial areas of small and medium sized shops. The land use map is shown in Figure 5. 5.



Source: Revised "Master Plan in Phnom Penh City, Office of Urban Affairs, Phnom Penh City", January 2005

Figure 5. 5 Master Plan in Phnom Penh City

(4) Urban development plan

The urban development plan in the City is shown in Figure 5. 6.

Source: Revised “Plan of grandes infrastructures in 2020”

Figure 5. 6 Future Plan of Infrastructures in Phnom Penh City

(5) Infrastructure and underground facility

The six kinds of underground facilities shown in Table 5. 12 which are the sewage pipe, cable lines, water supply, electricity, telephone, television and optical cable are recognized in Phnom Penh City. Those facilities might be obstacles to the construction of the transmission line in this project.

Table 5. 12 Underground Facilities in Phnom Penh City

Facilities	Supt.	Supervisory Organization
Sewage	Public Sector	DPWT
	Public Sector	District office
Water supply	Public Sector	Phnom Penh Water Supply Authority (PPWSA)
Electricity	Public Sector	EDC
Telephones	Public Sector	Telecom Cambodia
	Private Sector	Camintel Company
Television	Private Sector	PPFOTV Company
Optical Cable	Private Sector	CFOCN Company

Source: "Basic design study report on the project for flood protection and drainage improvement in the municipality of Phnom Penh (Phase II) in the Kingdom of Cambodia "(2011, JICA)

It will be needed to get drawings of the existing underground facilities from each supervisory organization and reflect the information of the location, depth and diameter etc into the route design of this project in the detailed design phase. Since the breakage failure of those pipes or cables would have an adverse impact on the livelihood and economic activities in the related area, careful investigation and safety construction work are required. The constructor should be careful and check the location of those facilities with test drills at the site.

(6) Right of way

The ROW of the national road with one digit and two digits supervised by MPWT is specified by the "Sub-Decree on the Right of way of the National road and Railroads of the Kingdom of Cambodia" (2009). In cases where the road passes the capital city, provincial city or a crowded city area, however, this Sub-Decree does not apply. Table 5. 13 show the ROW dimensions regulated by the national government.

Table 5. 13 ROW Dimensions

Road Category	ROW Dimensions
National Road with one digit	30 m from the centerline
National roads with two digit	25 m from the centerline
Provincial/city roads with three digits	20 m from the centerline
Commune/village roads	15 m from the centerline

Source: Sub-Decree on Right of way of National road and Railroads of the Kingdom of Cambodia, 2009
Sechkdey Prakas No.6: Measures to Crack Down on Anarchic Land Grabbing and Encroachment, 1999

(7) Topics to be cared for related to indigenous groups and ethnic groups

Cambodia is composed of 90 % Khmer, 1% Chinese, 5% Vietnamese and other minorities such as the Cham people. The percentage of those who are poverty-stricken has been decreasing these days. The minority ethnic group mostly settled in a very remote area such as in the Northeast plateaux of the country (in Rattanakiri, Stung Treng, and Mondul Kiri province) and North of country (in Preah Vihea province). In the center of the country, most people are Khmer and the communities along the rivers are the mixing of Khmer and Cham. In urban areas, there is a mixture of Khmer, Vietnamese, and other nationalities.

In Phnom Penh City, the population at the class of absolute deprivation was less than 1% in 2007.[2],[3] On the other hand, some issues regarding the resettlement caused by the urban development has appeared. The resident people in Basak slam were resettled involuntarily in 2006.

[2] http://www.phnompenh.gov.kh/phnom-penh-city-notable-data-339.html （website of Phnom Penh as of Jan 26,2013）
[3] Final report of the survey on poverty line in the King of Cambodia (JICA, 2010)

5.4 Alternative Analysis

This project includes the construction work of the underground T/L at the center of the Phnom Penh metropolis. It is anticipated that there might be some possibility of an impact to the surrounding social environment during the construction work. In this Survey, the Survey Team raised some plans concerning the project outline and considered their impact on the neighborhood residents and surrounding environment based on the overall information indicated in the materials, collected data, hearings from related people and a reconnaissance survey. Then, the Survey Team proposed an appropriate outline of the project plan.

5.4.1 Alternative of the Project Outline

The total four project plans were proposed as shown in Table 5.14. In the Zero option, no construction work has been planned. In Plan 1, the two substations are installed outside the city and 22kV distribution lines transfer power to the metropolitan area. In Plan 2, new substations where power is supplied from the neighboring substations are installed inside the metropolitan area. In Plan 3, the new substation links with each other inside the metropolitan area, in addition to Plan 2.

Minus the project, there is no adverse impact on natural and social environment and no construction costs. However, this plan is not satisfied with increasing future power demand. Minus the project, the period of the blackout would be longer and a sufficient amount power would not be supplied to the city. As a result, a Zero option would not be realistic because it interferes with the development of Phnom Penh City.

Plan 1, Plan 2 and Plan 3 could possibly have a temporary and limited impact of the noise due to the construction work or impact to the neighboring traffic conditions, but those plans provide enough power for current and future demand. The Project area has been already developed so that it is anticipated that there will be little impact on the natural environment unless the Plan 1 involves the protected area. Regarding to the resettlement and land acquisition, Plan1, Plan 2 and Plan 3 can select the T/L route to avoid those issues. In fact, the suggested route in Plan2 and plan3 does not require them. Thus, Plan 2 and Plan 3 do not have more negative effect than Plan 1. For the technical aspect, Plan1 does not bring more advantage than Plan 2 and Plan3 because Plan 1 has much risk of blackout and power loss even though it has low cost. Considering overall, Plan 2 and Plan 3 are recommended since they can make a contribution to the better quality life and development of Phnom Penh City due to the stable electric power.

Compared to Plan2 to Plan3, Plan 2 will have the shorter T/L than Plan 3 but the construction period of T/L is very short. Thus the there will not be significant difference of impact on noise and traffic between them. The economic efficiency depends on the outage cost. If the outage cost is smaller than 2USD/kWh, Plan2 will have an advantage. However, it is predicted that the outage cost would be higher with the development of Phnom Penh Metropolis so that Plan3 would be the best plan with all things considered.

Table 5. 14 Comparison of Alternative Project Plan

Item		Zero Option	Plan1	Plan2	Plan3
Project Summary	Feature	No construction	Distribution line of 22kV from the new two substations outside of the metropolitan area	New substations inside the metropolitan area	New substations and its links inside the metropolitan area
	New/ Expansion of Substation	N/A	AIS Substation：2	GIS Substations：:2	GIS Substations：:2
	Total length of T/L	0 km	22kV UG cable(30MVA):50km 22kV UG cable (10MVA):10 km	115kV UG cable(150MVA): 8km 22kV UG cable(10MVA):10km	115kV UG cable (300MVA):8km 115kV UG cable(150MVA):8km 22kV UG cable (10MVA): 10km
Technical aspect	Power supply	- High risk of blackout - The supply capacity cannot satisfy the increasing demand.	- The supply capacity meets the power demand in the City. - High loss and high risk of blackouts	- Increased transformer capacity serves to avoid planned blackouts and offers stabilized power supply. - The system is quickly restored after the distribution line failure	- Increased transformer capacity serves to avoid planned blackouts and offers stabilized power supply. - The system is quickly restored after the distribution line failure - Risks for the blackout of the Phnom Penh system are reduced by installing links between the new substations.
	Main Spec	N/A	The 15 distribution lines (22kV) per one substation are installed and directly connected to the distribution substations in the metropolitan area.	- Installation of distribution automation system - Installation of special protection scheme	- Installation of distribution automation system - Installation of special protection scheme - Installation of links between the new substations and operation of the system in the ring configuration.
	Construction Cost	N/A	High(Approx. 34milliom USD) - However loss costs and blackout costs are high.	High(Approx. 34.3million USD) - Though the construction costs is higher than that of Plan 1, Plan 2 has the advantage of total cost because of lower loss cost and blackout cost.	Higher than Option 2(Approx. 51million USD) - Though the construction cost is higher, Plan 3 has the biggest advantage in the future because the loss cost and blackout costs are very limited.
	Consistency with the urban development plan	Not enough power supply would prevent the urban development	This plan serves enough power capacity for metropolitan area, but the less reliability would obstruct the urban development	This plan contributes to the urban development of Phnom Penh City.	This plan contributes to urban development of Phnom Penh City.
Environmental and Social Considerations	Pollution control	No impact on environmental pollution	Impact of noise and vibration to the neighborhood are anticipated during the construction work.	Impact of noise and vibration to the neighborhood are anticipated during the construction work.	Impact of noise and vibration to the neighborhood are anticipated during the construction work.
	Natural environment	No impact to the natural environment	The construction work is mostly implemented outside of the metropolitan area. Some impact to the natural environment might occur depending on the selected location of the substation.	It is has been anticipated that Plan 2 has little impact on the natural environment because the project area is already a developed urban area.	It is anticipated that Plan 2 has little impact on the natural environment because the project area is already a developed urban area.

Item		Zero Option	Plan1	Plan2	Plan3
	Social environment	- No impact on the social environment due to the construction work. - This plan cannot satisfy the increasing power demand in the future. - Minus this project, an insufficient amount of power will cause an incalculable loss of life and business activity to the people living in the area.	-This plan might require the land acquisition for SS. -The resettlement can be avoided at the selection process of T/L route and SS site. - This plan could have a temporary and limited impact on neighboring traffic conditions. - The total number of projects AP might be less than the one in Plan 2 and Plan 3 because some constructions are implemented outside of the metropolitan area. On the other hand, the total length of the T/L is longer and it affects people in larger areas. - In operation phase, enough capacity for power demand is supplied, but the reliability is much lower.	-This plan might require the land acquisition for SS, but it can be avoided if the public or EDC's land is provided. -The resettlement can be avoided at the selection process of T/L route and SS site. - This plan could have a temporary and limited impact on neighboring traffic conditions. - In operation phase, this plan will supply stable power which contributes the improvement of life environment of local people and development of city economy such as social service, tourism and job growth in the project area.	-This plan might require the land acquisition for SS, but it can be avoided if the public or EDC's land is provided. -The resettlement can be avoided at the selection process of T/L route and SS site. - This plan could have a temporary and limited impact on neighboring traffic conditions. - In the operation phase, this plan will supply stable power which contributes to the improvement of the life environment of the local people and the development of city's economic and social services and tourism, and job growth in the project area. - The risk of the blackout is less than Plan 2.
Proposed optimum plan and reason		This plan is not recommended. - The power supply is not enough for now and future demand. It would interfere with the development of Phnom Penh City.	This plan is not recommended. - The power supply is unstable, so it has few advantages.	This plan is recommended. - The adverse impact to the surroundings is temporary and limited. - The stable and sufficient amount of power supply will contribute to the development of the project area and stable civilian lives. - If the outage cost is less than 2 USD/kWh, an evaluation including construction costs, power loss and supply reliability indicates that this plan would have economically advantage.	This plan is strongly recommended - The adverse impact to the surroundings is temporary and limited. - The stable and sufficient amount of power supply will contribute to the development of the project area and stable civilian lives. - A comprehensive evaluation including construction costs, power loss and supply reliability indicates that this plan is the best considering the increasing outage cost in the future.

Source: JICA Survey Team

5.4.2 Alternative Transmission Line Route

The proposed T/L will involve long distance digging operations. Some candidate routes for Route 1, Route 2 and Route 5 were compared in Table 5.15 and the optimum route was selected. With the following point considered, the route which likely have the minimum impact on environment are suggested.

- The T/L route does not cross the river.
- The T/L route is shorter.
- The road width is wider.
- There is less traffic jam around the route

Table 5. 15 Alternative Transmission Line Route

Route	Candidate route	Description of the route	Proposed optimum route and reason
Route1: GS1 - EDC SS	Route A (toward north to National Highway 5 from GS1)	There is a primary school between the intersection of Str.93 and Str.60.Str.60 is narrow.	- Not Recommended - It is better to avoid the narrow road and school to minimize the possible impact.
	Route B (from GS1 through Str.62 to National Highway 5)	Str.68 takes the shortest way from GS1 to the National Highway 5. The width of Str.68 street is wider than the other candidate road.	- Recommended - The impact on the social environment is smaller than the other candidate.
	Route C (from GS1 toward south , through the street going to the Cambodian-Japan Friendship Bridge, and to National Highway 5)	Str.93 in the South of GS1 is very narrow and has the traffic jam. There are the hardware shops on the both side of the road	- Not Recommended - It will be a major impact on the traffic and nearby shops.
Route2 : EDC SS - Hunsen Park SS	Route A (easterly course shown in Figure 6.3)	The road along the river is wider and has much space on the road side. There is no stall on the river.	- Recommended - The impact on the social environment is smaller than the other candidate
	Route B (western course shown in Figure 6.3)	This route goes through the shop street and narrow.	- Not Recommended
Route 4: Olympic Stadium SS - Hunsen Park SS	Samdach Preah Sihanouk Blvd.	The Samdach Preah Sihanouk Blvd. connects between Olympic Stadium SS and Hunsen Park by the most direct way and the best candidate because it is the wider road than the other neighbor road.	- Recommended - This route has least impact on the traffic and nearby commercial activities.
Route5: GS3 – Olympic Stadium SS	Route A (Northerly course from Olympic Stadium shown in Figure 6.5)	Str. 182 (Tep Phan Str.) is a main road between GS3 and Olympic Stadium.	- Recommended - This route is selected in terms of the natural environment, technical difficulties and traffic and nearby commercial activities.
	Route B (through Str.230 in Figure 6.5)	The route from Olympic Stadium is the shortest route directly toward GS3. However it does not go through finally and has to turn on right toward Str.182 and take the same route as Route A.	- Not Recommended - Route B is not simpler and better than Route A
	Route C (Southerly course shown in Figure 6.5)	This route goes a long way round and crosses the river. It has some technical difficulties of construction for the T/L to cross the river.	- Not Recommended - It is better to avoid the long way and crossing the river..

5.5 Scoping

The environmental scoping for this project, which clarifies the conceivable environmental and social impacts due to proposed project activities, was conducted as shown in the below Table, in consideration of the project's character and result of the baseline survey. This scoping table was revised to reflect the comment from the stakeholders and EDC after ItR.

Table 5. 16 Scoping

No.	Item	Initial Rating		Reason
		Construction Phases	Operation Phases	
Pollution Control				
1	Air pollution	B-	D	(Construction phases) Air pollution such as soil dust caused by paving of roads or the backfill of soil associated with the substation or T/L construction is anticipated.
2	Water pollution	C-	C-	(Construction phases) Though there seems to be little possibility that soil flowage may cause river water pollution, the more information by IEAE etc. is required. (Operation phases) It is anticipated that waste water discharged by the substation workers might have an impact. Though the impact is temporary and minor, more information from IEIA etc. is required.
3	Waste generation (construction debris, extra soils on the construction site)	B-	B	(Construction phases) The waste produced at the construction site needs to be disposed in an appropriate manner and at an appropriate place. (Operation Phases) Though the impact from the waste produced by the new substation is small, such general waste should be disposed in an appropriate manner and at an appropriate place.
4	Soil contamination	C-	D	(Construction phases) Although it is anticipated that the project does not have any factor which may cause new soil contamination, more information by IEIA etc. is required because the project is not sure of the contamination of the extra soil at the construction site.
5	Noise and vibration	B-	D	(Construction phases) Impact of noise and vibration on the neighborhood is anticipated during construction work.
6	Ground subsidence	D	D	It is anticipated the project does not have any factors which may cause ground subsidence because the large-scale cut or digging has not been planned.
7	Offensive odor	D	D	It is anticipated that the project does not have any factors which may cause an offensive odor.
Natural Environment				
8	Protected area	D	D	There is no national park or protected area in this Project area. It is anticipated that the project has no impact on the protected area.
9	Biogeocenosis	D	D	The endangered species have not been confirmed in the project area. It is anticipated that the project has little impact on the ecosystems.
10	Hydrological situation(including under water)	C-	C-	For now, the project does not plan to create any routes that will have the T/L cross over any rivers. More information by IEIA etc. is required in parallel with the route planning.
11	Topography and geographical features	D	D	It is anticipated that there is little possibility of a mudslide or land fall because the large-scale filling or cut has not been planned. The dug soil will be returned to the dug hole after the line is burned so that the project does not have any factors that will affect topography and geography.
12	Logged street trees	C-	D	(Construction phases)It is anticipated that there will be no impact to the street trees because the T/L route will avoid the point that requires the logging of street tress as much as possible. However, more information by IEIA etc. is required in parallel with the planning of the route.
Social Environment				
13	Land Acquisition /Resettlement	C-	D	(Construction phases) This project does not require resettlement because the proposed sites are public land or EDC's land. In addition, the project has not planned any new land acquisition for itself. In terms of the land history, it is anticipated that compensation will not be necessary. On the other hand, temporary land occupation might occur to provide a stockyard for construction materials or construction camp. Their impact is unknown because the construction plan has not been prepared yet. More information by IEIA etc. is required (Operation Phases) This project does not require resettlement and new land acquisition.

No.	Item	Initial Rating		Reason
		Construction Phases	Operation Phases	
14	Poverty group	D	D	It is anticipated that there are no factors to affect the livelihood of a poverty group.
15	Minorities and indigenous people	C-	C-	It is anticipated that there is no possible impact on the indigenous people. However, more information by IEIA etc. is required.
16	Regional economy such as job opportunities or livelihood	B-/B+	A+	(Construction phases) It is anticipated that the impact on the neighborhood shops via the construction of a T/L is limited. On the other hand, job opportunities for local people will be increased. (Operation Phases) It is expected that the project will contribute to development in parallel with the development of the local economy.
17	(Surrounding) Land use and utilization of local resources	D	D	It is anticipated that the project will not impact land use and local resources.
18	Water usage or water rights	C-	C-	It is anticipated that there is little possibility of impact on water usage in the neighborhood, but more information from IEIA etc. is required.
19	Disturbance to social infrastructures and services	B-	A+	(Construction phases) Although the local infrastructure and tourism will be slightly affected the during construction work, the impact will be limited. (Operation phases)This project contributes to power system improvements and support to develop future social services and tourism.
20	Living environment of residents	B-	A+	(Construction phases) The temporary and small impact on the surrounding traffic situation is anticipated. However, the impact is limited. (Operation phases) This project contributes to the improvement of the power conditions and living environment of residents.
21	Local conflict of interests	C-/ C+	C-/ C+	More information by IEIA etc. is required.
22	Historical and cultural heritage	B-	D	(Construction phases) This project does not require a cultural heritage transfer. However it is anticipated that there may be an impact on the neighborhood pagoda due to noise and vibration from the construction equipment.
23	Destruction of landscape	B-	B-	The appearance of SS shall be harmonized with the surrounding landscape in terms of scale, color and design.
24	Gender	D	D	The project does not have any factors that will affect the rules of male and female survival, distinction and inequality caused by gender differences.
25	Children's right	**C**-	D	(Construction phases)The possibility that children may work at the construction site is not clear. More information by IEIA etc. is required.
26	Increase the risk of infectious diseases such as HIV/AIDS	B-	D	(Construction phases) There is the possibility that the laborers who come to the project area can trigger a spread of infection such as HIV/AIDS etc.
27	Work environment including work safety	B-	C-/ C+	(Construction phases) Paying attention to the safety of the construction work is required. (Operation phases) The safety of the work environment for the construction is still unconfirmed. More information by IEIA etc. is required.
Others				
28	Accident	B-	D	(Construction phases)The traffic accident might happen.

Rating:

A+/- : Significant positive/negative impact is expected
B+/- : Positive/negative impact is expected to some extent
C+/- : Extent of positive/negative impact is unknown (Further examination is needed, and the impact could clarified as the study progresses)
D : No impact is expected

Note) The hatching cell indicates the re- rating of A-, B- or C-.
Source: JICA Survey Team

5.6 Result of Assessment

Regarding the scoping item whose impact is rated as negative or unknown, the anticipated impact was assessed based on information from the material, reconnaissance survey, hearing survey and practice from a similar project, in view of the project component. The result of the SS and Transmission/distribution line separately is summarized in Table 5. 17. Some survey results are already shown in Chapter 4.

(1) Air pollution

During the construction period of SS and transmission/distribution line, soil dust caused by the construction equipment or emission gas from construction vehicles might be increased. However, the impact is anticipated o be limited and temporary. Especially, the impact at the transmission/ distribution construction site where the construction time period is very short would be very minor.

(2) Water pollution

Referring to other similar projects with digging work, the dug solid has the potential to increase the suspended solids or turbidity downstream. However, the cut construction activities will be carried out only in the dry season and water from construction site is not discharged to public water bodies or rivers. Thus, the impact is limited. On the other hand, though the operation staff working in SS will discharge the drainage at the operation phases, it will discharge the sewage and the number of staff is limited (approximately three per one working hour). Thus, there will be little impact to the public water environment.

(3) Waste generation

Domestic waste will be generated from the construction workers during the construction period and from employees working in SS during the operation phase. In addition, some construction materials and soil will be left at the construction site. Those wastes will be transferred and disposed by a waste collection service, following Phnom Penh Municipality’s guidance. Thus, the impact is small. Furthermore, transformer oil may have leaked from a transformer so that an approximate measurement is required.

(4) Soil contamination

Soil contamination caused by natural heavy metal and contraction work has not been confirmed in the Survey area.

(5) Noise and vibration

The impact of the noise and vibration on the neighborhood cased by the construction equipment or construction vehicle is anticipated during the construction work. The impact near the SS will be more than one at the T/L route. However, in total, it is temporary and can be migrated by selecting a better construction method or equipment.

(6) Hydrological situation

The current draft route does not plan to cross the river or channel. Thus, there will be no impact to the hydrological situation for now. On the other hand, considering the possibility of changing the route, it is better to check its impact at the design phase.

(7) Logged street trees

In the proposed site of SS, the large sale of logging operation of trees has not been planned. Though the under cable transmission/distribution line route also does not involve the logging operation of trees, it shall be checked again at the detailed design phase in consideration that the route might be changed.

(8) Land acquisition and resettlement

At first, the proposed sites of SS are owned by EDC or public authorities. In terms of the future plan and land history, it is anticipated that compensation not be necessary. On the other hand, if the proposed site at Olympic Stadium is not available for this project and EDC acquires an other site for SS, land acquisition shall be implemented in an appreciative way. Furthermore, temporary land occupation might occur to provide a stockyard for construction materials or a construction camp. Their impact is unknown because the construction plan has not been prepared yet.

Secondarily, the public roads managed by the national government or Phnom Penh Municipality will be provided to the underground transmission/distribution line. On the other hand, some space on the public road in Phnom Penh is used by the stalls generally. In this Survey, the transmission line route was selected to avoid the high density area. According to the hearing results from the EDC staff in charge of the environment, a street stall does not have any approval from the authorities and the right to receive compensation under the Cambodian law. Furthermore, it is confirmed at the site survey that the proposed underground line is on the edge of car lane and any stalls or shops on that space are movable. The construction range is limited so that there are some spaces for those street stalls to move themselves by their wheel. Thus, they can continue their sales during the construction period and come back to the original space after the construction. However, the project proponents etc. need to publicize the construction schedule before starting construction and avoid significant impact to their livelihood.

(9) Minorities and indigenous people

Based on information received from EDC's staff and the survey of subcontracting work, the negative impact on minorities and indigenous people caused by this project has not been confirmed.

(10) Regional economy such as job opportunities or livelihood

The neighbor shops around the transmission/distribution line might suffer some impact due to the restricted traffic. However, such an impact is limited because the dust bank system will be applied to prevent the long-term open cut. On the other hand, this project will provide chances for local people to work with and support the development of the city.

(11) Water usage or water rights

Water Supply networks are contributed to all people living in the project areas. The construction work underground might damage/affect the tubes of the water supply system. At the operation phases, it is anticipated that there is no impact to water usage.

(12) Disturbance to social infrastructures and services

If there is traffic jams around the construction zone, temporary impact to the surrounding traffic and tourism is anticipated. Furthermore, the constructor should be careful to avoid any breakage failure of existing underground facilities such as the water supply, drainage and telecommunication lines etc when they dig underground.

(13) Living environment of residents

As mentioned above, there might be some temporary impact to the neighborhood of traffic or noise.

(14) Local conflict of interests

There might be some local conflict of interests if the neighbor shops on/along the road suffers negative impacts as mentioned above.

(15) Historical and cultural heritage

The proposed site of EDC HQ is near the What Phnom, but the site is the opposite side of What Phnom. The noise of the construction work will not affect the visitors of What Phom because the distance between What Phnom is over approximately 90m and there is the other building between them.

(16) Destruction of landscape

Though the Project area does not include a scenic area, some consideration is required such as a fence around the construction site etc. because Municipality is taking care of the scenery of tourist spot and the construction site might cause an oppressive or anxiety feeling of people. In addition, the building's design of SS should be coordinated with the other building upon request of EDC. It should be checked at the detailed design phase.

(17) Children's right

EDC's staff informed that children would never be hired by EDC's project. However, appropriate consideration is necessary not to hire children, just in case.

(18) Increase the risk of infectious diseases such as HIV/AIDS

The risk of infectious diseases such as HIV/AIDS might increase if many construction workers come from outside of the project area. However, this project will not require a significant number of workers and the construction period is for just only around two years. Thus the impact is limited.

(19) Work environment including work safety

At the construction site, the workers might experience an unexpected accident because they work with some big equipment. Furthermore, the staff in SS works near the high-voltage equipment at operational phases. Appropriate safety controls are required.

(20) Accident

Construction work has some risk of accident. The project should take measure for a pedestrian or driver not to enter the construction site.

Table 5. 17 Result of Assessment

No.	Item	Initial Rating at scoping		Description	Evaluation after survey			
					SS		**Transmission and distribution Line**	
		Construction Phases	Operation Phases		Construction Phases	Operation Phases	Construction Phases	Operation Phases
Pollution Control								
1	Air pollution	B-	D	(Construction phases) Air pollution such as soil dust caused by paving of roads or the backfill of soil associated with the substation or transmission/distribution line construction is anticipated. Construction vehicles and equipment could increase gas and dust emissions. However, the impact is temporary and limited.	B-	D	B-	D
2	Water pollution	C-	C-	(Construction phases) Total suspended solids and turbidity downstream might be increased. However the cut construction activities will be carried out mainly only in the dry season and the water from construction site is not discharged to the public water body or river. Thus the impact is limited. (Operation phases) The waste water discharged by the substation workers drains to the sewage pipe. In addition, the number of workers in the new substation is small. Thus, the SS will not affect to the public water quality. Furthermore there will be no factor of water pollution caused by transmission/distribution line.	B-	D	B-	D
3	Waste generation (construction debris, extra soils on the construction site)	B-	B	(Construction phases) During and after finishing works, construction wastes might remain on the construction sites of SS and transmission/distribution line. Domestic wastes also will be generated from the workers. However, waste collection service firm will be cooperated and collect these wastes. The waste produced at the construction site needs to be disposed in an appropriate manner and at an appropriate place. (Operation phases) The generation of litter in SS is anticipated and shall be treated appropriately though the impact will be limited. In addition, the leakage of oil from the electrical transformer unit might be occurred in operation and maintenance phase in substations. An appropriate waste management is required. On the other hand, the transmission/distribution line in operation will not generate waste.	B-	B-	B-	D
4	Soil contamination	C-	D	(Construction phases) There will be no factor of soil contamination for SS and transmission/distribution line.	D	D	D	D

No.	Item	Initial Rating at scoping		Description	Evaluation after survey			
					SS		Transmission and distribution Line	
		Construction Phases	Operation Phases		Construction Phases	Operation Phases	Construction Phases	Operation Phases
5	Noise and vibration	B-	D	(Construction phases) Impact of noise and vibration on the neighborhood of SS and transmission/distribution line cased by the construction equipment or construction vehicle is anticipated during construction work, but the impacts will be temporary and short in duration.	B-	D	B-	D
Natural Environment								
10	Hydrological situation(including under water)	C-	C-	(Construction phases)Even though the project does not plan to create any routes that will have the T/L crossing over any river currently, it should be checked again at the detailed design of the route. On the other hand, SS will not involve the construction work which affects to hydrological situation. (Operation phases) It is expected that the construction of SS and transmission/distribution line do not affect to the hydrological situation.	D	D	C-	D
12	Logged street trees	C-	D	(Construction phases)The transmission/distribution line route is on the road's edge; trees will not be cut or affected. The project will take care for the route to avoid the point that requires the logging of street tress. It shall be checked at the detail design phase. On the other hand, there is no wide-scale logging of trees in the proposed site of Substations.	D	D	C-	D
Social Environment								
13	Land Acquisition and Resettlement	C-	D	(Construction phases) This project does not require resettlement because the proposed sites are public land or EDC's land. In addition, the project has not planned any new land acquisition for itself. In terms of the land history, it is anticipated that compensation will not be necessary. On the other hand, temporary land occupation might occur to provide a stockyard for construction materials or construction camp. Their impact is unknown because the construction plan has not been prepared yet.	C-	D	C-	D
15	Minorities and indigenous people	C-	C-	(Construction phases and operation phases)The project area is located in the urban area of Phnom Penh City. Thus no minority ethnic group who suffers the negative impact has not been confirmed.	D	D	D	D
16	Regional economy such as job opportunities or livelihood	B-/ B+	A+	(Construction phases) It might affect to livelihood of people making business along the selected streets due to the restricted traffic. However, these impacts are made minor and temporally. The construction of SS will not have such an adverse impact. Moreover, people will have chance to work with this project in construction phase.	B+	A+	B-/ B+	A+
18	Water usage or water rights	C-	C-	(Construction phases)The neighbor area and people might have negative impact if the construction work cuts the underground water supply by mistake during the construction of transmission/distribution line. On the other hand, there will be no impact for the SS construction. (Operation Phases) It is expected that there is no impact of water usage or water rights.	D	D	C-	D
19	Disturbance to social infrastructures and services	B-	A+	(Construction phases) It will affect to the quality of resident's life and tourism by traffic congestion for short time during the contraction of transmission/distribution line. The impact will be limited and temporary. In addition, the constructor should be careful to avoid any breakage failure of existing underground facilities such as a water pipe or telecommunication line etc when they dig the ground for transmission/distribution line. Regarding to the SS, there will not be such an impact.	D	A+	B-	A+
20	Living environment of residents	B-	A+	(Construction phases) The temporary and small impact on the surrounding traffic situation is anticipated due to the construction of SS and transmission/distribution line. However, the impact is limited.	B-	A+	B-	A+

No.	Item	Initial Rating at scoping		Description	Evaluation after survey			
					SS		**Transmission and distribution Line**	
		Construction Phases	Operation Phases		Construction Phases	Operation Phases	Construction Phases	Operation Phases
21	Local conflict of interests	C-/ C+	C-/ C+	(Construction phases)The street stalls and other shops along the selected streets for project might have conflicts for the route selection when some of them hate the construction, but the impact is minor and temporally. It is important to obtain their understanding. (Operation phases) There is no factor which affects to the local conflict of interests. The benefit of the project extends over the area of Phnom Penh City.	D	D	B-	D
22	Historical and cultural heritage	B-	D	(Construction phases) There are no any historical and cultural heritages to be damaged by the project.	D	D	D	D
23	Destruction of landscape	B-	B-	(Construction phases) The construction site near the tourist spot might affect to the surrounding landscape regarding to SS and transmission/distribution line, but the impact is minor and temporally. (Operation phases) If the substation building has any specific or unpleasant features, the adverse impact might be made. The design of the building should be coordinated for SS to be match with surrounding landscape and buildings. Regarding to the T/L, there is no impact because the lines are buried underground.	B-	B-	B-	D
25	Children's right	**C-**	D	(Construction phases) During construction phase, the consideration shall be provided for children labor not to be hired to work.	B-	D	B-	D
26	Increase the risk of infectious diseases such as HIV/AIDS	B-	D	(Construction phases) HIV/AIDS is still prevalent in Cambodia thus it may happen due to influx of workers from various provinces, however, these impacts will be minor by training before starting construction.	B-	D	B-	D
27	Work environment including work safety	B-	C-/ C+	(Construction phases) Some accidents inevitably might happen during the construction of SS and transmission/distribution line. Paying attention to the safety of the construction work is required. (Operation phases) Some accidents inevitably might happen at the operated substations. The safety management of the work environment is required.	B-	B-	B-	D
Others								
28	Accident	B-	D	(Construction phases) Accidents can happen when people enter the construction site because there are some dangerous equipments or excavation. A safety measurement such as a warning sigh should be taken.	B-	D	B-	D

Rating:
A+/-：Significant positive/negative impact is expected
B+/-：Positive/negative impact is expected to some extent
C+/-: Extent of positive/negative impact is unknown (Further examination is needed, and the impact could clarified as the study progresses)
D：No impact is expected
Note) The hatching cell indicates the re- rating of A-, B- or C-.

Source: JICA Survey Team

As a conclusion, it is anticipated that improving the power supply by reinforcing T/Ls, substations and distribution lines per this project will definitely result in a better quality of life and local economics. The result of the survey indicates there is no significant impact to the environment and society in this F/S. However, the project area is located in a crowed urban area and there will be some possibility of impact from noise, traffic and neighborhood shop activities. These impacts are minor and temporary, but an adequate mitigation measure shall be taken.

