Kingdom of Cambodia
Electricité du Cambodge

PREPARATORY SURVEY
FOR
PHNOM PENH CITY TRANSMISSION AND DISTRIBUTION SYSTEM EXPANSION PROJECT PHASE Ⅱ
IN THE KINGDOM OF CAMBODIA

FINAL REPORT

December 2014

Japan International Cooperation Agency

NEWJEC Inc.
The Chugoku Electric Power Co., Inc.

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Preparatory Survey for Phnom Penh City Transmission and Distribution System Expansion Project (Phase II) in The Kingdom of Cambodia

FINAL REPORT

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Abbreviations

Symbol	Abbreviations
AAC	All Aluminum Conductor
AC	Aluminum Clad steel wire
ACSR	Aluminum Conductor Steel Reinforced
ACSR/AC	Aluminum Conductor Aluminum Clad Steel Reinforced
ADB	Asian Development Bank
AIMS	The ASEAN Interconnection Master Plan Study
AIS	Air Insulated Switchgear
APEC	Asia-Pacific Economic Cooperation Conference
APG	ASEAN Power Grid
ASEAN	Association of South - East Asian Nations
BOO	Build, Own and Operate
BOT	Build, Operate and Transfer
BT	Build and Transfer
CDC	The Council for the Development of Cambodia
CIA	Central Intelligence Agency
COD	Commercial Operation Date
CPI	Consumer Price Index
CPP	Cambodian People's Party
DCC	Design and Construct Contractor
DEIA	Department of Environmental Impact Assessment
DLMUPC	Department of Land Management, Urban Planning and Construction
DMS	Detailed Measurement Survey
DOE	Department of Environment
DPWT	Department of Public Works and Transport
DS	Disconnecting Switch
DSCR	Debt Service Coverage Ratio
DWQS	Drinking Water Quality Standards
EAC	Electricity Authority of Cambodia
EDC	Electricité du Cambodge
EDS	Every Day Stress
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMO	Environmental Monitoring Organization
EMP	Environmental Management Plan
EPC	Engineering, Procurement and Construction
EPP	East Phnom Penh Substation
EVN	Electricity of Vietnam
F/S	Feasibility Study
FDI	Foreign Direct Investment
FDIC	International Federation of Consulting Engineers
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Gas Insulated Switchgear
GMS	The Greater Mekong Sub-region
GREPTS	General Requirements of Electric Power Technical Standards of the Kingdom of Cambodia
GS	Grid Substation
GSW	Galvanized stranded Steel Wire

Symbol	Abbreviations
HV	High Voltage
IAEA	International Atomic Energy Agency
ICEA	Insulated Cable Engineers Association
ICEM	International Center for Environmental Management
IDC	Interest During Construction
IEC	International Electrotechnical Commission
IEIA	Initial Environmental Impact Assessment
IFAD	International Fund of Agricultural Development
IGES	Institute for. Global Environmental Strategies
ILO	International Labour Organization
IPCC	International Panel on Climate Change
IPP	Independent Power Producer
IRC	Inter-ministerial Resettlement Committee
IRR	Internal Rate of Return
ITTO	International Tropical Timber Organization
ITU	International Telecommunication Union
IWGIA	International Work Group for Indigenous Affairs
JEPIC	Japan Electric Power Information Center, Inc.
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
L/A	Loan Agreement
LBS	Load Break Switch
MEF	Ministry of Economy & Finance
METI	Ministry of Economy, Trade and Industry
MH	Manhole
MIME	Ministry of Industry, Mines and Energy
MLMUPC	Ministry of Land Management, Urban Planning and Construction
MME	Ministry of Mines and Energy
MOC	Ministry of Commerce
MOE	Ministry of Environment
MOI	Ministry of Interior
MPWT	Ministry of Public Works and Transport
MV	Medium Voltage
MW	10^6 W, Mega Watt
MWT	Maximum Working Tension
NBC	National Bank of Cambodia
NCC	National Control Center
NGO	Non-Governmental Organizations
NOx	Nitrogen Oxide
NPP	North Phnom Penh Substation
NPV	Net Present Value
O&M	Operation and Maintenance
ODA	Official Development Assistance
OHL	Over Head Line Transmission Facilities
OPGW	Optical Fiber Ground Wire
PCM	Public Consultation Meeting
PEC	Private Electricity Company
PEO	Provincial Environment Office
PEU	Public Electricity Utilities
PFP	Fiber Reinforced Plastics
PIC	Project Implementation Consultant
PKO	United Nations Peacekeeping Operations
PMO	Project Management Office

Symbol	Abbreviations
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PRSC	Provincial Sub-Committee
RAP	Resettlement Action Plan
RD	Resettlement Department
REE	Rural Electricity Enterprise
SC	Shunt Capacitor
SCADA	Supervisory Control and Data Acquisition
SCF	Standard Conversion Factor
SEZ	Special Economic Zone
SMP	Safety Management Plan
SNC	Supreme National Council of Cambodia
SOx	Sulfur Oxide
SPC	Special Purpose Company
SPDRE	Strategy and Plan for Development of Rural Electrification in the Kingdom of Cambodia
SPP	South Phnom Penh Substation
SREPTS	Specific Requirements of Electric Power Technical Standards of the Kingdom of Cambodia
T/L	Transmission Line
TACSR	Thermal-resistant Aluminum alloy Conductor Steel Reinforced
TC	Thermal Conduction
TOR	Terms of Reference
UG	Underground Transmission Facilities
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
UNTAC	United Nations Transitional Authority in Cambodia
USAID	United States Agency for International Development
UTS	Ultimate Strength Tensile
VAT	Value Added Tax
WB	World Bank
WFP	World Food Programme
WHO	World Health Organization
WPP	West Phnom Penh Substation
WTO	World Trade Organization
XLPE	Cross-Linked Polyethylene

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE SURVEY

Recently, the economy of Cambodia is growing stably riding on the upswing of the markets of apparel, tourism, and agricultural industries. In 2013, GDP (Gross Domestic Product) growth rate of 7.2% has been achieved and the steady growth is expected in the future. Along with the stable economic growth in Cambodia, the amount of the electric power sales from 2003 to 2013 has increased at an average rate of 19.8% per annum. Under such situations, expansion of the facilities in power sector is the pressing issue. The “Power Development” is the most important area included in the “Infrastructure Development” which is one of the four pillars in the “Rectangular Strategy-Phase III” of the Government of Cambodia.

Phnom Penh is the center of economic and social activities with population of 1,688,044[1]. The city consumes 70% of the whole domestic power demand, and the stable electricity supply in the area is acknowledged as one of the most prioritized policies by “National Strategic Development Plan (2014-2018). Electricité du Cambodge (EDC) has agreed on the principle that they prepare the Phnom Penh System as the most prioritized systems in the country. In Phnom Penh, there are problems that huge area is affected by power cut and it takes for hours to restore. Those problems are attributed to lack of system control and the shortage of capacities of the transmission line, substation and distribution facilities. To improve the situation, expansion of these facilities is essential, and it is necessary to be worked on immediately.

Considering these situations, JICA (Japan International Cooperation Agency) implemented the “Preparatory Survey for Phnom Penh Transmission and Distribution System Expansion Project” from November 2012 through November 2013. The study conducted includes construction of the new 115/22kV substations at Olympic Stadium and EDC Headquarters, upgrading of GS[2] 1 and GS3, installations of 115kV underground transmission line and 22kV distribution lines for the expansion of the capacities of transmission line, substations and distribution lines. Based on the result of the Survey, on 10 July 2014, JICA signed Japanese ODA loan agreement to provide loans for the Phnom Penh Transmission and Distribution System Expansion Project.

On the other hand, according to the result of the Study, as the power demand is forecasted to increase even after completion of the Phnom Penh Transmission and Distribution System Expansion Project, further development of transmission line, substation and distribution line is to be required. This Project is aiming to construct those facilities such as transmission line, substation and distribution line facilities to cope with the increasing power demand in Phnom Penh. By doing so, it is possible to supply stably power to the grid and to contribute to the improvement of industrial infrastructures.

In the “Policy for Assistance to the Kingdom of Cambodia (2012)” of the Japanese government, “Development of Economic Infrastructure” is positioned as the strategic field. The priority for assistance to Cambodia is given to the stable power supply system which is the important factor to accelerate the private sector investment from the foreign countries.

JICA has been providing assistance to the power sector of Cambodia, such as Mekong Region Power Network Project (Cambodian Growth Corridor) of which the Loan Agreement was concluded in March, 2007 for construction of transmission line, and Transmission and Substation

[1] NIS - General Population Census 2013

[2] GS : Grid Substation

System Operation Capacity Building Project to support the improvement of capability of EDC's Transmission and Substation Department for operation and maintenance of transmission and substation network.

1.2 OBJECTIVE OF THE SURVEY AND THE STUDIES CARRIED OUT

1.2.1 Objective of the Survey

The objective of the Survey is to conduct the Feasibility Study (F/S) for Phnom Penh City Transmission and Distribution System Expansion Project - Phase 2 (the Project) and to carry out the necessary study on the evaluation for implementation of the Project as ODA loan project such as the necessity of the Project, outline, preliminary design, project cost, implementation schedule, procurement and construction method, organization structure for the Project, operation and maintenance organization, environmental and social consideration, etc.

1.2.2 Subject Area

Phnom Penh Capital City

1.2.3 Scope of the Survey

This Survey is conducted based on the Minutes of Discussion concluded between EDC and JICA on January 23, 2014. The Survey covers the following main items.

(1) Study of the current situation of the power sector and Phnom Penh Capital City (Review)

- To confirm national development policy and electricity industrial policy of Cambodia,
- To study institutional and organizational structures of power sector,
- To study current situation of power supply and demands in Cambodia, especially in Phnom Penh City,
- To analyze current situation of power supply and demands in Cambodia, especially in Phnom Penh City transmission line in detail,
- To assess the EDC's financial condition
- To confirm the funds flow to EDC, and
- To confirm the large city development plan in Phnom Penh Capital City, such as Chroy Changvar and Camko City.

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

- To review of the "Feasibility Study of New Underground Cable in Phnom Penh" undertaken in 2008", "Data Collection Survey on Electric Power Sector in Cambodia (March 2012, JICA)" and "Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project (November 2013, JICA)", and update of the Project scope and preliminary design (including study on the possibility to adopt the Japanese advanced technology), and

- To forecast future power demand, as well as energy data

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

- To confirm the design and specification of the existing 230kV/115kV transmission line, 115kV/22kV Grid Substations, 22kV distribution line,

- to conduct power flow analysis, considering forecasted future demands,
- to identify the bottle neck of grid in Phnom Penh city,
- to examine the countermeasures against the bottlenecks, and
- to confirm the priority of 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 Social Considerations (April 2010), and
- To conduct study for supporting EDC to obtain the necessary permit including IEIA (Initial Environmental Impact Assessment), EIA (Environmental Impact Assessment) and land issues.

(5) Feasibility Study

- To confirm institutional and organizational structures for the project implementation,
- To evaluate the alternative plan as stated above,
- To design the project outline (preliminary design),
- To conduct geographical and topographical survey necessary for the basic design,
- To conduct the basic of the planned and relevant facilities,
- To set the implementation schedule,
- To estimate the project cost,
- To analyze economic and financial analysis by calculating EIRR (Economic Internal Rate of Return), FIRR (Financial Internal Rate of Return), Equity IRR and affordable sub-loan ratio,
- To analyze the project risk,
- To estimate of GHG (Greenhouse Gas) reduction by comparing with the project and without it, and
- To recommend appropriate indicators to assess the project output.

(6) Confirmation of Operation, Maintenance and Management

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

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

1.3 SCOPE OF THE WORKS FOR THE PROJECT

The candidate facilities to be installed are shown below.

Table 1.3-1 Candidate Installation Facilities at the Beginning of the Survey

	Alternative 1	Alternative 2
Transmission line	230kV NPP/WPP~NCC S/S Overhead [OHL_Route1] / Underground line [UG_Route2] / double circuit	230kV NPP/WPP~GS5 Overhead line[OHL_Route3] / double circuit
	---	230kV GS5~NCC S/S, Underground [UG_Route4] / single circuit
	115kV NCC S/S~GS3 Underground line [UG_Route5] / double circuit	Same as on the left
	115kV GS5~Ghroy Changvar Overhead line [OHL_Route6] / double circuit	Same as on the left
	115kV GS5/GS1~Toul Kork (*) Overhead Line [UG_Route7] / 2 feeders	Same as on the left
Grid Substation	230/115/22kV NCC S/S,GIS Grid Substation	Same as on the left
	115/22kV Toul Kork, GIS Grid Substation	Same as on the left
	115/22kV Chroy Changvar AIS Grid Substation	Same as on the left
	---	Installation of GS5 230/115/22kV AIS
22kV Underground / Overhead Distribution Line		

* Alternative B
OHL_Route8 : 115kV Toul Kork ~ GS5, single circuit
UG_Route9 : 115kV Toul Kork ~ NCC S/S, single circuit

Source: JICA Study Team

1.4 IMPLEMENTATION STRUCTURE

1.4.1 Counterpart of EDC

EDC assigned the following members as counterpart for this Preparatory Survey.

Table 1.4-1 EDC Counterpart

Name	Position
Overall Management	
Dr. Praing Chulasa	Deputy Managing Director, Planning & Techniques
Mr. Chun Piseth	Director of Corporate Planning and Projects Department (DCPP)
Mr. Nou Sokhon	Director of Transmission Department(DT)
Coordinator	
Ms. Ngin Kanida	Deputy Head of Planning, Management Information System and Tariff Office, DCPP
Mr. Sorn Phearun	Deputy Chief of Project Studies Division, DCPP
Development Planning Team	
Mr. Rann Seihakkiry	Deputy Director of DCPP
Mr. Hang Touch	Head Office, Department of Business & Distribution(DBD)
Mr. Hang Ouk Chetra	Chief of Distributive Technical Office, DBD
Mr. Thack Sovannreasy	Head of GIS Office, DCPP
Mr. Thouk Mony	Deputy Chief of Transmission Department (DT)
Mr. Lors Puthy	Deputy Office, DT
Mr. Som Chansopeak	Deputy Head of GIS Office, DCPP
Mr. Touch La	Chief of Project Studies Division, DCPP
Mr. Try Soban	Deputy Chief of Division, DT
Mr. Muong Vadhna	Staff, DT
Facilities Design Team	
Mr. Plong Titia Phalkum	Deputy Director of DT
Mr. Or Vaddhana	Chief of Distribution Control Center, DBD
Mr. Chea Saem Chantara	Head Office, DCPP
Mr. Khy Sokhan	Head Office, DT
Mr. Hem Ratana	Deputy Head of SCADA, DT
Mr. Prom Chan Nareth	Chief of Substation Section, DCPP
Mr. Chon Virak	Deputy Chief of Transmission System Section, DCPP
Mr. Heng Socheat	Staff, Telecommunication/SCADA, DT
Environment	
Mr. Mao Visal	Head Of Environment Office, DCPP
Mr. Heav Chanvisal	Deputy Head of Environment Office, DCPP

Source: JICA Study Team

1.4.2 JICA Study Team Members

This Survey was implemented by the following team members (JICA Study Team).

Name	Assignment	Organization
Yukao Tanaka	Project Manager/ System Planning	NEWJEC
Junya Shinohara	Deputy Project Manager /Power Demand Forecast	Chugoku Electric
Koichi Uchida	System Analysis	NEWJEC
Masayoshi	Electric Power Civil Engineering	NEWJEC
Syunsuke Matsumoto	Transmission Facility 1(Overhead Line)	Chugoku Electric
Kenichiro Yagi	Transmission Facility 2(Underground Line)	NEWJEC
Yuzuru Okada	Substation Facility	Chugoku Electric
Shinobu Tanaka	Distribution Facility	Chugoku Electric
Yoshiko Oishi	Environmental and Social Consideration	NEWJEC
Masaru Nishida	Economic and Financial Analysis	NEWJEC
Miki Haga	Project Coordinator	NEWJEC

CHAPTER 2

POWER SECTOR IN CAMBODIA

CHAPTER 2 POWER SECTOR IN CAMBODIA

2.1 ECONOMY OF CAMBODIA

2.1.1 Population

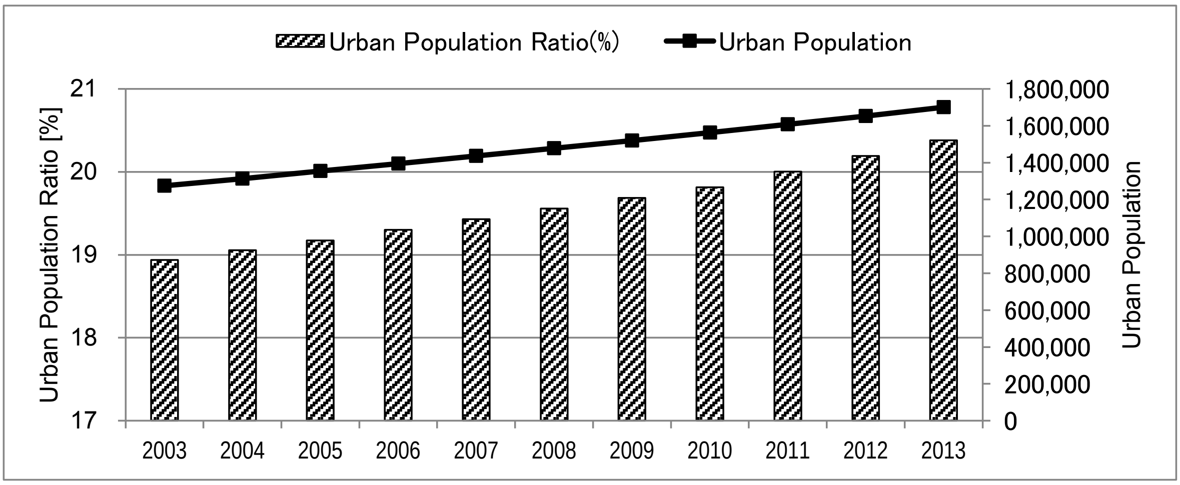
Provincial population from Cambodia Inter-censal Population Survey, Cambodia's population in 2013 was 14,670 thousand, and average growth rate is 1.83% p.a. Population by Province in 2013 is shown in the table below. The Project area, Phnom Penh Special District and surrounding Kandal Province took 19.1% of national population. As the inflow of population into urban areas has been continuing, the present population of the said area can be more than 20% of national population.

Table 2.1-1 Population by Province [in 2013]

	Province	Population	Proportion		Province	Population	Proportion
1	Banteay Meanchey	729,569	5.0%	14	Prey Veng	1,156,739	7.9%
2	Battambang	1,121,019	7.6%	15	Pursat	435,596	3.0%
3	Kampong Cham	1,757,223	12.0%	16	Ratanak Kiri	183,699	1.3%
4	Kampong Chhnang	523,202	3.6%	17	Siem Reap	922,982	6.3%
5	Kampong Speu	755,465	5.1%	18	Preah Sihanouk	250,180	1.7%
6	Kampong Thom	690,414	4.7%	19	Stung Treng	122,791	0.8%
7	Kampot	611,557	4.2%	20	Svay Rieng	578,380	3.9%
8	Kandal	1,115,965	7.6%	21	Takeo	923,373	6.3%
9	Koh Kong	122,263	0.8%	22	Otdar Meanchey	231,390	1.6%
10	Kratie	344,195	2.3%	23	Kep	38,701	0.3%
11	Mondul Kiri	72,680	0.5%	24	Pailin	65,795	0.4%
12	Phnom Penh	1,688,044	11.5%		**Total**	**14,676,591**	
13	Preah Vihear	235,370	1.6%				

Source : NIS - Cambodia Inter-censal Population Survey 2013

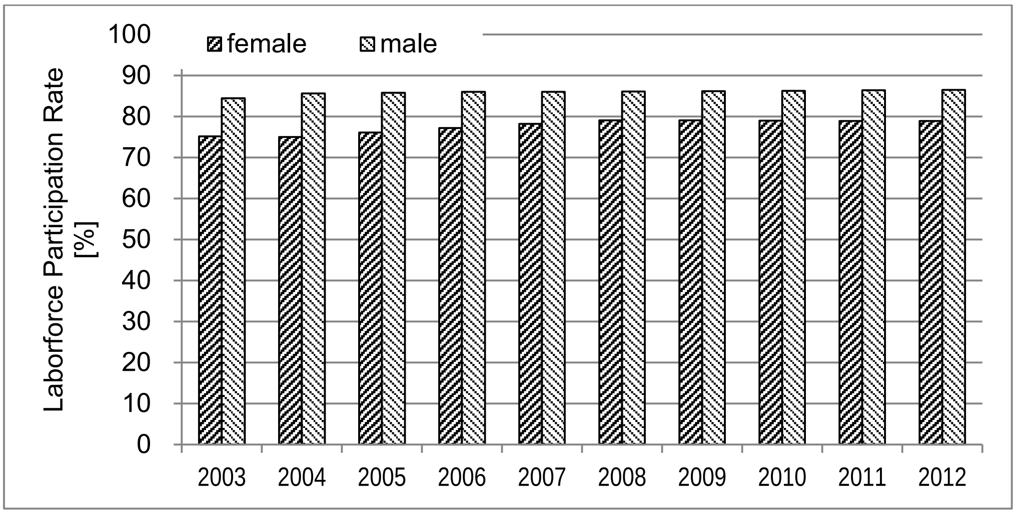
Urban population has been growing. The ratio of urban population is shown in the figure below.



Source : World Bank, World Development Indicators

Fig. 2.1-1 Urban Population Ratio

Labor force in 2012 was 8.43 million, 57% of the total population. Labor force participation rates are shown in the figure below.



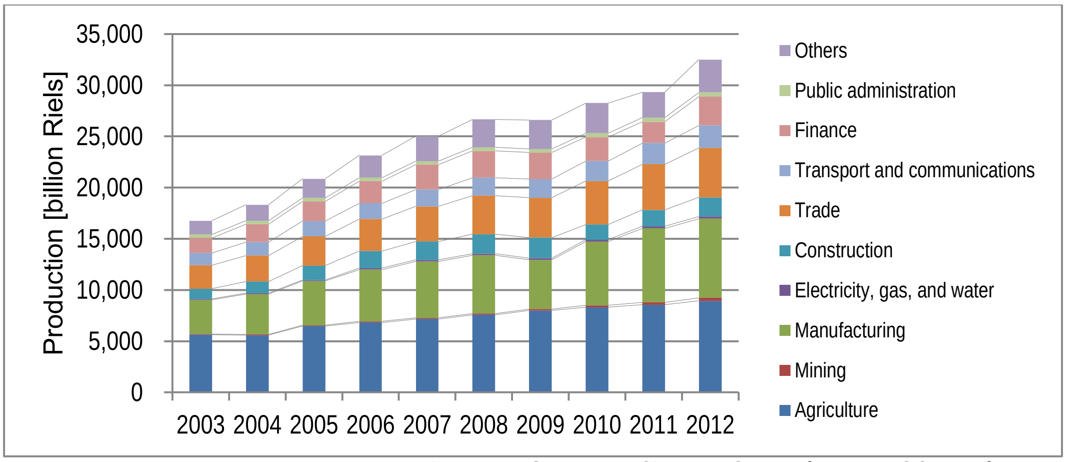
Source: World Bank, World Development Indicators

Fig. 2.1-2 Labor Force Participation Rate

Unemployment rate in 2012 was estimated at 1.5%, according to the ILO (International Labour Organization) method.

2.1.2 Economy

GDP (Gross Domestic Product) in 2013 was US$ 15,250 million; in per capita GDP approximately US$1,000. Production by industry in constant Cambodian Riel for the year 2000 is shown below.



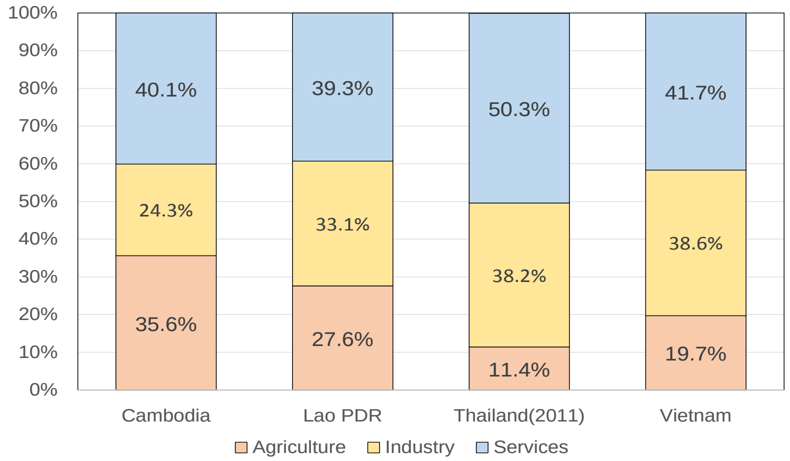
Source: ADB (Asian Development Bank), Key Indicators for Asia and the Pacific 2013

Fig. 2.1-3 Cambodia's GDP by Industrial Origin (year 2000 constant price, riel)

Cambodia's economy grew at more than 10% p.a. during 4-year period of 2004 and 2007. However, the economy was hit by the world economic downturn in 2008, and the growth rate for

2009 dropped to 0.1% p.a. The economy bounced back next year, resumed its growth and is expected to keep it at around 7% p.a. The factors that are contributing the growth are; manufacturing sector including garment and shoes, service sector including wholesale, retail, tourism, and construction sector. In agricultural sector, where more than 50% of labor force engages, the growth rate has been steady at around 4 to 5 % p.a.

The structure of Cambodia's GDP is compared with those of neighboring countries for 2012 in the figure below.

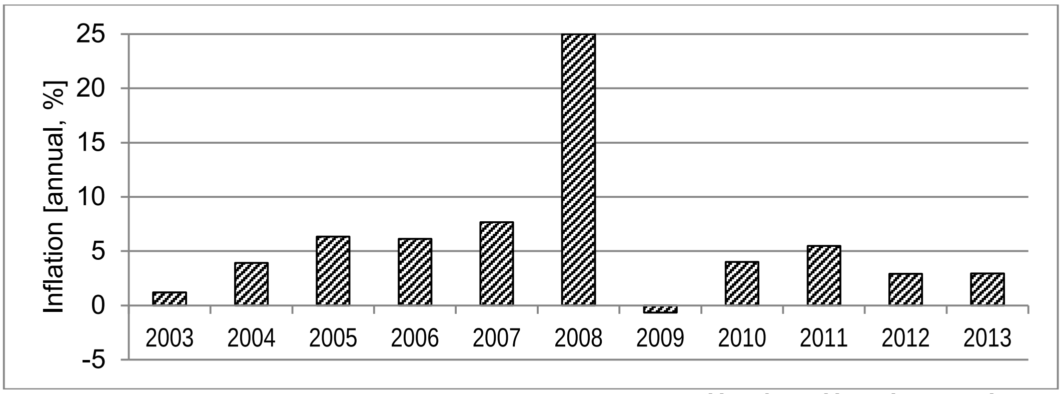


Source : ADB Key Indicators for Asia and the Pacific 2013

Fig. 2.1-4 GDP Structure of Cambodia and Neighbor Countries

The economy of Cambodia is still at the initial stage of industrialization, as is the case for Lao.

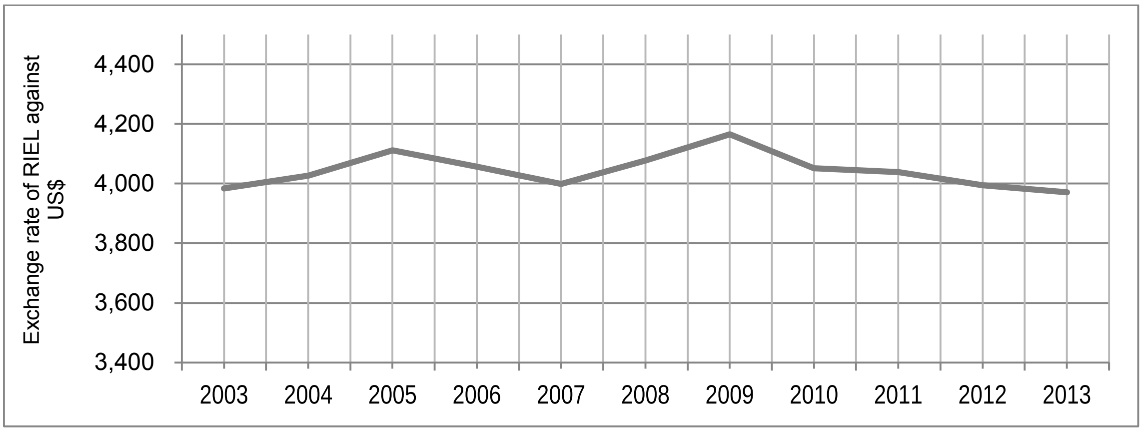
Change of CPI (Consumer Price Index) for the recent years is shown in the figure below. The indices were severely affected in 2008 and 2009 by the world financial crisis, but otherwise they have been within the range between 3 to 6 per cent.