5.7 Mitigation Measures

Based on the results of the assessment, mitigation and management measures are proposed as shown in Table 5. 18. The cost of the design and implementation is included in the total cost. The others cost is shown in Table 5.18.

Table 5. 18 Mitigation/Management Measures

Item		Activity	Mitigation/Management Measures	In charge of Implementing /Responsible Organization
1. Construction and Renovation of SS				
Pollution Control				
1-1	Air pollution	Design and Construction Phase	- Use good quality of project construction machineries and trucks/vehicles with lowest emission air pollution, and properly maintenance to make sure all those machineries are keep in low emission of polluted air. - Regularly spray water on the community earth road that will be used by the project and the access earth road to the project site during dry day. - Cover on the construction materials (cement, aggregate, sand, etc.) when they are transported into the construction site.	DCC PIC, EDC
1-2	Water pollution	Design and Construction Phase	- Put trapped cloth around the construction site near the water body, earth refill with good compaction and concreting soon after construction each site. - The contractor will cooperate with waste collection service to collect the extra soil if it remained after refilling at the construction site.	DCC PIC, EDC
1-3	Waste generation (construction debris, extra soils on the construction site)	Design and Construction Phase	- Minimize the production of waste - Waste will be properly recycled or disposed of in the local landfill or prepared landfill.	DCC PIC, EDC
		Operation Phase	- Minimize the production of waste - Waste will be properly disposed and buried by the waste collection service firm. - The Substation has the oil collection container from the transformer with suitable dimension and equipped unit for separation oil from water in each transformer.	EDC
1-5	Noise and vibration	Design and Construction Phase	- Construction method and machine shall be selected to minimize the noise and vibration - The construction schedule should be informed to the local communities in advance. - Limit the hours of construction to daylight hours. Local residents should be consulted if some evening work is required	Contractor, EDC
1-13	Land Acquisition , Resettlement	Design and Construction Phase	- The contractor deals with the selection and occupation of the temporary land which provides the stockyard for construction materials or construction office/camp, with the responsibility. The compensation policy shall comply with the new JICA Guideline(2010). - The land acquisition procedure for the SS site in Olympic Stadium follows the Cambodian regulation and new JICA Guideline(2010).	DCC PIC, EDC
1-20	Living environment of residents	Design and Construction Phase	- Traffic order or facilitator will be provided near the gate of the substations where the construction vehicle goes in and out during the period of the project construction.	DCC PIC, EDC
1-23	Destruction of landscape	Design and Construction Phase	- The construction area will be fenced not to bring a feeling of insecurity or spoil the sight.	DCC PIC, EDC
		Operation Phase	- The building of the substation should have the harmonious color and design.	EDC
1-25	Children's right	Design and Construction Phase	- The adult labor should be hired for the construction work for compliance with the regulations.	DCC PIC, EDC
1-26	Increase the risk of infectious diseases such as HIV/AIDS	Design and Construction Phase	- Local labor will be hired. - Educate or campaign on hygienic and HIV/AIDS to workers/staffs in prior the commencement of the works.	DCC PIC, EDC

Item		Activity	Mitigation/Management Measures	In charge of Implementing /Responsible Organization
1-27	Work environment including work safety	Design and Construction Phase	- Contractor will prepare and implement a health and safety plan. All safety working standards by providing safety tool and equipment such as boot, gloves, eye-glasses, and helmet will be followed. The safety plan will be in place and monitored regularly. - The training and information on the safety will be arranged. - Provide camp with adequate sanitation latrine for the project workers especially in construction site of substations. - Provide clean water and properly manage the waste in construction site.	DCC PIC, EDC
		Operation Phase	- The health and safety plan will be followed. - The training and information on the safety will be arranged. - The safety equipment is installed for the case of an accident happened. - In period of the operation of high-voltage system, it can be a risk such as an electrocution to the workers. Danger and warming signs will be put up.	EDC
Others				
1-28	Accident	Design and Construction Phase	- All safety working standards by providing safety tool will be obeyed.	DCC PIC, EDC
2. Construction of Transmission and distribution Line				
Pollution Control				
2-1	Air pollution	Design and Construction Phase	Same as 1-1	Same as 1-1
2-2	Water pollution	Design and Construction Phase	Same as 1-2	Same as 1-2
2-3	Waste generation (construction debris, extra soils on the construction site)	Design and Construction Phase	Same as 1-3	Same as 1-3
2-5	Noise and vibration	Design and Construction Phase	Same as 1-5	Same as 1-5
Natural Environment				
2-10	Hydrological situation(including under water)	Design and Construction Phase	- The T/L route which crosses the river should be avoided if the route is re-selected in the design phase.	Contractor, EDC
2-12	Logged street trees	Design and Construction Phase	- The cutting trees will be done within areas of the project site where construction activities are required. - Shifting substation base and alignment/route of the T/L to avoid cutting trees is required in some places..	Contractor, EDC
Social Environment				
2-13	Land Acquisition , Resettlement	Design and Construction Phase	- The contractor handles the selection and occupation of the temporary land which provides the stockyard for construction materials or construction office/camp, with the responsibility. If the compensation for such a temporally site is required, it shall be indicated in the contract document with contractor that all the procedure shall follow the new JICA Guideline (2010). The contractor's activities shall be checked. - The project executive company/EDC will do properly negotiation with shop owner to solve for getting permission to construct T/L passing their places or inside their shops.	DCC PIC, EDC
2-16	Regional economy such as job opportunities or livelihood	Design and Construction Phase	- The project executive company/EDC will do properly consultation and negotiation with the local communities before the construction.	EDC

Item		Activity	Mitigation/Management Measures	In charge of Implementing /Responsible Organization
2-18	Water usage or water rights	Design and Construction Phase	- The prior confirmation should be done before the construction work in order to avoid any accident of the damage of water supply tube by construction.	DCC PIC, EDC
2-19	Disturbance to social infrastructures and services	Design and Construction Phase	- Traffic order or facilitator will be provided at crossing points of busy road in period of the project construction. - The special construction method such as the duct bank system or pipe jacking method will be considered in order to avoid traffic intersections at the intersection, heavy traffic etc in that case the open cut method is unable to be permitted by the authorities concerned. - The existing underground facilities on the transmission/distribution line will be studied before the construction. The test digging is recommended before the excavation.	DCC PIC, EDC
2-20	Living environment of residents	Design and Construction Phase	- Traffic order or facilitator will be provided at crossing points of busy road in period of the project construction.	DCC PIC, EDC
2-21	Local conflict of interests	Design and Construction Phase	- The consultation with local communities and neighborhood shops should be done in advance of the construction. If there is any significant issue occurs, the T/L route might be considered to change.	DCC PIC, EDC
2-23	Destruction of landscape	Design and Construction Phase	- The construction area will be fenced not to bring a feeling of insecurity or spoil the sight.	DCC PIC, EDC
2-25	Children's right	Design and Construction Phase	Same as 1-25	Same as 1-25
2-26	Increase the risk of infectious diseases such as HIV/AIDS	Design and Construction Phase	Same as 1-26	Same as 1-26
2-27	Work environment including work safety	Design and Construction Phase	Same as 1-27	Same as 1-27
Others				
2-28	Accident	Design and Construction Phase	Same as 1-28	Same as 1-28

DCC : Design and Construct Contractor
PIC : Project Implementation Consultant

Source: JICA Survey Team

5.8 Stakeholder Meetings

The Survey Team required two stakeholders meetings (SHMs) during this Survey period to EDC. The Minutes of the 1st mission of this Survey between EDC and the Survey Team indicates that EDC agreed to hold two SHMs in consideration of the necessary budget. The 1st one was held on 19th March, 2013 to share the information and exchange the opinion on the draft scoping and project plan. The 2nd one was held on 30th May, 2013 to share the DF/R. The summary of the meeting is shown in Table 5.19 and Table 5.20. The minutes of the meetings are shown in Appendix-5.8-1 and Appendix-5.8-2. The opinions from stakeholders were reflected to the Survey such as a modification of draft scoping.

Table 5. 19 Result of 1st stakeholder meeting

a) Style of stakeholder meeting	Meeting
b) Date	18th March, 2013
c) Venue	EDC Head Office
d) Participants	Representatives from; - DPWT, Phnom Penh Municipality - Khan(District) 7 Makara - Khan Don Penh - EDC - JICA Survey Team
e) Summary	- The representatives from EDC explained the outline of the project - The scoping plan and information on the likely adverse impact on the natural and social environment by the implementation of the project were shared. - The required considerations and approval for the project were shared. - Some comments on the project plan from Stakeholders were exchanged.

Source: JICA Survey Team

Table 5. 20 Result of 2nd stakeholder meeting

a) Style of stakeholder meeting	Meeting
b) Date	30th May, 2013
c) Venue	EDC Head Office
d) Participants	Representatives from; - Department of the Environmental Impact Assessment, Ministry of Environment - Phnom Penh Municipality - Department of Land Management, Urban Planning and Construction, Phnom Penh Municipality - Related Khans where the planed substations and T/L are located. - EDC - JICA Volunteer to EDC Distribution Department - JICA Survey Team
e) Summary	- The representatives from EDC explained the outline of the project - The draft IEE was shared. - Some comments on the project plan from Stakeholders were exchanged.

Source: JICA Survey Team

5.9 Environmental Checklist

Environmental Checklist (Power Transmission and Distribution Lines) is attached in Appendix 5.9. This Checklist includes the contents of Environmental Management Plan and Environmental Monitoring Plan which are shown in Chapter 8.3.

5.10 IEIA Report

An approval of the IEIA report is required for this project. A draft of the IEIA report was prepared based on the DFR and its summary was explained at the 2nd Stakeholder meeting. The Survey Team confirmed that EDC will submit the IEIA report for its approval after its finalization.

5.11 Considerations

Considering the time schedule of the project implementation, it is important for EDC to follow the necessary procedures to obtain the approval of IEIA as soon as possible. In addition, it is recommended that the international consultant in charge of the environment and social considerations is assigned in the detailed design phase to take care of those considerations when the T/L and D/L route is finalized.

Chapter 6 Outline Design of Equipment

6.1 Underground Transmission Line

6.1.1 Route Profile of the Underground Transmission Line

The total 5 routes of the 115kV underground transmission lines are shown in Table 6. 1 and the detailed route maps will be shown below.
The transmission line of the "UG-Route3" was decided to be excluded from the scope of work of this project following the discussion between JICA and EDC.

Table 6. 1 The Route Profile of 115kV Underground Transmission Lines

Route name	Location	Route distance (m)	Duct bank system (Circuit)	Join bay 7m (numbers)	Duct bank system (length)
UG_Route1	[GS1～EDC SS]	2,330m	Duct bank system(1cct) including spare duct for future circuit(1cct)	8	2,274m
UG_Route2	[EDC SS～Hunsen Park SS]	3,330m	Duct bank system(1cct)	11	3,253m
UG_Route3	[Hunsen Park SS～GS2]	(3,810m)	Duct bank system(1cct)	(12)	(3,726m)
UG_Route4	[Olympic Stadium SS～Hunsen Park SS]	3,330m	Duct bank system(1cct)	11	3,253m
UG_Route5	[GS3～OlympicStadium SS]	4,370m	Duct bank system(1cct) including spare duct for future circuit(1cct)	14	4,272m
Total		**13,360m (17,170m)**		**44 (56)**	**13,052m (16,778m)**

( ) : UG_Route3 distance

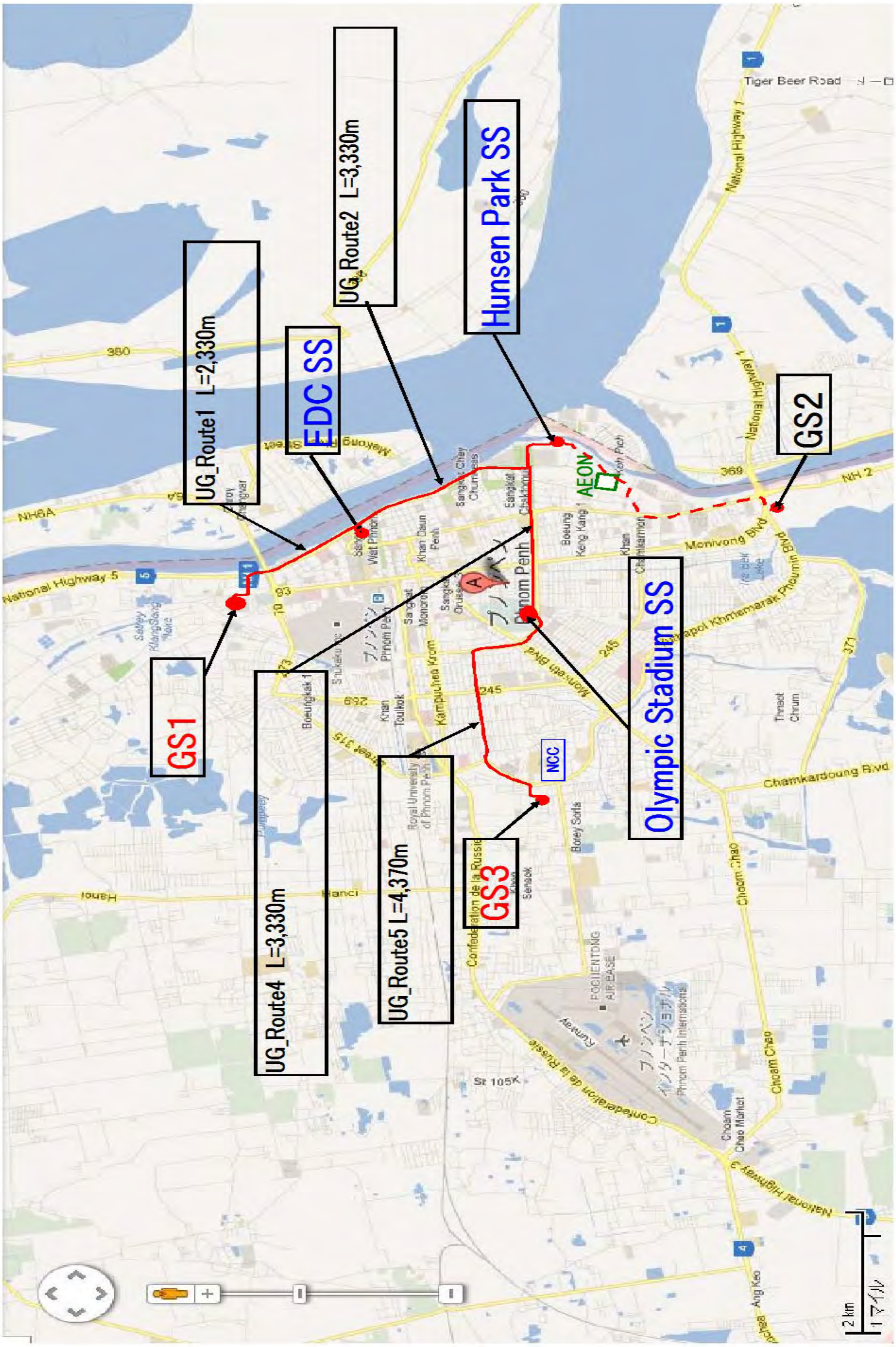


Figure 6. 1 General view of the UG Route

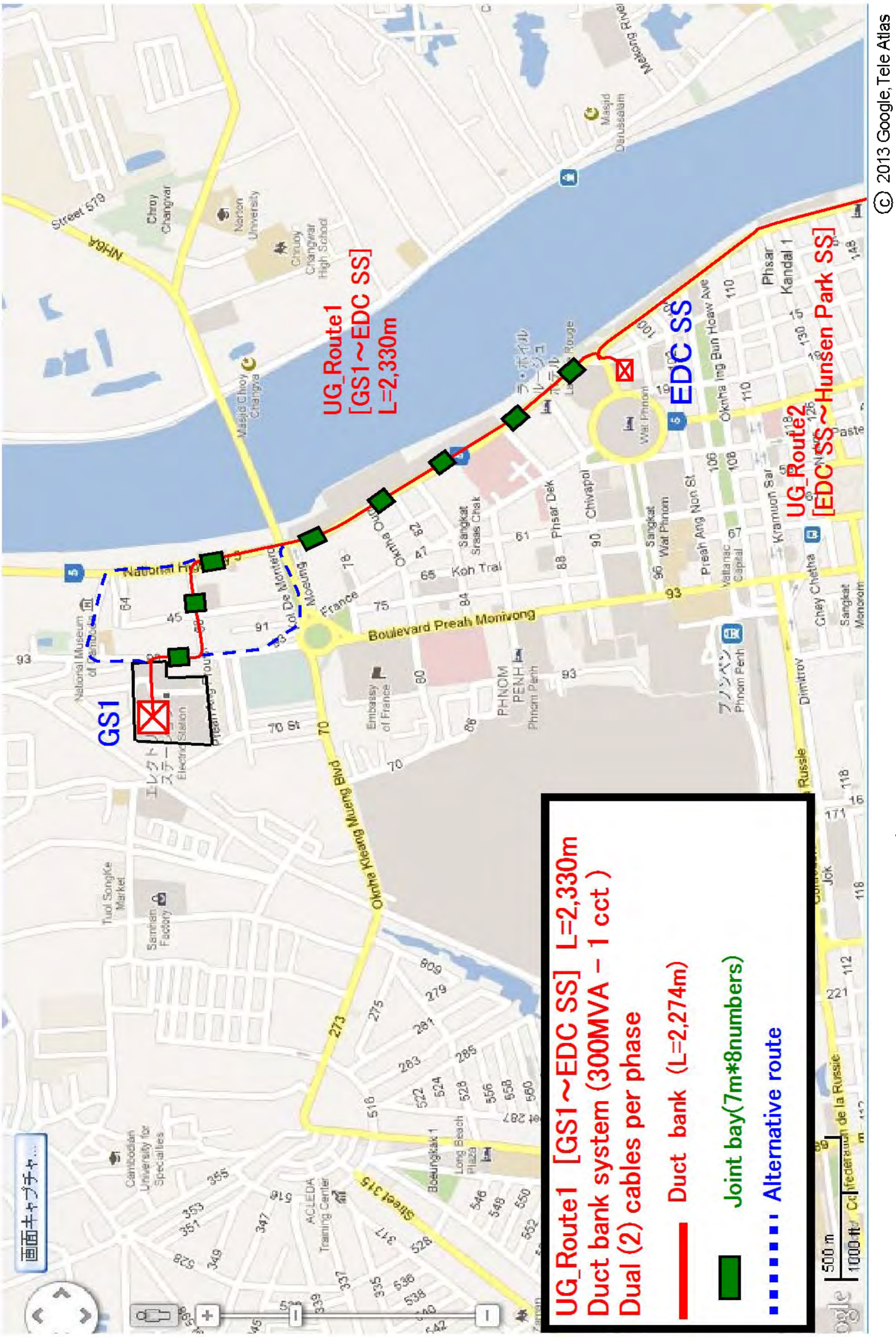


Figure 6. 2 UG Route 1 Map

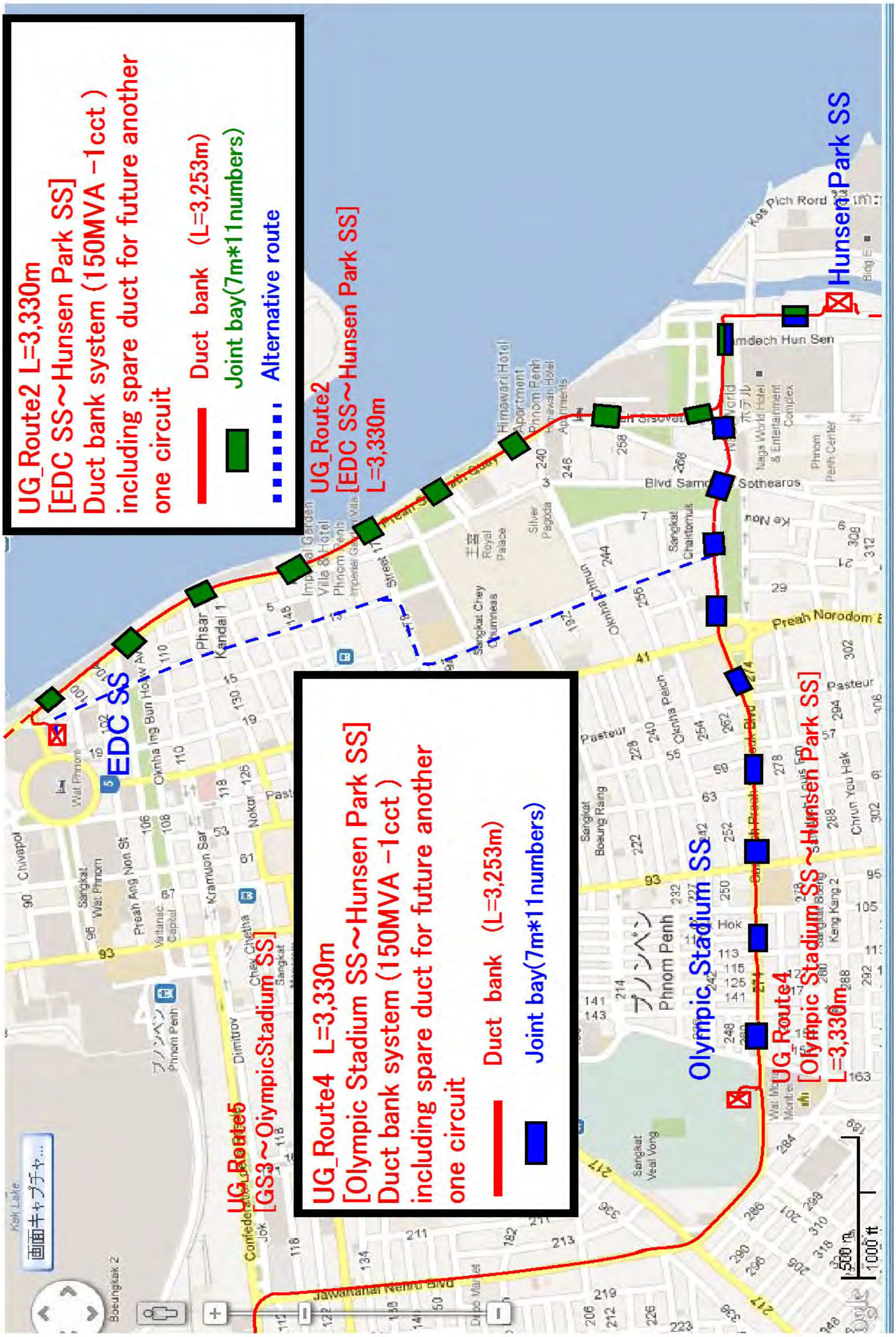


Figure 6. 3 UG Route 2,4 Map

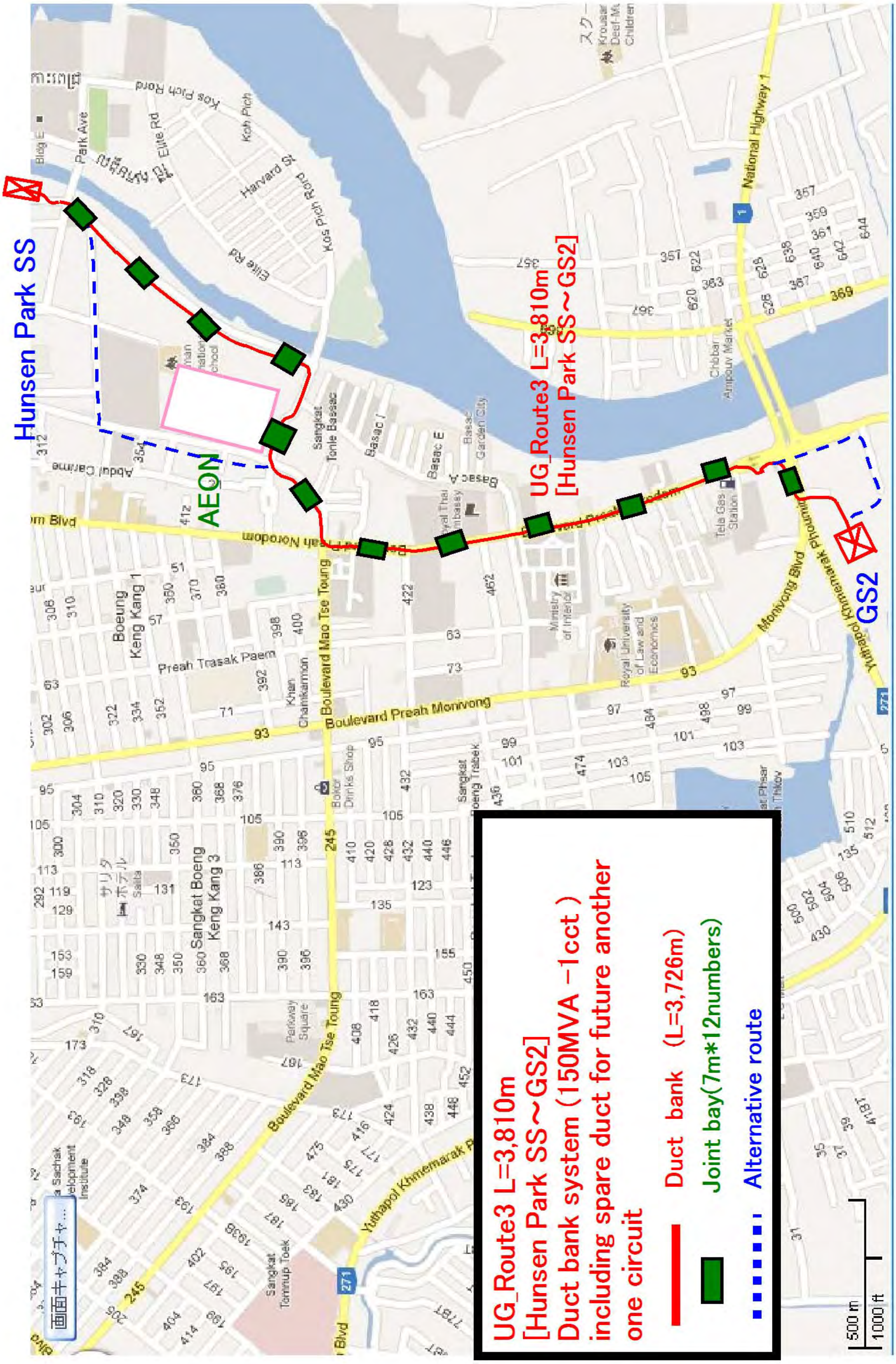


Figure 6. 4 UG Route 3 Map

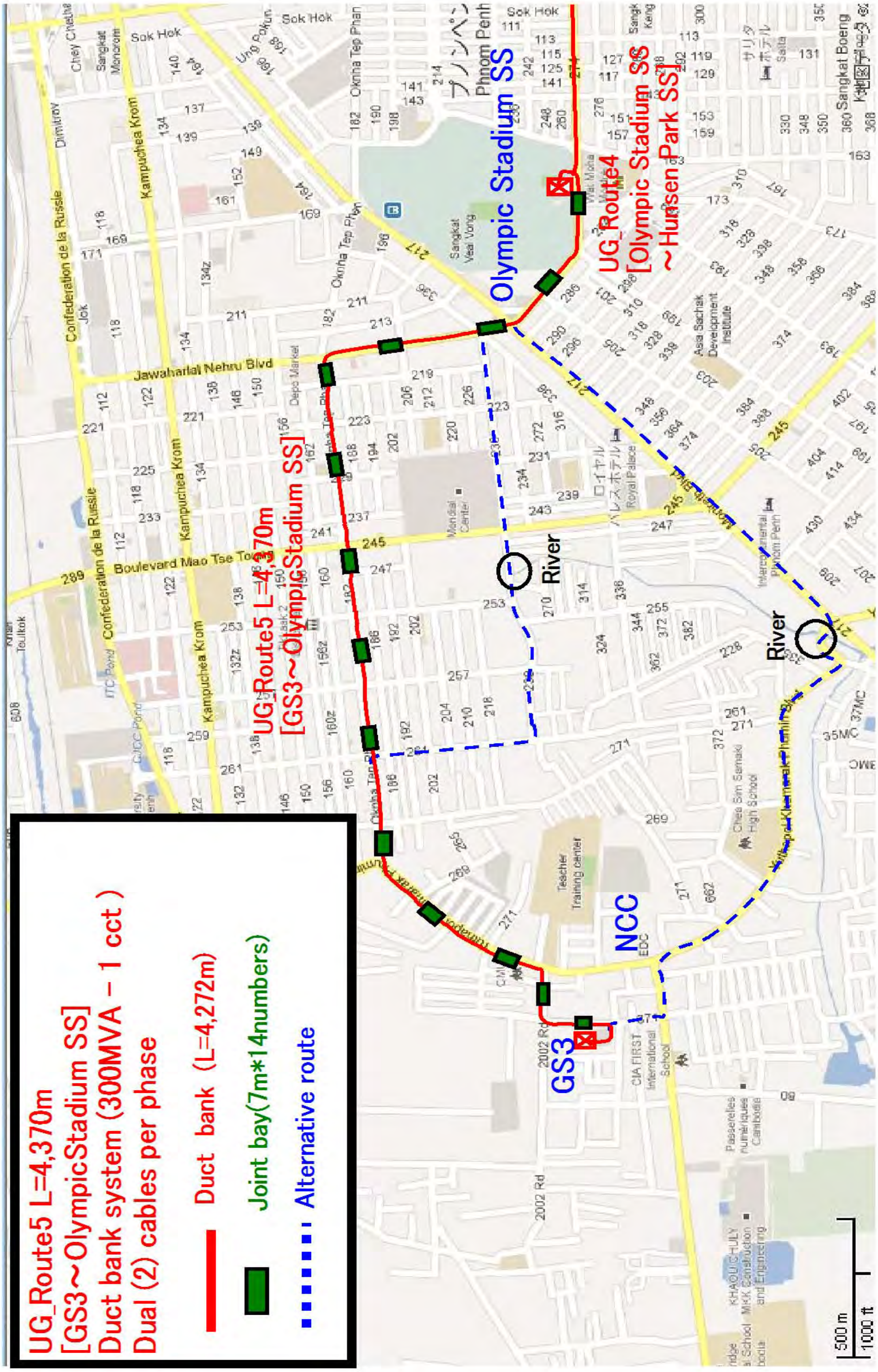


Figure 6. 5 UG Route 5 Map

6.1.2 Transmission Capacity of Underground Power Cable Line

The transmission capacity of the underground power cable lines shall be 300MVA for the lines between the existing substations of GS1, GS3 and the new substations of EDC, Olympic Stadium, and 150MVA for the interconnection lines between the new substations. However, the transmission capacity between the new substations, the survey team has decided to consider the double 150MVA circuits configuration to study installation configuration, cable type and cable size considering that one more 150MVA circuit will be installed for each circuit in the near future.

6.1.3 Type of 115kV Underground Cable and Installation Method

From an economical point of view, and in consideration of the construction time, a direct burial installation method shall be considered as a basic philosophy subject to protect and eliminate hindrances to the life of neighborhood and traffic disturbances etc.. If the standard trenching method will be applied, open cut trenching will remain for about one month, thus there is the possibility of hindrances occurring to the life of the neighborhood and traffic disturbances etc. especially in congested areas, narrow roads, heavy traffic roads etc. To protect the above inconveniences, the duct bank system shall be applied to eliminate open cut places.

(1) Burial Depth, Soil Temperature and Soil Thermal Resistivity

For the calculation of the current carrying capacity of the underground power cable, it is recommended that the maximum conductor temperature be 90 deg. C as a mandatory condition to keep the XLPE insulation in sound condition from the thermal deterioration/impact during its design life of 30 years.

In particular, if the burial depth is deeper, then the cables may be more safety from the outside mechanical damages, but current carrying capacity of cables will be reduce according to the burial depth.

In Cambodia, the burial depth of underground equipment such as the distribution cables and communication cables have been specified at 1.2m, and the surrounding countries such as Thailand and Vietnam have also specified the depth of the 132kV grade underground cables as 1.2m. Based on the above facts, the survey team decided that the burial depth should be a minimum of 1.2m from the surface of the ground.

On the other hand, the soil temperature and soil thermal resistivity were specified as 30 deg. C and 1.2 K.m/W according to the same specified value of surrounding countries such as Thailand and Vietnam.

(2) 300MVA Cable Type and Installation Configuration

The current carrying capacities with related conductor sizes of 115kV underground cables shall be shown in Figure 6. 6 calculated on the conditions of Table 6. 2.