Source: World Bank, World Development Indicators

Fig. 2.1-5 CPI

Cambodian Riel is managed to be stable against US dollar by the NBC (National Bank of Cambodia). There were large scale interventions made in 2009 and 2010, but afterwards it has been stabilized on its own[1]. The end-of-the-year values for the recent years are shown in the figure below.



Source: World Bank, World Development Indicators

Fig. 2.1-6 Exchange Rate of Cambodian Riel against US Dollar

2.1.3 Foreign Investment

Cambodian economy has been growing at more than 6% p.a. in terms of real GDP in recent years. Among the factors behind this record are the growth of manufacturing sectors including garment/footwear industry, and the FDI (Foreign Direct Investment) that supports its growth. This is a strategy that Cambodia took over from more advanced ASEAN (Association of South-East Asian Nations) countries where low-cost labor force attracts the foreign investment in simple labor-intensive industries, which would lead the development of the country as a whole.

To accelerate this, the Government has implemented non-discriminatory investment laws and is putting in large resources in developing SEZ (Special Economic Zones). SEZs are in Phnom Penh outskirt, Thai and Vietnamese border areas and coastal zones facing the Gulf of Thailand. There are 25 SEZs operational in 2013.

FDI in 2011 and 2012 are summarized in the table below. FDI from Japan is small in numbers but large in the amount, positioned the third in 2012. Overall FDI to Cambodia has been decreasing in size but increasing in numbers.

On the other hand, Japanese investment in SEZs is far larger than any other country both in numbers and the amount. The areas of investment are shifting, however, from traditional garment/footwear industry to more technically advanced industries such as car and electronic part industry.

1 Japan External Trade Organization (JETRO) Website

Table 2.1-2 FDI to Cambodia by Country and Regions

(Unit: number, US$ million, per cent)

	2011		2012			growth
	Nos.	Amount	Nos.	Amount	Proportion	
Korea	28	146	29	281	20.5	92.5
PRC	22	1,191	41	264	19.2	△77.9
Japan	3	6	5	212	15.5	3,350.10
Thailand	0	-	8	121	8.8	all increased
Hong Kong	19	331	15	117	8.6	△64.5
Taiwan	22	82	23	97	7.1	18.4
Vietnam	17	631	6	90	6.5	△85.8
Singapore	1	14	9	83	6	501
Samoa	1	4	2	41	3	997.1
United Kingdom	2	2,238	5	37	2.7	△98.3
Others	17	441	11	28	2	△93.6
Total	**132**	**5,080**	**154**	**1,371**	**100**	**△73.**

Source: JETRO

Table 2.1-3 FDI in SEZs in Cambodia by Country and Regions

(Unit: number, US$ million, per cent)

	2011		2012			growth
	Nos.	Amount	Nos.	Nos.	Amount	Nos.
Japan	15	95.6	18	65.6	34.4	△31.4
PRC	6	28.9	11	33	17.3	14.3
Malaysia	0	-	4	30.8	16.1	all increased
Singapore	1	1	1	16.6	8.7	1,564.50
Thailand	1	10	0	-	-	all decreased
Taiwan	3	9.9	0	-	-	all decreased
France	1	1	0	-	-	all decreased
USA	1	1	0	-	-	all decreased
Others	6	29	5	44.7	23.4	54.2
Total	**34**	**176.4**	**39**	**190.8**	**100**	**8.2**

Source: JETRO

The government intends to expand the growth of garment/footwear industry to other areas, and move from labor intensive industries to knowledge intensive industries. To realize this, the country needs to keep the inflow of foreign investment. However, underdevelopment of infrastructure in comparison with surrounding countries, in particular, higher cost of electricity[2] and frequent black out experienced outside Phnom Penh have been the impediments to foreign investors. The advancement of power sector has become the key to the continued economic development of the country.

[2] In Phnom Penh, tariff is around US¢15-20/kWh, while in Thailand US¢6-12, and in Vietnam (in 2011) around US¢6/kWh

2.2 BASIC POLICY[3]

2.2.1 National Development Policy

The Cambodian Government has developed a second quadrilateral strategy in 2008. 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 Cambodian 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

The Cambodian Government formulated “Rectangular Strategy - Phase III” in 2013 which is the comprehensive framework for national development. “National Strategic Development Plan” (2014 - 2018), the important strategies are 1) Secure power supply capacity, 2) Development of power supply area, 3) Cheap power tariff, 4) Strengthening of power sector related organizations and capacity development, and 5) Improvement of people’s standards of living by electric power.

Besides, the following targets are set regarding electrification rate:

1) Village electrification rate to be 100% by 2020 including battery lighting, and
2) Household electrification rate to be 70% by 2030 of which power is supplied by grid system

The village electrification rate as of the end of 2013 is 79.71% according to the data of EAC (Electricity Authority of Cambodia), while the household electrification rate is 48% as of March 2013 (94% in urban area and 36% in rural area) according to the mid-term population census.

(1) Government policy

As a comprehensive national development plan, the "National Strategic Development Plan" was developed in 2014, the followings are the priority area in the energy sector.

1) Further expanding the capacity of low-cost and hi-tech electricity production, especially from new and clean energy sources, along with continued development of all levels of the transmission network aimed at strengthening energy security and ensuring efficient, safe,

3 Updated by JICA Study Team based on “Final Report of Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project”, JICA, November 2013.

high quality, reliable and affordable electricity supply and distribution to respond to development needs.

2) Further encouraging the private sector to invest in electricity generation, and transmission and distribution infrastructure by focusing on technical and economic efficiency and minimization of environmental and social impacts.

3) Stepping up the implementation of the electrification strategy to realize the goal “by 2020, all villages in the Kingdom of Cambodia will have access to electricity supplied by the national grid and other sources”.

4) Further supporting the rural electrification fund aimed at achieving equitable electricity access for the population, through government budget, social fund from EDC and seek support fund from other development partners.

5) Pursuing rationalization measures for electricity consumption by reducing power tariffs during off-peak hours to serve production and irrigation systems aimed at improving agricultural productivity and accelerating the development of industry and handicraft sectors.

6) Stepping up the exploration and commercialization of the oil and gas sector which has enormous potential for ensuring energy security and will provide valuable resources for Cambodia’s economic development in the long term.

7) Further strengthening institutional capacity, human resources as well as planning and management of the energy sector.

8) Continuing active involvement in energy cooperation under the regional framework.

2.3 LAWS, REGULATIONS, STANDARDS, ETC. RELATED TO POWER SECTOR

2.3.1 Electricity Law of the Kingdom of Cambodia

Table 2.3-1 shows Electricity Law of the Kingdom of Cambodia and the related regulations. Electricity Law of the Kingdom of Cambodia was promulgated on February 2, 2001 for the following objectives;

- General rules on the operation of electric power business and the activities of enterprises providing electric power services,
- Creation of acceptable conditions for the investment in the power facilities and its business activity,
- Principle on the regulation for electric power business in Cambodia,
- Protection the right of consumers to access to the reliable and adequate electricity at reasonable price,
- Promotion of private owned facilities for power supply services,
- Establishment of competition in power sector, and
- For regulation of power supply services, establishing EAC giving authority and obligation and applying penalty to the power suppliers and consumers related to the power generation and supply facilities at the need arises.

Table 2.3-1 Laws and Regulations on Power Sector Services and Use of Electricity

No.	Name of Documents	Promulgated by	Date Promulgated
1	Electricity Law of the Kingdom of Cambodia	The King	February 2, 2001
2	Sub-Decree on the Rate of the Maximum License Fees applicable to Electric Power Service Providers in the Kingdom of Cambodia	Royal Government	December 27, 2001
3	Procedures for Issuing, Revising, Suspending, Revoking, or Denying Licenses	Electricity Authority of Cambodia	September 14, 2001
	Revision 1		December 12, 2002
	Revision 2		March 16, 2004
4	Regulations on General Conditions of Supply of Electricity in the Kingdom of Cambodia	Electricity Authority of Cambodia	January 17, 2003
	Revision 1		December 17, 2004
5	Regulatory Treatment of Extension of Transmission and Distribution Grid in the Kingdom of Cambodia	Electricity Authority of Cambodia	October 28, 2003
6	Regulations on Overall Performance Standards for Electricity Suppliers in the Kingdom of Cambodia	Electricity Authority of Cambodia	April 2, 2004
7	Procedure for Filing Complaint to EAC and for Resolution of Complaint by EAC	Electricity Authority of Cambodia	April 2, 2004
8	General Requirements of Electric Power Technical Standards of the Kingdom of Cambodia	Ministry of Industry, Mines and Energy	July 16, 2004
	First Amendment		August 9, 2007
9	Sub-Decree on Creation of Rural Electricity Fund of the Kingdom of Cambodia	The King	December 4, 2004
10	Sub-Decree on Principles for Determining the Reasonable Cost in Electricity Business	Royal Government	April 8, 2005
11	Prokas on Principles and Conditions for issuing Special Purpose Transmission License in the Kingdom of Cambodia	Ministry of Industry, Mines and Energy	July 21, 2006
12	Specific Requirements of Electric Power Technical Standards of the Kingdom of Cambodia	Ministry of Industry, Mines and Energy	July 17, 2007
13	Regulations on General Principles for Regulating Electricity Tariffs in the Kingdom of Cambodia	Electricity Authority of Cambodia	October 26, 2007
14	Procedures for Data Monitoring, Application, Review and Determination of Electricity Tariff	Electricity Authority of Cambodia	October 26, 2007
15	Grid Code	Electricity Authority of Cambodia	May 22, 2009

Source: EAC Annual Report, 2011

2.3.2 General Requirements of Electric Power Technical Standards

GREPTS (The General Requirements of Electric Power Technical Standards of the Kingdom of Cambodia) was prepared funded by JICA with the assistance of MIME (Ministry of Industry, Mines and Energy), and it was promulgated as a ministerial decree on August 16, 2004. GREPTS are composed of the total of 65 clauses in Chapter 1 General Conditions (14 clauses) and Chapter 2 Fundamental Requirements for Power Facilities (51 clauses). Chapter 1 provides; Definition of terms, Purpose of technical standards and applicable areas, Kinds of voltage and frequency, Prevention of electric shock and fire, Prevention of power supply trouble, Preservation of environment, etc. Table 2.3-2 shows the composition of Chapter 2.

Table 2.3-2 Composition of Chapter 2 of GREPTS

Composition of Chapter 2 (Clause 15 ~ Clause 65)	
Part 1	General Requirements for All Facilities(Clause 15 ~ Clause 20)
Part 2	General Requirements for Thermal Generating Facilities (Clause 21 ~ Clause 25)
Part 3	General Requirements for Hydro Power Generating Facilities (Clause 26 ~ Clause 28)
Part 4	General Requirements for Other Generating Facilities (Clause 29 ~ Clause 30)
Part 5	General Requirements common for Transmission and Distribution Facilities (Clause 31 ~ Clause 39)
Part 6	General Requirements for High Voltage Transmission Facilities (Clause 40 ~ Clause 48)
Part 7	General Requirements for Medium and Low Voltage Distribution Facilities (Clause 49 ~ Clause 56)
Part 8	General Requirements for House Wiring (Clause 57 ~ Clause 65)

Source : Final Report of Electric Power Sector Basic Data Collection and Feasibility study of the Kingdom of Cambodia

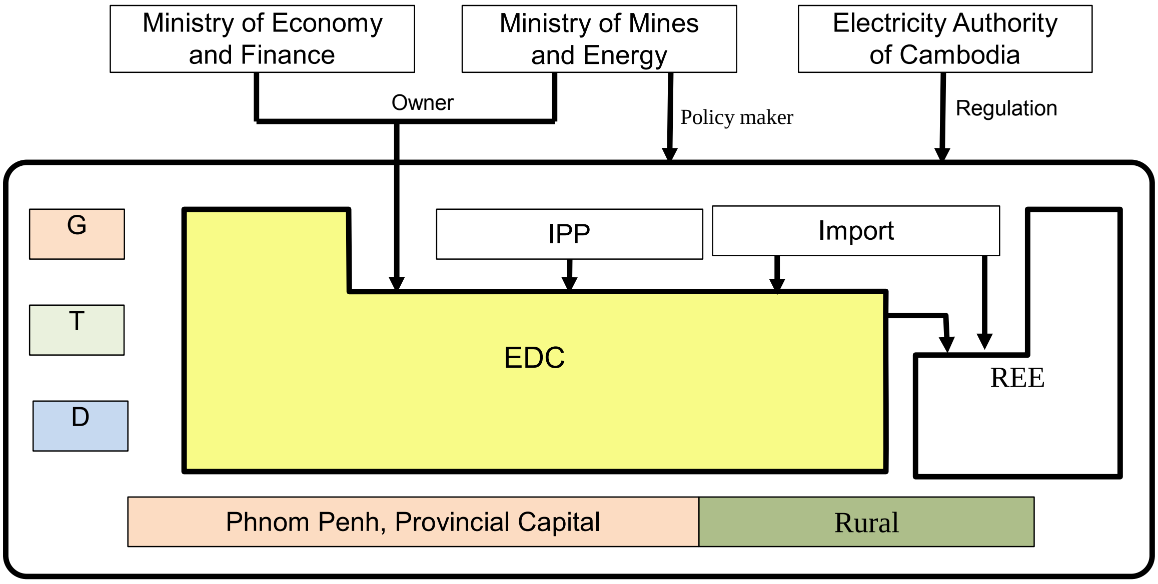
GREPTS is “Specific safety guidelines,” and no “Detailed specification” to which particular numeric data is provided. In the advanced countries including Europe and American countries, the electric power industry system has been well established, as the suppliers of electricity’s “ Voluntary security” is assumed to be a basic concept, the electric power technical standard is made based on the standard of “Specific safety guidelines” type.

However, since the structure of electric industry in Cambodia is vulnerable and the capacity is said to be not high, MIME and EAC couldn’t apply well only with the Electric Power Technical Standards. Therefore, SREPTS (Specific Requirements of Electric Power Technical Standards of the Kingdom of Cambodia) on Thermal Generation, Transmission, Substation and Distribution was prepared during a period from 2004 through 2007 funded by JICA together with the improvement of the capacity of EAC, and it was promulgated as regulation on July 17, 2007. Thereafter, SREPTS on Hydropower was also prepared for a period from 2008 through 2009 by the support of JICA, and it was also promulgated as regulation in 2010.

2.4 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, MME (Ministry of Mines and Energy) 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 MME and MEF (Ministry of Economy & Finance). As for the rest, REE (Rural Electricity Enterprise) as PEC (Private Electricity Company) are divided into consolidate enterprises which generate and distribute by themselves and distribution enterprises which distribute the electricity purchased from EDC, IPP (Independent Power Producers) or etc. to people in the licensed area.

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

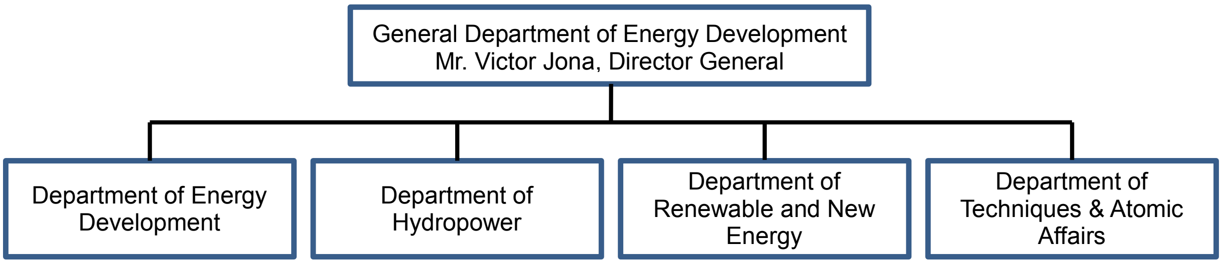


Source: JICA Data Collection Survey on Electric Power Sector in Cambodia

Fig. 2.4-1 Relation on Power Sector

2.4.1 MME

MME was newly established as an independent Ministry since the MIME was split into Ministry of Industry and Handicraft, and Ministry of Mines and Energy due to the restructuring of Ministry of Industry, Energy and Mines in the end of December, 2013. MME is responsible for energy sector administration, i.e. to formulate power sector policy in Cambodia, decision making, and formulation of power development plan. Those functions of the organization remain the same as before. However, General Department of Energy Development, which is responsible for development of power sector, has been split from the previous three departments into four departments as shown below. Department of Techniques & Atomic Affairs was newly established as a new department.

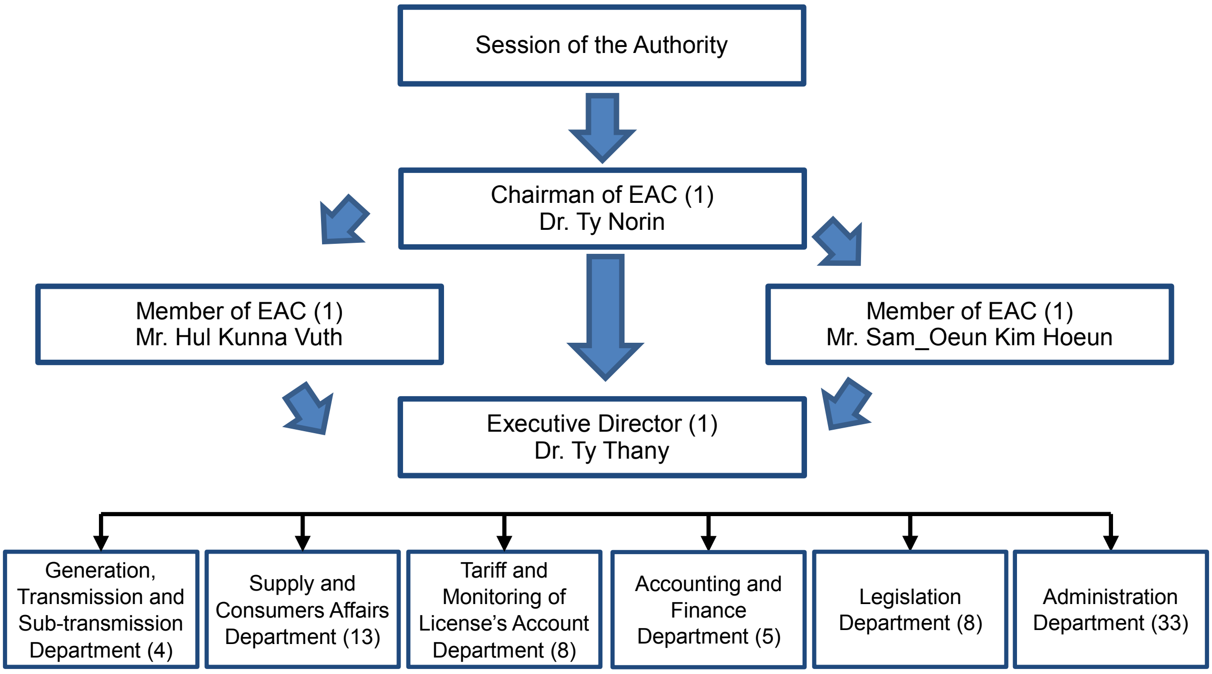


Source: Interview at MME

Fig. 2.4-2 Organization of General Department of Energy Development in MME

2.4.2 EAC

EAC is an organization that was established to authorize regulation, standard, power tariff and license for power companies and rural electrification enterprises related to the electricity business in Cambodia. The main roles are giving and suspending business licenses, authorizing the tariff of electricity, making electricity technical standard, supervision of power business, and collecting data and information related to the power business. The organization chart of EAC is shown in Fig. 2.4-3.

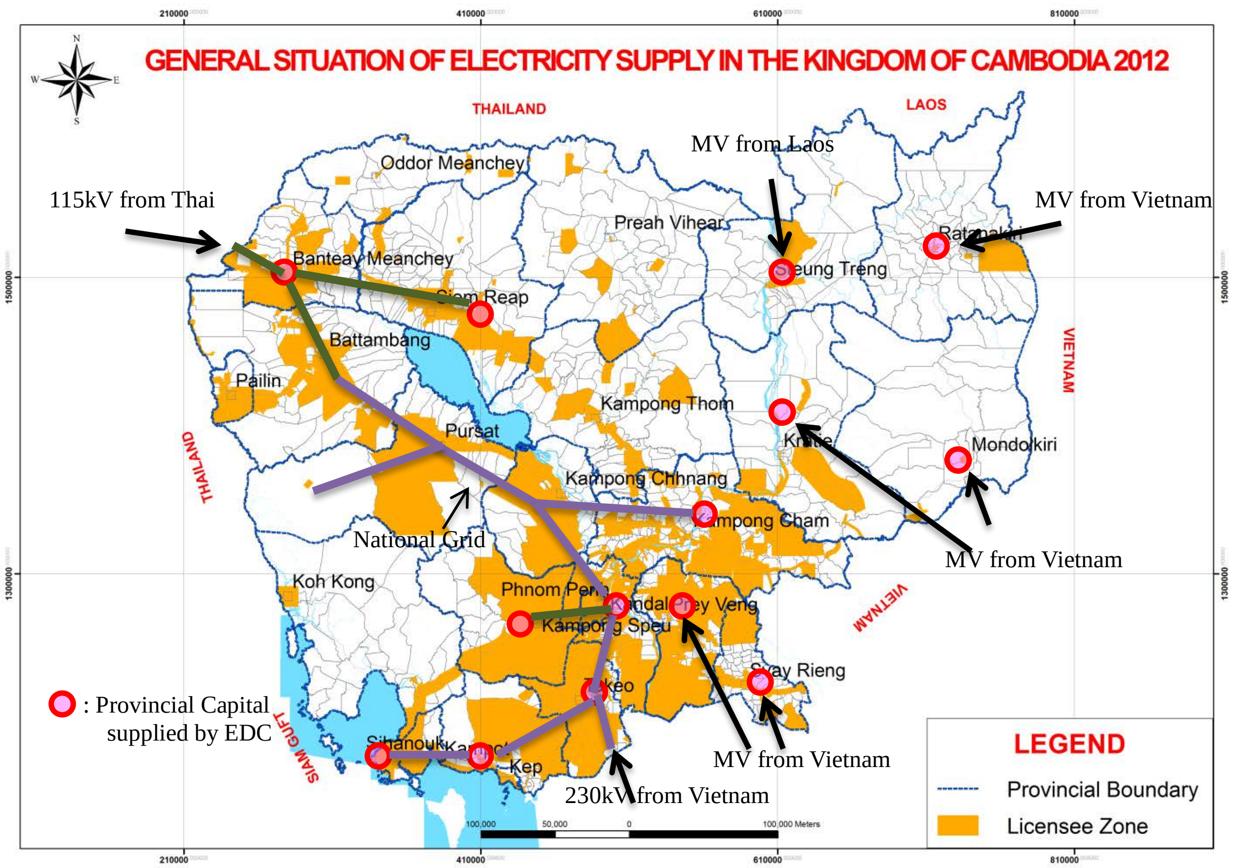


Source: Interview at EAC (Figure in bracket means number of staff.)

Fig. 2.4-3 EAC Organization Chart

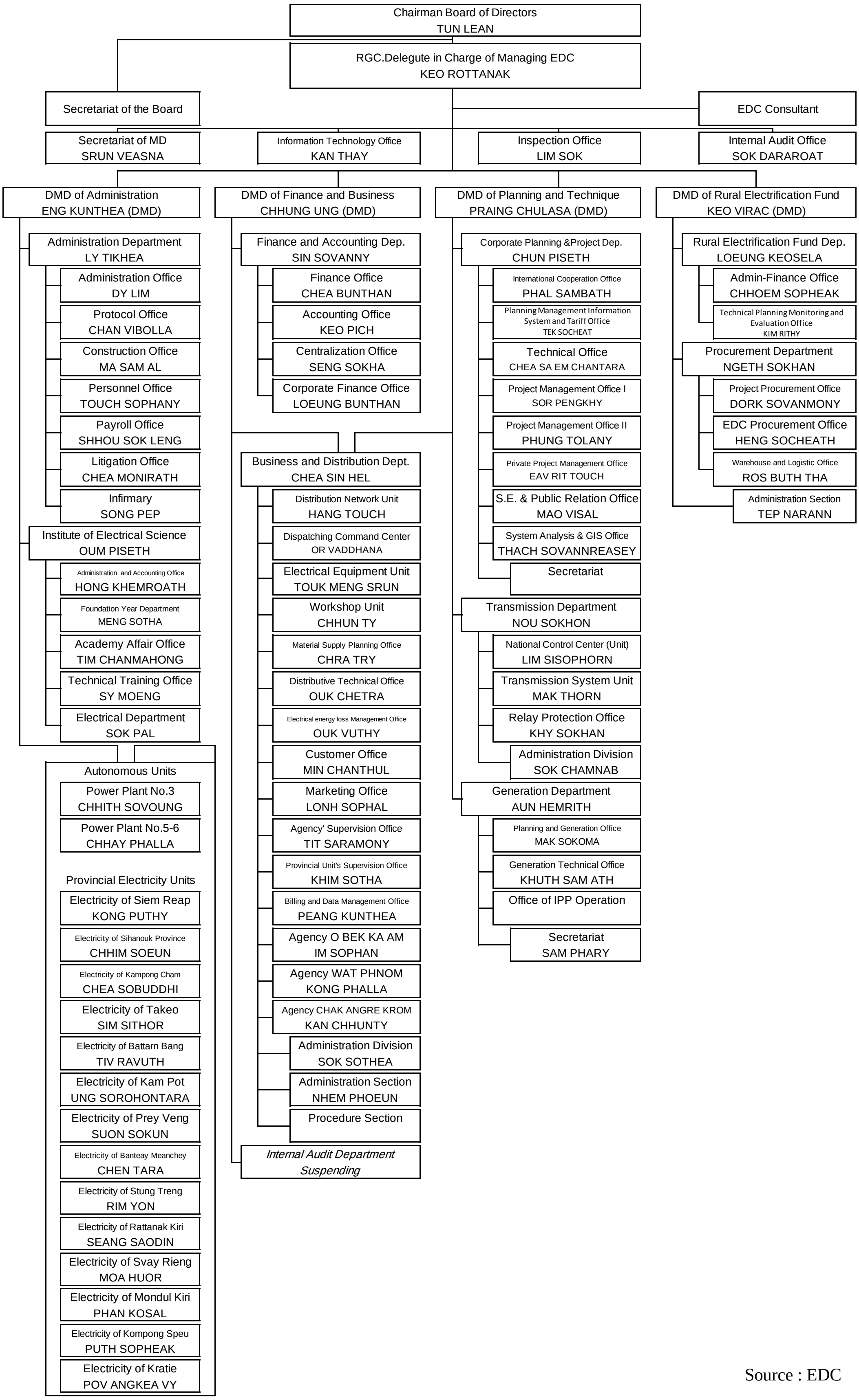
2.4.3 EDC

EDC is an electric public cooperation in Cambodia, which is running transmission and distribution business in Cambodia. EDC is importing power from adjacent countries, purchasing from independent power business, and constructing and managing transmission and distribution line. Electricity is supplied by EDC in the metropolitan area (Phnom Penh and part of Kandal Province) and provincial capitals of Siem Reap, Sihanouk, Kampong Cham, Takeo, Battambang, Kampot, Preyveng, Banteay Meanchay, Stung Treng, Ratanak Kiri, Svay Rieng, Mondul Kiri, Kampong Speu, and Kratie as well as some area near the Cambodia-Vietnam border. The below figure shows the electricity supply area including REEs, the province capitals supplied by EDC, and connection status with the neighboring countries as of the end of 2013.



Source: EAC, JICA Study Team

Fig. 2.4-4 Additional Number EDC Supply Status



Source : EDC

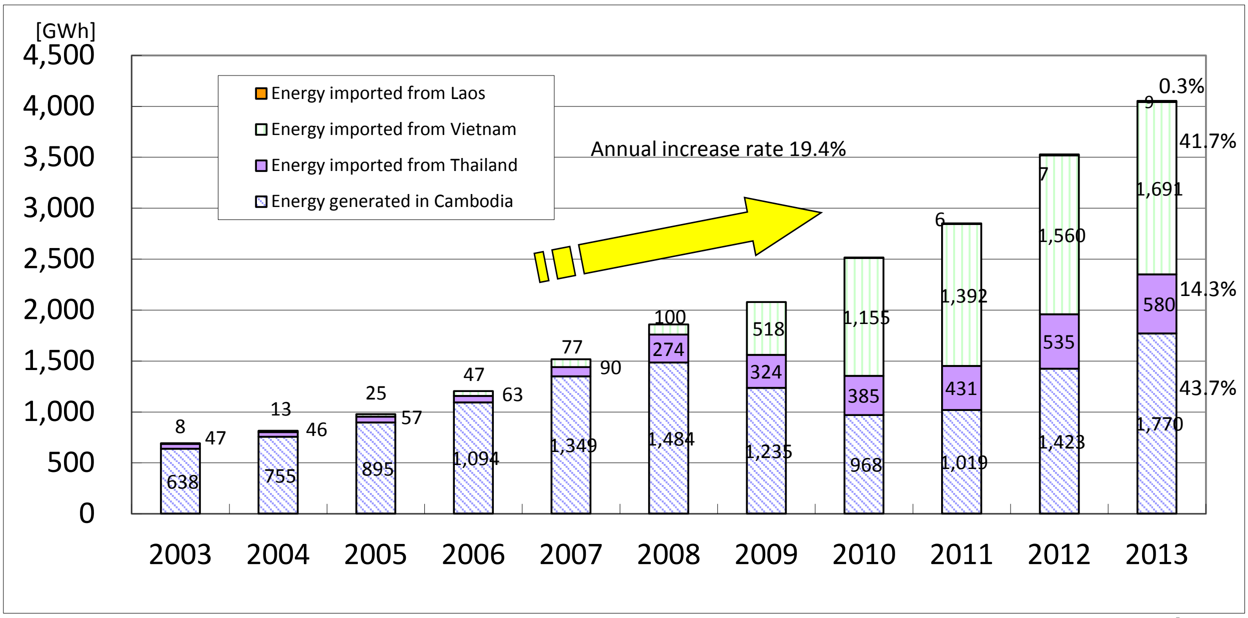
Fig. 2.4-5 Organization Chart of EDC (June 2014)

2.5 BALANCING SUPPLY AND DEMAND SITUATION

2.5.1 Electric Power Demand

(1) Trend of generation record

Generation record including power import for whole country from 2003 until 2013 is shown below. The average annual increase rate is 19.4%. In 2013, at the result of changing from domestic expensive internal-combustion power generation to inexpensive imported electricity, more than half of generation was imported from neighboring countries.