Table 6. 2 Calculated Conditions of Underground Cable Capacity

Burial depth (Top of ducts)	1.2 m
Phase sepastion	210 mm
Soil thermal resistivity	1.2 K.m/W
Soil temperature	30 ℃

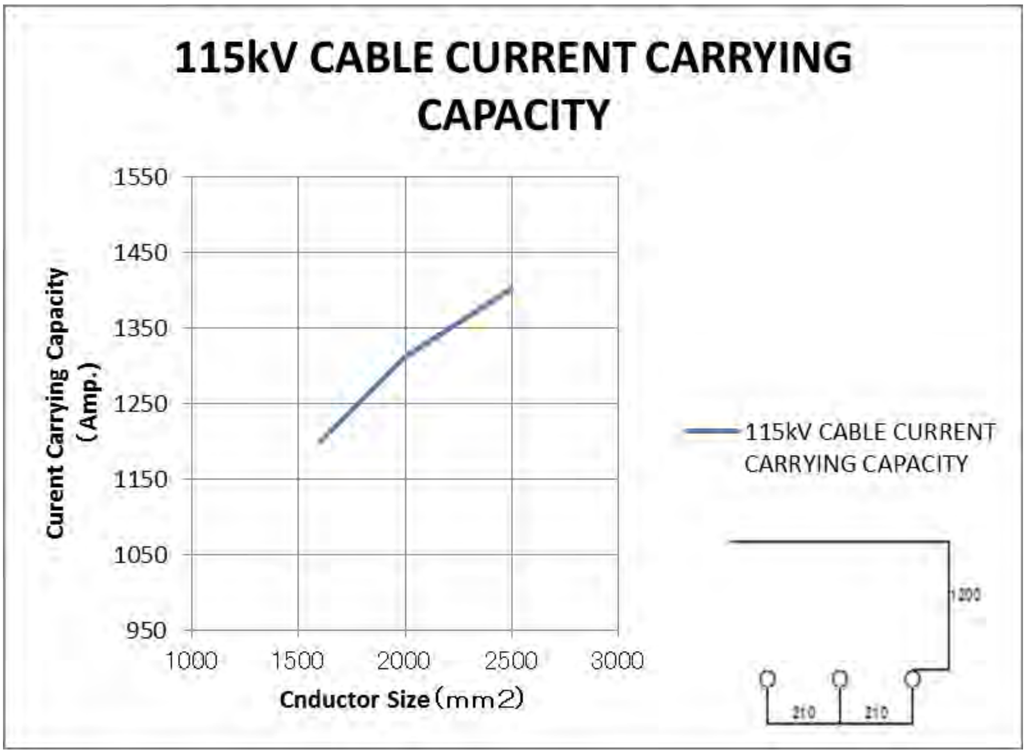


Figure 6. 6 Current Carrying Capacities of 115kV Underground Cables

The 300MVA transmission capacity is too large for the 115kV voltage grade, the required current carrying capacity of 300MVA transmission capacity is 1506A

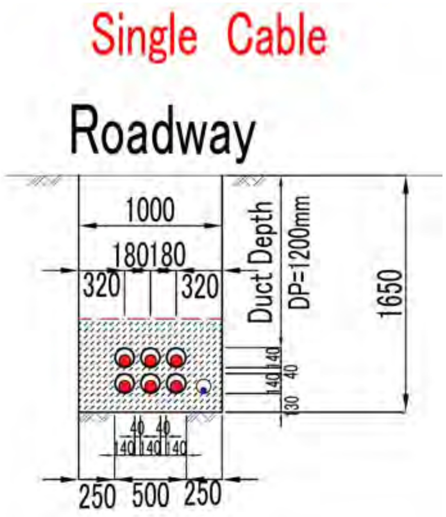
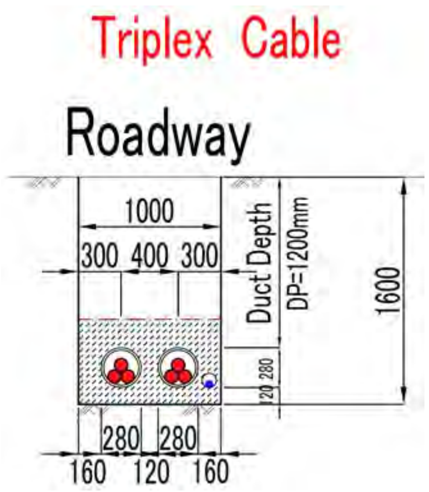
As shown in Figure 6. 6, the current carrying capacity of the maximum conductor size of 2500sqmm is 1,402 A which is unable to pass the required capacity of 1,506A at a 300MVA transmission capacity.

Based on the above study, it is necessary to have two (2) cables per phase to carry the 300MVA transmission capacity. In other words, a total of six cables are necessary for the one circuit, and these numbers of cables may lead to a longer construction time and high construction work costs due to the necessity of a number of ducts installed.

For countermeasures to deal with construction cost increases and longer construction times, the survey team will consider the application of a 3-core cable which is capable of reducing the number of ducts such as a two number of cables and ducts and also the cable laying procedure. The comparison sheet between the single core cable and 3-core cable shall be shown in Table 6. 3 below.

Table 6. 3 The Comparison Sheet between Single Core Cable and 3-Core Cable

(In case of 300MVA transmission capacity)

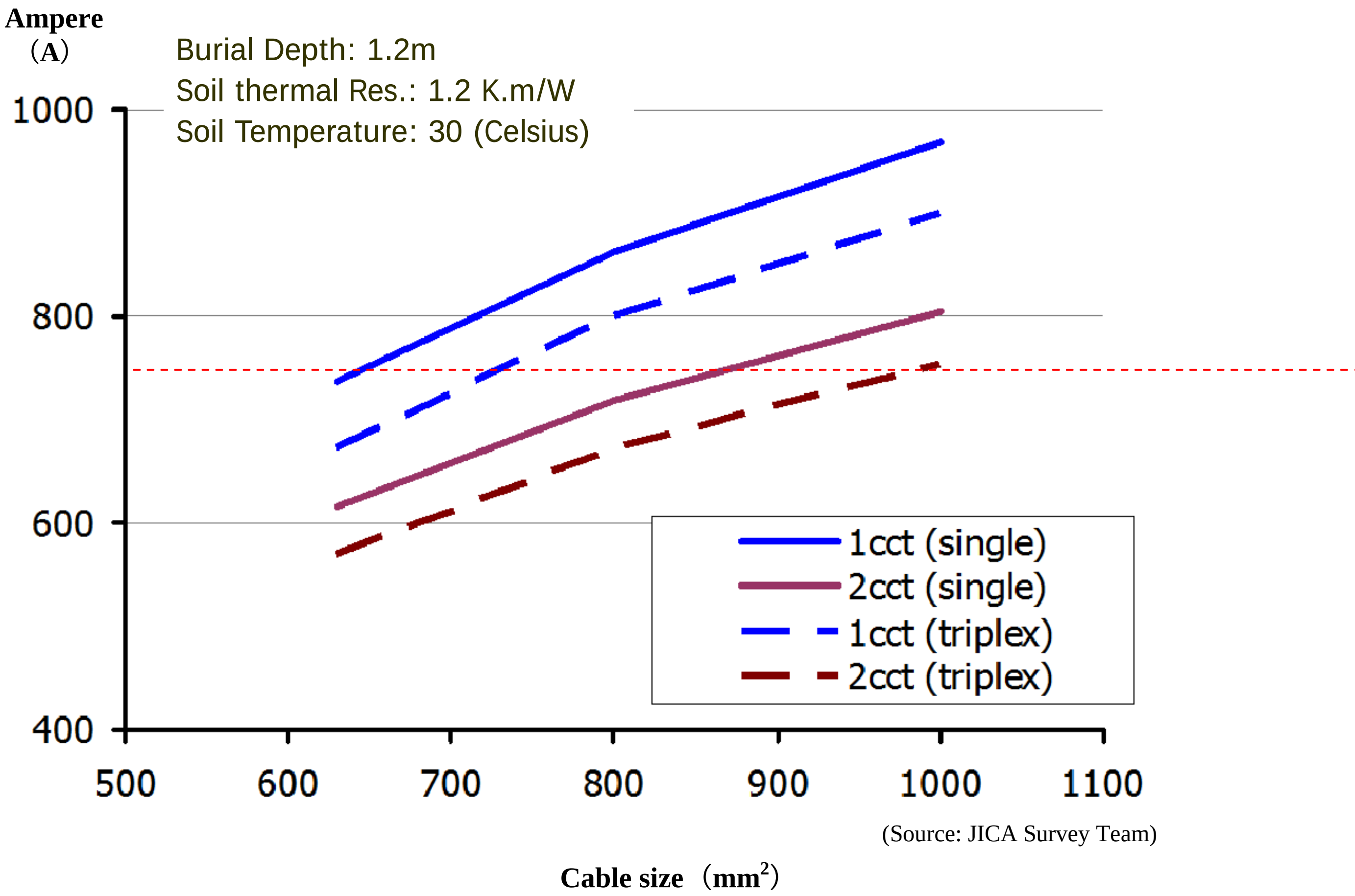
<table>
<tr><td></td><td>Single core cable</td><td>3-core cable</td></tr>
<tr><td>Installation configuration</td><td>
</td><td>
</td></tr>
<tr><td>Cable size</td><td>1000mm2</td><td>1000mm2</td></tr>
<tr><td>Construction time</td><td>12 months</td><td>11 months</td></tr>
<tr><td>Evaluation</td><td>△</td><td>◎</td></tr>
</table>

（In case of 3.6km cable route）

(Source: JICA Survey Team)

From the above comparison sheet, the application of 3-core cables is preferable due to cheaper construction costs and shorter construction time.

As for the application of the 3-core cables of over 100kV voltage grade all over the world, only 154kV triplex type (3- cable assembly type) XLPE cables were developed and put into service in Japan. Based on the above actual experience, the survey team considered the application of triplex type XLPE cables and calculated the current carrying capacity of the cables as shown in Figure 6. 7.



(Source: JICA Survey Team)

Figure 6. 7 Current carrying capacity of single core and 3-core cables

From the above calculation results shown in Figure 6. 7, dual cables with 1000sqmm copper conductor are capable to pass the required capacity of 1506 A and therefore applicable for a 300MVA circuit.

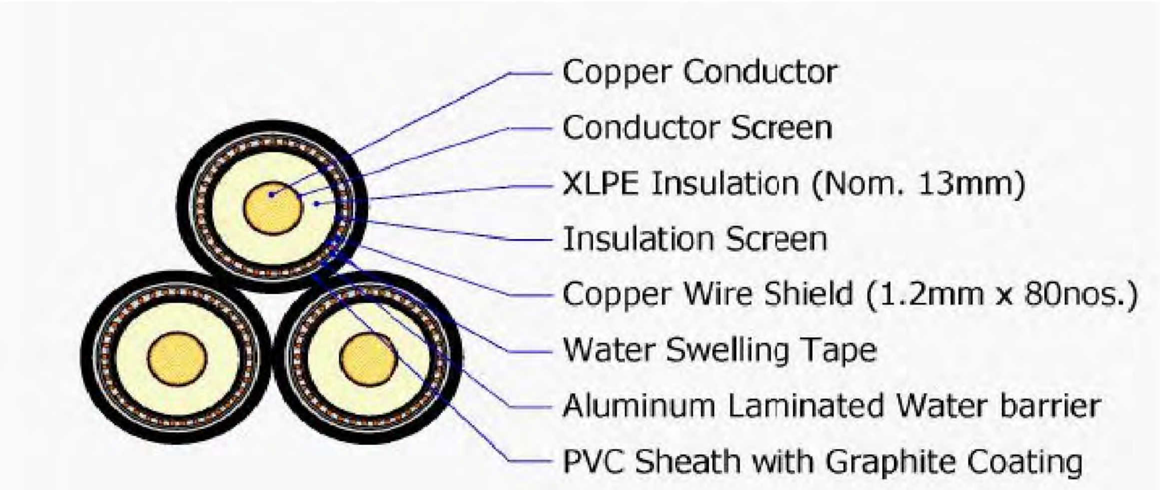
(3) 150MVA Cable Type and Installation Configuration

For the 150MVA circuits, the required current carrying capacity is 753 A. However, the transmission capacity between the new substations, the survey team has decided to consider the double 150MVA circuits configuration to study the installation configuration, cable type and cable size considering that one more 150MVA circuit will be installed for each circuit in the near future.

Based on the above philosophy, it is necessary to study 2 x 150MVA circuits which are the same results of the 300MVA circuits. Then, finally dual cables with a 1000sqmm copper conductor shall be applied for the 150MVA circuits.

(4) Cable construction

Typical cable construction of 115kV 1000mm2 triplex type XLPE cable shall be shown in Figure 6. 8.



Core diameter	Approx. 82mm
Overall diameter	Approx. 177mm
Weight	Approx. 46kg/m
Drum length	Max.400m

(Source: JICA Survey Team)

Figure 6. 8 Typical Cable Construction of 115kV 1000mm2 Triplex Type XLPE Cable

The cable consists of a 4 segmental copper conductor (Milliken type) of 1000mm^2, XLPE insulation having a thickness of 13mm in consideration of BIL and withstand testing values specified by IEC60840, then copper wire shield of 80 nos. x 1.2mm copper to withstand fault current 40kA 0.5sec.

To apply the triplex type XLPE cable specified the above mentioned construction, there is the advantageous merit to neglect the metallic sheath losses during service operation of cable circuit due to the triplex type cable construction which consists of assembled cable cores. The comparison table of cable losses of triplex type cable and single core cable shall be shown in Table 6. 4.

Furthermore, the triplex type cables installed cable duct bank have the self-absorption characteristics of cable longitudinal expansion and contraction behavior, it is not necessary to provide countermeasures for cable expansion and contraction behavior inside joint bay. From the above advantageous characteristics of triplex type cables, the utility can enjoy the merit to reduce the joint bay length of 2m.

Table 6. 4 Cable losses of 115kV 1000mm2 Single/Triplex Cables

(Unit: W/m)

	Single cable	Triplex Cable
Conductor losses	13.37	13.37
Dielectric losses	0.43	0.43
Metallic sheath losses	0.67	0.00
Total losses	14.47	13.80

(Source: JICA Survey Team)

6.1.4 Study of Construction Method of Underground Transmission Lines

The study of the construction method of underground transmission lines shall be done considering the following factors.
Conditions of the road, such as the width, nos. of lanes, intersection, interruption, congestion, etc.
Underground equipment, such as the manhole of a drainage system, water air valve, etc.
Surrounding conditions, such as land estates, buildings, etc.

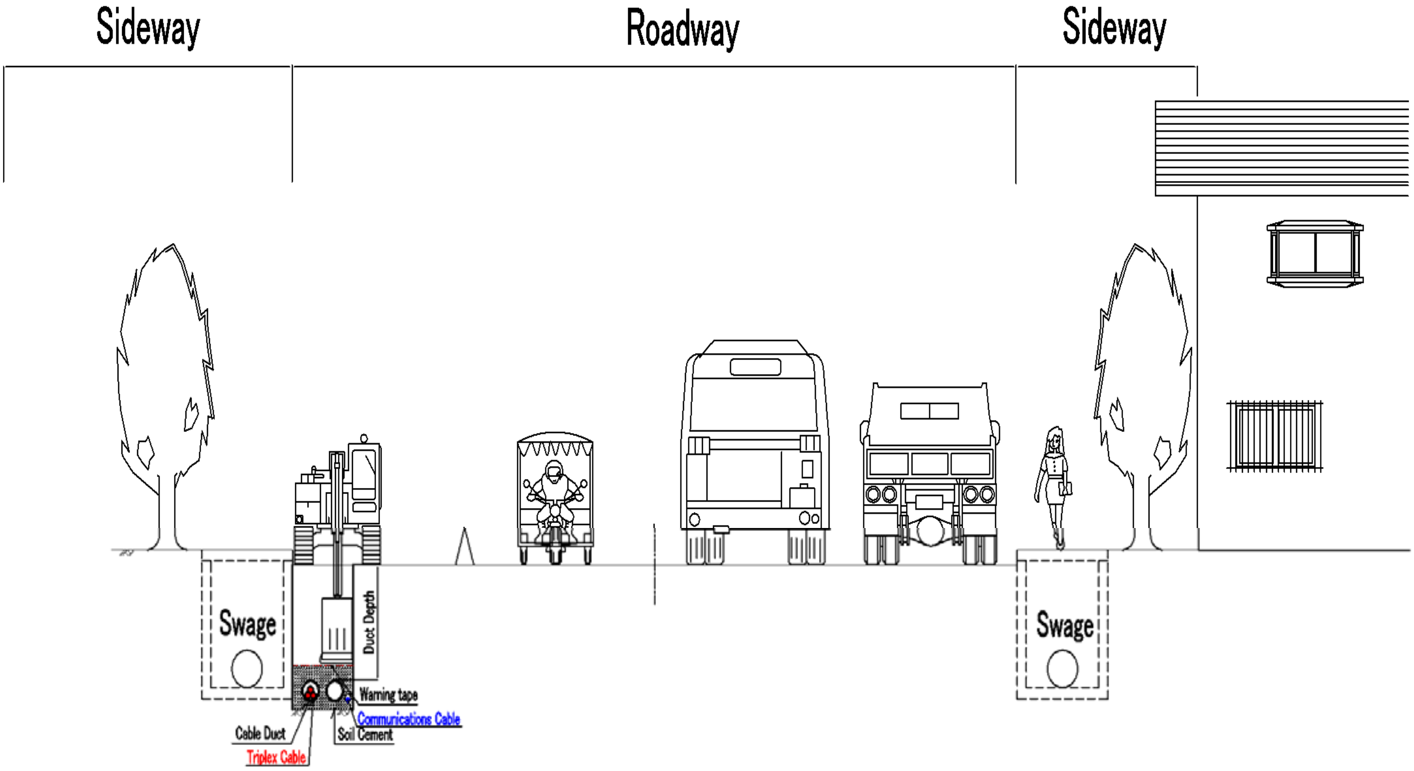
(1) Construction Method

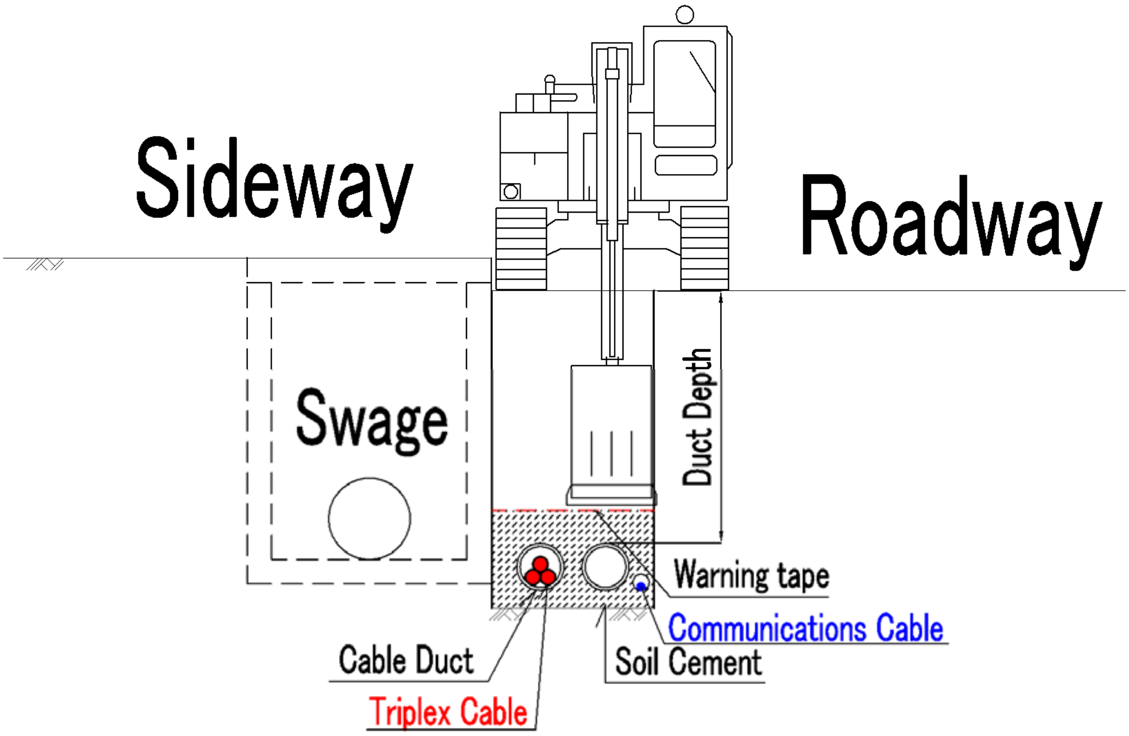
Considering existing man made trees and manholes onto the sideway, and underground distribution cables beneath the sideway, 115kV underground cables will be installed under the roadway especially inside the space alongside the sideway. Furthermore, to avoid traffic jams, the opposite side of the shopping market/arcade will be used.

The following methods are considered as a construction method.
1) Duct Bank Method (Figure 6. 9)
2) Open Cut Method (Figure 6. 10)
3) Pipe Jacking Method (Figure 6. 11)

The cost rises in order of 2) Open Cut Method, 1) Duct Bank Method, 3) Pipe Jacking Method.
However, due to the following conditions, the Duct Bank Method will be applied for the standard construction method.
A backfill is enabled on the day by adopting a Duct Bank Method, thereby Duct Bank Method can avoid a state digging for the long term.
According to the results of the existing underground facilities and traffic volume survey, the Survey Team judged that the adoption of the Duct Bank Method was possible.

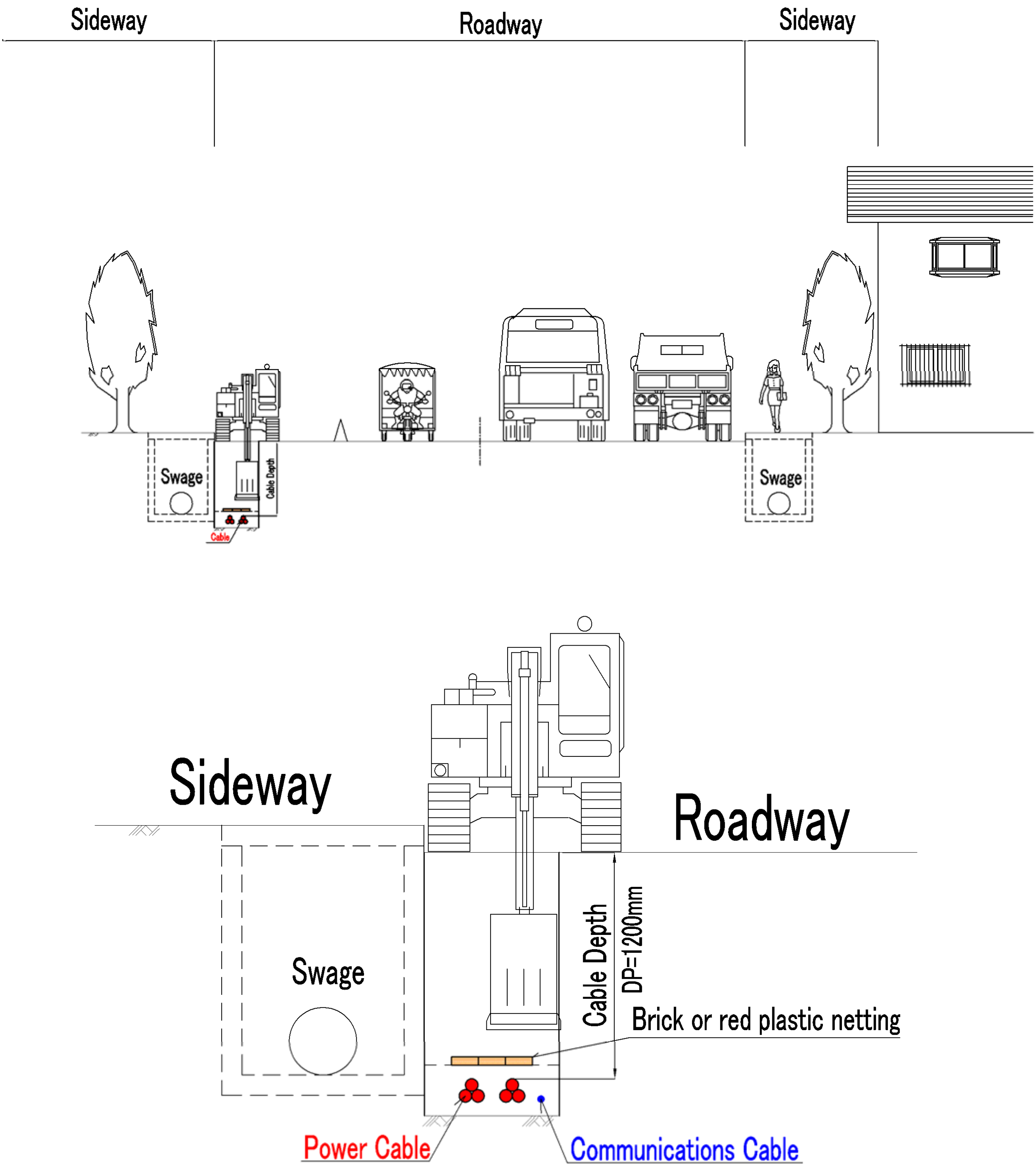
- ✓ There are many crossings.
- ✓ There are the important facilities such as palaces.
- ✓ There are some narrow roads.
- ✓ There are many shops in the roadside.





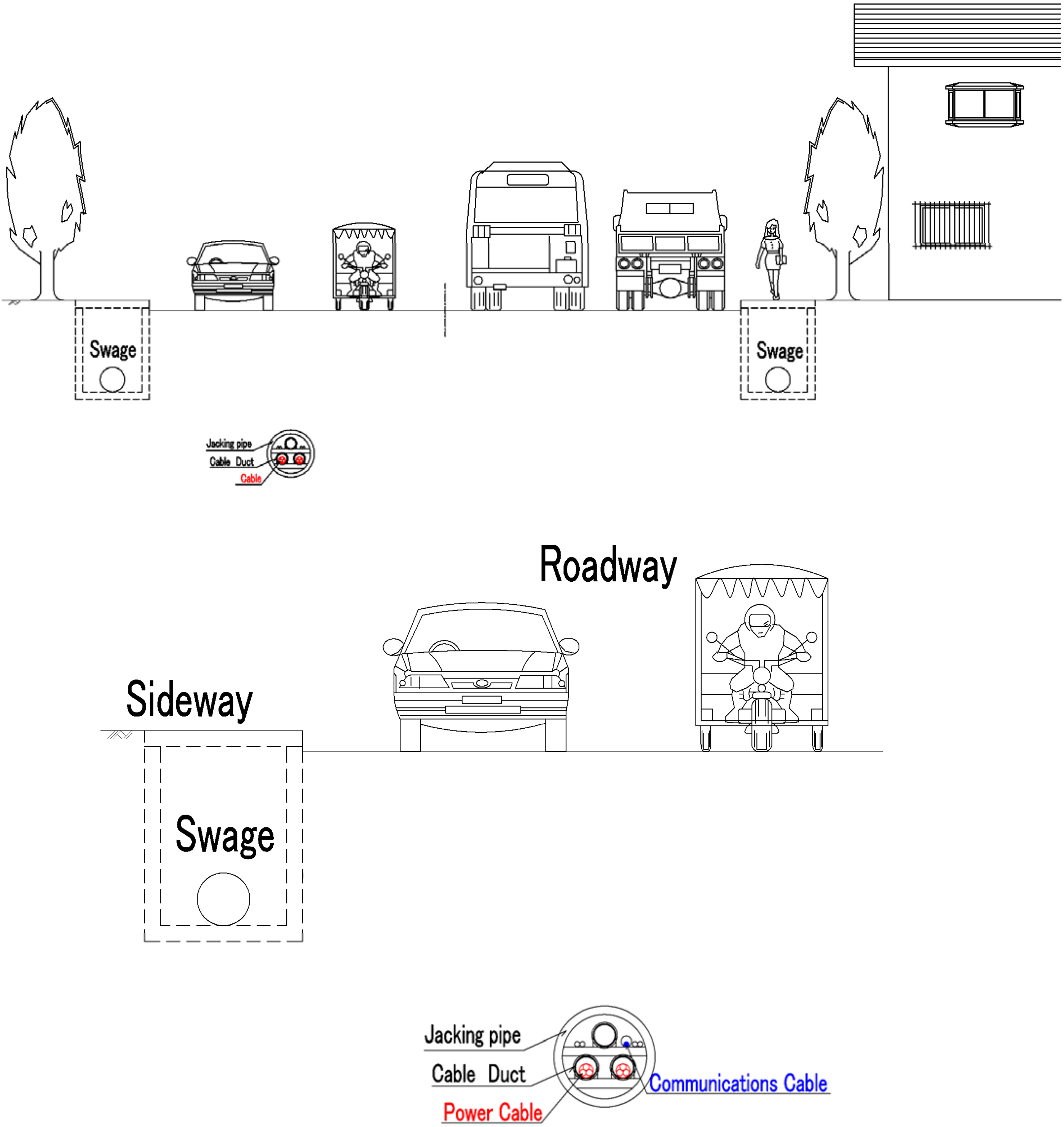
(Source: JICA Survey Team)

Figure 6. 9 Duct Bank Method (Adoption)



(Source: JICA Survey Team)

Figure 6. 10 Open Cut Method (Non-adoption)



(Source: JICA Survey Team)

Figure 6. 11 Pipe Jacking Method (Non-adoption)

(2) Study of the Joint Bay

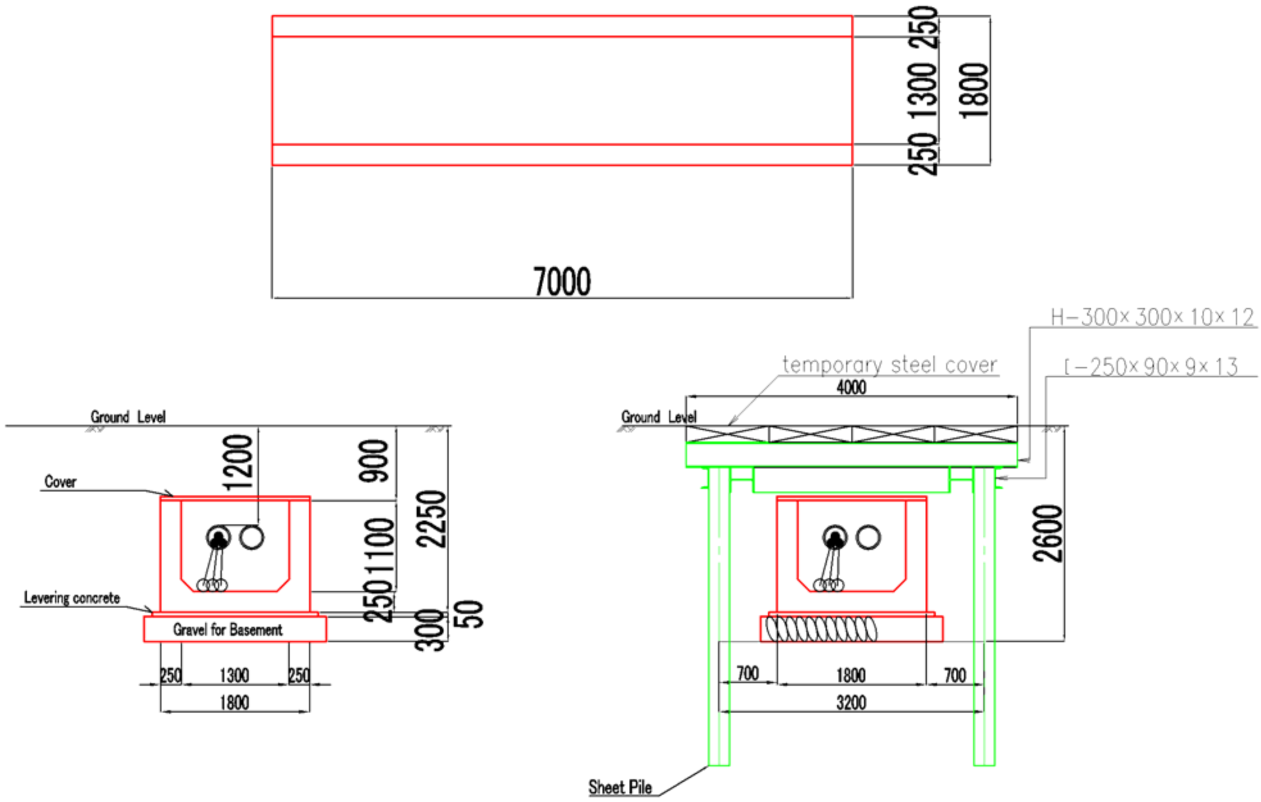
The survey team studied the Joint Bay which was necessary for power cable connections. The structure figure and temporary figure of the Joint Bay be shown in Figure 6. 12.

(a) Structure of the Joint Bay

The empty dimensions among the Joint Bay are shown below.
Width;1.2m/length;7.0m/height;1.1m

(b) Construction method of Joint Bay

It will take approximately six months from the laying of the power cable to the connection.
By adopting a temporary steel cover, general vehicles are able to pass through except during construction periods.