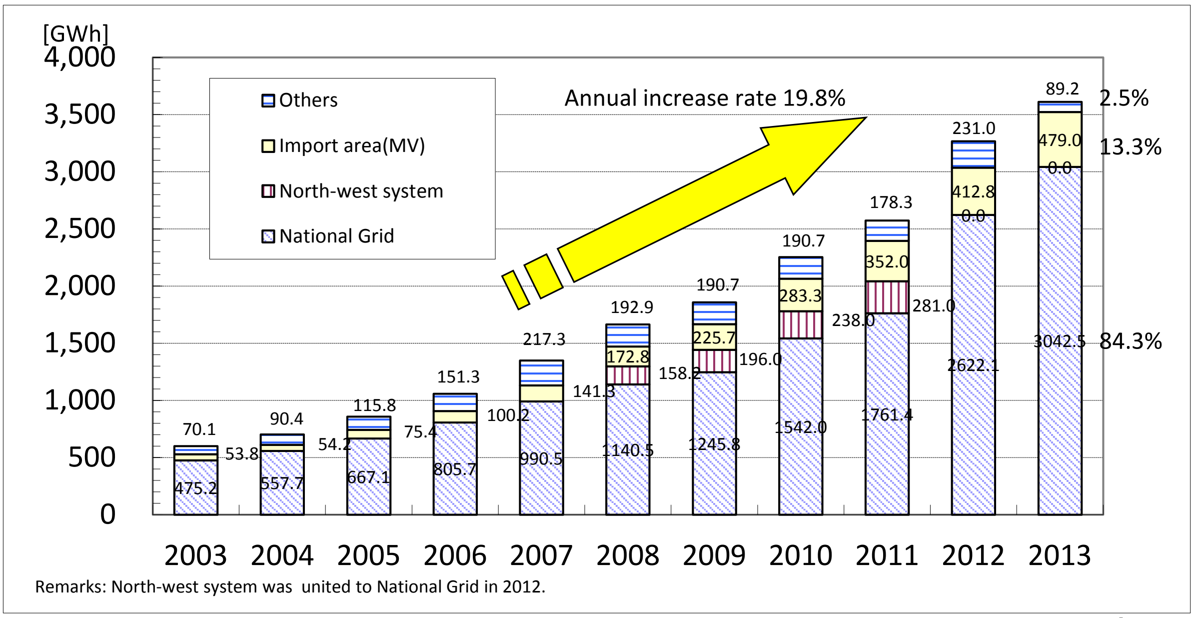


Source: EAC Annual Report

Fig. 2.5-1 Trend of Generation Record in Cambodia

(2) Trend of energy sales

Energy sales record for whole country from 2003 until 2013 is shown below. The average annual increase rate is 19.8% and the energy sales in the National Grid which is the backbone system connected by 115kV or 230kV transmission lines including Phnom Penh accounts for more than 80% of the total sales.

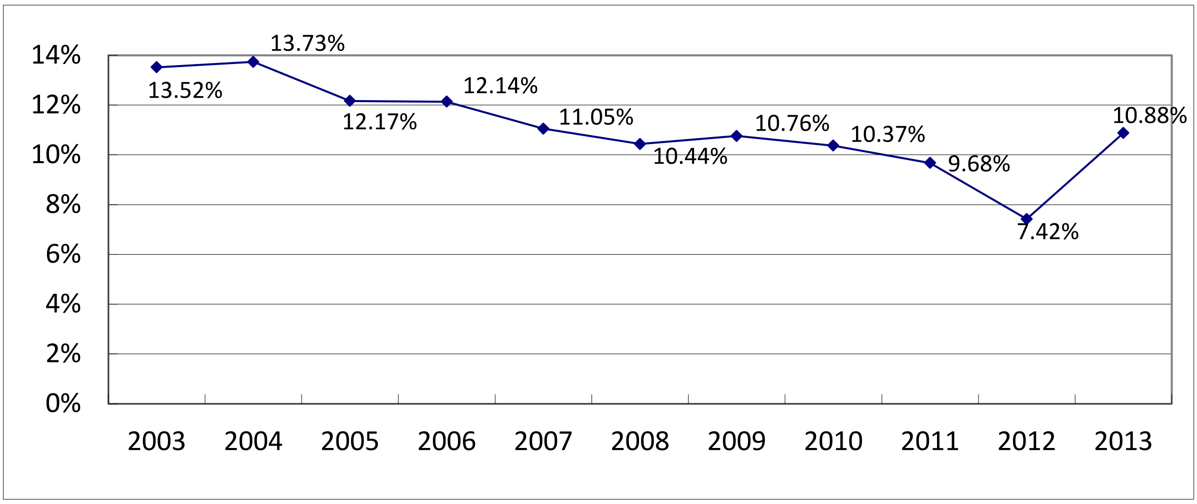


Source: EAC Annual Report

Fig. 2.5-2 Trend of Energy Sales in Cambodia

(3) Trend of system loss

System loss for whole country from 2003 until 2013 is shown below. According to the expansion of transmission and distribution system, system loss was gradually decreasing and it was 7.42% in 2012. However it increased as 10.88% in 2013. According to EAC, the main reason why it increased was that the distribution lines were extended to the low demand density area in 2013. Therefore, the system loss was increased compared to the demand.



Source: EAC Annual Report

Fig. 2.5-3 Trend of System Loss in Cambodia

(4) Trend of peak demand

As for peak demand, there is no record for REE. Therefore, peak demand records of each EDC system from 2001 until 2012 are shown in the below table because only EDC has peak demand record.

Table 2.5-1 Trend of Peak Demand in EDC System

(unit: MW)

Location	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Phnom Penh, Kandal and Kampong Speu	70.3	77.6	88.0	100.9	116.3	133.1	165.0	204.5	239.0	244.1	300.2	349.4	410.0
Siemreap	2.6	3.1	3.1	4.8	6.4	10.9	14.4	18.9	27.6	30.0	35.0	39.1	47.4
Preah Sihanouk	3.0	3.5	3.5	4.7	4.9	5.2	7.4	8.6	9.5	10.2	13.4	16.4	18.5
Kampong Cham	1.4	1.4	1.4	1.6	1.5	1.7	2.1	2.5	2.5	6.8	7.3	8.5	10.5
Krek				0.9	1.5	2.2	1.9	4.1	4.1	5.5	5.0	6.5	6.5
Memot				1.0	1.6	2.6	1.2	3.8	3.8	3.0	3.0	3.9	3.9
Takeo	0.5	0.5	0.5	0.6	0.7	0.7	1.0	1.2	1.4	2.3	2.7	4.7	6.7
Battambang		2.5	2.8	3.2	3.9	4.4	5.2	5.6	7.0	8.0	10.5	16.8	20.5
Kampong Trach				0.1	0.2	0.3	0.2	0.7	0.8	1.2	2.1	2.4	3.1
Kampot					1.1	1.3	1.3	1.3	1.9	2.4	4.5	5.5	5.3
Prey Veng					0.7	0.2	0.5	0.6	0.8	0.8	0.9	1.5	3.2
Banteay Meanchay						1.5	2.3	2.6	3.9	4.3	5.5	6.3	8.8
Steung Treng						0.8	0.5	0.7	1.0	1.1	2.0	2.4	3.2
Rattanakiri					1.1	1.5	1.5	1.3	1.7	1.8	1.9	2.2	3.7
Svay Rieng						0.9	0.8	1.3	2.2	2.8	3.7	5.4	5.3
Bavet				0.8	0.8	1.7	2.7	4.5	4.8	9.5	11.0	11.2	15.1
Mondul Kiri											0.5	0.6	0.7
Keoseyma													0.4
Kratie												2.1	1.2
Snoul													1.5

Legend:
- National Grid in 2012
- Imported from Vietnam by MV
- Imported from Laos

Source: EDC Annual Report

As of 2012, all supplied area of EDC are connected to Vietnam or Thailand or Laos. And as of March 2014, compared to 2012, Kampong Cham system is connected to National Grid.

And as of the end of March 2014, the maximum demand at the National Grid was 699.5MW at the generation point at 10:00 on Monday, March 31, 2014. Generation record and supply power for normal grid and Phnom Penh system on that day are shown in the below tables.

Table 2.5-2 Generation Record at the National Grid (Monday, March 31, 2014)

Time	Vietnam	Kamchay PH1	Kamchay PH2	Kirirom 1	Kirirom 3	CEL	Phnom Penh Sugar	SL Garment	Sovanna Phum	KEP	CEP	Colben	CUPL	C6	C5	C3	Colben Sihanoukville	GTS	Siemreap	Thai	Othres	Power cut	Total
	-	IPP	IPP	IPP	IPP	IPP	IPP	IPP	IPP	IPP	IPP	IPP	IPP	EDC	EDC	EDC	IPP	IPP	EDC	-	EDC	-	
1:00	170.5					103.0	1.5		8.0	16.0	22.0									74.2			395.2
2:00	170.0					103.0	1.5		8.0	12.0	17.0									69.8			381.3
3:00	168.5					102.6	1.5		8.0	7.0	12.0									68.2			367.8
4:00	167.3					102.8	1.5		8.0		6.0									65.2			350.8
5:00	169.6					102.8	1.6		8.0		6.0									65.4			353.4
6:00	168.0					103.0			8.0	7.0	10.0									69.5			365.5
7:00	155.5					103.0	3.0		8.0	35.0	35.0	4.0	25.5	12.0			2.0	5.5		70.8			459.3
8:00	170.6	76.5	3.1			103.6	5.0		8.0	43.2	45.0	5.9	28.5	15.0	8.0		2.0	7.0		91.1			612.5
9:00	165.2	123.3	6.0			103.5	5.0		8.0	43.2	45.0	5.9	28.5	15.0	8.0		2.0	7.0		98.4			664.0
10:00	171.1	140.5	8.8			102.9	5.0		8.0	43.2	45.0	8.0	27.5	15.0	8.0		2.0	7.0	3.3	99.4	4.8		699.5
11:00	141.6	101.6	8.7			103.0	5.0		8.0	43.2	45.0	9.0	27.5	15.0	7.8		2.0	7.0	3.5	99.5	3.6	5.0	636.0
12:00	171.5	38.0	4.1		17.0	102.5	4.0	0.1	8.0	32.0	38.0	9.0	25.0	12.0	7.8		2.0	7.0	6.8	85.7	4.1	5.5	580.1
13:00	168.9	84.7	3.9		17.1	102.8	5.0		8.0	42.0	45.0	9.0	27.5	15.0	7.8		2.0	7.0	7.0	91.5	4.2	5.0	653.4
14:00	168.0	117.6	7.7		16.3	102.9			8.0	42.0	45.0	9.0	27.5	15.0	7.8		2.0	7.0	7.0	100.1	5.0	5.0	692.9
15:00	163.1	108.5	6.9		15.0	103.1	5.0		8.0	42.0	45.0	9.0	27.5	15.0	7.8		2.0	7.0	9.9	94.7	5.0	13.3	687.8
16:00	166.2	96.6	5.2		15.0	103.5	5.0		8.0	42.0	45.0	9.0	27.5	15.0	7.8		2.0	7.0	9.9	93.2	4.9	3.0	665.8
17:00	162.6	71.5	5.4		15.1	102.0	5.0		8.0	42.0	45.0	9.0	28.5	15.0	7.8		2.0	7.0	9.9	87.7	4.9	3.0	631.4
18:00	158.7	35.1	2.9		16.0	103.0	4.0	0.1	8.0	31.0	30.0	8.5	26.5	12.0	7.4		2.0	7.0	9.9	75.8	5.1		543.0
19:00	166.8	35.4	2.9		16.0	103.1	2.9	0.1	8.0	42.0	45.0	9.0	28.5	15.0	7.4		2.0	7.0	10.5	96.7	5.0		603.3
20:00	168.2	36.1	2.9		16.0	103.3	2.4		8.0	42.0	37.5	9.0	33.0	15.0	7.4		2.0	7.0	10.5	99.5	5.0		604.8
21:00	167.4	36.1	2.9		16.0	102.9	2.4	0.3	8.0	39.0	40.0	8.5	30.0	12.0	7.4		2.0	7.0	10.5	97.4	5.0		594.8
22:00	169.4		2.7			103.0	2.0	0.3	8.0	42.0	45.0	8.5	30.0	12.0	5.6		2.0	7.0	10.5	86.8	-0.5		534.3
23:00	167.3					103.6	1.6	0.4	8.0	42.0	45.0	8.5		15.0			2.0	7.0	3.3	77.4	0.1		481.2
0:00	164.7					103.2	1.6	0.2	8.0	43.2	37.5	5.9								73.7			438.0

Source: EDC

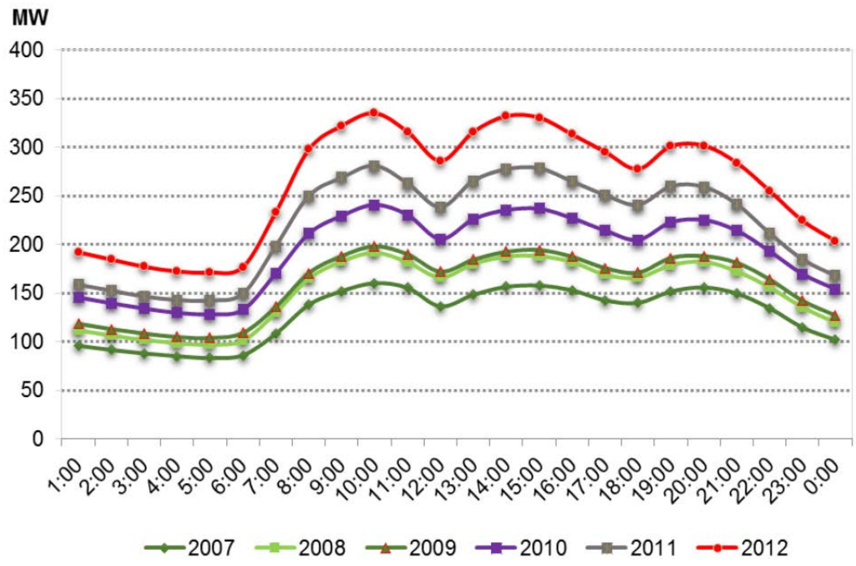
Table 2.5-3 Generation Record at the Phnom Penh Grid (Monday, March 31, 2014)

Time	GS4	Kampong Cham GS	Kampong Speu GS	Phnom Penh Sugar	SL Garment	Sovanna Phum	KEP	CEP	Colben	CUPL	C6	C5	C3	Others	Power cut	Total
	-	-	-	IPP	IPP	IPP	IPP	IPP	IPP	IPP	EDC	EDC	EDC	-	-	
1:00	245.6	-12.0	-4.0	1.5		8.0	16.0	22.0								277.1
2:00	245.4	-10.0	-3.9	1.5		8.0	12.0	17.0								270.0
3:00	244.2	-10.0	-3.8	1.5		8.0	7.0	12.0						0.1		259.0
4:00	243.0	-9.0	-3.8	1.5		8.0		6.0								245.7
5:00	245.0	-9.0	-4.1	1.6		8.0		6.0								247.5
6:00	242.2	-10.0	-4.3			8.0	7.0	10.0								252.9
7:00	215.4	-10.0	-5.2	3.0		8.0	35.0	35.0	4.0	25.5	12.0					322.7
8:00	316.7	-19.0	-6.8	5.0		8.0	43.2	45.0	5.9	28.5	15.0	8.0				449.5
9:00	357.6	-20.0	7.1	5.0		8.0	43.2	45.0	5.9	28.5	15.0	8.0				503.3
10:00	378.0	-17.0	7.9	5.0		8.0	43.2	45.0	8.0	27.5	15.0	8.0				528.6
11:00	311.9	-17.0	9.7	5.0		8.0	43.2	45.0	9.0	27.5	15.0	7.8			5.0	470.1
12:00	283.5	-12.0	8.9	4.0	0.1	8.0	32.0	38.0	9.0	25.0	12.0	7.8		0.5	5.5	422.3
13:00	321.4	-15.0	9.6	5.0		8.0	42.0	45.0	9.0	27.5	15.0	7.8		-0.4	5.0	479.9
14:00	355.2	-17.0	8.2			8.0	42.0	45.0	9.0	27.5	15.0	7.8		-0.4	5.0	505.3
15:00	344.0	-18.0	7.8	5.0		8.0	42.0	45.0	9.0	27.5	15.0	7.8		-0.4	13.3	506.0
16:00	332.5	-17.0	8.0	5.0		8.0	42.0	45.0	9.0	27.5	15.0	7.8		-0.4	3.0	485.4
17:00	306.9	-17.0	8.5	5.0		8.0	42.0	45.0	9.0	28.5	15.0	7.8		-0.4	3.0	461.3
18:00	267.4	-3.0	9.9	4.0	0.1	8.0	31.0	30.0	8.5	26.5	12.0	7.4				401.8
19:00	269.4	-18.0	9.7	2.9	0.1	8.0	42.0	45.0	9.0	28.5	15.0	7.4				419.0
20:00	270.0	-19.0	9.6	2.4		8.0	42.0	37.5	9.0	33.0	15.0	7.4				414.9
21:00	272.2	-17.0	10.0	2.4	0.3	8.0	39.0	40.0	8.5	30.0	12.0	7.4				412.8
22:00	259.6	-12.0	-4.7	2.0	0.3	8.0	42.0	45.0	8.5	30.0	12.0	5.6				396.3
23:00	259.2	-14.0	-4.4	1.6	0.4	8.0	42.0	45.0	8.5		15.0			-0.3		361.0
0:00	237.8	-14.0	-4.2	1.6	0.2	8.0	43.2	37.5	5.9							316.0

Source: EDC

(5) Trend of daily load curve

Trend of daily load curve in Phnom Penh system including Kampong Speu is shown below. There are peaks at 10:00, 15:00 and 20:00, but the peaks at 10:00 and 15:00 are the biggest.



Source: EDC Annual Report 2012

Fig. 2.5-4 Trend of Daily Load Curve (Annual Average)

And generation record at Phnom Penh system including Kampong Speu was 2479.73GWh and the peak demand was 410MW in 2012. Therefore the load factor is 69.0%.

2.5.2 Power Development Plan

At present, the Power Development Plan, which was formulated under the World Bank support in 2006, is being revised with the support from the Chugoku Electric Power Co., Inc. The revised Power Development Plan includes demand forecast, generation development plan and transmission development plan until 2030 and will be approved by the Minister by the end of December 2014. Therefore, the power development plan described below shows ascertained items only.

(1) Generation Development Plan

At present for revision work, the generation development plans as below, which have been already contracted and will be operated by 2017, are fixed. The generation development plan after that will be reviewed according to the revision work. The below table shows the generation development plan including generation projects which were launched after 2012.

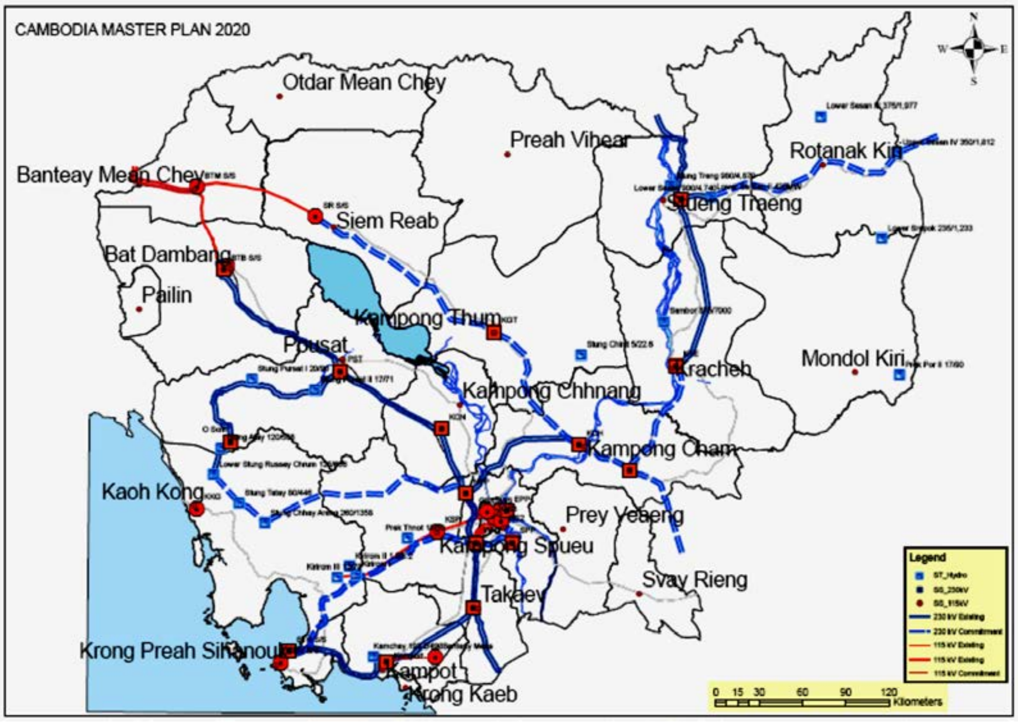
Table 2.5-4 Generation Development Plan

No.	Project Name	Type	Capacity (MW)	Scheduled commencement progress	Company	Condition as of July 2014	Connection point to National grid
-	Kamchay	Hydro	194.1	2012	Sinohydro Kamchay Hydroelectric Project Co. Ltd.（China)	Operation	180MW: Kampot S/S 14.1MW: Local
-	Kirirom III	Hydro	18	2012	CETIC Hydropower Development Co. Ltd. (China)	Operation	Kirirom I P/P
-	Stung Atay	Hydro	120	2013	C.H.D. (Cambodia) Hydropower Development Co. Ltd. (China)	Operation	O'soam S/S
-	100 MW Coal Fired Power Plant on BOO Basin in the Preah Sihanouk Province	Coal	100 (net)	2013	Cambodian Energy Limited (Malaysia)	Operation	Sihanouk Province Terminal S/S
1	Stung Tatay	Hydro	246	2014	Cambodian Tatay Hydropower Ltd. (China)	Test Operation	O'soam S/S
2	Lower Stung Russei Churum		338	July, 2014	China Huadian Lower Russei Churum Hydroelectric Project (Cambodia) Company Ltd. (China)	Operation	
3	270MW Phase 1 of the 700MW Coal Fired Power Plant on BOO Basin in the Preah Sihanouk Province	Coal	270 (net 240)	2014 (135MW) 2015 (135MW)	Cambodia International Investment Development Group Co. Ltd. (China)	Under construction	Sihanouk Province Terminal S/S
4	135MW Coal Fired Power Plant on BOO Basin in the Preah Sihanouk Province		135 (net 120)	2017		PPA signed with EDC	
5	Lower Sesan 2	Hydro	400	2017	Hydro Power Lower Sesan 2 Company Co., Ltd. (Royal Group (Cambodia) and Hydrolancang International Energy Co., Ltd. (China) (90%), and EVN International Joint Stock Company (EVNI) (10%))	Under construction	Steung Treng GS

Source: JICA Study Team

(2) Transmission Development Plan

At present, the transmission development plan is being revised. The planned expansion of the National Grid until 2020 described in SPDRE (Strategy and Plan for Development of Rural Electrification in the Kingdom of Cambodia) as Ministerial order (PRAKAS) in November 2011, is shown in Fig. 2.5-5.



Source: SPDRE

Fig. 2.5-5 Map showing planned National Grid and Substations in 2020

And transmission facilities over 115kV including at planning stage is shown below.

Table 2.5-5 Transmission Facilities including at Planning Stage

Transmission Line		Voltage [kV]	Length [km]	Circuit	Conductor	Capacity [MVA/cct]	Commercial Operation Year	Owner
From	To							
West Phnom Penh	Takeo	230	46	2	ACSR 632	430	2008	EDC
Takeo	Vietnam Border	230	50	2	ACSR 400	302	2008	EDC
Takeo	Kampot	230	73	2	ACSR 400	302	2012	EDC
Kamchay Hydro	Kampot	230	11	2	ACSR 400	302	2012	EDC
West Phnom Penh (GS4)	Kampong Chhnang	230	88	2	ACSR 632×2	861	2012	CPG
Kampong Chhnang	Pursat	230	83	2	ACSR 632×2	861	2012	CPG
Pursat	Battambang	230	122	2	ACSR 632×2	861	2012	CPG
Pursat	O'soam	230	132	2	ACSR 632×2	861	2012	CPG
Kampot	Sihanoukville	230	82	2	ACSR 632	430	2013	EDC
Sihanoukville	Stueng Hav Thermal	230	-	2	-	-	2013	BOT
North Phnom Penh (GS6)	Kampong Cham	230	97	2	ACSR 632×2	861	2013	CTL
South Phnom Penh (GS7)	West Phnom Penh (GS4)	230	24	2	ACSR 632×2	861	(2014)	EDC
Stung Tatay	O'soam	230	65	2	ACSR 400	302	2014	BOT
Lower Russey Chrum (upper 87 MW×2)	O'soam	230	32	2	ACSR 400	302	2014	BOT

Transmission Line		Voltage [kV]	Length [km]	Circuit	Conductor	Capacity [MVA/cct]	Commercial Operation Year	Owner
From	To							
Lower Russey Chrum (lower 82 MW×2)	O'soam	230	40	2	ACSR 400	302	2014	BOT
Stung Treng	Kratie	230	-	2	ACSR 632×2	861	(2015)	EDC
Kampong Cham	Kratie	230	-	2	ACSR 632×2	861	(2015)	LYP
Stung Treng	Lao	230	-	2	ACSR 632	430	(2016)	EDC
West Phnom Penh (GS4)	Sihanoukville	230	-	2	ACSR 632×2	861	(2016)	CHMC
Stung Treng	Lower Sesan2 Hydro	230	36	2	ACSR 400×2	604	(2017)	BOT
Sre Ambil	Koh Kong	230	-	2	-	-	(2018)	-
North Phnom Penh	Chhay Areng Hydro	230	-	2	-	-	(2018)	-
Chhay Areng Hydro	O'soam	230	-	2	-	-	(2018)	-
Koh Kong	O'soam	230	-	2	-	-	(2019)	KTC
Chay Areng Hydro	Chamkar Luong	230	-	2	-	-	(2019)	EDC
GS1	GS3	115	11.3	1	AAC 250×2	238	2000	EDC
GS3	CEP	115	5.0	1	AAC 250×2	238	2009	EDC
CEP	GS2	115	7.0	1	AAC 250×2	238	2009	EDC
GS2	KEP	115	6.6	1	AAC 250×2	238	2009	EDC
KEP	Old GS4	115	14.3	1	AAC 250×2	238	2009	EDC
Old GS4	SWS (GS5)	115	21.4	1	AAC 250×2	238	2009	EDC
GS5	GS1	115	5.3	1	AAC 250×2	238	2009	EDC
Old GS4	GS4	115	10.3	2	ACSR 632	215	2009	EDC
GS5	Kampong Speu	115	40.9	2	ACSR 150	85	2000	EDC
Kampong Speu	Kirirom1 hydro	115	65.2	2	ACSR 150	85	2000	EDC
Kirirom1 hydro	Kirirom3 hydro	115	38.0	2	ACSR 150	85	2012	EDC
Stung Atay(1st 20 MW)	Stung Atay(2nd 100 MW)	115	15	1	ACSR 150	85	2012	BOT
Stung Atay (2nd 100MW)	O'soam	115	8	2	ACSR 500		2012	BOT
SPP (GS7)	GS2	115	16.4	2	ACSR	-	(2014)	EDC
GS5	NPP (GS6)	115	24.8	2	ACSR	-	(2014)	EDC
Thai Border	Industrial Estate GS	115	4.0	1	AAC400	-	2007	CPTL
Industrial Estate GS	Banteay Meanchay	115	43.0	1	AAC400	-	2007	CPTL
Banteay Meanchay	Siem Reap	115	85.0	1	AAC400	-	2007	CPTL
Banteay Meanchay	Battambang	115	53.0	1	AAC400	-	2007	CPTL
SPP (GS7)	Neak Loeung	115	-	-	-	-	(2016)	CHMC
Neak Loeung	Svay Rieng	115	-	-	-	-	(2016)	CHMC

* ACSR : Aluminum Conductor Steel Reinforced
* AAC : All Aluminum Conductor
* LYP : Ly Yong Phat Group
* CHMC : China National Heavy Machinery Corporation
* KTC : KTC Cable Co., Ltd.
* ACSR/AC : Aluminum Conductor Aluminum Clad Steel Reinforced
* CPG : Cambodian Power Grid Co., Ltd.
* CTL : Cambodian Transmission Limited
* CPTL : Cambodian Power Transmission Line Co., Ltd.