(Source: JICA Survey Team)

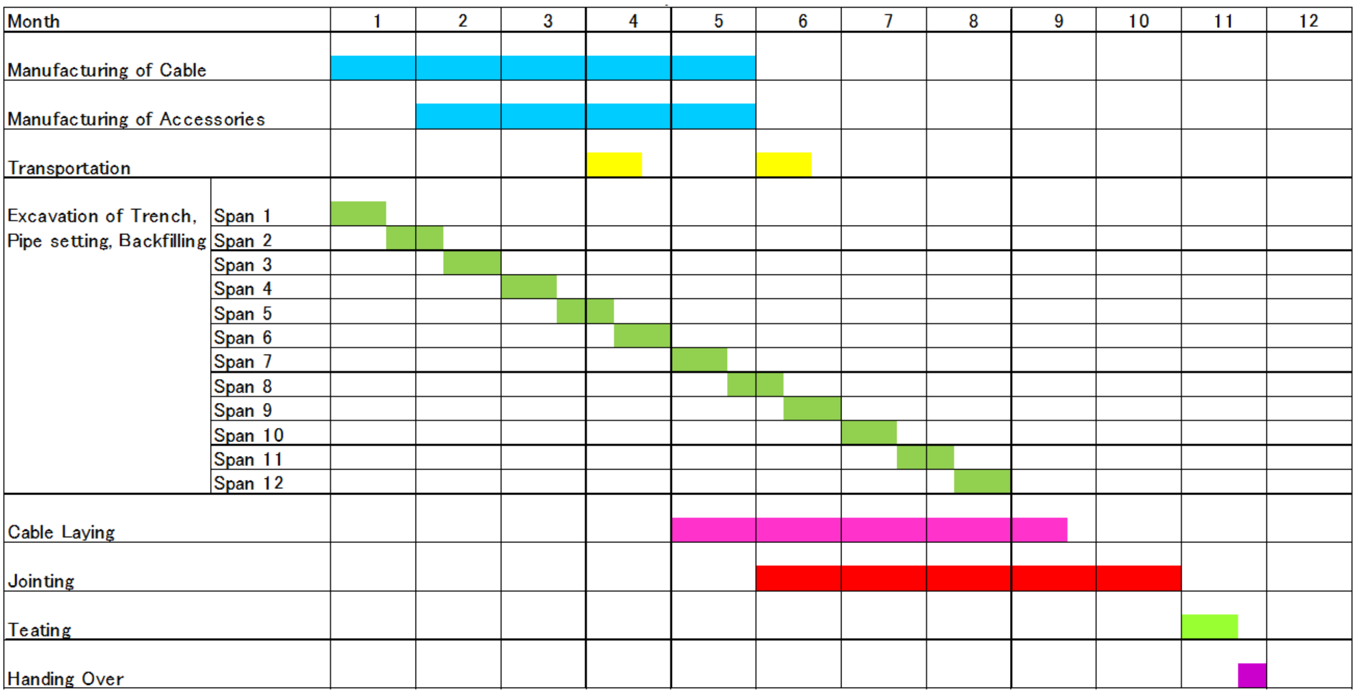
Figure 6. 12 Structure Figure and Temporary Figure of Joint Bay

6.1.5 Construction Schedule

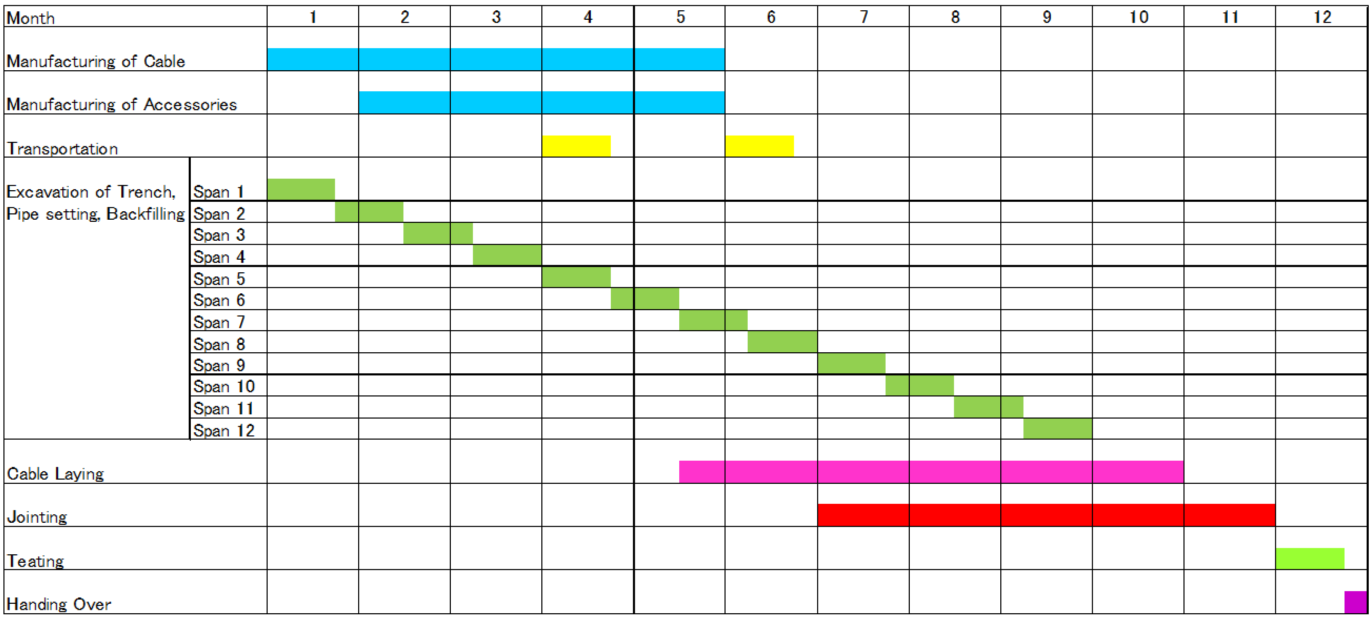
The construction schedule of both the triplex cable and single core cable of the 300MVA circuits will be shown in Table 6. 5. This construction schedule is based on the model case of the route length of 3.6km, (300m span with 12 spans).

Table 6. 5 115kV Underground Cable Erection Schedule

【Triplex Cable】



【Single Core Cable】



6.2 Substation Equipment

6.2.1 New Substation

(1) Design concept

(a) Substation type

One of the fundamental decisions to be made at the planning stage is the selection of the type of substation to be applied.

The general characteristics of a gas insulated switchgear (hereafter "GIS") substation make it particularly suitable for applications in urban areas, in environmentally sensitive areas, and in areas with high levels of atmospheric pollution. A GIS substation may also be of benefit where the replacement of an existing air insulated switchgear (hereafter "AIS") substation and new substation construction must be carried out within limited site boundaries.

In this project, the candidate sites planning to construct new substations are all located in urban Phnom Penh city such as on the site of EDC HQ and Olympic stadium. Therefore, the survey team is determined to apply the GIS substations of the in-door type from the above perspective.

(b) Capacity of the substations

The capacity of the new substations shall be 150MVA, which is identical to the existing 115kV substation in Phnom Penh city.

(c) Capacity and number of 115kV transformers

In this report, the JICA survey team compares the two options of the substations that have 150MVA of their capacity. One option is a case of adopting two banks of a 75MVA-transformer. Another one is a case of adopting three banks of a 50MVA-transformer. Table 6. 6 shows a comparison between two options.

Table 6. 6 Comparison of Two Options

Item	75MVA	50MVA
Iron loss	59 kW	44 kW
Copper loss	278 kW	194 kW

(Source: JICA Survey Team)

1) Comparison of losses

The main factors of the transformer loss are the no-load loss, which has no relationship with the load rate, and the load loss, which is in proportion to the square of the load rate. Since the load rate is changing momentarily during all of the day. The JICA survey team conducted a loss estimation based on the simulation shape of a one-day load as shown in Figure 6. 13, which has not changed during the one year. (It is not simulated as the load of time series, it is simulated in descending order of the load during the one day.)

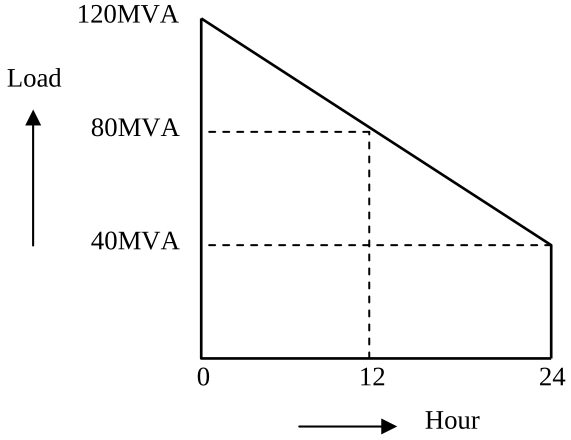


Figure 6. 13 Load Shape

The estimation result of a transformer loss during one year based on the above load shape is shown below.

Table 6. 7 Estimation Result of Transformer Loss during One Year

Item	Option1(75MVA×2)	Option2(50MVA×3)
Iron loss	980 MWh	1,068 MWh
Copper loss	1,545 MWh	1,635 MWh
Total	2,525 MWh	2,703 MWh

(Source: JICA Survey Team)

According to Table 6. 7, the transformer loss of Option 1 is slightly lower than that of Option2.

2) Comparison of the Supply Reliability

Since the number of transformers for Option1 differs from that of Option2, the impact to the grid when a transformer failure happens are different between the options. Therefore, there are also some differences in the supply reliability between the options. In case of Option1, the supply ability will drop down to 75MVA due to one bank failure. Meanwhile, in the case of Option2, it will be able to sustain the supply ability of 100MVA (50MVA x 2).

Transformer failure seldom happens, but there isn't no-chance for it to happen. Besides, when it happens, the impact to the grid is very large and it would take so many times to achieve recovery works (to replace the broken transformer and to install/energize a new one).

In this section, it will be estimated based on the conditions that a transformer failure happens once every 200-years, and it will take 20-days for the recovery work. In addition, the load shape is based on that of Figure 6. 13.

Table 6. 8 Expectation of outage

Item	75MVA×2	50MVA×3
Expectation of outage	61 MWh	18 MWh

(Source: JICA Survey Team)

3) Total evaluation

An economic comparison is conducted such as for Table 6. 9, adding the viewpoint of the transformer loss (loss cost) and supply reliability (outage cost).

The loss cost of the transformer is estimated at 0.16USD/kWh, the outage cost is estimated at 1USD/kWh.

Table 6. 9 Total Evaluation

(thousand USD/annum)

	Option1(75MVA×2)	Option2(50MVA×3)
Capital cost of every year	437	522
Loss cost	404	432
Outage cost	61	18
Total coat	902	972
[Difference]	Base	[+ 70]

(Source: JICA Survey Team)

According to the results of the total evaluation, it is advantageous to adopt Option1, and the JICA survey team chooses it.

(d) Protection rely system

The protection relay of the new substation shall be to match as much as possible with that of the existing substation equipment from the viewpoint of maintenance and operations. The main protection relays shall be as shown in the following:

- 115kVline protection relay: differential relay
- 115kVBus protection relay: differential relay
- 115kVtransformer protection relay: differential relay
- 22kVdisribution line relay: over current relay, earth fault relay

(2) Basic specifications of the main equipment

(a) Transformer
It is shown in Table 6. 10.

(b) Switchgear
It is shown in Table 6. 10.
.

Table 6. 10 Basic Specification of Main Equipment

				Basic specification
General		Bus bar configuration		Single Busbar type
		Switchgear(115kV/22kV)		Full GIS type/Conventional type
115kV Transformer		Type		YNd11
		Rated voltage		115/√3 kV / 22/√3 kV
		Rated capacity (primary/secondary)		75MVA
115kV Switchgear	General	Rated voltage		115kV
		Rated current	Bus bar/line	3,150A
			Bank	3,150A
		Rated short-time withstand current		31.5kA

(Source: JICA Survey Team)

(3) New GIS substation at site of EDC HQ

(a) Location

According to the result of the first on-site survey, the candidate location is a part of the car park in EDC HQ. Figure 6. 14 shows a picture of candidate place, whose size is approximately 50m x 20m.

(Source: the survey team prepared based on google earth.)

Figure 6. 14 Candidate Place of GIS Substation at EDC HQ

(b) Equipment & layout

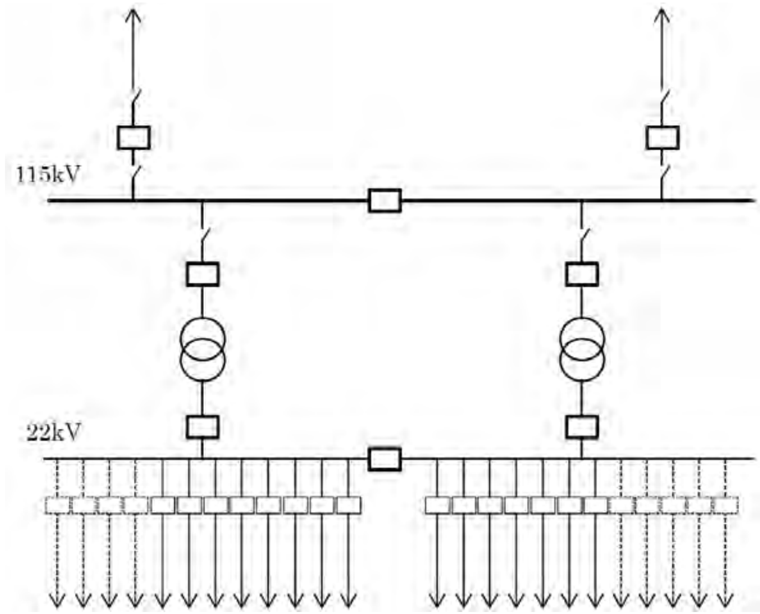
Substation equipment shall be as shown in Table 6. 11.

Table 6. 11 Substation Equipment (EDC HQ)

	Number of equipment
115kV line	2 lines
115kV Transformer 75MVA	2 Banks
22kV line	15 lines (24 lines in the future)

(Source: JICA Survey Team)

In addition, Figure 6. 15 shows the single line diagram of the substation.

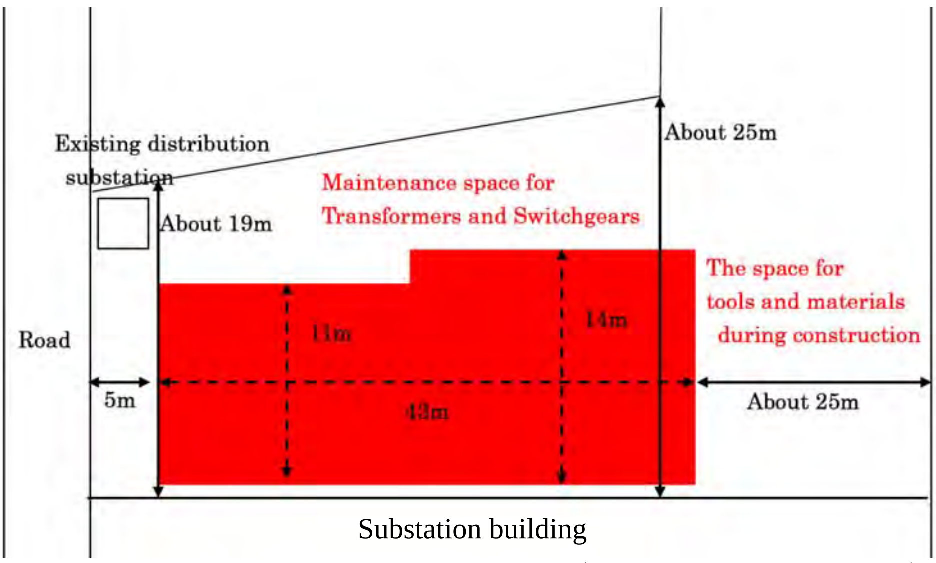


(Source: JICA Survey Team)

Figure 6. 15 Single Line Diagram of Substation at EDC HQ

Regarding the equipment layout, the JICA Survey Team conducted the compact design of the substation building due to using confined space in the site of EDC HQ. Therefore, transformers, which are heavy equipment, shall be allocated on the ground floor, 115kV GISs shall be allocated on the mezzanine floor, and control and protection panels and 22kV switchgears shall be allocated on the 1st floor, respectively.

As for the equipment layout drawings, Appendix6.2.1-1 shows the drawings of each floor for the building. In addition, allocation image of the substation building is shown in below.



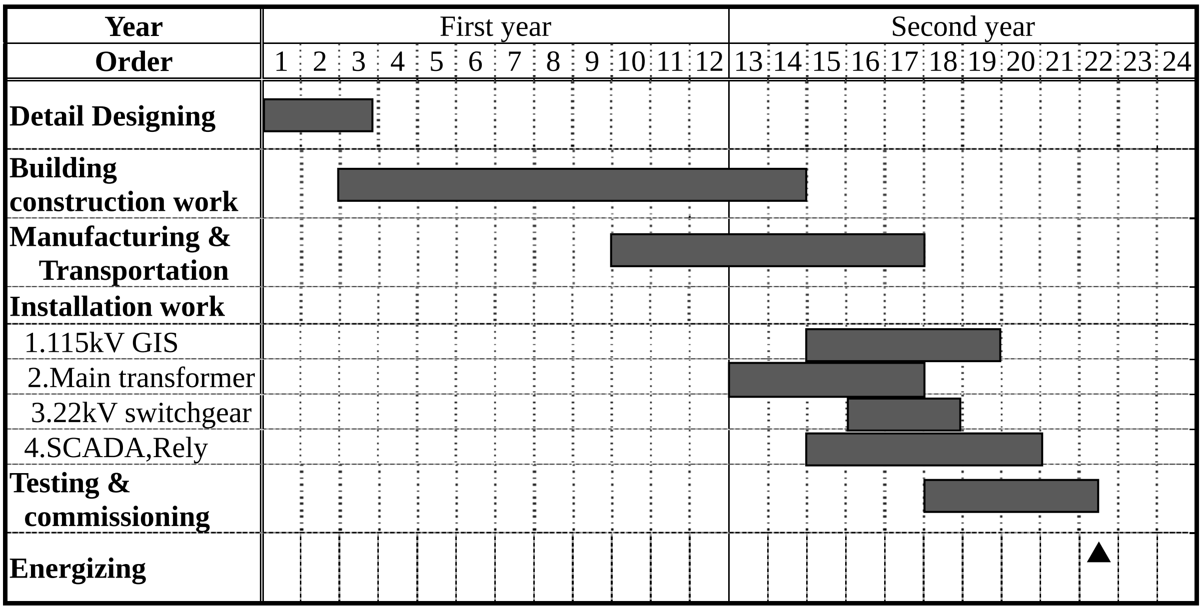
(Source: JICA Survey Team)

Figure 6. 16 Allocation Image of Substation Building at EDC HQ Site

(c) Construction schedule

The construction schedule of the substation is shown in Table 6. 12.

Table 6. 12 Construction Schedule (EDC HQ)



(Source: JICA Survey Team)

(4) New GIS substation at the Olympic Stadium site

(a) Priority among the candidate sites

The land of the Olympic Stadium is owned by Cambodia's Educational Authority, and there is an abundant amount of unused space in the stadium, which could be utilized for substations from 2012. The Survey team and an EDC representative conducted a field survey, and nominated four candidate sites for the new substation as indicated in the following satellite-picture of the Olympic Stadium. The Survey team assumes the form of the substation as being a GIS type and the necessary land as 35 x 50 m by taking into consideration that the location is quite urbanized and it is difficult to secure a 50 x 100m space, which is the minimum amount of space needed for a conventional air insulated substation.

(Source: the survey team prepared based on google earth.)

Figure 6. 17 Candidate Sites in the Olympic Stadium

The following table summarizes the comparison of the pros and cons of the four candidate sites. Since the new substation is supplied from GS3 via the 115kV underground transmission line, the total cost of the new substation depends on the distance from the GS3.

Table 6. 13 Comparison of the four options

	Option 1	Option 2	Option 3	Option 4
Picture				
Land Condition	Flat land, best condition for construction work	Flat land, used for a soccer field	Poundage with plants (water hyacinth), land fill is necessary	Swamp, land fill is necessary
Distance from GS3	Closest to GS3	Second best	Second best	Farthest
Necessary space for construction work	Easy to secure enough spaces for construction work	Possible to secure necessary space in the field of stadium	Necessary for land fill near the SS site	Possible to secure necessary space in the field of stadium
Flexibility of Distribution line routes	Facing a boulevard (possible to lay distribution lines in two directions)	Facing a boulevard (possible to lay distribution lines in two directions)	Located on the corner of the land (possible to lay distribution lines three directions)	Facing a boulevard (possible to lay distribution lines in two directions)
Others	Already sold to third entities ?	Necessary to provide another soccer field ?		
Priority	1 (top)	2	3	4 (least)

(Source: JICA Survey Team)

As the above table suggests, Option 1 is the best site because of its flat land and the distance to GS. However, the Survey team has received some unconfirmed information indicating that the land for option 1 could have been sold to other entity(ies) as a site for a shopping center, thus the availability of the site should be readily confirmed by EDC. When Option 1 is not feasible, Option 2 could be second best, and the replacement of a soccer field should be studied. Options 3 and 4 have significantly less priority because of the necessity of a land fill that requires a longer construction period and increased costs.

(b) Equipment & layout

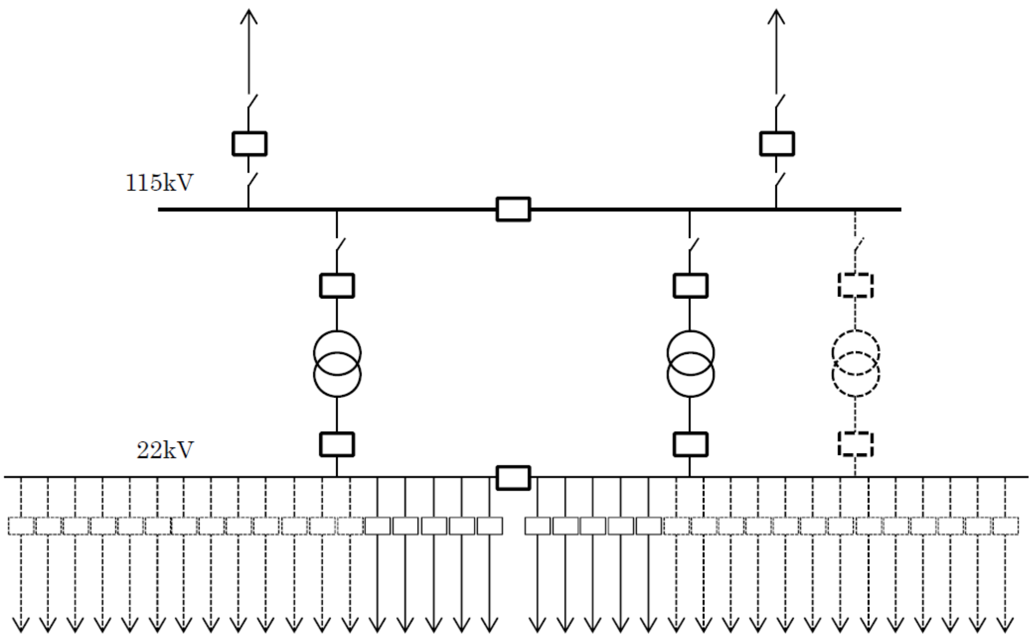
Substation equipment shall be as shown in Table 6. 14.

Table 6. 14 Substation Equipment (Olympic Stadium)

	Number of equipment
115kV line	2 lines
115kV Transformer 75MVA	2 Banks (3 Banks in the future)
22kV line	10 lines (36 lines in the future)

(Source: JICA Survey Team)

In addition, Figure 6. 18 shows a single line diagram of the substation.

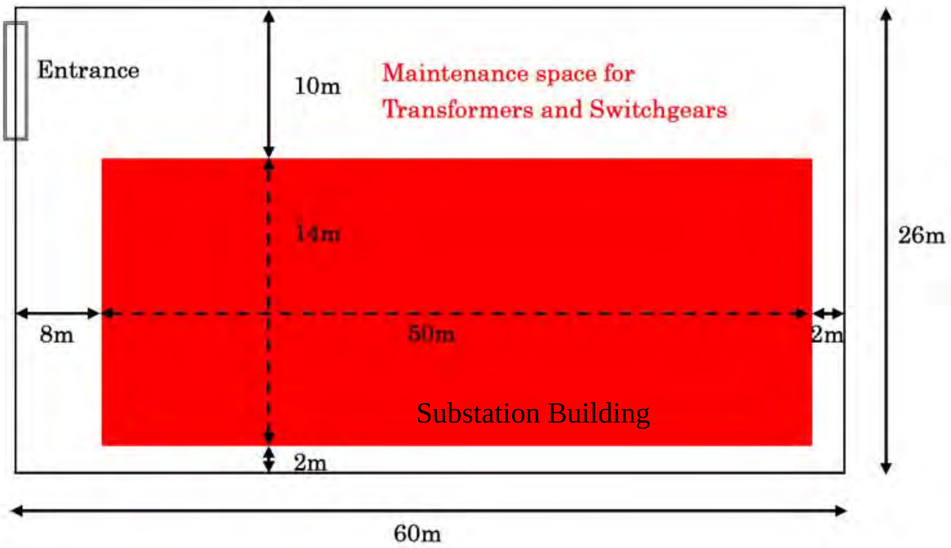


(Source: JICA Survey Team)

Figure 6. 18 Single Line Diagram of Substation at Olympic Stadium

Regarding the equipment layout, the JICA Survey Team conducted the compact design of the substation building in the same ways as the design for EDC HQ, in order to purchase the land for the substation more easily in the Olympic stadium site. Therefore, transformers, which are heavy equipment, shall be allocated on the ground floor, 115kV GISs shall be allocated on the mezzanine floor, and control and protection panels and 22kV switchgears shall be allocated on the 1st floor, respectively.

As for the equipment layout drawings, Appendix6.2.1-2 shows the drawings of each floor for the building. In addition, allocation image of the substation building is shown in below.



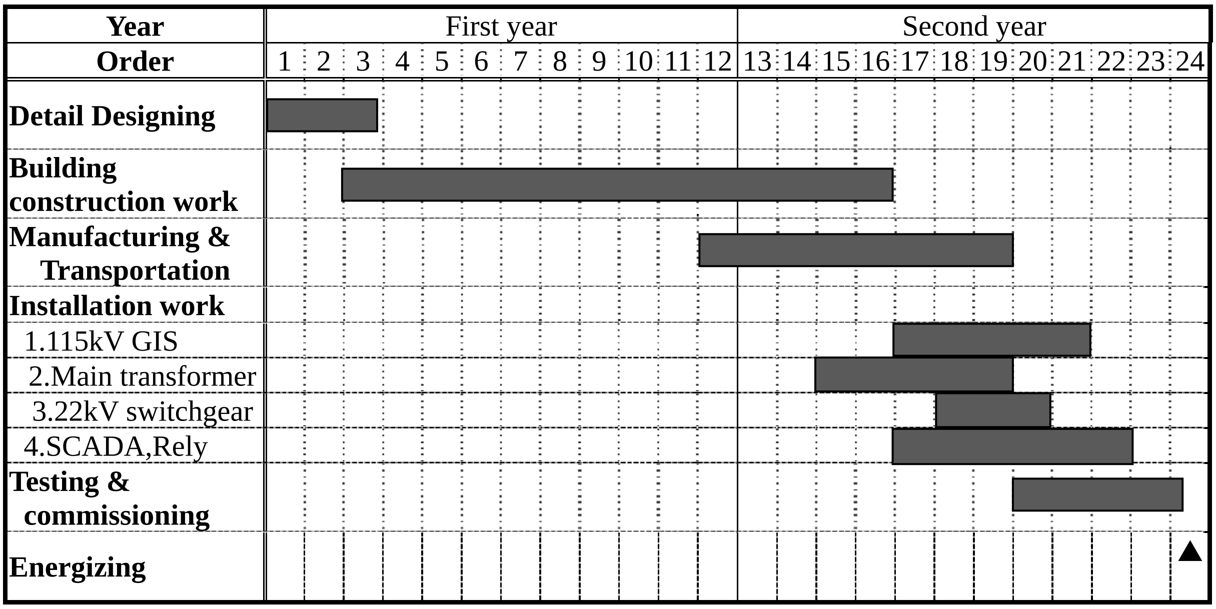
(Source: JICA Survey Team)

Figure 6. 19 Allocation Image of Substation Building at Olympic Stadium Site

(c) Construction schedule

The construction schedule of the substation is shown in Table 6. 15.

Table 6. 15 Construction Schedule (Olympic Stadium)



(Source: JICA Survey Team)

6.2.2 Modification of GS1 and GS3

(1) Present Conditions and Expandability of GS1 and GS3

GS1 was originally designed in consideration of the future expansion of a maximum six (6) transmission line feeder bays in total. Since the two bays out of the six bays are currently being used for transmission line feeders going to GS1 and GS4 (West Phnom Penh Substation). The remaining four (4) feeder bays are currently not in use although some feeder bays are now equipped with an unused switchgear which can be removed.

GS3 was also designed in the same manner that has a maximum of six (6) transmission feeder bays which include two (2) bays currently used for the transmission line to the KEP IPP power plant and to the CEP IPP power plant. The remaining four (4) bays are out of use now.

The single line diagrams and equipment layout drawings for GS1 and GS3 are shown in Appendix-6.2.2-1 and Appendix6.2.2-2.

(2) EDC's Plan to Reinforce the Transformer Capacity at GS1 and GS3

The present transformer capacity at GS1 and GS3 is 100MVA (50MVA x 2 units) for each. In order to solve the shortage of transformer capacity against power demand rapidly increasing in Phnom Penh, EDC has a plan to install additional transformers at GS1 and GS3.

The 50MVA x 2 transformers will be replaced with 75MVA x 2 transformers at GS1 so as to be 150MVA in total. Meanwhile, 50 MVA x 2 transformers at GS3 will be increased to 50MVA x 3 transformers at GS3 in the near future.

(3) Outline of the Modifications of GS1 and GS3

In order to newly construct the 115kV underground transmission lines from GS1 to the EDC substation and from GS3 to the Olympic Stadium Substation, one transmission line feeder bay equipped with 115kV switchgear will be additionally installed in GS1 and GS3 for each. These new feeder bays are indicated in the same drawings as the existing layout and single line diagrams in Appendix-6.2.2-1 and Appendix6.2.2-2. As shown in Figure 6. 20, the feeder bays are currently kept free for future use.

GS1

GS3

Picture taken by the Survey Team in GS1 and GS3 in December 2012.

Figure 6. 20 Vacant Transmission Feeder-bay in GS1 and GS3

In addition to the above additional installation of switchgear, the following items will be necessarily installed or modified under this Project.

1) 115kV underground transmission line feeder control and protection
2) Modification of existing SCS (Substation Control System)
3) SCADA and telecommunication equipment for the new transmission line system

(4) Outline of Technical Data of 115kV Switchgear in GS1 and GS3

115kV switchgear shall be Air Insulated Switchgear (AIS), the same as the existing one. The technical outlines are mentioned below.

(a) 115kV Gas Circuit Breaker	
- Rated Voltage	123 kV
- Rated Current	3,150 A
- Rated Short Circuit Breaking Current	31.5 kA
(b) 115kV Disconnector (w/wo earthing switch)	
- Rated Voltage	123 kV
- Rated Current	1,600 A
- Short Time Withstand Current	31.5 kA/s
- Operating Mechanism	Motor
(c) 115kVCapacitor Voltage Transformer	
- Nominal Primary Voltage	115 kV
- Rated Secondary Voltage	110-110/√3 V
- Accuracy Class	0.5(measuring), 3P (protection)
(d) 115kV Capacitor Voltage Transformer	
- Rated Voltage	123 kV
- Ratio of Current Transformation	1000/1/1/1 A (Class-X)
and Accuracy	1000/1 A (15VA, 0.5CL)
(e) 115kVSurge Arrester	
- Nominal Voltage	115 kV
- Standard Nominal Discharge Current	10 kA
(f) 115kV Cable Head	
- Rated Voltage	123 kV
- Lightning Impulse Withstand Voltage (BIL)	550kV

(5) Implementation Schedule

The implementation schedule for the modification of GS1 and GS3 is expected as below.

Table 6. 16 Implementation Schedule

Work Item	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Design, Manufacturing and Tests/Inspection																	
Transportation and Delivery																	
Installation/Pre-Commissioning																	
Commissioning																	

Source: Prepared by Survey Team

6.3 Distribution Equipment

(1) The necessity or not of examining the new MV distribution line

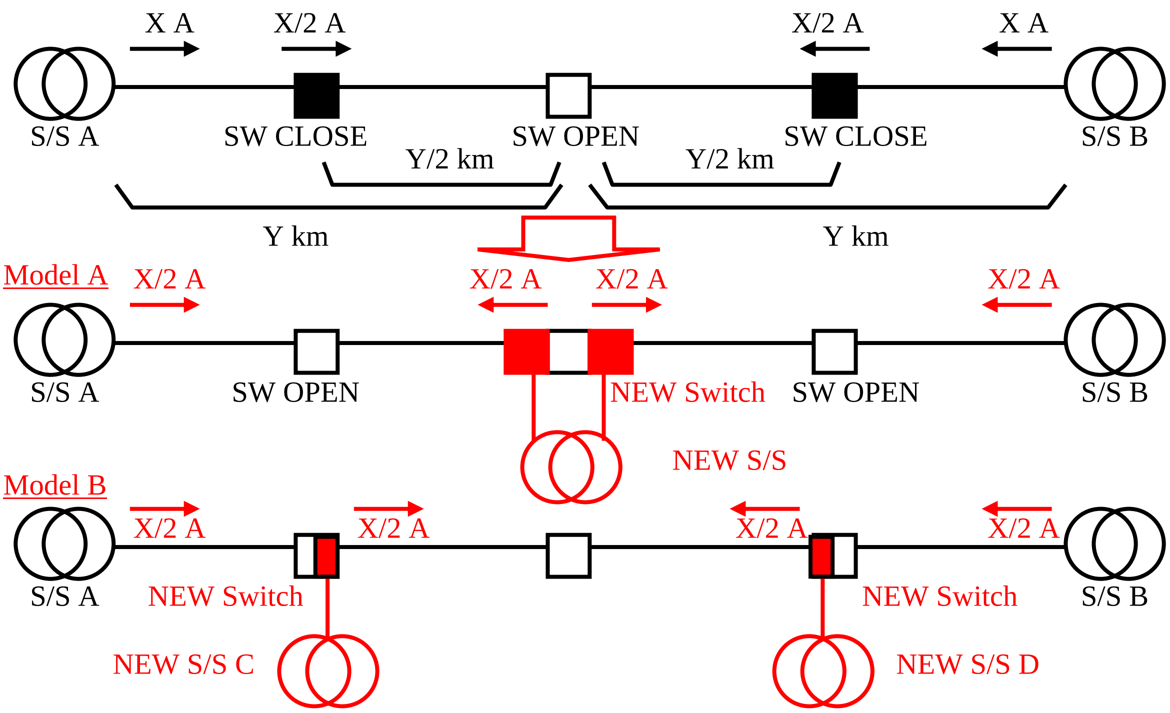
The recent loading records of 22kV distribution lines, which are connected to the existing distribution substations (GS1, GS2, GS3), shows that these distribution lines have not been heavily overloaded until now, by switching a part of its loading to neighboring lines and/or enforcing rolling blackouts of some distribution parts. Thus, the Survey Team concluded that the load division of the existing supply of the electric power distribution substation (GS1, GS2, GS3) should be prioritized rather than planning new MV distribution line installations.

In addition, after conducting interviews as part of the first field work duties, the Phnom Penh city center’s northeast demand will be heavy under the present conditions.

(2) The connection from the new power station to an existing MV 22kV UG distribution line

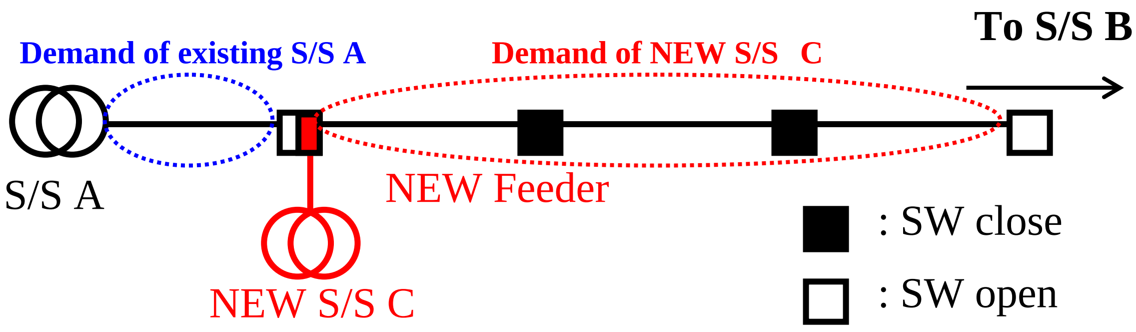
Based on the situation of 6.3 (1), the fundamental view of the load division method is shown in Figure 6. 21. In this model A case, the loss of a MV 22kV distribution line is set to one fourth before the distribution substation establishment for electric power distribution. However, by using the model A method in a situation where the length per one power line has a short (approximately 4-5km), Given that the power line section where the demand after the load division will become so small, so do not adopt this method basically. The connection method in the new distribution substation constructing plan position neighborhood adopts a model B method. In this method, the total loss of MV 22kV distribution line is also set to one fourth ideally. Show the load division and new feeder connection method at the distribution substation building for the supply of electric power by model B in Figure 6. 1.

The connection route proposal to the established 22kV MV distribution line based on this idea and the discussion results with the EDC distribution engineers and site survey results of the second investigation is shown in Figure 6. 28 and Figure 6. 29.

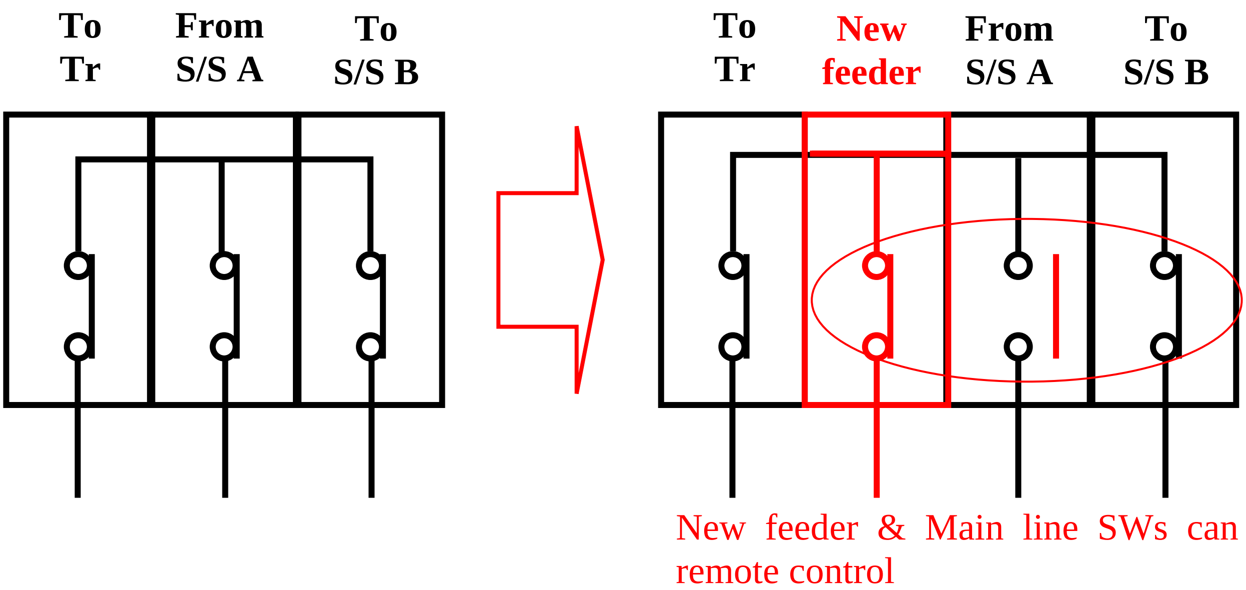


(Source: JICA Survey Team)

Figure 6. 21 Image of Basic Demand Division with Distribution Substation New Establishment for Supply of Electric Power



(a) New feeder connection and Load divides image of established distribution line



(Source: JICA Survey Team)

(b) Add one circuit SW gear

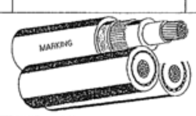
Figure 6. 22 Load Divides Method of Distribution Substation.

(3) The specification outline in connection with the MV 22-kV under-ground distribution system

(a) MV 22kV under-ground cable

- standard IEC60502
- cable type 3×240mm^2 Al MV 22-kV Twisted underground cable

Table 6. 17 MV 22-kV Underground Cable

MV underground cables			
	MV twisted underground cable		
Type	3 x 240 mm^2 Alu	3 x 150 mm^2 Alu	3 x 70 mm^2 Alu
EDC nomenclature EDC	0840 1178	0840 1014	
Photograph	 MARKING		
Implementation range	MV underground network		
Standards	IEC 60502		

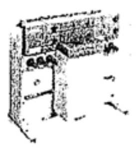
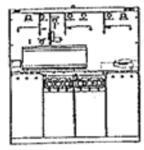
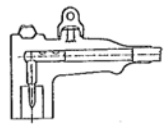
(b) Straight line Joint

- standard IEC
- requirement 3×240mm2 Al MV Twisted underground cable

(Source: ELECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

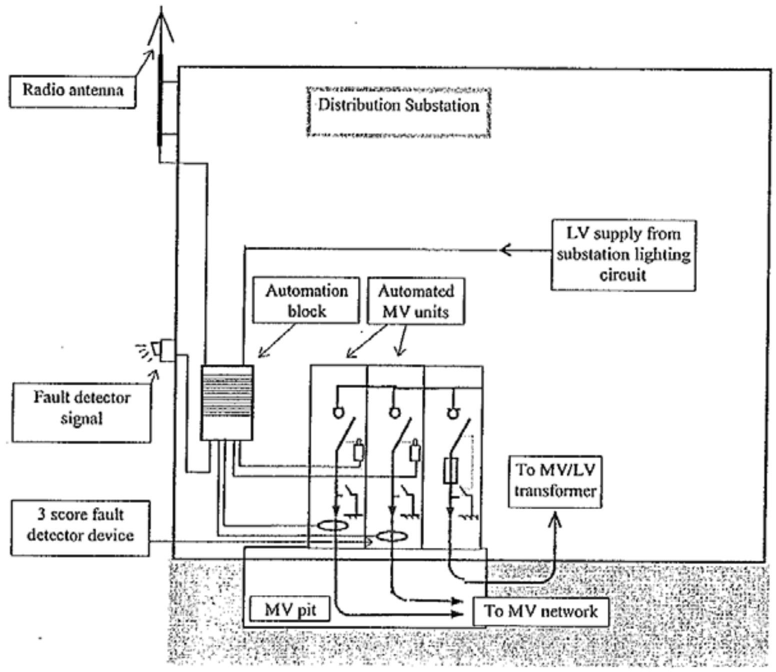
(4) SW gear and cable terminal

Table 6. 18 Standards of SW Gear and Cable Terminal

Ring main units and 630 A plug-in connector			
	RMU 2S + T	RMU 2S + 2T	MV plug-in connector
EDC nomenclature			a) 630 A = b) 200 A =
Photograph			
Implementation range	Load break switches ensuring incoming / outgoing feeder sectioning and transformer protection	Load break switch ensuring incoming / outgoing feeders sectioning and protection for two transformers	Plug-in connector for MV single core cables on ring main units
Standards	IEC 60298, 60265, 60129, 60694, 60420, 60056		IEC

(Source：ELECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

(5) Devices of the distribution substation building



(Source: ELECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

Figure 6. 23 Schematic Figure of Remote Control Function Equipped Distribution Substation Building

(6) Radio transceiver equipment

The radio transceiver is in the remote control box. The radio system installed is used only for data communication requirements of the EDC Dispatching Center.

Bandwidth UHF allocated: UHF 459 – 459.5 MHz
469 – 469.5 MHz

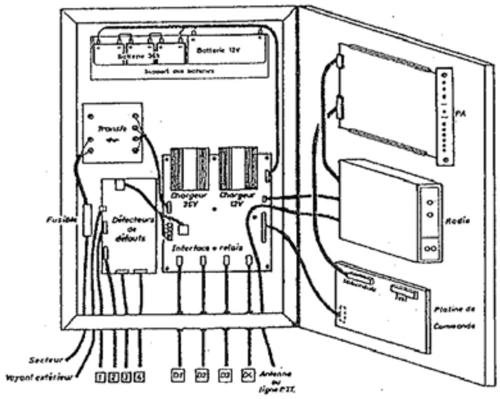
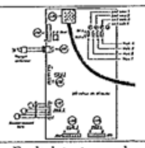
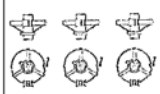
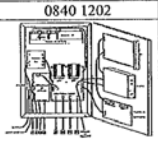
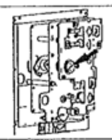


Figure 6. 24 Radio Transceiver Equipment on Distribution Substation Building

Table 6. 19 Standards of Distribution Substation Radio Transceiver Equipments on Distribution Substation Building

Radio station, radio antenna, fault detector card, fault detector magnetic coils				
	Radio transceiver	Radio antenna	Fault detector card	Fault detector magnetic coils
Type	UHF 450 MHz	a) Low gain b) High gain		
EDC nomenclature				0840 1221
Photograph				
Implementation range	Radio transceiver to ensure data transmission between the PA4 card and the radio network	Data reception and data emitting between the distribution substation and the dispatching control center	Fault detector card accommodating up to 4 fault detector sets. Special order with the remote control box	Fault current detector
Standards				IEC

Remote control box, PA4-MXR card, cubicle motorization and connecting cables				
	Remote control box	PA4-MXR card	Cubicle motorization	Connecting cable
Type				
EDC nomenclature	0840 1202			
Photograph				
Implementation range	Control box for all the remote functions of MV/LV substations	Electronic card for remote control and remote information	MV switchgear remote motorization	Data transmission cable between remote control box and MV switchgear
Standards			HN 64-S-43	IEC

(Source: ELECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

(7) The standers in the construction of the MV 22kV under-ground distribution system

(a) The burial method

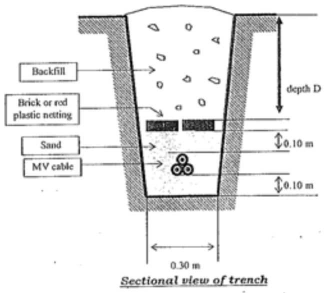


Figure 6. 25 Standers of the Burial Method

(b) Burial depth

Table 6. 20 Burial Depth

Depth in case of direct burial system	
Installation position	**Depth**
At a place where there is a danger of receiving pressure from vehicles or other objects	D = 1.2 m or more
Other place	D = 0.6 m or more

(c) Separation distance

Table 6. 21 Separation (Underground Cables)

Clearance between plural underground lines		
New line	Other electrical lines	
	Low-voltage	Medium-voltage
Low-voltage	0.15m	0.3m
Medium-voltage	0.3m	0.3m

Table 6. 22 Separation (other Electrical Lines)

Clearance between plural underground lines				
New line	**Other electrical lines**			
	Communication line	**Gas**	**Water**	**Sewerage**
Low-voltage	(* 0.1)0.3m	Shall not contact directly		
Medium-voltage	(* 0.1)0.6m	1.0m	0.3m	0.3m

(*) Approval of the owner of the communication line shall be required

(d) Digging width

Table 6. 23 Digging Width

Trench width related to the number of cables

		Number of LV cables*						
		0	1	2	3	4	5	6
Number Of MV Cables	0		0.30 m	0.50 m	0.70 m	0.90 m	1.10 m	1.30 m
	1	0.30 m	0.60 m	0.80 m	1.00 m	1.20 m	1.40 m	1.60 m
	2	0.60 m	0.90 m	1.10 m	1.30 m	1.50 m	1.70 m	1.90 m
	3	0.90 m	1.20 m	1.40 m	1.60 m	1.80 m	2.00 m	2.20 m

** The street lighting cable laid with the LV cable is taken into consideration in this table.*

(Source: ELECTRICITE DU CAMBODE DESIGN STANDARD/DISTRIBUTION NETWORK Ver.1,2 JUNE 2007)

(e) Others (underground cable protection objects)

A pipe is constructed in the heavy-trafficked road crossing part. (*Those with a saving provision)

In this report, the JICA survey Team choose the duct pipe protection method in the all new 22-kV MV under-ground cable route in consideration of shortening the working time from the road digging to the refill and pavement.

An example of the duct pipe is shown in Figure 6. 26. The PVC duct pipe is used for the strait part (Figure 6. 26 (a)), and the free percent steel tubes are used for the point where the cable line turns largely (Figure 6. 26 (b)). An example of the multi duct pipe layout is shown in Figure 6. 27.

(a) PVC pipe duct **(b) free percent steel tubes**

Figure 6. 26 Underground Distribution Line Protection Objects

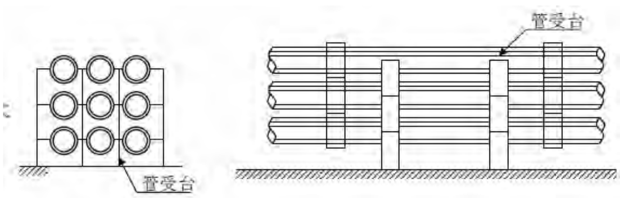
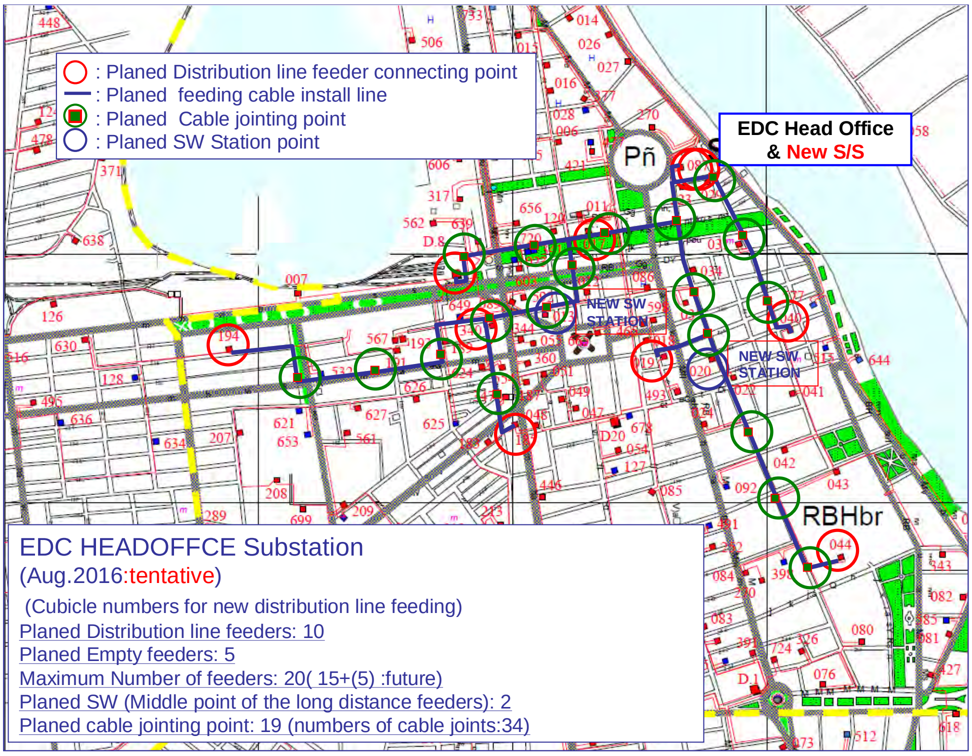


Figure 6. 27 Example of Duct Pipe Layout

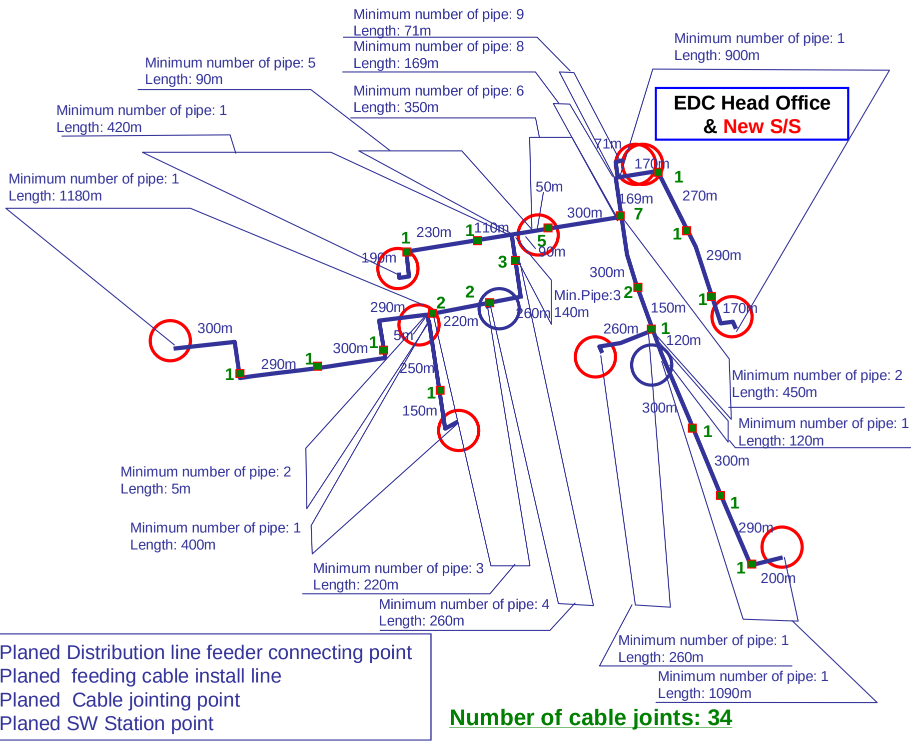
(Source: JICA Survey Team)

(8) 22kV underground cable route proposal and expense of the construction outline from the new S/S.

The new 22-kV MV underground feeder line route proposal based on the 2nd investigation shown below.



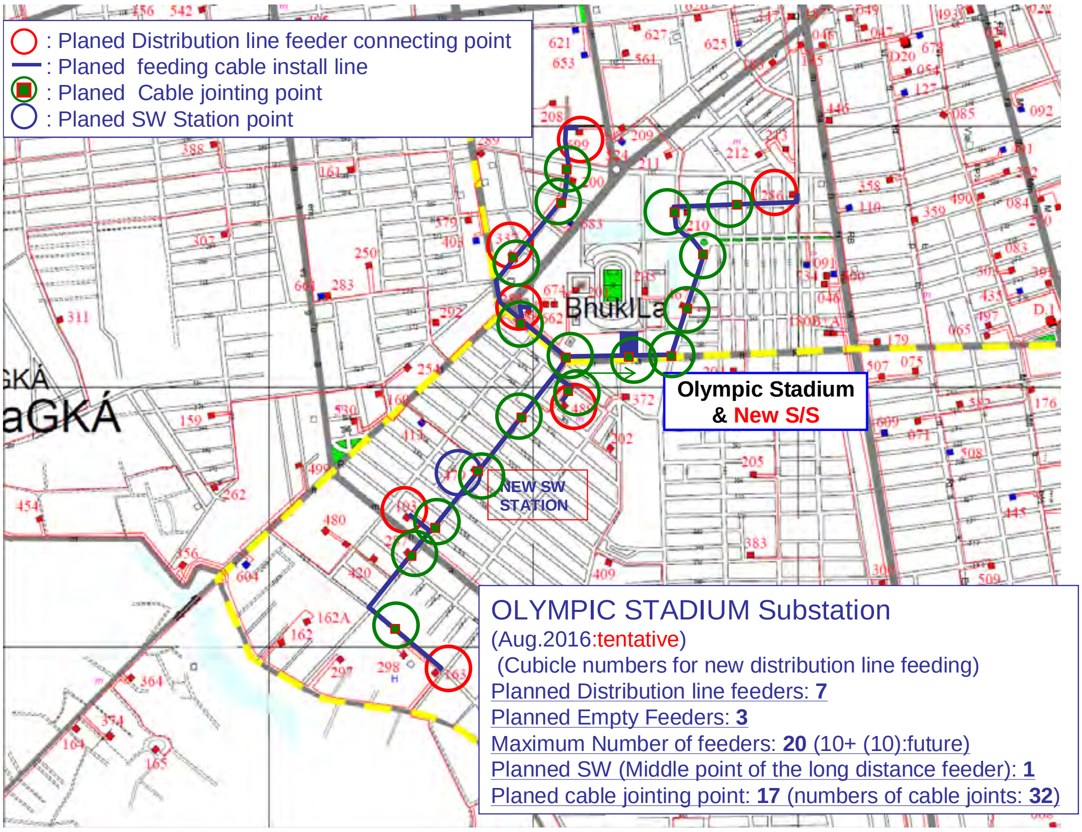
(a) Feeder line connection point, feeder line route and UG cable jointing points



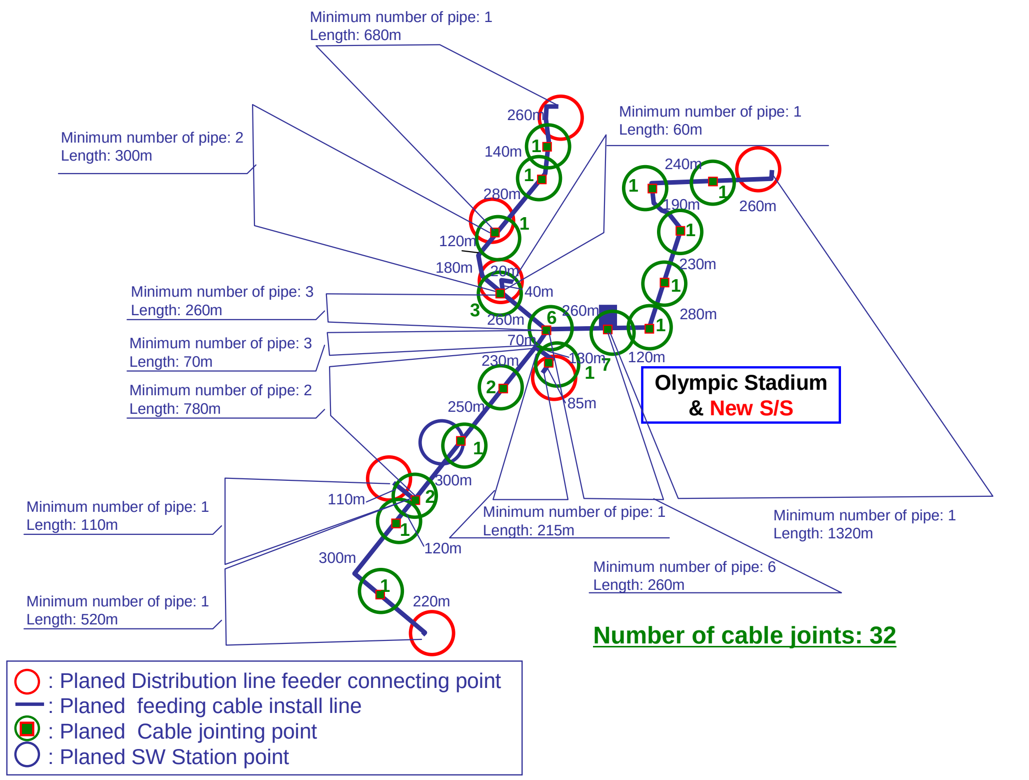
(b) Number of duct pipe and cable connection points

(Source: EDC distribution map 2010 & JICA Survey Team)

Figure 6. 28 New Distribution Line Route Proposal Near EDC HQ



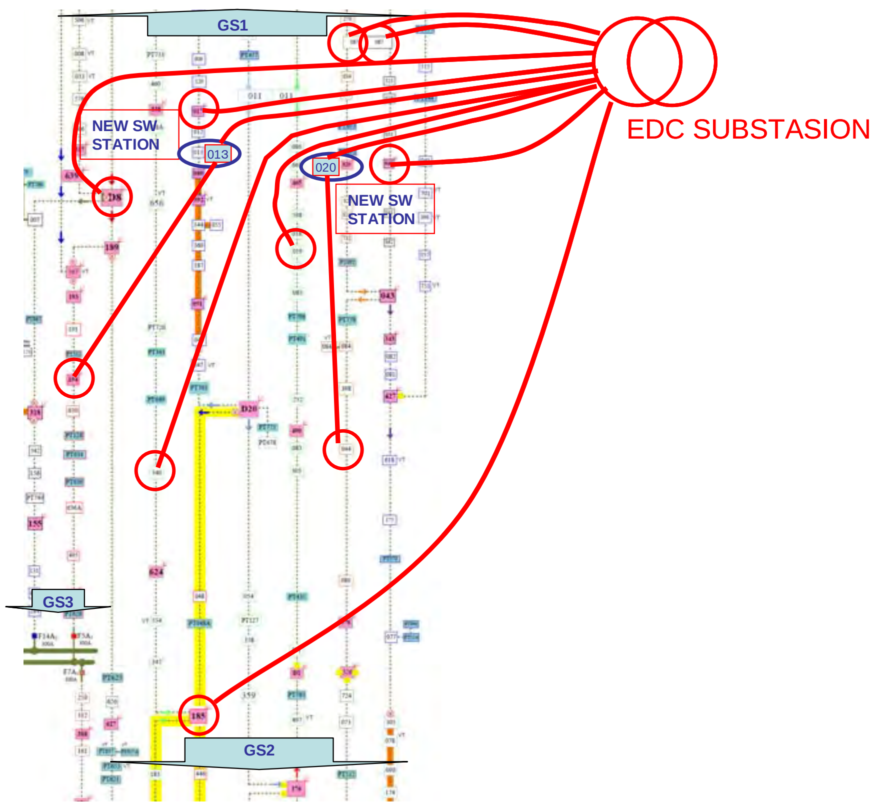
(a) Feeder line connection point, feeder line route and UG cable jointing points



(b) Number of duct pipe and cable connection points

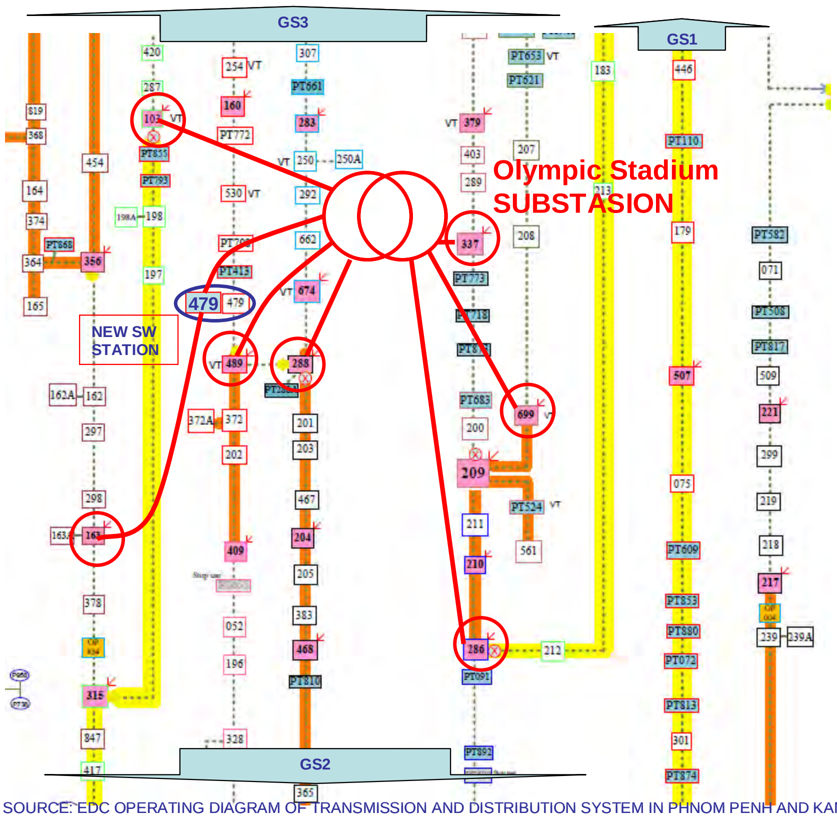
(Source: EDC distribution map 2010 & JICA Survey Team)

Figure 6. 29 New Distribution Line Route Proposal Near Olympic Stadium



SOURCE: EDC OPERATING DIAGRAM OF TRANSMISSION AND DISTRIBUTION SYSTEM IN PHNOM PENH AND KANDAL PROVINCE

(a) New S/S near EDC head office



SOURCE: EDC OPERATING DIAGRAM OF TRANSMISSION AND DISTRIBUTION SYSTEM IN PHNOM PENH AND KANDAL PROVINCE

(b) Near Olympic Stadium (Source: EDC distribution system Diagram & JICA Survey Team)

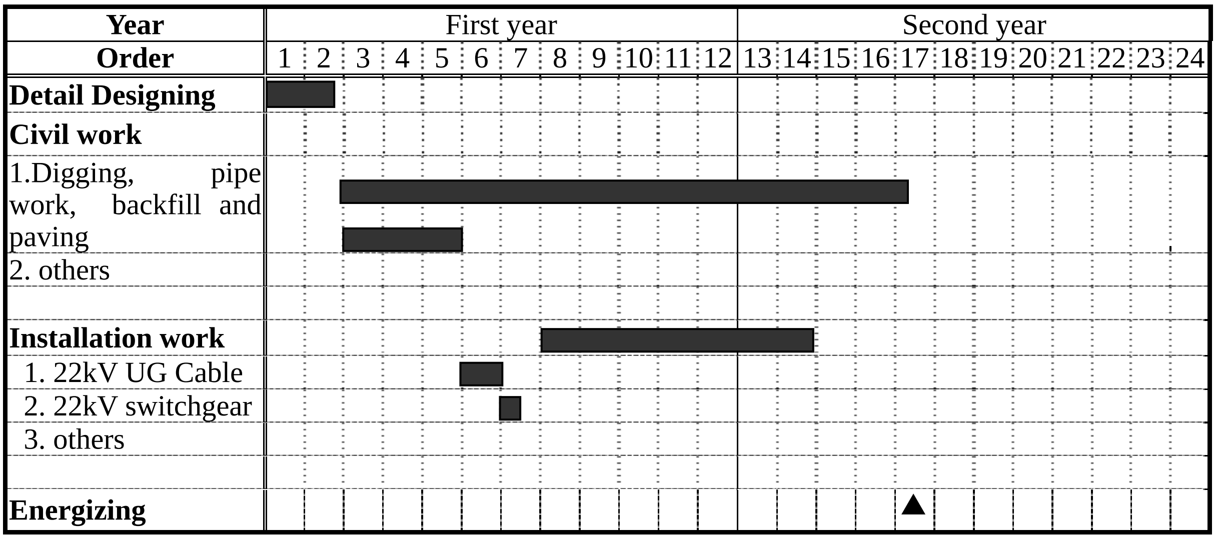
Figure 6. 30 New Feeder Line Connection Proposal for Established Distribution Lines

(9) 22-kV MV underground distribution facilities construction schedule

(a) Construction schedule

The construction schedule of the distribution facilities are shown in Table 6. 24.