Source: JICA Study Team

2.6 ASSISTANCE FROM OTHER DONORS

2.6.1 World Bank

World Bank's assistance in Cambodian power sector in the recent years is summarized in the table below. The assistance seems to focus on the reinforcement of transmission lines, to support the realization of international power trade and rural electrifications.

Table 2.6-1 World Bank's Assistance in Power Sector in Recent Years

Project Name	Duration	Project Cost (WB portion) US$ 1,000	Objectives	Executing Agency	Outline
GMS Power Trade (Cambodia) Project	5 Jun 2007 - 31 Dec 2011	20,000 (18,500)	Infrastructure development, Regional integration, Rural infrastructure	EDC	Project realizes international connections between Lao, Vietnam and several regions in Cambodia (1) 115 kV TL: Ban Hat (Lao) - Stung Treng (Cam) (2) 115 kV TL: Tan Bien (Viet) - Kampong Cham (Cam), for international trade (3) 115 kV TL: Xeset1 - Saravan, to be international interconnection between western Thai, Lao and southern Cambodia (4) Study, design and construction of Lao's Load Dispatch Center (5) Technical Assistance to Hydro development, project implementation and organizational strengthening
Rural Electrification and Transmission Project	16 Dec 2003 - 31 Jan 2012	67,920 (40,000)	Infrastructure development, Rural infrastructure, Rural policy/ institution, Competitive Market policy, Climate change	MIME	TL Component: - 220kV 2cct, Vietnam-Phnom Penh - 2 new Substations - Augmentation of distribution network in/around Phnom Penh (3 substations, 22kV distribution network) - Establishment of NCC (National Control Center) - Capacity development of EDC Rural Electrification Component: - Rural electrification by extension of middle-, low-voltage lines - Augmentation of relationship between EDC and REEs (licensing, collection, contract management, etc.) Rural Electrification Foundation Pilot Component: - Mini/off-grid electrification programs, - Support of REEs and regional organizations, - New connection, connection to Solar Home System-using households, small-hydro development, etc.
Renewable Energy Development Project	16 Dec 2003 – 31 Jan 2012	5,920 (0)	Climate change, Infrastructure development, Rural infrastructure, Rural policy/ institution, Environmental poicy/ institution	—	Technical assistance to support the projects above

Source: JICA Study Team

2.6.2 Asian Development Bank

ADB (Asian Development Bank)'s assistance in Cambodian power sector in the recent years is summarized in the table below. The assistance seems to focus on the reinforcement of transmission lines, to support rural electrifications.

Table 2.6-2 ADB's Assistance in Power Sector in Recent Years

Project Name	Date of Approval	ADB fund ($1,000)	Objectives	Outline
Rural Energy Project (formerly Rural Energy Pilot Project) (grant)	15 Jan 2013	AusAid 6,110	Economic development, Sustainable environment, Climate change	(i) Svay Rieng Province: Electrification of 13,700 households (extension of 22 kV middle voltage TL, expansion of low voltage distribution network, metering) (ii) Kampong Cham Province: introduction of high efficiency ovens (90,000 units) (iii) Capacity development of EAC
Medium-Voltage Sub-Transmission Expansion Sector Project (former name: Rural Electrification Project) (loan)	14 Dec 2012	45,000	Economic development,	Electrification in Provinces of Kampong Thom, Kampong Cham, Siem Reap, Kandal, Banteay Meanchey (i) 22 kV TL extension, 2,110 km (ii) Assistance of implementation (iii) Support to improve EDC's efficiency
Rural Electrification Project (TA)	29 Nov 2010	1,300	Economic development,	Technical Assistance to support above projects
CAM: CPTL POWER TRANSMISSION PROJECT (private)	27 Jun 2007		Economic development, PPP Regional integration	Expansion of national grid in north-western regions (Banteay Meanchey, Siem Reap, Battam Bang) (i) 115kV TL (1cct) extension, 221 km (ii) 3 new substations (iii) 1 switching station
Second Power Transmission and Distribution Project (loan)	4 Oct 2006	20,000	Economic development,	Expansion of the existing transmission network to replace inefficient diesel units in Sihanoukville (i) 230kV TL extension (Kampot to Sihanoukville), (ii) Installation of new substations and distribution equipment (iii) Capacity development of EDC

Source: JICA Study Team

2.6.3 Other Donors

Assistance from other donors includes one from KfW, German Foundation for Reconstruction.

Project Name: Electrification in Rural Cambodia

Project Outline: Construction of new Kampot Substation, 230kV Transmission line connection between Kampot and Takeo Substations, electrification in Takeo and Kampot Provinces by expansion of middle- and low-voltage transmission/distribution networks, technical assistance, etc.

Total Project Cost: EUR 30 million, including KfW's loan EUR 22million

Duration: 2010 to 2014

CHAPTER 3

NECESSITY AND VALIDITY OF THIS PROJECT

CHAPTER 3 NECESSITY AND VALIDITY OF THIS PROJECT

3.1 ISSUE OF PHNOM PENH POWER SYSTEM AND POSITIONING OF THE PROJECT

3.1.1 Present Condition and Issue of Phnom Penh Power System

The power system of Cambodia consists of three systems which are the National Grid connected by 230kV or 115kV transmission lines, the medium voltage system connected to the neighboring country such as Vietnam, Thai or Laos, and the independent system. The main power system of Cambodia is the National Grid including Phnom Penh. In this system, the power supplied from the Vietnam interconnected line and the hydropower plant of the Kampot area and the western area are also transmitted to the Phnom Penh area which is the largest power consumption area through the 230kV backbone transmission line.

As a main issue of the power system, there is the technical issue resulting from the power supply in the Phnom Penh system.

Technical issues originated in the power supply in Phnom Penh which is the largest power consumption area are listed below:

(1) Frequent occurrence of planned power outage during dry season
(2) Destabilization of the system in case of shutdown of interconnection line with Vietnam
(3) Lack of transformer capacity of substations (115/22kV) in Phnom Penh City
(4) Lack of outer link transmission lines (230kV or 115kV system)

(1) Frequent occurrence of planned power outage during dry season

The power outage occurrence conditions in 2008 - 2013 are shown in Table 3.1-1. This expresses the number of times of a power outage and power outage time according to cause and the lowest row shows the sum total. The data in 2013 is the record by April and more than half of the number of times of a power outage and the power outage time are the power outages by the shortage of supply capability. The shortage of supply capability in 2008 has been improved by the power import from Vietnam in 2009, and the power outage by the shortage of supply capability in 2009 and 2010 decreased. However, since the power import from Vietnam has upper limit, the number of times of a power outage and power outage time are continuing the upward tendency by a demand rise in 2011 and afterwards. As reference, the annual (the 2007 fiscal year) power outage time per house in Japan is 16 minutes, the number of times of a power outage is 0.14 times, and it is 1/100 or less.

Table 3.1-1 Number of Times of a Power Outage and Time according to Factor

	Cause Description	2008		2009		2010		2011		2012		2013 (Data by April)	
		SAIFI TIMES	SAIDI Minutes	SAIFI TIMES	SAIDI Minutes	SAIFI TIMES	SAIDI Minutes	SAIFI TIMES	SAIDI Minutes	SAIFI TIMES	SAIDI Minutes	SAIFI TIMES	SAIDI Minutes
BO	Generator fault	1.0	205.0										
	Other	1.0	267.0	5.0	485.5	1.0	30.0	1.0	17.0	1.0	55.0	1.0	104.0
	Total	***2.0***	***472.0***	***5.0***	***485.5***	***1.0***	***30.0***	***1.0***	***17.0***	***1.0***	***55.0***	***1.0***	***104.0***
CUT	Generator	2.1	64.0	1.3	34.1	0.3	9.2	0.2	5.2	0.7	14.0	1.1	19.4
	Power lack	101.4	11,001.5	41.3	3986.7	12.0	920.3	49.4	3,979.5	64.0	6,378.5	55.3	4,693.8
	Over load									3.8	320.2	7.9	933.7
	Install new power network	0.2	28.7	0.6	136.0	0.8	112.2	1.5	165.8	0.9	113.2	0.9	150.5
	Install electrical equipment	0.2	32.5	0.2	28.6	0.5	62.3	0.1	20.5	0.3	31.1	0.8	163.5
	Repair network	1.4	240.0	0.9	208.7	2.1	452.6	4.2	591.1	2.5	297.7	3.0	483.1
	Repair electrical equipment	0.1	12.2	0.3	44.6	0.9	116.8	0.4	43.0	0.2	21.3	1.1	220.5
	Other incidents	0.1	16.7	0.9	130.1	1.2	109.5	3.7	349.2	3.4	317.3	2.3	194.2
	Maintenance electrical equipment	0.1	2.3	0.1	2.3	1.1	65.9	1.0	81.2	0.7	95.4	1.1	59.7
	Trip CB	1.6	57.6							0.5	25.4	0.1	2.8
	Trip 11.1, 11.2	0.7	19.1										
	Total	***107.8***	***11,474.7***	***45.5***	***4,571.1***	***19.0***	***1,848.8***	***60.6***	***5,235.5***	***76.9***	***7,614.0***	***73.4***	***6,921.1***
Trip	Generator fault	1.2	30.2	0.5	4.8			0.1	0.4			0.1	0.3
	Wave of Frequency			0.3	1.8	0.1	0.4						
	Power lack	0.4	14.7	0.0	0.3								
	Over load	0.6	7.4	0.7	2.3	2.4	19.3	1.7	78.1	1.1	88.4	0.4	7.8
	Network Fault												
	Overhead line, Cable fault	1.4	105.2	0.6	54.1	1.6	159.5	1.3	85.6	1.7	156.3	1.1	95.7
	Electrical equipment fault	0.5	24.6	1.2	143.0	1.4	107.6	0.7	27.4	1.4	54.3	1.1	172.8
	Have affected from another feeder	0.2	3.7	0.3	3.9	0.1	4.2	0.0	0.1	1.0	17.4	0.3	13.2
	Unknown fault	7.4	149.4	11.2	251.4	12.8	199.0	16.7	299.4	18.3	524.0	19.0	404.7
	Digging	0.1	9.4	0.1	8.3	0.2	22.1	0.1	9.4	0.2	18.8	0.1	17.8
	Animal	0.0	0.0	0.0	0.9	0.0	2.7	0.4	13.0	0.2	3.4	0.2	8.6
	Tree or Something	0.2	9.3	0.4	25.2	1.2	58.9	1.2	47.0	0.8	35.6	0.7	20.1
	Lightning	0.0	3.7			0.0	10.9	0.4	18.8	0.1	1.9	0.0	0.0
	Rain, Wind	1.5	23.3	1.9	32.8	1.8	32.7	0.5	6.1	2.1	50.4	1.4	27.9
	Other fault	0.8	25.3	0.3	6.9	0.5	19.1	0.4	25.3	0.2	3.0	0.2	15.3
	Trip GS1									1.2	38.9	1.9	35.5
	Trip GS2									0.1	2.1	0.1	4.7
	Trip GS3									0.0	1.6	0.0	1.3
	Trip GS4									0.0	0.1		
	Total	***14.2***	***406.4***	***17.6***	***535.6***	***22.2***	***636.5***	***23.5***	***610.6***	***28.4***	***996.1***	***26.6***	***825.8***
Grand Total		**124**	**12,353**	**68**	**5,592**	**42**	**2,515**	**85**	**5,863**	**106**	**8,665**	**101**	**7,851**

Note) SAIFI shows the number of times of a power outage per house, and SAIDI shows the power outage time per house.

Source: Final Report of "Data Collection Survey on Electric Power Sector in Cambodia", JICA, March 2012, and JICA Study Team

(2) Instability of the system following interception of the Vietnam system

Since the rate of the power purchased from Vietnam is large (see Fig.2.5-1), a possibility that the frequency of the Phnom Penh system will drop and all the systems of Phnom Penh will fail when an interconnected line with Vietnam is intercepted by the fault, etc., and the Phnom Penh system is in the conditions where the big risk is held on the stable supply. It also became a cause that the artificial mistake overlapped and all the systems of Phnom Penh had actually failed for power in 2010.

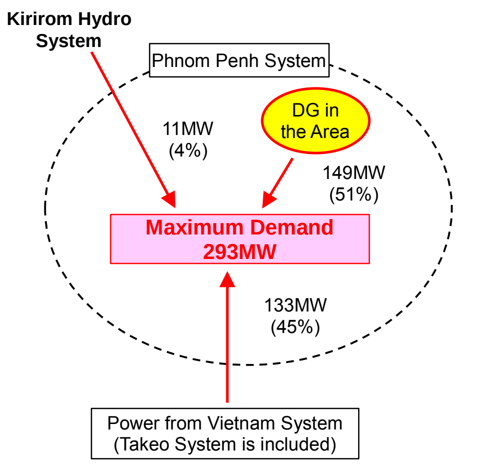


Fig. 3.1-1 Power Supply Composition at the Time of Maximum Load

Source: JICA Study Team

The composition of the power supply to the Phnom Penh system when the past maximum power consumption occurs is shown in Fig. 3.1-1. Since the Phnom Penh system depends for about 45% of the supply capability on the power supply from the Vietnam system, it needs to shift for the independent system by diesel generators, such as IPP (Independent Power Producer) within the area connected with a city system, safely at the time of the Vietnam system interception. For that purpose, system control which intercepts load is needed so that load power may become almost an equivalent amount with power generation power within the area.

(3) Shortage of the transformer capacity of substations (115/22kV) in Phnom Penh

The power flow of the Phnom Penh city system in 350 MW (50 MW of planned power outages, 300 MW of real supplies) of the largest ever demand recorded at 10:00 on October 24, 2011 is shown in Fig. 3.1-2. Although the 115/22kV transformer capacity of GS1, G2, and GS3 which is a substation supplied to city load is 100MVA (50MVA × 2), respectively, for securing supply capability, a load change in the distribution system is indispensable to the disconnection of one transformer. On the other hand, when it takes into consideration that the growth of the power demand of this area is large, there is a danger that the supply restriction by transformer capacity will occur in the near future.