Table 6. 24 Construction Schedule



*including Optical fiber cable work

(Source: JICA Survey Team)

(10) The proposal of the next-generation distribution automation system

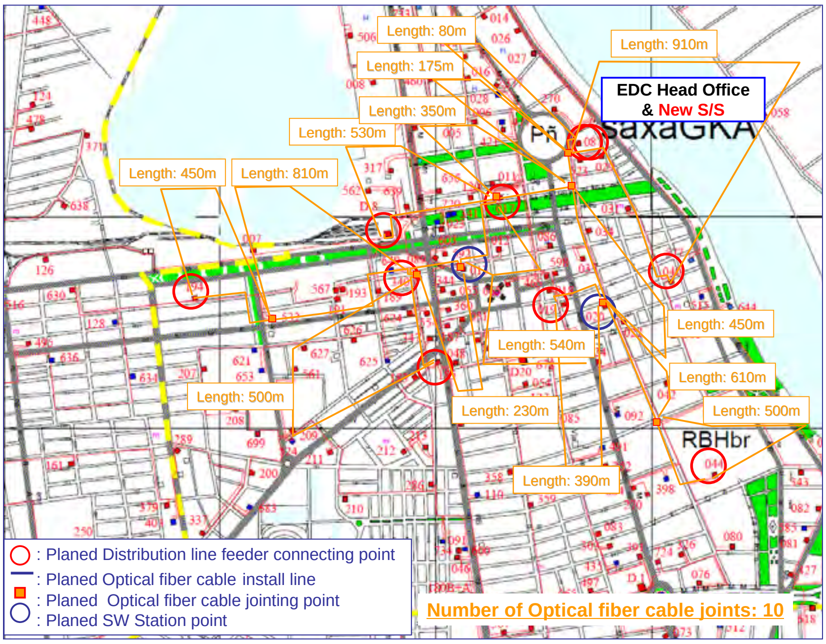
By introducing a 22kV distribution line monitoring system coinciding with a review of the existing MV 22kV distribution line sections to utilize the newly built substations, the advanced operation of MV distribution lines, such as reliability improvements via the automatic removal of the faulty distribution line section just after the accident, can be achieved. In order to let these advanced operations function completely, high-speed mass communication equipment by updating and the optical cable of SCADA of the EDC head office is needed.

In the case of updating the distribution control system of the key station, it is necessary to confirm and examine the existing communication sub-station and the switching equipment (monitoring equipment) specifications of all the distribution facilities, to choose the Distribution Automation System (DAS) or the latest SCADA as the EDC head office distribution system control point.

In the opinion of the EDC management layer at the time of the 2nd investigation, there was not a plan of SCADA system regeneration now. However, they think about the near future distribution system update, and the opinion to install the optical fiber cable to the connection point with the established distribution line of the new distribution line was ordered.

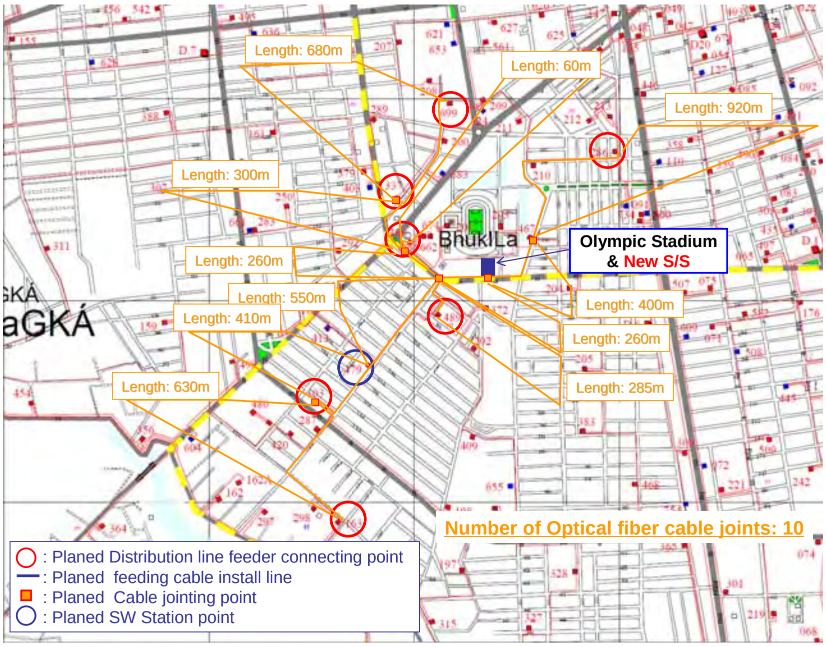
(11) Optical fiber cable for distribution line control

The new optical fiber cable route proposal based on the 2nd investigation is shown in Figure 6. 31 (a)(b).



(Source: JICA Survey Team)

(a) Near EDC S/S



(Source: JICA Survey Team)

(b) Near Olympic Stadium S/S

Figure 6. 31 New Optical Fiber Cable for Distribution Line Control Route Proposal

(12) Optical fiber cable for the control distribution line facilities construction schedule

The optical fiber cable construction for the distribution line controlling should construct it with the underground distribution line construction at the same time and it is assumed that it was included in the construction schedule of Table 6. 24.

6.4 Power System Operation

6.4.1 Reinforcement of the technical bases in EDC for the introduction of stabilizing the relay system

More than 30 % of total electricity demand in the EDC Phnom Penh power system is fed through the inter-tie connected to the Vietnam power system. System stability and frequency cannot be maintained once the inter-tie is down due to a fault on the tie line.

EDC will consider introducing some countermeasures to this kind of network failure in order to maintain stable operations and minimize fault outage demand.

The countermeasures considered are the introduction of

(a) Predictive out-of-step prevention relay system

This relay system automatically makes some amount of loads in the EDC power system trip all at once immediately after the inter-tie is down and maintains stabilized operations of the isolated EDC system.

(b) Under frequency relay system

This relay system automatically sheds each pre-determined lump of loads step by step according to the system frequency drop immediately after the inter-tie is down. The EDC power system may be stabilized as its result.

It is considered to be too early to introduce the countermeasure (a), judging from the current situation of the power system operation in EDC.

As for the countermeasures (b), the under frequency relay system has been recently introduced. However, the setting values are based only on the experience and intuition of EDC technical personnel. A technical computation and study has not been conducted.

It is doubtful if the relay system will work effectively in the case of faults. It is appropriate to recognize the current situation as a preparatory reinforcement stage towards the future introduction of these relay systems.

The status quo in EDC, the background of reaching this recognition, and suggestions based on these are described hereafter.

6.4.2 Status Quo in EDC in Terms of Power System Stabilization and Protection

(1) Power system stabilization

Even though the EDC power system was stabilized after the inter-tie fault, EDC personnel does not have proficient skills to conduct step-by-step dispatching related to power system restoration and to use the supportive functions provided by the SCADA system in NCC such as automatic real time data collection, network status reproduction on tools and equipment. It is most likely that the current situation like this will lead to wider electricity outage and further delayed restoration, as restoration operations are going through ever changing electricity demand, network power flow and voltages, and so on while controlling generating power and grasping the power system status. Generally speaking, achieving a restoration from an intentional total blackout sometimes takes less time than restoration accompanied by lack of skill proficiency and technique in the case of a large scale power system fault. EDC has almost no experience in system stability computation which is indispensable to determine the setting values for the relay system (a) and (b). While new power plants are constructed one after another and network expansion continues with the rapid growth of system demand, the frequency of revising the setting values are expected to increase. It is difficult for EDC to keep revising the setting values on its own after EDC has introduced these kinds of relay systems with the support of other experienced countries. This situation tends to leave these systems obsolete or practically ineffective. EDC has installed the relay system (b) and determined their setting values. But as described above, EDC has almost no experience in system stability computation. That is the reason why, EDC says, setting values have to be determined based on their experience and intuition.

EDC is aware of the necessity of system stability computation for effective and practical settings based on technical grounds and has tried to work on the PSSE (Power System Simulator for Engineering). But this challenge has not yet been successful. Some of the reasons for it are that EDC has to start working on PSSE software from scratch and the PSSE user manual is difficult to understand for the people who start tackling it. Above all, it hinders EDC from going forward that required basic data such as the generators modeling data, generators control system diagram, facilities impedance and so on have not been arranged. EDC has not yet found which direction it should take to go step by step. They have not exactly grasped what kind of data is necessary for the computation.

(2) 115kV transmission line protective relay

Current differential relays made by AREVA are placed at each 115kV grid substation in the Phnom Penh power system. Communication circuits made by Alcatel-lucent are also hooked up between these relays. But communication signals are not exchanged through the communication circuits and the relay systems do not work as current differential relays though they are physically connected. Actual main protection coverage is done by distance relays incorporated in the AREVA differential relays. KEP and CEP, which are IPP’s, place their own protective relays made by ABB because they doubt if the relays prepared by EDC (AREVA relays) work properly in the case of network faults. EDC does not know how to lead the contractor (Alcatel-lucent) to repair the malfunction as they do not have the knowledge and know-how on telecommunication protocol based on international telecommunication standards.

The Corporate Planning & Project Dept. is in charge of determining the setting values of the newly placed protective relays and the Transmission Dept. is in charge of real time relay operations and maintenance after the newly placed relays are handed over from the former Dept.. The procedure and the way to hand them over from the former to the latter involve some problems and a final function check on the signals exchange between the relays through communication circuits has not been satisfactorily conducted. This is the main reason why this kind of trouble happens. It is necessary to have common technical knowledge & know-how and develop human communications across the two departments.

The transmission line between the GS 1 and GS 3 is always opened now because

+ To find the appropriate setting values of the distance relays as the main protection described above is difficult in a looped network condition.
+ Some of the intact transmission lines may have been overloaded when the looped network is disconnected due to a fault.

A looped operation is expected to be realized to enhance power system security and reliability during the comparatively less power flow through the looped network, when the current differential relays come to being practically used.

EDC has to conduct power flow computation to realize this. However, the computational technique and know-how have not yet settled in among operational personnel. A study team was established to acquire them on power flow computation but has not yet come to good results. Some support is necessary.

6.4.3 Suggestions toward EDC power system stabilization

(1) Effective use of the newly installed SCADA system in the National Control Center (NCC)

It is necessary to gain capability to swiftly restore faulty facilities and electricity outages and maintain secure power system operation in the case of network faults. This is realized by the accumulated experiences of the day and night practices of effectively supervising and swiftly controlling the power

system status including generators, substation loads, network voltages and so on with the help of the SCADA system. This is true for both normal and emergency conditions.
The following things should be done for that.

(a) Hasten full operation of the NCC SCADA system

Electricity information related to other companies like IPP's has not come up to NCC SCADA systems due to telecommunication protocol difference. The NCC full operations supported by a reliable SCADA system should be hastened by solving this problem.
Power system operation personnel should be also reorganized so that they enhance their operational technique and ability with the help of the SCADA system.
The electricity information now coming up to the SCADA system is not necessarily correct due to some adjustment deficiency. Some acquired information in SCADA is different from the monitored information in the fields. Swift causes research and their correction is necessary.

(b) Develop human resources for proper and swift restoration of the power system

Restoration procedures have not been properly arranged and restoration training has not been properly conducted. These procedures and systematic training should be arranged and established to enhance restoration ability.

(2) Gain practical technique and know-how on computational analyses

Computational analyses are indispensable for establishing restoration procedures as well as maintaining relay systems, so that secure and reliable electricity supply at a satisfactory level is realized.

(a) Acquisition of techniques for computation and analyses

EDC has been making an effort to acquire technique and know-how on computational analyses, either by starting a study team or sending personnel to neighboring countries for the study.
However, these efforts have not bore fruit now. This is because EDC lacks the practical usage of their daily jobs reflecting their own power system conditions.
Though the JICA project "Project for improvement of transmission system operation and maintenance", which started from January of 2013, does not directly aim at supporting this kind of area, the scope of this project may well involve it.

(b) Basic data arrangement and accumulation of computational analyses

Now, EDC collects, records and accumulates this data by using a telephone and manual writing every hour. EDC recognizes that this data lacks in the precision for computational analyses.

- ■ Network data, facilities data etc.
  EDC has not arranged the basic data for power flow and system stability computation.
  - ✓ Impedance of step-up transformers, transmission lines, substation transformers etc.
  - ✓ Generator model data, generator control system data etc.
  - ✓ Transformer model data (wire connection type, tap data etc.)
- ■ Daily records related to load dispatching
  Record and accumulate load dispatching related data (time synchronous power system operational records) by using the SCADA system at a predetermined time interval.
  - ✓ Total system demand, supplied energy (kWh), exchanged power and energy to and from neighboring countries, system frequency etc.
  - ✓ Generating power and energy of each generator (active and reactive power), generator terminal voltage etc.
  - ✓ Bus bar voltage, active and reactive power through each transmission line and transformer, power factor etc.

(3) Practical use of 115kV current differential relays between GS 1 and GS 3 in real time operation 115kV

Knowledge and know-how on telecommunication protocol based on international telecommunication standards should be conveyed to related EDC personnel, so that EDC leads Alcatel-lucent to repair the malfunction.

Brief but to-the-point explanation for it is enough for that because to make Alcatel-lucent face this problem is the main purpose. Tangible intricate work is done by Alcatel-lucent.

There is a high possibility that the current differential relays work properly if EDC deals with this problem in strong earnest to have the relays in practical use and moves forward step by step.

As for the relay settings work, only the relay setting result values have been recorded and documented in EDC. No calculation records required to reach the setting values that have been left.

Establishment and standardization of the relay settings procedure is necessary.

Support for this should be incorporated into work in the JICA project "Project for improvement of transmission system operation and maintenance" which started from January of 2013.

(4) Support by making proper use of the JICA project JICA

The major purpose of the JICA project "Project for improvement of the transmission system operation and maintenance" is to establish job flows and their settlement in EDC. This project has to be in a phase with a change of work and organizational circumstances toward NCC full operations.

In this sense, it may well be considered that this project involves support for things described so far within its work scope.

Computational analyses based on the technical or technological facts are definitely necessary so that power system operational personnel in EDC can accomplish their jobs, namely a secure and stable supply of electricity, while system demand grows increasingly and the EDC network expands rapidly.

A secure and stable supply of electricity should be the major responsibility for EDC.

In power system operations, computational analyses and operation related jobs themselves stick together and are unified together.

The purpose and scope of the JICA project described above does not deviate from some of the suggestions described in this report.

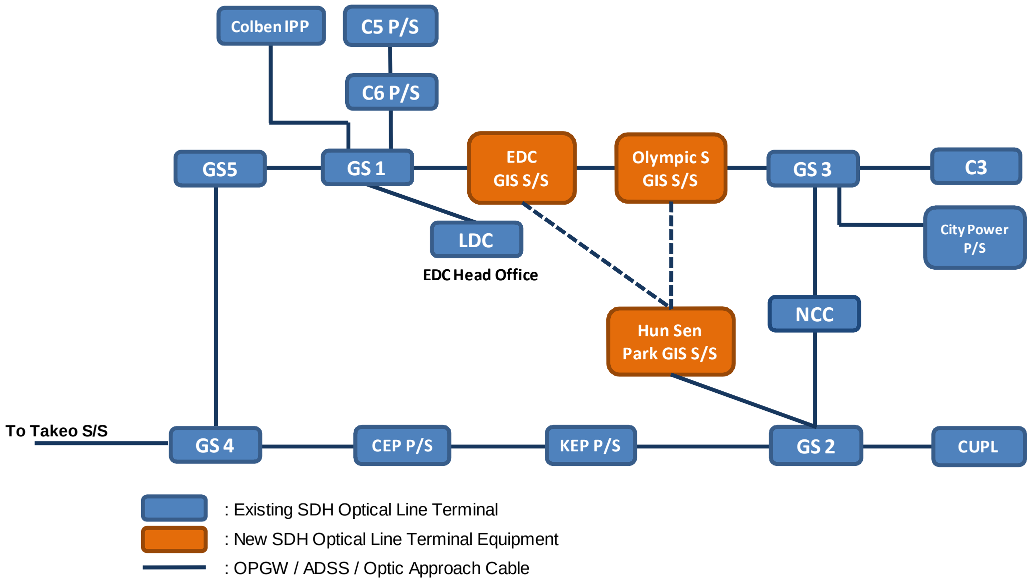
6.5 Telecommunication Design

6.5.1 Fiber Optic Telecommunication (FOT) System to be Newly Installed

The following FOT system will be newly installed under the Project.

1) GS1 to EDC Substation
2) GS3 to Olympic Stadium Substation
3) Olympic Stadium to Hun Sen Park
4) EDC Substation to Hun Sen Park

In consideration of redundancy, the existing EDC's FOT system shown in Figure 3. 8 will be modified to the system shown in Figure 6. 32 below, so as to connect the EDC substation and Olympic Stadium Substation to the loop system in the telecommunication network.



Source: JICA Survey Team

Figure 6. 32 EDC's Telecommunication Network Diagram after the Project

6.5.2 Procurement Specifications

The recommended items needed for the modification of the telecommunication system are stipulated below.

Underground Optic Fiber Cables (for direct burying)
SDH Optical Line Terminal Equipment (OLTE) and Multiplexer
Teleprotection Signaling Equipment
Telephone System
Remote Terminal Unit (RTU)
Optic Fiber Distribution Frame, Splice Box, etc.

(1) Direct Buried Optic Fiber Cable (for Direct Burying)

The Optic Fiber Cable will be directly buried in the same trench with the 115kV power cables, as shown in Figure 6. 9. The optic fiber cable shall have the necessary mechanical and thermal characteristics to accommodate the stretching, bending and crushing force, vibration, and varying operational temperatures.

<u>Characteristics of Optical Fibers</u>	
Type:	ITU-T recommendation 652D
Fiber type:	Single mode
Concentricity error:	Not more than 1.0 µm
Cladding diameter:	125 ± 3µm

<u>Cable Construction</u>	
Installation:	Outdoor Direct buried installation
Number of core:	24 cores
Construction:	Loose tube type
Armor:	Corrugated steel or stainless armor
Cable sheath:	Polyethylene

Amount:

For GS1 to EDC S/S:	2.33 km
EDC S/S to Hun Sen Park S/S	3.33 km
Olympic Stadium S/S to Hun S P S/S	3.33 km
For GS3 to Olympic Stadium S/S:	4.37 km
Total	13.36 km

(2) SDH Optical Line Terminal Equipment (OLTE) and Multiplexer

GS1 and GS3

SDH OLTE and the multiplexer are already installed in the GS1 and GS3, which will be used for connecting with the new substations in the telecommunication system.

EDC Substation and Olympic Substation

A new SDH OLTE and multiplexer will be installed. Considering the connectivity with the existing stations (GS1 and GS3) in the opposite side, both SDH OLTE and the multiplexer are recommended to designate the same model as the GS1 and GS3. In addition, tele-protection signaling equipment will be equipped with SDH OLET and a multiplexer for controlling the signals for the relay systems.

(3) Telephone System

As discussed in the Sub-Clause 3.1.4, the EDC uses its own telephone system by using their telecommunication system. It is recommended that the same telephone system may be installed at the new substations, including the following systems.

- PABX equipment
- Telephone for PABX system
- Hot-line telephone console
- Vice recording system

(4) Remote Terminal Unit (RTU)

Remote Terminal Unit (RTU) is a device to send and receive the signals each together between substation equipment and the master station in NCC, so as to enable to monitor and control the substations from NCC. Since the NCC master station uses IEC 60870-5-101 protocol, the RTUs will be required to be applicable to this protocol.

The new RTUs will be installed at GS1, GS3, Olympic Stadium, and EDC Substation. To avoid user confusion by mixing more than one models of RTU, it is recommended that the existing model (Remsdaq Callisto NT) be designated for all RTUs installed under the Project.

6.5.3 Implementation Schedule

Table 6. 25 Implementation Schedule

Work Item	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Design, Manufacturing and Tests/Inspection																	
Transportation and Delivery																	
Installation/Pre-Commissioning																	
Commissioning																	

Source: JICA Survey Team

Chapter 7 Project Plan

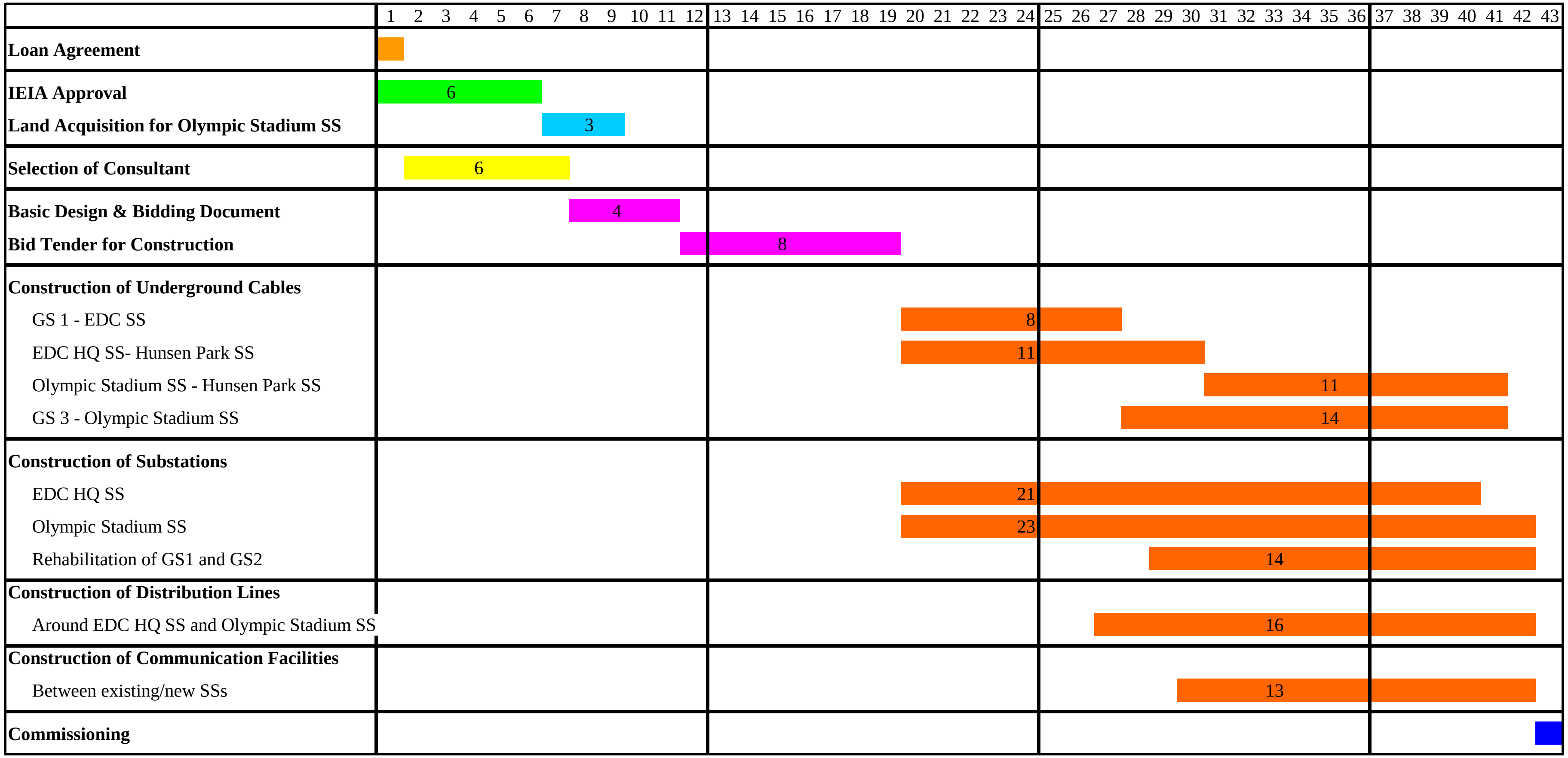
7.1 Construction Schedule

This chapter discusses the specific construction schedule for the Project, which should be finalized after a series of JICA examinations.

7.1.1 The Whole Construction Schedule for the Project

The implementation schedule is shown in Table 7. 1. The Project will be completed in 43 months from the Loan agreement to commencement of operations.

Table 7. 1 Implementation Schedule for the Project



(Source: JICA Survey Team)

7.2 TOR

7.2.1 Work Contents of Implementation Agency, Consultant and Contractor

The following works will be implemented by the implementation agency (EDC), consultants, and contractors.

(1) Implementation Agency of Cambodia (EDC)

EDC shall allot the following roles during implementation.

1) Organizing a new Project Implementation Unit for the Project,
2) Coordination among the related ministries for smooth implementation of the Project,
3) Acquisition of land for substations,
4) Prior securing of the environmental certificate for the Project from the MOE,
5) All necessary certificates to start the construction for the Project
6) Appointment of the Project consultants, and cooperation with /assistance to them,
7) Close communication with institution(s) of the Project fund on bidding, contracts, procurement, project progress, and other information,
8) Proper actions for necessary procedures on facility import for the Project,
9) Issue of payment certificates for consultants and contractors,
10) Claim management of contractors, local people, and others,
11) Prosecution of the commissioning test of the Project,
12) Education and training of employees for operation and maintenance for underground transmission lines and GIS substations,
13) Proper and operations and maintenance of the facilities after commissioned, and
14) Securing budget and staffs to execute the above matters..

(2) Project Consultants

The consultants shall allot the following particulars.

1) Basic design related to preparation of bid documents for the Project including a field survey and line route investigation,
2) Preparation of the design report for the Project and submission to EDC,
3) Preparation of the bidding documents for the Project and submission to EDC,
4) Evaluation of proposals forwarded by bidders and assistance to EDC evaluation committee in selecting prospective bidders for the contracts,
5) Assistance to EDC in contract negotiations with prospective bidders and in conclusion of the contracts,
6) Examination on manufacturing/working drawings and various communications from the contractors for approval,
7) Inspections and tests for equipment and materials to be carried out at the contractors’ factories prior to shipment,
8) Project management and supervision of the contractors’ field works,
9) Preparation of the completion report for the Project and submission to EDC,
10) Inspection on facilities immediately prior to expiration of the guarantee period for facilities and
11) Transfer of knowledge to EDC staff in charge of the Project.

(3) Contractors

The Project will be executed in full-turn-key contracts. The contractors shall allot the following works.

1) Implementation design to complete the Project based on site survey and route survey,
2) Manufacturing and tests of the equipment and materials,
3) All civil/building works, installation of equipment and materials and the factory test
4) Verification of proper functions of all the facilities completed,
5) Commissioning of the facilities to EDC,
6) Transfer of knowledge to EDC through their working period for construction, maintenance and

operation of the project facilities.

Equipment/materials for the Project and construction works at the site will be procured in the ICB full turn-key base. EDC will be responsible for special particulars required for the project execution. The following table shows major works allotted for the contractors and EDC should arrange its staff and budget around the execution of the allotted works.

7.2.2 Manning Plan of the Project

The following staff from EDC and the consultants will proceed the Project.

(1) EDC

1) Project manager in the EDC's project office is to be assigned throughout whole project period. (He will also be a counterpart of the consultants.)
2) Staffs of the EDC's related environment division for monitoring environmental measures taken by the contractors are to be timely dispatched to the sites. Persons from the related province and/or district may also monitor the situation.
3) Underground transmission line inspectors including persons from EDC: at least one civil work inspector throughout the contractors' civil works, at least one inspector for cable installation. Those inspectors should be responsible not only for the supervision of the contractors' work but also for communication and negotiation with authorities on the matters over which EDC has responsibility.
4) The contractor may simultaneously execute works of two substations. EDC's inspectors will be lined up with one person for civil/building works and one person for electrical works per each substation. OJT participants for the O&M of each substation under the Project are separate from the inspectors.
5) The contractor will construct distribution lines and communication lines. PLN's inspectors will be lined up with one person for these installation works.
6) In addition to the aforementioned inspection team and trainees, a procurement committee, project implementation unit, management committee, and bid evaluation committee will be organized as a standard rule of EDC for project implementation and perform each duty for the Project. As demanded, EDC sections concerning the customs of imported goods, payment procedures, and communications with other authorities will execute their duties for the Project

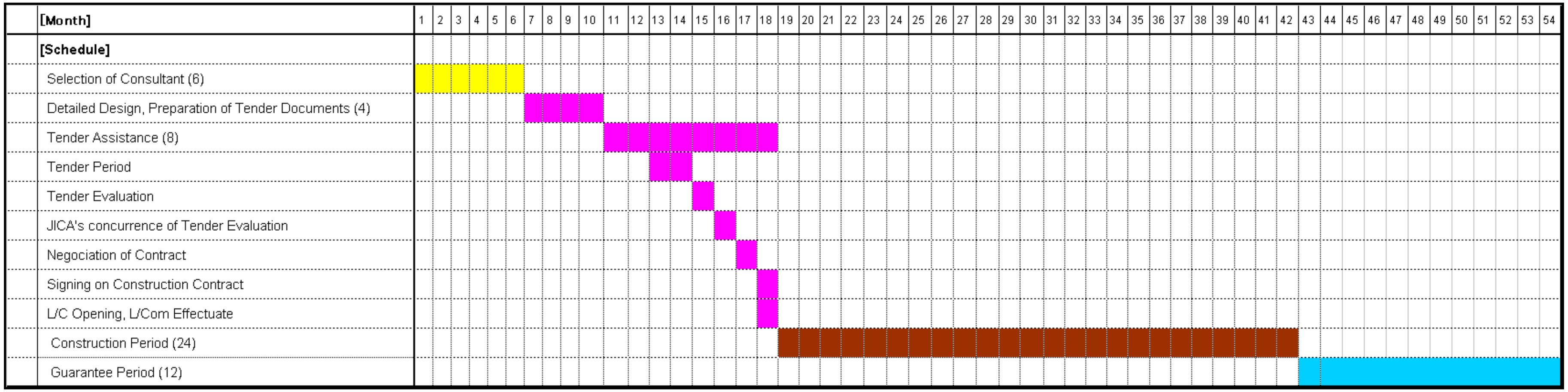
(2) Consultants

1) Consultant works

- Basic Design and Preparation of Bidding Documents
  The consultants will execute the basic design, cost estimate and detailed implementation plan for the Project through discussions with EDC and in accordance with results of the field survey and investigation. Design report prepared by the consultants will cover whole results of the design. After approval of the report by the funding institutions or in parallel with report preparation, the consultants will produce bidding documents for the Project.
- Public Bid and Contract
  The consultants will carry out assistance to EDC during public announcements of the bid, bid opening, bid evaluation, contract negotiation and preparation of the contract documents.
- Procurement Management
  The consultants will manage all works for examinations on the contractors' drawings and designs, and inspection/tests of equipment/materials at the contractors' factory.
- Supervision of Contractors' Field Works
  Through the whole period of the Contractors' field works, the consultants will supervise all the field works. The consultants will have responsibility for education of EDC's operators and maintenance people for the facilities after completion of the Project.
- Commissioning Test and Inspection for Defect Liability Period
  After completion of the construction of all facilities, the consultants will supervise the contractors' commissioning tests of individual facilities for the underground transmission lines,

substations, distribution lines and communication facilities and also for the system’s operation test combining both the transmission line and the substation. Furthermore, the consultants will check and approve the project completion report of the completed facilities to be submitted by the contractors, and assist EDC with their procedures for issuing the taking-over certificates to the contractors. Immediately before the expiration of the defect liability period of the Project facilities, the consultants in conjunction with EDC will inspect all the project-related facilities to issue the final certificates to the contractors.

Table 7. 2 Project Schedule



(Source: JICA Survey Team)

2) TOR for consultant works

Outline of TOR for consultant works are shown as the following.

[Scope of the Project]

The Project consists of:

1) Construction of about 13 km of the following 115 kV underground transmission lines
   - GS1 (Existing) – EDC HQ SS (New)
   - EDC HQ SS – Hunsen Park SS (To be constructed by other project)
   - Hunsen Park SS – Olympic Stadium SS (New)
   - Olympic Stadium SS – GS 3 (Existing)
2) Construction of 115/22kV GIS substations at EDC HQ and Olympic Stadium, and rehabilitation of exiting GS 1 and GS 2
3) Construction of about 20 km distribution lines around EDC HQ SS and Olympic Stadium SS
4) Installation of communication facilities the following sections
   - GS1– EDC HQ SS – Hunsen Park SS – Olympic Stadium SS – GS 3

[Scope of Consulting Services]

The Scope of the Consulting Services is to;

Detail Design and Tendering

a) Collect all engineering data required for designing the Project facilities,
b) Prepare detailed designs for transmission lines, substations, distribution lines and communication facilities taking into account, the design practices used by EDC and current international standards,
d) Prepare pre-qualification (PQ) document according to JICA's Guidelines,
e) Prepare bidding documents for all equipment and services required to implement the project to be suitable for international competitive bidding procedures, and
f) Assist EDC to invite and evaluate PQ and award contracts.

Coordination

a) Assist EDC to maintain the proper coordination and communication between PLN and JICA.

Supervision during Implementation Stage

a) Review and approve the contractor's design drawings and witness tests on equipment, if necessary,
b) Review contractor's manufacturing and delivery schedule of equipment and materials,
c) Supervise the construction of project facilities and help contractors conform to the specifications,
d) Assist EDC to institute cost control, project accounts, and quality assurance mechanisms, and check and approve the contractor's bills, and
e) Review and compile as-built drawings, and review the operation and maintenance manuals made by the contractor for accuracy and adequacy.

Commissioning and Tests

a) Check and approve contractor's procedure of commissioning and acceptance tests,
b) Witness commissioning and acceptance tests, and assist EDC in association with EDC's engineers to take over the completed facilities, and
c) Submit a detailed test report to EDC.

Submission of Report

a) Submit Monthly Progress Reports to EDC,
b) Assist PLN in preparing Quarterly Progress Reports to JICA, and
c) Submit a Project Completion Report providing details of project implementation, problems

encountered, solution adopted, and detailing and explaining any variation in project costs and implementation from the original estimates.

Capacity Building for O&M of Underground Transmission Line and GIS Substation

a) Confirm the current status of PLN's power system facilities and O&M,
b) Assist PLN to establish the work contents of the underground transmission line and GIS substation,
c) Assist PLN to establish the organization and management of these facilities,
d) Assist PLN to establish O&M criteria/manuals, and
f) Give O&M training for these facilities

In addition to the above tasks, we should adhere to the Guidelines published by JICA in carrying out the Consulting Services.

7.3 Japanese Technology to be applied

7.3.1 115kV XLPE Cable

According to the study in clause 6.1, as the first 115kV underground transmission lines to be introduced in Cambodia, the survey team has considered applying the triplex type XLPE cables which were developed and introduced in Japan from the economical point of view.
The comparison between both types of cables shall be shown in Table 7. 3.

Table 7. 3 The Comparison between Single Cable and Triplex Cable

	Single cable	Triplex cable
Transmission system	To achieve the same level of transmission losses of triplex cable, the following techniques shall be applied:- *Phase transposition of each cable, *Application of cross bonding system for earthing.	Simple transmission system scheme
Dimension of joint bay	It is necessary to absorb cable expansion behavior by using an off-set system at a joint bay. Due to the above treatment, Dimension of cable joint bay will be increased by about 30% of that of the triplex cable.	To reduce joint bay dimensions due to the self-absorption characteristics of cable expansion.
Unit length	Standard	Although cable weight will be heavy, it is capable of supplying the same length of single cable.
Cable unit price	Standard.	Same as 3 x Single cables

To select the triplex cables, it is capable to make the simple transmission system scheme, shorten the construction time due to the decrease of cable numbers, compact the joint bay dimensions due to the self-absorption characteristics of the cable expansion and expected to reduce the total cable project costs.

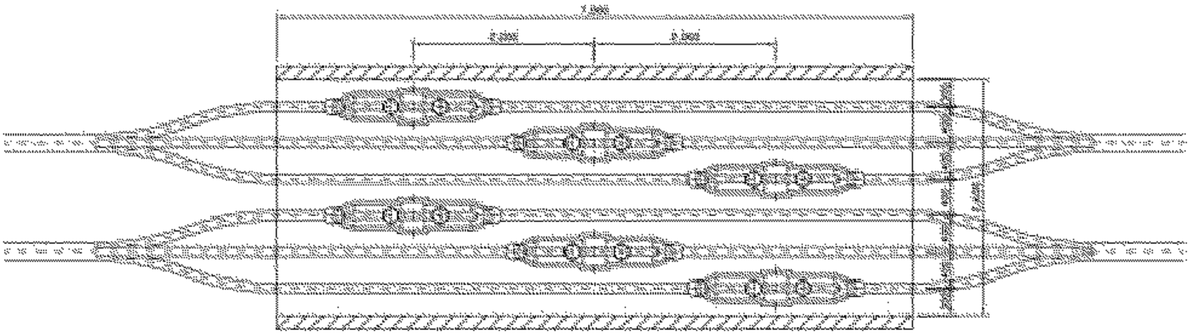


Figure 7. 1 Typical Joint Arrangement

The survey team firstly feared increasing the numbers of joints due to the 3–core cable construction, but as a result of the selected conductor sizes of 1000sqmm for the transmission capacities of 300MVA and 150MVA, it is capable of delivering the standard unit length of cables which means no increase of the

numbers of joints.
In terms of the application of triplex cables, 66kV triplex cables were developed and put into service more than 40 years and 154kV triplex cables were developed and put into service in 2005 in Japan. On the other hand, In Cambodia, 22kV 3 x 240sqmm triplex cables with 33kms in total were applied and introduced in Phnom Penh under the Japan Grant Project in 2002.
Based on the above background, it is suitable to apply the triplex cables for this project.

7.3.2 Distribution Automation System (DAS)

The merits by introducing the latest DAS using the optical fiber for the communication between the sub-stations and the key station, and utilizing the above-mentioned monitoring information is as follows.
On-line condition monitoring of on-site switches and other devices on the DAS system.
Operational information acquisition of the distribution lines: by processing the monitoring data, phase currents, line-to-line voltages, phase voltages, zero-phase current and voltage, phase angles, power factors, and harmonic currents can be displayed on DAS.
Preventive operations against line faults: by analyzing the information above, preventive measures, such as the detailed monitoring of abnormal lines, repairs, and replacements can be planned.
Better distribution system planning by utilizing daily and hourly operational data that is monitored.
Minimization of supply interruption duration and section which is caused by the distribution equipment faults and by performing automated switching and real-time based on-line monitoring of distribution lines.
Minimization of technical losses in distribution lines by identifying the overloading of distribution lines, and shifting loads evenly throughout the available distribution lines.
Better Customer Satisfaction by providing a website which shows the on-line operation of the distribution system.
Maintenance support by implementing a self-diagnosis of the distribution system components.

About the function of these DAS, it has almost the same function as the newest SCADA except for the "shortening of the accident power outage and the minimization of the accident blackout section".
The survey team decided to see off the update of the distribution line control system order SCADA system installed in the EDC headquarters building in this report maintenance business by an EDC management layer opinion at the time of the second investigation.　In addition, the survey team let the optical fiber cable line comply with a new feeder line start and decided to install an optical fiber cable for it in the future.

Chapter 8 Improvement Proposals on Project Organization and O&M organization

8.1 EDC's financial statements

Table 8. 1 shows the balance sheet of EDC from 2002 to 2010. The current ratios, which is used as an index for evaluating short-term safety, deteriorated from 2002 to 2008, but has started improving since 2009. Capital ratios, an index that is used to evaluate long-term safety, showed a similar trend.

Table 8. 1 EDC's Balance Statement

(unit: 1,000 Riels)

Items	2002	2003	2004	2005	2006	2007	2008	2009	2010
Assets	**687,753,261**	**667,144,307**	**740,468,273**	**846,617,646**	**974,158,618**	**904,851,713**	**1,065,255,733**	**1,377,817,340**	**1,757,763,688**
Long-term assets	494,026,177	473,565,097	510,666,518	539,338,097	625,450,726	567,080,343	671,103,095	791,072,614	970,353,074
Property, Plant and equipment	485,418,785	466,929,191	510,631,674	539,318,695	563,234,083	566,903,776	670,965,708	790,960,747	969,951,942
Intangible	8,607,392	6,635,906	34,844	19,402	50,044	176,567	137,387	111,867	401,132
Recievable from MEF	-	-	-	-	62,166,599	-			
Current assets	193,727,084	193,579,210	229,801,755	307,279,549	348,707,892	337,771,370	394,152,638	586,744,726	787,410,614
Cash and cash equivalents	20,964,005	34,460,057	23,558,474	41,667,975	43,071,197	60,999,351	45,798,220	153,350,951	289,457,512
Trade and other receivable	90,927,224	55,388,999	78,352,918	90,452,227	102,207,917	86,536,313	137,623,747	150,873,266	174,691,472
Inventories	33,744,075	34,523,599	43,395,450	43,695,072	51,863,932	58,009,813	66,123,313	79,074,471	117,391,960
Other assets	48,091,780	69,206,555	84,494,913	131,464,275	151,564,846	132,225,893	144,607,358	203,446,038	205,869,670
Liabilities and owner's equity	**687,753,261**	**667,144,307**	**740,468,273**	**846,617,646**	**974,158,618**	**904,851,713**	**1,065,255,733**	**1,377,817,340**	**1,757,763,688**
Non current liabilities	134,304,800	142,464,251	133,382,847	180,273,288	255,963,735	192,359,250	294,428,754	391,288,665	432,139,130
Borrowings	111,448,070	117,187,474	105,174,116	148,298,288	154,675,159	145,601,398	239,975,006	330,724,570	361,525,204
Customer deposits	22,856,730	25,276,777	28,208,731	31,975,000	38,646,042	46,255,959	53,787,756	59,898,913	68,164,789
Payable to Tax Department	-	-		-	62,166,599	-		-	1,585,002
Provision for retirement benefit	-	-	-	-	475,935	501,893	665,992	665,182	864,135
Current liabilities	136,498,304	118,974,521	190,926,112	299,787,738	314,065,990	294,141,293	317,808,940	395,479,335	503,458,446
Trade and other payables	49,749,583	54,865,277	73,053,754	130,319,719	120,021,248	182,252,205	213,665,252	234,557,571	272,301,325
Borrowings	21,524,881	10,115,348	42,481,752	55,645,923	64,478,533	81,353,377	78,092,672	94,906,670	138,279,382
Interest payable	22,127,872	28,180,007	34,441,452	41,668,732	49,254,101	29,188,459	22,410,380	42,701,150	61,969,026
Current income tax liabilities	43,095,968	25,813,889	40,949,154	72,153,364	80,312,108	1,347,252	3,640,636	23,313,944	30,908,713
Owner's equity	416,950,157	405,705,535	416,159,314	366,556,620	404,128,893	418,351,170	453,018,039	591,049,340	822,166,112
Capital	511,994,849	512,192,242	568,275,518	573,771,280	597,073,404	599,852,950	605,698,016	614,393,127	662,390,444
Accumulated losses	(95,044,692)	(106,486,707)	(152,116,204)	(207,214,660)	(192,944,511)	(181,501,780)	(152,679,977)	(23,343,787)	159,775,668
流動比率	142%	163%	120%	102%	111%	115%	124%	148%	156%
自己資本比率	61%	61%	56%	43%	41%	46%	43%	43%	47%

Source: EDC Annual Report

The income statements of EDC from 2002 to 2010 are shown in Table 8. 2. EDC's sales rapidly grew with the power demand increase, e.g., the sales increase in 2010 was 545% compared to 2002. Meanwhile, operating expenses increased similarly, e.g., the increase in 2010 was 461% compared to 2002. The net profit has been in the red until 2005 but went into the black in 2006.

Regarding the uncollected balance from government organizations, EAC said that the Prime minister issued an order of payment normalization in 2011 and it will be solved soon.

Table 8. 2 EDC's Income Statement

(unit: 1,000 Riels)

Items	2002	2003	2004	2005	2006	2007	2008	2009	2010
Operation income	**293,061,919**	**336,332,001**	**400,134,917**	**527,093,532**	**733,428,428**	**924,952,838**	**1,302,204,274**	**1,231,327,270**	**1,598,138,626**
Electricity sales	286,305,991	330,092,888	394,396,785	517,685,044	719,042,874	900,026,129	1,206,179,617	1,215,763,623	1,577,667,850
Connetion fees	5,918,709	5,441,240	4,873,640	7,185,446	10,922,201	12,134,765	12,401,745	10,574,579	12,866,750
Grant income from RGC	-	-	-	-	-	-	79,595,200	-	-
Other income	837,219	797,873	864,492	2,223,042	3,463,353	12,791,944	4,027,712	4,989,068	7,604,026
Operating expenses	**290,571,123**	**335,837,198**	**431,320,666**	**563,782,416**	**704,310,742**	**898,914,084**	**1,242,149,827**	**1,047,906,569**	**1,339,733,438**
Purchased power	162,292,413	192,342,404	230,893,090	360,502,165	500,357,575	690,342,369	1,008,753,238	875,453,346	1,144,613,037
Fuel costs	48,456,656	68,423,998	111,695,943	114,559,510	114,957,751	113,066,222	131,107,946	61,018,894	32,782,648
Import duty	5,401,899	5,251,139	7,687,802	7,296,857	5,582,079	6,619,234	12,233,008	10,596,794	31,262,376
Salaries and staff costs	10,059,450	10,308,366	11,670,937	12,523,776	15,601,724	19,509,664	24,633,947	29,764,019	47,764,116
Other operating expenses	31,387,565	24,387,657	26,151,649	30,012,308	29,380,152	33,537,872	30,540,803	34,410,007	43,199,471
Depreciation	27,033,581	27,602,409	36,620,183	38,854,882	38,421,062	35,820,632	34,841,705	36,663,509	40,111,790
Amortisation	5,939,559	7,521,225	6,601,062	32,918	10,399	18,091	39,180	-	-
Operating profit	2,490,796	494,803	(31,185,749)	(36,688,884)	29,117,686	26,038,754	60,054,447	183,420,701	258,405,188
Finance costs (net)	(10,898,965)	(7,840,475)	(9,890,248)	(13,009,085)	(6,400,139)	(5,230,267)	(19,009,403)	(19,768,955)	(30,670,516)
Profit before income tax	(8,408,169)	(7,345,672)	(41,075,997)	(49,697,969)	22,717,547	20,808,487	41,045,044	163,651,746	227,734,672
Income tax expense	(5,049,575)	(4,096,343)	(4,705,742)	(5,123,493)	(8,447,398)	(9,365,756)	(12,223,241)	(34,315,556)	(44,615,217)
Net profit for the year	(13,457,744)	(11,442,015)	(45,781,739)	(54,821,462)	14,270,149	11,442,731	28,821,803	129,336,190	183,119,455

Source: EDC Annual Report

Table 8. 3 shows EDC's cash flow from 2002 to 2010. The cash flow was in the red in 2008 but it improved from 2009 and at the end of year 2010, the balance was 289.5 billion Riel. According to the comments of EAC that is checking the financial status of REEs, EDC has the ability to extend distribution lines in its supply area and construct sub-transmission lines to REEs by its own budget. The government has a policy where the private companies will invest a large-scale power plant and transmission system via a BOT scheme and EDC should use its own budget for those fields the private sector does not want to invest in.

Table 8. 3 EDC's Cashflow Statement

(unit: 1,000 Riels)

Items	2002	2003	2004	2005	2006	2007	2008	2009	2010
Cash flows from operating activities	**4,060,755**	**41,871,879**	**3,820,371**	**28,047,426**	**12,558,448**	**43,514,068**	**34,221,473**	**115,721,969**	**216,382,520**
Cash generated from operations	4,277,718	62,481,794	8,034,664	32,277,324	26,277,385	82,221,071	62,698,541	130,229,827	257,239,702
Interest paid	-	-	-	(720,014)	(1,475,470)	(28,492,124)	(18,547,212)	-	(5,421,736)
Taxes paid	(216,963)	(20,609,915)	(4,214,293)	(3,509,884)	(12,243,467)	(10,214,879)	(9,929,856)	(14,507,858)	(35,435,446)
Cash used in investing activities	**(4,889,861)**	**(20,493,992)**	**(78,419,449)**	**(28,200,444)**	**(7,650,641)**	**(25,508,900)**	**(37,208,083)**	**(15,098,547)**	**(87,804,709)**
Purchases of property, plant and equipment	(4,965,733)	(20,525,072)	(78,733,080)	(28,425,686)	(9,239,704)	(25,774,548)	(38,225,583)	(15,435,505)	(92,213,377)
Purchases of software	-	-	-	(17,476)	(41,041)	(144,614)	-	(20,950)	(357,010)
Proceeds from sale of property, plant and equipment	75,872	31,080	313,631	242,718	1,630,104	410,262	1,017,500	357,908	4,765,678
Cash flows from financing activities	**2,972,912**	**(7,881,835)**	**63,697,495**	**18,262,519**	**(3,504,585)**	**(77,014)**	**(12,214,521)**	**6,929,309**	**7,528,750**
Borrowing during the year	15,282,685	4,212,610	65,607,854	24,859,192	4,098,468	4,792,032	6,681,473	6,872,146	6,235,352
Repayment of borrowing	(12,309,773)	(12,094,445)	(6,206,604)	(6,596,673)	(7,603,053)	(4,869,046)	(20,050,794)	(181,088)	(10,694)
Grants, Interest received	-	-	4,296,245	-	-	-	1,154,800	238,251	1,304,092
Increase in cash and cash equivalents	**2,143,806**	**13,496,052**	**(10,901,583)**	**18,109,501**	**1,403,222**	**17,928,154**	**(15,201,131)**	**107,552,731**	**136,106,561**
Cash and cash equivalents at beginning of year	18,820,199	20,964,005	34,460,057	23,558,474	41,667,975	43,071,197	60,999,351	45,798,220	153,350,951
Cash and cash equivalents at end of year	20,964,005	34,460,057	23,558,474	41,667,975	43,071,197	60,999,351	45,798,220	153,350,951	289,457,512

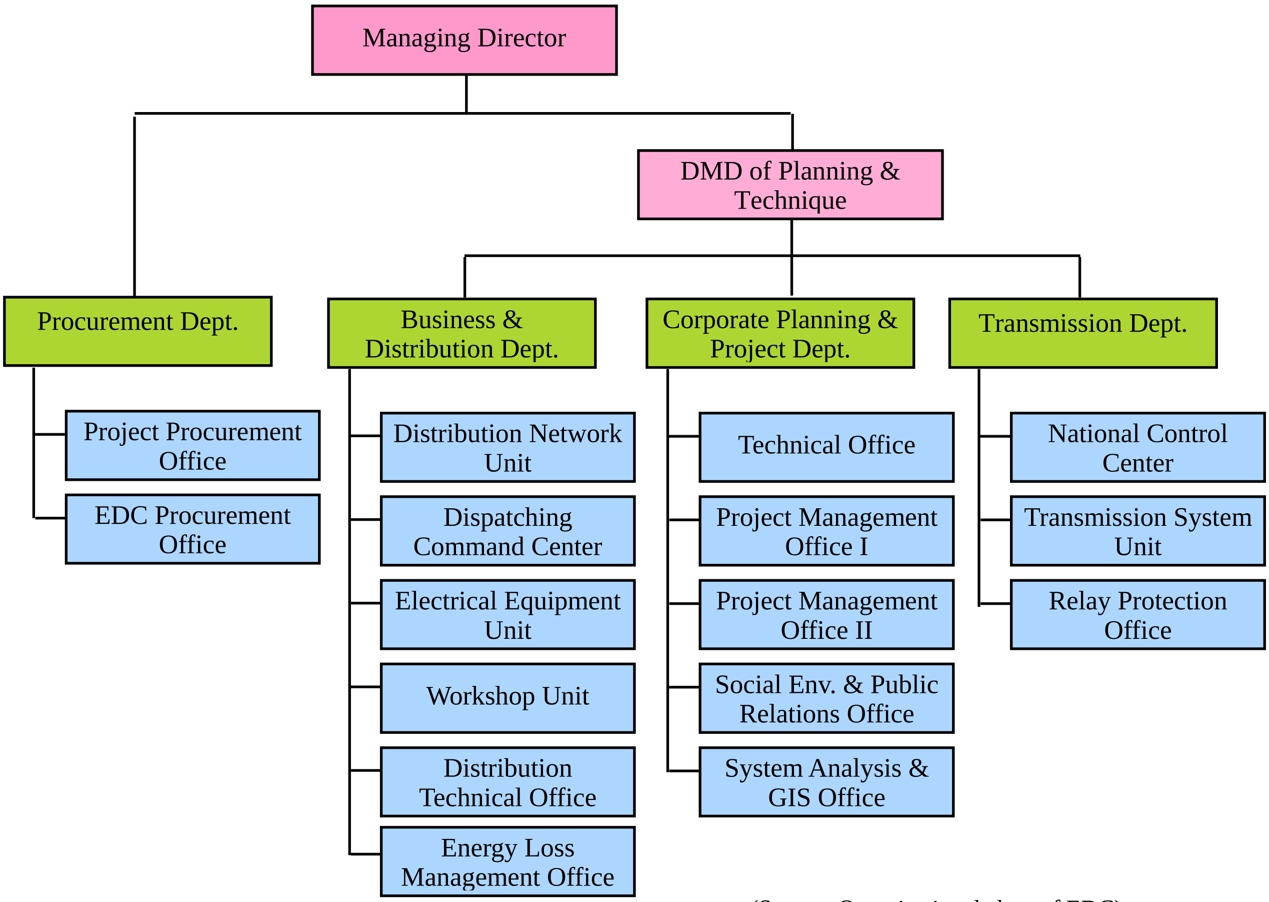
Source: EDC Annual Report

8.2 EDC's Project Organization and O&M Organization

8.2.1 Current Project Organization and O&M Organization

(1) Head office

At present, EDC and the IPPs generate power and the EDC transmits and distributes power exclusively to the Phnom Penh metropolitan area. The following is an organizational chart of EDC who is involved with this project.



(Source: Organizational chart of EDC)

Figure 8. 1 Organizational chart of EDC (organizations related to the project only)

(2) Project Organization

The Project Management Office (PMO)-I or II under the Corporate Planning & Project department manages projects sponsored by international organizations.

(3) Operations and Maintenance (O&M) Organization

The operation and maintenance of the existing substation (GS1, GS2, GS3, GS4) is carried out by the substation head + operator (each 3 operators of 4 groups), and a total of 13 staff (excluding the security guard).

The SCADA system has already been introduced into all substations, and NCC has the equipment that can acquire operational data and information on the substation directly from NCC. However, the signal is not transferred by the difference of the protocol of the SCADA system between NCC and the substations. Because the counter test has not been executed even if the data and information can be taken into the NCC SCADA system, these are inaccurate and untrustworthy. Therefore, the NCC SCADA system does not function.

8.2.2 Proposal for the Project and O&M Organizations

(1) Project implementation

Given that EDC promotes a lot of Projects, EDC will decide which organization executes this Project immediately before this Project starts. However, it is assumed that PMO will execute this Project.

The Survey Team believes that the PMOs have enough capacity to implement the project with the technical advice of a consultant, since they have been doing the same kind of work. It is necessary to consider that there is no engineer who is well versed in 115kV underground cable at EDC because this equipment has been set up for the first time in Cambodia. Concretely, EDC establishes a system to acquire a sufficient amount of technical knowhow by participating in the construction of the Project and the engineer who can become the person in charge of operations and maintenance of the 115kV underground cable in the future is arranged in the PMO of this Project.

(2) Operations and maintenance

It is expected that the Transmission Dept. and Business and Distribution Dept. of EDC will be responsible for the operation and maintenance of the new facilities (115kV underground cables and GIS substations) after construction is completed. The Transmission department was separated from the former Transmission and Distribution department in 2007. They have enough experience in the maintenance of the distribution system, but, limited experience in transmission system maintenance work.

Given that 115kV underground cable is basically laid underground, daily checks and patrols are unnecessary, and a special organization for O&M is unnecessary. However, it is important to grasp the buried position and depth accurately from the perspective of checking the relation between the other underground structures and to take proper action in the event of some abnormality. It is necessary to acquire information on the construction dug up near the location laid underground at an early stage so that the underground cable may evade the risk of being affected by other construction work, and to urge the execution of countermeasures for those who execute construction.

It is thought that 13 staff have been arranged at the newly established substation for operations and maintenance as well as the existing substations. The problem is not caused in the same organization as the existing substation because there is not such a big difference between the two types of substations through using GIS and the indoor type.

8.3 Environmental Management/Monitoring Plan

8.3.1 Institutional Arrangement

The key parties who are responsible for the implementation of EMP are indicated in Table 8. 4. EDC is wholly responsible for the implementation of the project. DCC (Design and Construction Contractor) prepares a safety management plan and construction environmental management plan which are included in the construction plan and implements them. PIC (Project Implementation Consultant) reviews the plan and supervises its implementation.
If the public people have any grievance, it will be dealt with by the PMO (Project Management Office) of EDC. Social, Environmental & Public Relations Office, in charge of environment in EDC, also takes care of those problems with PMO. The grievances which are communicated to the district and Municipality are also handed over to the EDC and EDC will solve it.

Table 8. 4 Environmental Management Responsibilities

Organization	Tasks
EDC	- EDC is directly responsible for the implementation, management and supervision of the project, including the IEIA and EMP requirement. This state-owned enterprise is jointly owned by MIME and MEF so that the project is under their joint control. MIME will have overall responsibility for implementation of the project, whilst MEF will fund the implementation of the Resettlement Plan, if any. - The monitoring is implemented by DCC, supervised by PIC, and approved by EDC. - A PMO (Project Management Office) of EDC will be in charge of the overall management of project design and construction, including implementation and internal monitoring of the EMP. - A site engineer is the construction manager and performs the regular monitoring if there are any environmental and safety concerns at the construction site. - Social, Environmental & Public Relations Office under the Corporate Planning & Project Department of EDC cooperates with PMO and go to check the construction sites if an environment and social consideration occurs. - PMO receives all complaints and grievances which arise in the course of the implementation of project, if any.
Design and Construct Contractor(DCC)	- The DCC will prepare the final project design which is according to EMP. - The DCC will prepare and implement a construction plan including safety management plan and construction environmental management plan and will be responsible for ensuring that the EMP are adhered to.
Project Implementation Consultant(PIC)	- The PIC will manage the overall project. Management duties will include ensuring that the EMP is fully implemented and resolving any related issues that arise.
MOE and technical & Environmental Impact Inspection office of Phnom Penh Municipality	- They are in charge of the monitoring of IEIA and EMP requirement. - Phnom Penh Municipality will also receive all complaints and grievances which arise in the course of the implementation of project and inform them to EDC.

Source: JICA Survey Team

The environmental management plan includes the items for the design, construction, public consultation, provision of the information on safety, and monitoring as shown in Table 5. 18. The Project involves with the construction at the center of Phnom Penh City so that the enough consideration for other underground facilities, local residents, commercial activities and surrounding traffic condition are required. The draft detailed design of T/L and D/L shall be sent to the related agencies and confirmed if there are any interferences with other facilities as shown in Figure 8. 2. In addition, the Kick-off meeting with Municipality, local district, traffic police and others will be organized by EDC. The considerations for local people and policies dealing with likely social issues are confirmed at the meeting. Before the construction at each construction area, DCC will have the public consultation with local residents. The construction shall be implemented with the enough understanding by local people (Figure 8. 3).

Draft detailed route map and design of UG cable	■ DCC prepares the detailed route map and design of UG cable supervised by PIC. ■ EDC sends the design drawing to the related agencies and request them to check it. ■ The candidate of the related agencies are; - DPWT - District office - Phnom Penh Water Supply Authority (PPWSA) - Post office and Telecommunication - Telecom Cambodia - Camintel Company(Telephones) - CFOCN Company(Optical Cable)
⇩	
Review of the route map and design	■ The related agencies checks the drawing if other underground facilities interferes the T/L or D/L. ■ The related agencies reply their comment to EDC, if any.
⇩	
Finalization of the route map and design	■ DCC revises the design and finalize it. ■ EDC approves it.

Figure 8. 2 Checking Procedure for underground facilities

Kick-off meeting	■ EDC organizes kick-off meeting and provide the detailed project design and schedule. ■ The project implementation procedure and policy dealing with the likely social problems such as a grievance from residents are confirmed. ■ The candidate of participants are: - Municipality - DPWT - District Office - Traffic Police ■ EDC receives the comments from the participants and reflect them to the project design and schedule.
⇩	
Local public consultation	■ Before the construction, EDC holds the public consultation and provides the construction schedule to local residents at each construction area, supported by DCC. ■ The construction schedule can be rescheduled if residents have a claim.
⇩	
Construction	■ The construction shall be implemented with understanding by residents. ■ If the local residents have any grievances, the EDC will receive them and deal with appropriately.

Figure 8. 3 Procedures of Local Consultation

8.3.2 Monitoring plan

The monitoring plan according to the Mitigation/Management Measures are proposed in consideration of the Cambodian side's capacity and feasibility as shown in Table 8. 5. It is better for the environment management plan to be included in the safety management plan prepared by the contractor and implemented. The monitoring form is shown in Appendix-8.3. The monitoring plan and monitoring form can be brushed up at the detailed design phase.

Table 8. 5 Environmental Monitoring Plan

Item	Mitigation measure	Parameters to be Monitored	Location	Frequency	Implementing /Responsible Organization
Pre-construction phase					
All items	- Prepared alignment for T/L and substation shall be chosen to avoid land issues and environmental sensitive issues. - The project design shall be prepared to meet the technical standard, budget, and environmental mitigation measures.	Checking the final engineering design and layout of the substations	Project office	One time for draft final design and one time for final design	EDC, PIC
Construction phase					
Air Quality, Noise and vibration	Protection air pollution, noise and vibration from all construction activities and transportations.	Checking the construction site, construction activities and transportation and storage of construction materials.	in construction sites and storage places	Weekly	EDC
				Monthly	EDC, DCC
		Air Quality	near SSs	One time before the construction and two times during the construction work	DCC
		Noise	near SSs	One time before the construction and two times during the construction work	DCC
Water pollution	Prevention of the water pollution of suspended solid or turbidity	Checking the turbidity and soil sediment visually	Surface water near the construction sites	Every week, during the cutting construction period	EDC
				Every month, during the cutting construction period	EDC, DCC
		Turbidity	Downstream from the construction site where the water pollution is expected (3 point at most for 1 site)	One time before the construction and two times during the construction work, if the water pollution is expected	DCC
Waste management	Properly waste management is in compliance with solid waste management of MoE.	Check waste management status	in construction sites and field office	Weekly	EDC
				Monthly	EDC, DCC
Destruction of landscape, living condition of residents	Visual observation to check if there are any environmental issues at the construction site	Check the construction site, construction activities	in construction sites	Weekly	EDC
				Monthly	EDC, DCC
Public Health, workers safety, Children's right	- Safety tools/equipment/clean water should be provided to workers - Education, information and safety indication on HIV/AIDS, safety management and	Worker's condition	in construction sites	Two times in construction period	EDC, DCC

	health and accident avoidance measurement should be provided to workers/staffs -				
Traffic	Traffic facilitator shall be provided at crossing busy road.	Patrol	Near the construction site	Weekly in construction crossing active road	EDC
				Monthly	EDC, DCC
Operation phase					
Safety health	Provide warning sign at the high-risk place	Checking the warning sign	Substation	Every year	EDC
Waste management	Properly waste management is in compliance with solid waste management of MoE.	Checking waste management status	Substation	Every year	EDC

EDC: Electricité Du Cambodge
DCC : Design and Construct Contractor
PIC : Project Implementation Consultant

Source: JICA Survey Team

Chapter 9 Conformation of the Project's Effects

9.1 Economic and Financial Analysis of the Project

9.1.1 Expected Benefit of the Project and Its Evaluation Criteria

The benefits of transmission facility project can be generally defined as the sum of the following three major effects

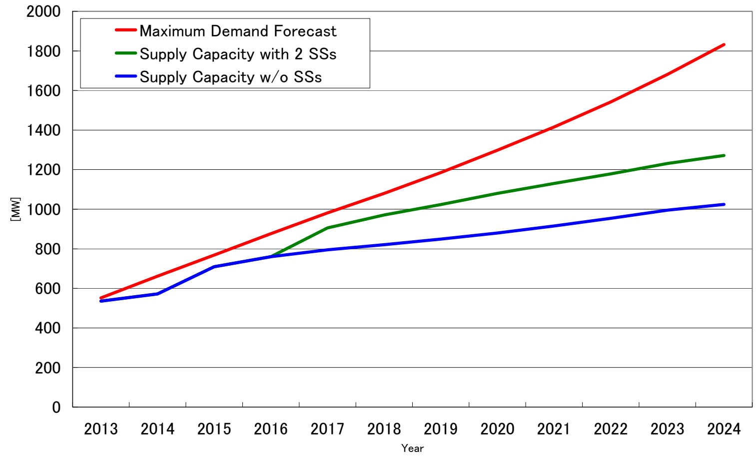
- Enable EDC to supply more electricity for the growing demand
- Improve supply reliability of power grid (reduce the duration of blackouts)
- Reduce transmission loss in throughout the power grid (including the reduction of CO_2)

Since the main objective of this particular transmission and distribution project is to satisfy the increasing demand of electricity in Phnom Penh, the first benefit can be calculated easily by subtracting the maximum supply capacity without any power grid expansion from the expected supply capacity that this project can improve to. However, from the viewpoint of electric power supplier, it is hardly realistic that the customers that are facing the lack of electricity supply will be kept not-served forever. It is more probable that a power company will provide such customers with the electricity transmitted with the best form of new power facility selected among some feasible power grid expansion plans. In the process of the selection of candidate projects, the decision maker for the project compares candidate plans by focusing on other project benefits, such as improvement of supply reliability and reduction of transmission loss.

The most important objective of power system planning is to develop the plan to satisfy the increasing demand forecasted. When the capacity of existing power grid is not sufficient for the future supply, power companies usually expand its transmission and distribution lines like this project. If the power company fails to satisfy the growing demand, the following typical adverse effects will become significant:

- Unable to satisfy the new electricity demand for new economic activities in Phnom Penh, and results in the decrease of GDP. (Considered in EIRR calculation)
- Customers that have sufficient financial savings will purchase personal engine generator(s) by themselves when they are not served by EDC because of the lack of supply capacity. (Considered in EIRR calculation)
- EDC misses the electricity fee income for the customer who should be served. (Considered in FIRR calculation)

This transmission line and distribution line project includes the construction of two substations (150MVA each) to supply electricity, and the increased capacity of the grid can be illustrated as Figure 9. 1.



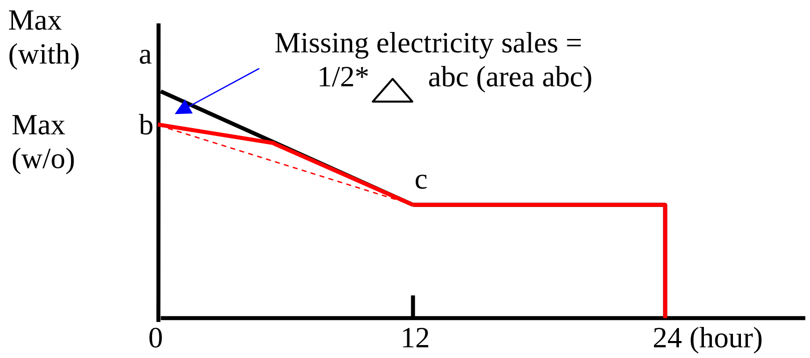
(Source: JICA Survey Team)

Figure 9. 1 The project's Benefit: capacity increase of the Phnom Penh power grid

The scenarios and assumptions for benefit evaluation in "With" case and "Without" case are summarized below:

<u>Assumptions for "Without Project" Scenario</u>

- The facilities in the power grid in Phnom Penh area will not be expand; the supply capacity accordingly stays at 2013 level. Based on this assumption, the shortage of electricity supply capacity will become significant, and the possible benefit from the increased demand will be missed, once the maximum demand excess the maximum supply capacity of each substation. To evaluate this missing sales, the survey team assumed the loading model of Phnom Penh as shown in Chapter 6, and also assumed that the daily load pattern doesn't change for 365 days in a year. By using this loading pattern, the survey team calculated the difference of electricity sales between "With" case and "Without" case as shown in Figure 9. 2.



(Source: JICA Survey Team)

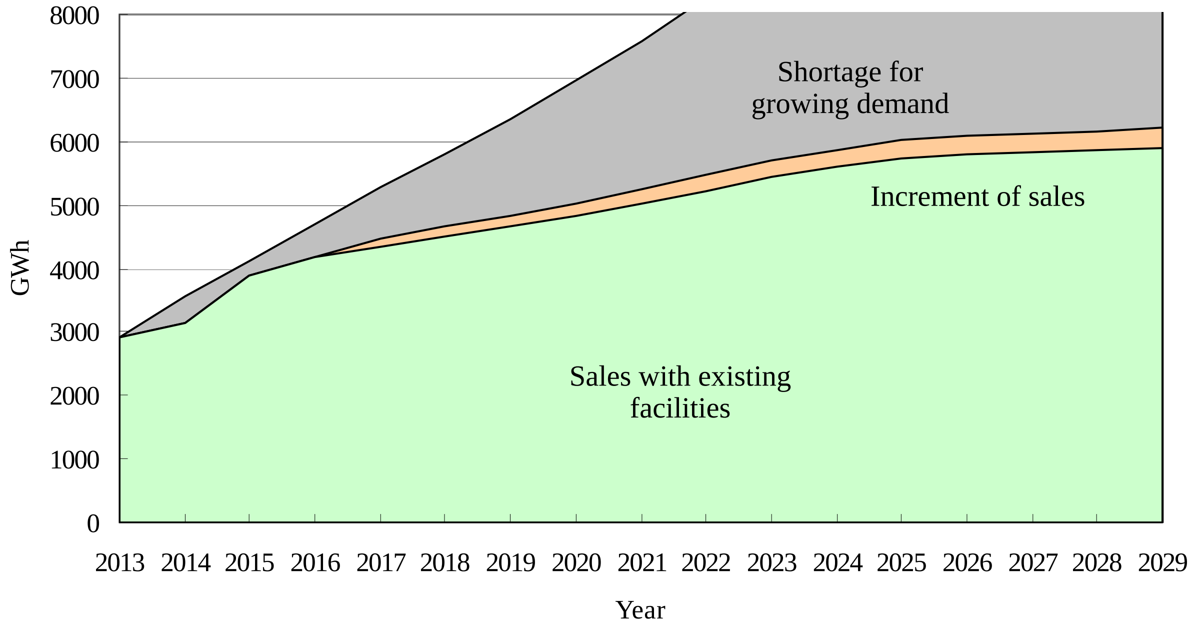
Figure 9. 2 The calculation model of the mismatch of demand and supply capacity.

Table 9. 1 and Figure 9. 3 shows the calculation of electricity sales, necessary electricity generation, and transmission losses in "With" and "Without" cases each year.

Table 9. 1 Calculation of Electricity Sales, Generation, and Losses in “With” and “Without” Cases

Scenario	Electricity Sales	2016	2017	2018	2019	2020	2021	2022	2023
"With"	Increment of electricity sales (GWh)	0.0	118.5	161.2	187.3	214.0	230.7	241.5	252.8
	Increment of power purchased (GWh)	0.0	121.6	165.1	191.7	218.9	236.0	247.0	258.6
	Transmission & Distribution loss (GWh)	0.0	3.0	3.9	4.4	4.9	5.3	5.5	5.7
	Shortage for growing demand (GWh)	635.1	900.5	1255.7	1653.5	2071.6	2503.2	2977.1	3499.9
"Without"	Shortage for growing demand (GWh)	635.1	1019.1	1417.0	1840.8	2285.6	2734.0	3218.6	3752.8

(Source: JICA Survey Team)



(Source: JICA Survey Team)

Figure 9. 3 The forecast of Electricity Sales, Generation, and Losses in “With” and “Without” Cases

9.1.2 Economic and Financial Analysis of the Project

(1) Analysis Procedure

The economic and financial analysis of the project are done by calculating profitability, which is defined as the sum of revenues/benefits subtracted by costs of “With” and “Without” cases. The example of the costs are project’s construction costs paid during 2014-2016, and maintenance cost. The economic internal rate of return (EIRR) and financial internal rate of return (FIRR) are then calculated by analyzing the project’s profitability. Also, sensitivity analysis of EIRR and FIRR are done in variation of electricity demand forecast, project cost, electricity tariff, and purchased price of outer power sources to evaluate the project’s financial stability.

The cash flows of “With” and “Without” cases based on the disbursement of the project cost shown in 9.1.1., electricity sales forecast, and foreseeable benefits of the project are made to evaluate the internal rate of returns. The expenses in the cash flows consists (a) project disbursement during 2014 – 2016, (b) additional maintenance costs for newly build facilities, and (c) power generation purchase for the additional electricity that new facilities can supply.

(2) Financial Internal Rate of Return (FIRR)

The revenue of the new project is defined as the increment of EDC's electricity sales. The internal rate of return is calculated using the expected revenues and costs based on the following assumptions and conditions:

(i) all prices for project materials and equipment are the prices monitored in 2013.
(ii) Project's lifecycle is set to be 25 years.
(iii) The border prices including CIF(Cost, Insurance and Freight) prices excluding customs and taxes are used for the prices of imported goods.
(iv) The operation costs for projects are defined as 1% of the project's construction costs.
(v) The power purchase unit price from domestic and foreign suppliers is calculated with the total amount of purchased power and costs for power purchase are reported both of which shown in on EDC's annual report 2011 (DRAFT) and 2010. Also the unit sales for additional electricity supply is calculated with the tariffs and composition of Phnom Penh customer categories shown in the annual reports.
  - Power Purchase Unit Price from domestic and foreign suppliers: USD 0.135 /kWh
  - Unit Sales for Additional Power Supply: USD 0.178 /kWh

The FIRR of the project is 10.04 % under the conditions above, which excesses EDC's Weighted Average Capital Cost 1.44 %. Thus, the survey team concluded that this project's financial profitability is preferably high.

(3) Economic Internal Rate of Return (EIRR)

Similar to FIRR, the benefit of the new project for EIRR is defined as the decrease of the customers' emergency generations of electricity with inefficient small size diesel generators, which is one of social losses caused by the lack of sufficient electricity supply. The unit generation monetary price for customers' emergency generations is set to USD 0.200 /kWh based on the average unit generation price of 200V 5kVA – 15kVA diesel generator's: 0.187 /kWh, and unit price for factories in Phnom Penh Economic Zone :USD 0.193 /kWh, which is equipped with a large size emergency generators. Other conditions for economic internal rate of return is as follows:

(i) All prices for project materials and equipment are the prices monitored in 2013.
(ii) Project's lifecycle is set to be 25 years.
(iii) The border prices including CIF(Cost, Insurance and Freight) prices excluding customs and taxes are used for the prices of imported goods.
(iv) The operation costs for projects are defined as 1% of the project's construction costs.
(v) Power Purchase Unit Price from domestic and foreign suppliers: USD 0.135 /kWh
(vi) Unit Generation Price for customers' diesel generators is set to be USD 0.200 /kWh

The EIRR of the project is 15.81 %, and the survey team concluded that this project's financial profitability is preferably high.

9.1.3 Sensitivity Analysis of the Proposed Project

The survey team also analyzed the sensitivity of FIRR and EIRR of this transmission and distribution facility project under unfavorable conditions of some important parameters with uncertainties. The four cases were considered: (a) increase of the project cost, (b) lower rate of electric demand increase, (c) increase of unit generation price for electricity purchase, (d) decrease of electricity sales unit price.

<u>Variation of key parameters in sensitivity analysis</u>

(i) 10% increase of the project cost
(ii) 10% lower rate of electric demand increase after the commissioning of the project in 2017
(iii) 10% increase of unit generation price for electricity purchase

(iv) 10% decrease of electricity sales unit price

For all of unfavorable conditions studied, the project remains favorable IRRs, and the survey team concluded the project has sufficient immunity against possible unfavorable change in key parameters.

Table 9. 2 Results of Sensitivity Analysis of the Project under Some Unfavorable Conditions

	Scenario	FIRR	EIRR
	Original Case	10.04%	15.81%
(i)	10% increase of the project cost	9.11%	14.67%
(ii)	10% lower rate of electric demand increase after 2017	9.92%	15.60%
(iii)	10% increase of unit generation price for electricity purchase	3.73%	12.4%
(iv)	10% decrease of electricity sales unit price	0.81%	

(Source: JICA Survey Team)

9.1.4 Comparison of Project Alternatives

As mentioned in 9.1.1, from the viewpoint of electric power supplier, it is hardly realistic that the customers that are facing the lack of electricity supply will be kept not-served forever: “Without” project. It is more probable that a power company will provide such customers with the electricity transmitted with the best form of new power facility selected among some feasible power grid expansion plans. In this survey, the team compared three alternatives in section 3.5 as shown in Table 9. 3.

Table 9. 3 Comparison of Project Alternatives (with year 2020 demand)

(Unit: GWh)

Plan	Plan 1	Plan 2	Plan 3
Description	Construct two substations in suburban area and lay 22kV distribution lines to supply to Phnom Penh center.	Construct two substations in the center of Phnom Penh to supply increasing demand	Provide interconnection among new 2 substations and existing substations
Electricity Sales	200.51	213.04	213.95
Anticipated Supply Interruption Duration	0.982	0.915	0
Transmission Loss	6.1	6.11	4.93
Electricity Purchase from Power Producer	219.08	219.15	218.89

(note) The total loss of power grid is assumed to be 2% of total demand. (Source: JICA Survey Team)

(1) Comparison of supply reliability

The accepted common definition of increased electricity supply reliability in terms of a monetary benefit value does not exist because the occurrence of facility trouble is statistical and the adverse effect of blackout to social life has not been fully clarified yet. In this survey, the team adopted the idea explained in section 3.3.2, which considers the facility fault as the decrease of electricity sales (kWh) until the electricity interruption recovers. The survey team also gathered the statistical information of transmission line faults in EDC grid, and concluded that Plan 1 yields 982MWh lower electricity sales as compared to plan3.

From the viewpoint of EDC, the electricity supply interruption is the lost of electricity sales. On the other hand, from the social point of view, since the electricity supply interruption unexpectedly stops all economic activities in the affected area, the interruption can be regarded as a social loss. Thus, as for the calculation of EIRR, the team defined the social loss coefficient as USD 3.00/kWh, which can be explained as the loss of Gross of Domestic Product of the nation. The justification of USD 3.00 /kWh is explained in the next paragraph.

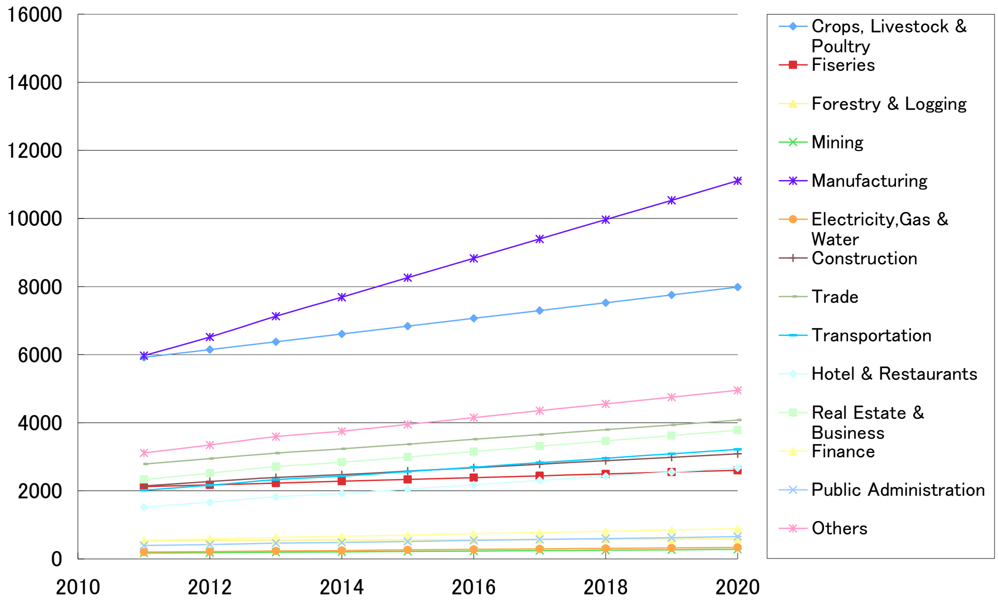
Because the project focuses on the electricity supply to the center of Phnom Penh, capital city and the most developed business area in Cambodia, its regional GDP is evaluated as the sum of linear regression of industry GDP with industry population derived from MEF's report on GDP by industrial sector, and industrial population in Phnom Penh metropolitan area according to the Census results in 2008. The result of the calculation of regional GDP shows that Phnom Penh has a larger ratio in particular industry that have higher growth rate, such as Manufacturing, Electricity sectors. Because of this higher population ratio in growing industries, Phnom Penh metropolitan area, which has 8.7% of overall Cambodia population produce 24.4% of domestic products. This means, the social loss in Phnom Penh city because of electricity interruption is three times larger than the conventional loss coefficient USD 1 / kWh.

Table 9. 4 Population in Phnom Penh Metropolitan area and the ratio to Overall Cambodia.

Population Comparison in Business Sectors Yr 2013

Business Category	GDP (2013)	Phnom Penh City	Overall	Percentage	GDPinPhnom Penh
Crops, Livestock & Poultry	6,378.00	12,516	4,931,465	0.25%	16.2
Forestry & Logging	549.00	519	5,554	9.34%	51.3
Fiseries	2,229.00	1,595	90,340	1.77%	39.4
Mining	199.00	123	5,084	2.42%	4.8
Manufacturing	7,126.00	158,663	433,392	36.61%	2608.8
Electricity,Gas & Water	237.00	6,470	15,618	41.43%	98.2
Construction	2,390.00	31,384	142,914	21.96%	524.8
Trade	3,111.00	151,006	539,553	27.99%	870.7
Transportation	2,328.00	41,247	156,440	26.37%	613.8
Hotel & Restaurants	1,825.00	21,246	60,542	35.09%	640.4
Real Estate & Business	2,715.00	800	1,624	49.26%	1337.4
Finance	635.00	7,721	16,987	45.45%	288.6
Public Administration	463.00	121,171	387,791	31.25%	144.7
Others	3,595.00	47,444	172,076	27.57%	991.2
				8.65%	**24.4%**

(Source: Cambodia's Census in 2008)



(Source: MEF Microeconomic Framework 2010-2011)

Figure 9. 4 GDP Growth Rate of Industry Sectors

(2) Reduction of Transmission Loss

The reduction of transmission loss of plan1: supply with long distribution lines, and plan 2,3: supply with 115kV underground transmission lines are evaluated based on the losses calculated in section 3.3.2. To calculate the monetary value of the loss reduction is defined as the reduction of electricity purchase from power producer to the new two substations. Generally speaking, the transmission loss increases when long power supply lines are operated low voltage. Since Plan 2,3 employs higher voltage with shorter total length of transmission lines as compared to plan 1, in which 22kV long distribution lines are employed, the total loss is significantly reduced. The value of transmission losses are also derived from the formula in 3.3.2. The loss in substations and neighboring distribution lines connected to the new two substations are assumed to be constant as the power flow in these parts doesn’t change.

(3) Internal rates of return of alternatives

Based on the assumptions mentioned in previous section, the survey team calculated IRRs of each project alternatives as shown in Table 9. 5.

Table 9. 5 Internal Rates of Return of Project Alternatives

	Plan 1	Plan 2	Plan 3
FIRR	10.04%	12.43%	10.04%
EIRR	13.02%	15.57%	15.81%

(Source: JICA survey team)

According to the IRRs calculated, plan 2 yields the best FIRR while Plan 3 yields the best EIRR. By considering the fact that the social impact of the electricity supply interruption doesn’t fully include the social impacts of long-duration blackout, the survey team concluded plan 3 is the best project for long-term reliable power supply.

9.1.5 Estimation of the Project's CO2 Reduction

Since the proposed project introduces the first 115kV underground transmission lines in Phnom Penh Metropolitan area, and it is expected to reduce some distribution losses in the area, the survey team also evaluated the project's CO2 reduction effect. Based on the forecast of future electricity demand, the possible reduction of transmission loss, which is the difference between the losses in the proposed project (plan 3) and the conventional supply scheme with long distribution lines (plan1) was calculated by utilizing JICA's Climate Finance Impact Tool for Mitigation (June 2011). The survey team selected #15 sheet for transmission line project, and derived some parameters from it.

As for the unit CO2 emission coefficient, the survey team didn't find any publicly disclosed value for Cambodia, thus derived the parameter from the Japanese MEF's report co-authored by Cambodia's Ministry of Environment, titled: Grid Emission Factor of the Phnom Penh Electricity Grid. Also the survey team selected diesel generators, such as CEP and KEP, as the target generators for operation, and set the value 0.68 t-CO2/kWh. The result of the tool yielded the 4062 ton equivalent of CO2 emission can be reduced in 2017, and 9213 ton in maximum when the electricity demand grows.

Table 9. 6 Estimation of CO2 Reduction

Calculation Sheet

Cambodia Phnom Penh Transmission and Distribution Line Project

GHG emission reduction by project ($t\text{-}CO_2/y$) $ER_y = BE_y - PE_y$ ($t\text{-}CO_2/y$)

1. Baseline Emission $BE_y = BL_y \times EF_{BL,y}$

BE_y	Baseline Emission GHG Emission without Project	9,688	$t\text{-}CO_2/y$
BL_y	Transmission Loss without Project	14,000	MWh/y
$EF_{BL,y}$	CO_2 Coefficient of the Grid	0.692	$t\text{-}CO_2/MWh$

2. Project's Emission $PE_y = PL_y \times EF_{BL,y}$

PE_y	Project's Emission GHG Emission withProject	475	$t\text{-}CO_2/y$
PL_y	Transmission Loss with Project	686	MWh/y
$EF_{BL,y}$	CO_2 Coefficient of the Grid	0.692	$t\text{-}CO_2/MWh$

3. Estimation of CO2 Reduction $ER_y = BE_y - PE_y$ ($t\text{-}CO_2/y$)

ER_y	Project's effect on Emission Reduction	9,213	$t\text{-}CO_2/y$
BE_y	Baseline Emission GHG Emission without Project	9,688	$t\text{-}CO_2/y$
PE_y	Project's Emission GHG Emission withProject	475	$t\text{-}CO_2/y$

9.2 Project Performance Index

9.2.1 Proposal for Project Performance Indicators

The operation and effect indicators for performing an ex-post valuation are proposed from the perspective of conducting a precise evaluation of the following two points.

- Improvement of national life level
- Ensuring that the Implementing Agency of the business is realizing a profit

In addition, in the proposal of the indicators for performing an ex-post valuation, the following points are given due consideration.

- Acquisition of data is easy. (It is data obtained via the processing of direct data obtained from the installed measuring instrument.)
- Data reliability is high. (Periodical proofreading should be performed in respect of the accuracy of the measuring instrument).
- Definition is clear. (There needs to be no room of an arbitrary element to enter, and even if who acquires, becomes the same value).
- Continuous trend management is easy. (Verifying the effects is easy if especially the past data is available.)

(1) Improvement of national life level

If the evaluation of the improvement of the national life level is focused on the side of the electric power sector, it is thought that the following three indexes will be suitable.

- Stability of the electric tariff in a suitable level
- Downward tendency of the frequency and duration of the outage
- Development of the economy

The common characteristic of these three indexes is that their direct impact to business is not readily apparent, in order to be changed by complex factors which includes non-business-related factors. Therefore, the indicators will be proposed taking the national viewpoint into consideration as much as possible.

(2) Improvement of conducting organization’s profits

In order to aim at improving the whole organization, the indicators that pursue only efficiency is not enough. The soundness of the facilities, which is related to the trade-off, is also an important factor. From such a perspective, the operation and effect indicators for performing an ex-post valuation are proposed. The following can be considered as candidates of the concrete indicators.

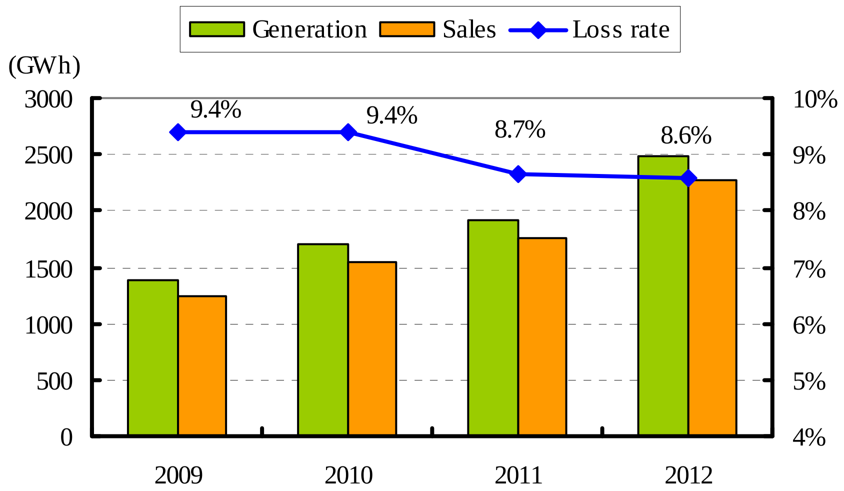
- Efficiency (revenue and expenditure, cost)
  - Electricity losses in the Phnom Penh area
- Soundness of facilities (stable power supply capacity): This is the relation of the trade-off to efficiency. The higher loading rate of the power grid components increases the efficiency of the power system operation, but sacrifices the loading margin of the components, and results in decreased reliability during operations.
  - Maximum loading rates and average loading rates, of the newly installed substations
  - Maximum power flow (MVA) of the newly installed underground lines
- Service (customer satisfaction): This is the relation of the trade-off to efficiency.
  - Expected SAIFI and SAIDI after the completion of the project
  - Expected number of large scale blackouts

9.2.2 Target Value of Project Performance Indicators

Regarding setting up the targeted value, the target year is set after two years (around 2020), which JICA recommended. However, only the factors requiring long-term improvements have long term targets set for them such as a ten-year period (around 2030).

(1) Transmission & Distribution (T&D) losses in the Phnom Penh area

The results of the T&D loss rate in the Phnom Penh area are shown below.



Source: EDC Annual report

Figure 9. 5 Results of T&D Loss Rate in Phnom Penh Area

The loss rate in 2012 is 8.6%. In the Project, because the transmission distance in distribution line (22kV) where the loss is large decreases due to constructing the substation in the central area, it is thought that the losses will for sure decrease. The power system reinforcement project around 2020 excluding this Project will contribute to the loss reduction, and it is very difficult to identify contribution of the loss reduction caused by this Project only. It is not appropriate to use this as the indicator.

(2) Maximum loading rates and average loading rates of the newly installed substations

The estimated load of each substation in 2020 is as follows. The total transformer capacity of each substation is 150MVA, and the load factor is calculated by assuming 95% of the power factor.

Table 9. 7 Estimated Load of each Substation in 2020

Substation	Maximum Load	Load factor
EDC HQ	98.9 MW	69.4 %
Olympic Stadium	116.4 MW	81.7 %

Source: JICA Survey Team

As for the above-mentioned load assumption, the Hun Sen Park substation, the Toul Kork substation, and the Chroy Changvar substation are required to be completed in 2020 in addition to these two substations. The estimated load will increase because of the necessity for allotting the load of the incomplete substation when some substations cannot be completed by 2020. The supply district in the substation is decided to some degree and all substations are interconnected by distribution lines. The load allotment of each substation is different according to the location where the distribution line is opened between substations. It is assumed that the expansion of the demand for the surrounding area in Phnom Penh City is large in 2020. Therefore, it is in the situation with a high load factor of the existing GS1, GS2, and GS3 substations, and there is the possibility that the new constructed substations are allotted a part of the load, too.

Thus, the maximum load factor of the new constructed substation is dependent on the expansion of the demand in each region and the load allotment of each substation at the time of 2020. As described before, the load factor should be as low as possible from the viewpoint of securing a stable supply, though the load factor should be high from an efficiency viewpoint. The target value of the maximum load factor in 2020 is assumed to be 70% - 90% in consideration of this aspect. (A case where the accident occurs in the system is excluded.)

In considering of about 62% of the load factor at present, the target value of the average load factor is assumed to be 43%-56% (this becomes an annual transmitted power of 500 – 700GWh).

(3) Power flow of the new underground cable

As a result of the system analysis, the power flow of the new constructed underground cable in 2020 peak periods under the normal operating conditions is as follows. This power flow shows the maximum power flow considering the various power system configurations and power generations. It is usually thought that there is maximum power flow in a stable situation, though it is assumed that power flow will increase more than the following flows temporarily at the accident.

Table 9. 8 Power Flow of the New Underground Cable in 2020 Peak Periods

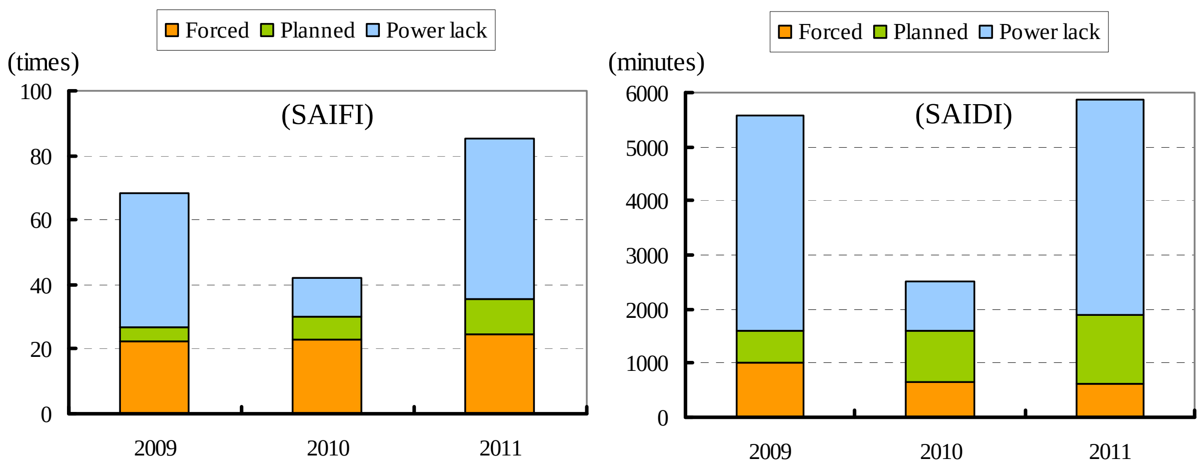
Underground Cable Route	Power flow	Case
GS1 → EDC HQ	99 MW	Radial operation
GS3 → Olympic Stadium	130 MW	Radial operation, partially loop operation
EDC HQ ← HunSen Park	106 MW	Loop operation, Power from south
Olympic Stadium ← HunSen Park	118 MW	Loop operation, Power from south

Source: JICA Survey Team

As for these underground cables, it is basically a power line for the supply to the substation, and the maximum current is assumed to be same level of the substation load if the system is radially operated. Considering the target value of the maximum load factor (70%-90%) of the substation and the transformer capacity of each substation (150MVA), it is assumed that 105MVA - 135MVA is a target value of the maximum power flow of the new constructed underground cable.

(4) SAIFI and SAIDI of Phnom Penh area

EDC collects SAIFI and SAIDI in the Phnom Penh area every year as power outage data. The results are shown below.



Source: EDC

Figure 9. 6 SAIFI, SAIDI

Minus the lack of power, SAIFI is 35.7 times and SAIDI is 1,884 minutes in 2011.
The transformer capacity increases by executing the Project, and the interconnecting system between the substations is strengthened. Therefore, some power outages due to the shortage of the transformer capacity and the maintenance work in the system will become avoidable. Moreover, because the mean distance between the substation and the load shortens from completing the substation in the Phnom Penh central area, the interconnecting system per the distribution line is strengthened, and it becomes easy to switch the distribution line at the accident, a great reduction in the power outage duration generated at the distribution line accident becomes possible. As a result, the supply reliability will be improved. The power system reinforcement project around 2020 excluding this Project will contribute to the supply reliability improvement, and it is very difficult to identify contribution of the supply reliability improvement caused by this Project only. It is not appropriate to use this as the indicator.

(5) Occurrence frequency of a wide-area blackout
In the Project, all substations constructed in the central area in Phnom Penh will be interconnected. The substation located in the Phnom Penh central area will have two or more power supply sources through these interconnecting lines. Therefore, it is thought that a substation blackout lasting for more than 10 minutes including duration for switching operation can be evaded because it is possible to supply it from other healthy supply sources even if an accident occurs somewhere else in the system.
The target value of the long term blackout lasting for more than 10 minutes caused by transmission line faults for a substation per year will be 0

(6) Summary
(a) Qualitative effect (which is difficult to identify the effect of this project only)

- Transmission and distribution losses in Phnom Penh area
  Constructions of substation in the demand center contribute to reducing losses because of short distance 22kV distribution lines which produce the lower loss.
- Supply reliability of Phnom Penh area (reduction in outage)
  Distances between substations and demands become shorter, and reinforcement of the distribution network contributes to easier switching of the distribution lines. The duration of outage can be largely reduced with highly meshed network.
- Economical development of Phnom Penh area

(b) Quantitative effect
The following table shows the proposed quantitative indexes.

Table 9. 9 Proposed Quantitative Indexes

Item		Target value
Newly installed substation	Maximum load factor	70% - 90%
	Average load factor (annual transmitted power)	43% - 56% (500 - 700GWh)
New underground cable	Maximum power flow	105MVA - 135MVA
Long term blackout lasting for more than 10 minutes for a substation per year		0 times