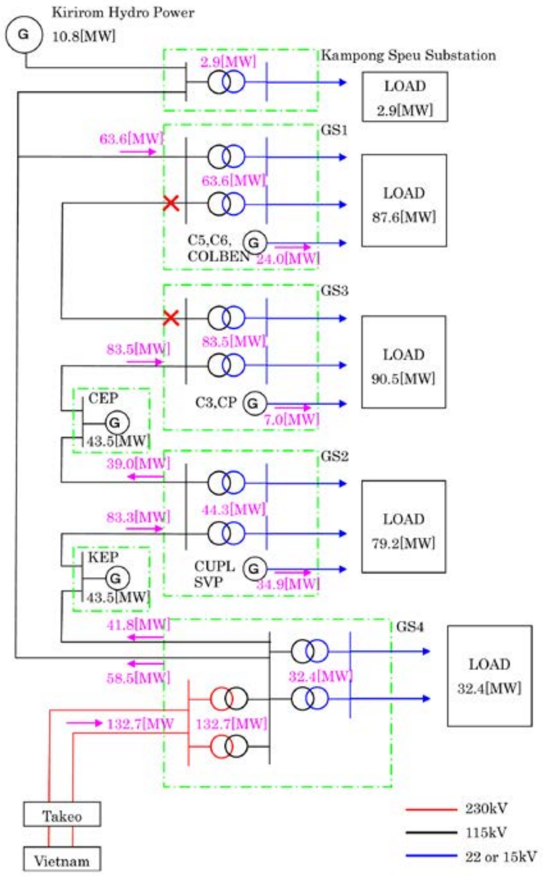


Fig. 3.1-2 Power Flow in Phnom Penh (10:00 on October 24, 2011)

Source: Final Report of "Data Collection Survey on Electric Power Sector in Cambodia", JICA, March 2012

However, if the following point is taken into consideration, it will be considered advantageous to pull out a 115kV system for the city from an existing substation, and to construct a substation newly inside of the city near load center:(i) there is no extension space in an existing substation, (ii) it is hard to secure the drawer route of a 22kV power distribution system, (iii) it does not become a radical countermeasure when the load of the city central part increases.

When constructing a substation newly in the city central part, it is necessary to perform a place and a facility design with careful attention to the following point.

The important point in the case of constructing a substation newly in the city central part

- Attain miniaturization by utilizing advantageous public land on a procuring of site, adoption of GIS (Gas Insulated Switchgear) and a gas cooling transformer, etc.
- In order to secure transmission / distribution drawer route, procure the site facing the road which has a sidewalk.
- Foreseeing the future increase in load, install a 22kV distribution duct line and a 115kV transmission duct line in precedence near important crossing parts of the major thoroughfare and near a substation drawer.
- When there is fear, such as storm and flood damages, consider sufficiently.

(4) Shortage of the redundancy of the Phnom Penh outer system (115kV system)

The hub system which supplies power in Phnom Penh is “single circuit radial system” with least redundancy, as shown in Fig. 3.1-3.

Although, on system construction, 115kV outer line of single circuit loop system on the basis of GS4 is constructed, as for the substation (GS1, GS2, GS3) and IPP plant which are supplied to Phnom Penh, on the operation, the radial system opened between GS1 and GS3 is constructed. Although it seems that this is based on the restrictions on a line protection relay, since a part of city system fails for power according to single circuit fault of an outer line with such composition, it is not desirable on electric supply reliability.

What is necessary is just to change into the line protection relay using a current differential system etc., for enabling loop operation of an outer line. However, considering that the transformer capacity of substations, which step down in 22kV of city system itself is insufficient as mentioned above, and that transformer extension is difficult, it is required to construct newly a substation (115kV/22kV) in the city. Therefore, it is judged to be advantageous to secure the redundancy of an 115kV transmission system together with the power supply line planning to a new substation.

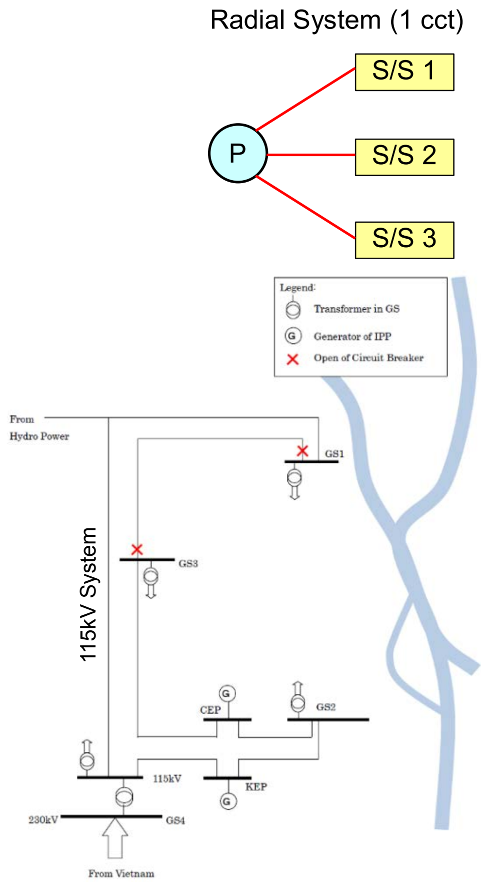


Fig. 3.1-3 Phnom Penh Outer System (115kV System)

Source: JICA Study Team

3.1.2 Positioning of this Project

For the Phnom Penh system which has the above technical issues, the "Preparatory Survey for Phnom Penh Transmission and Distribution System Expansion Project" was implemented by JICA from November 2012 through November 2013 as described in Section 1.1 "Background of the Survey". The study conducted includes construction of the new 115/22kV substations at Olympic Stadium and EDC Headquarters, upgrading of GS1 and GS3, installations of 115kV underground transmission line and 22kV distribution lines for the expansion of the capacities of transmission line, substations and distribution lines. Based on the result of the Survey, the Phnom Penh Transmission and Distribution System Expansion Project are scheduled to be implemented. And EDC is planning construction of the new 115/22kV substation at Hun Sen Park on its own. On the other hand, according to the result of the Study, further development of transmission lines, substations and distribution lines is to be required for covering the increasing of the power demand in Phnom Penh even after completion of such projects. This Project is especially conducted corresponding to (3) and (4) among above mentioned technical issues for the purpose of improving the stability of the power supply to Phnom Penh by construction of the new substations, transmission lines and distribution lines in Phnom Penh.

3.2 ENHANCEMENT PLANNING OF THE PHNOM PENH SYSTEM

3.2.1 Electric Power Supply to Phnom Penh and a Surrounding Area

(1) Preparatory Survey for Phnom Penh Transmission and Distribution System Construction Project Phase 1

For the system of Phnom Penh with the above technical issues, JICA implemented the "Preparatory Survey for Phnom Penh Transmission and Distribution System Construction Project" (The Preparatory Survey Project Phase 1) from November 2012 through November 2013. In the Study, as the result of considering the facility enhancement shown in Table 3.2-1 for the expansion of the capacities of transmission line, substations and distribution lines, the Transmission and Distribution System Construction Project Plan shown in Fig. 3.2-1 was drawn up. The route length of each underground transmission line is shown in Table 3.2-2.

Table 3.2-1 Main Facility Enhancement of Phnom Penh Transmission and Distribution System Construction Project Phase 1

115kV Underground Transmission Line	GIS Substation
GS1 -- EDC Head Office	EDC Head Office (115/22kV, 75MVA Tr. × 2)
GS2 -- Hun Sen Park	Hun Sen Park[1] (115/22kV, 75MVA Tr. × 2)
GS3 -- Olympic Stadium	Olympic Stadium (115/22kV, 75MVA Tr. × 2)

Source: JICA Study Team

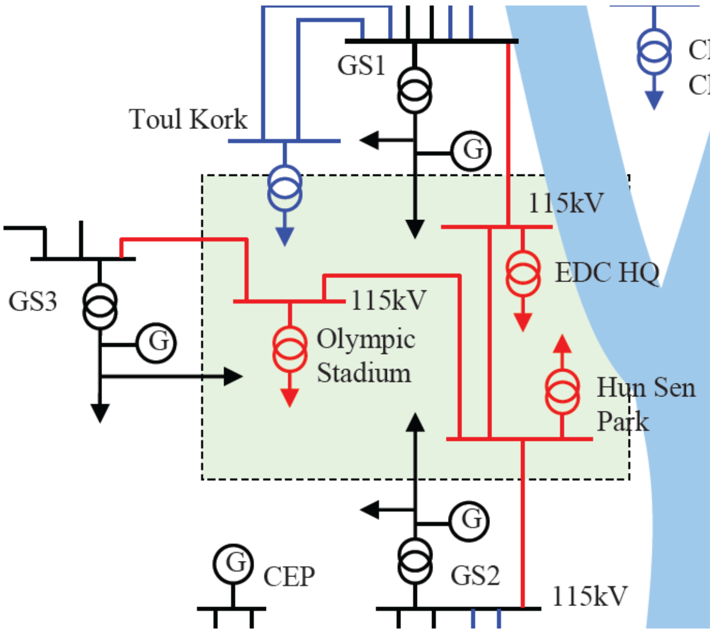


Fig. 3.2-1 Phnom Penh Transmission and Distribution System Construction Project Plan Phase 1 (Red Line Portion)

(Where, GS2 Between - Hun Sen Park and Hun Sen Park S/S are another projects.)

Source: Final Report of "Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project", JICA, November 2013.

1 During survey, it was decided this part would be separately developed with this project.

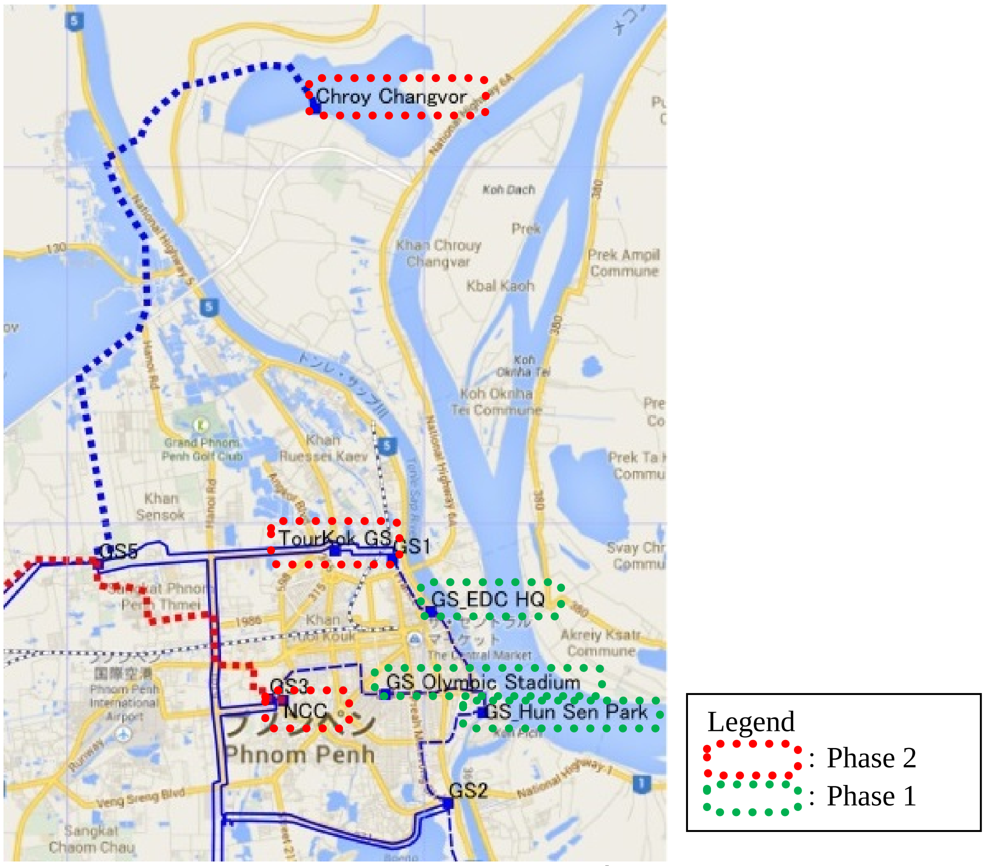
Table 3.2-2 115kV Underground Transmission Line Route Plan

Location	Route distance [m]
GS1 – EDC S/S	2,330
EDC S/S – Hun Sen Park S/S	3,330
Hun Sen Park S/S – GS2	3,810
Olympic Stadium S/S – Hun Sen Park S/S	3,330
GS3 – Olympic Stadium S/S	4,370
Total	17,170

Source: Final Report of "Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project", JICA, November 2013.

3.2.2 Planned Substations

There are six planned substations in this Phnom Penh Transmission Line and Distribution System Construction Project as shown below.



©2014 google Source: JICA Study Team

Fig. 3.2-2 Planned Substations in Phnom Penh

Among them, three candidate sites are the subject of Phase 2, and the status as of June 2014 is as follows.

(1) NCC (National Control Center)

This is a site of EDC ownership, and it is located near the center of Phnom Penh. There is NCC on north side of the site. Security guard is the gate facing the main street and the entry of ordinary people is restricted. The surroundings are urban area, and there are many shops and housing. The site is adjacent to C3 power plant as the internal combustion power plant of EDC and the business office of EDC. Enough area can be secured if GIS substation of 230kV substation is adopted at this site.

(2) Toul Kork

Substation construction site that EDC has been secured, facing the main road in the region is the route of the transmission line between the GS5 and GS1. It is a land elongated square. There is no building, only there is a volleyball court on site. Gate of the entrance is locked. There are shops and residential areas in the surrounding of the site, and they are densely located along the road.

(3) Chroy Changvar

The substation planned district is a peripheral of large-scale development area due to the new urban initiative and the like stadiums and housing estates. There is an opposite shore areas across the Tonle Sap River from Phnom Penh center. In addition, land acquisition and site selection is done by EDC in the future.

During land acquisition, EDC is aimed at ensuring the site area as well as the required site of 115kV AIS (Air Insulated Switchgear) substation and 230kV step-up in the future will also consider.

3.2.3 Power Supply to Chroy Changvar Area

(1) Development plan of Chroy Changvar Area

Chroy Changvar area is located on the other side of the central part of Phnom Penh crossing over the Tonle Sap River. Access from the central part of Phnom Penh is easy, and there is a new urban core design which develops a stadium, a residential estate, etc. on a large scale. Although there are still many undeveloped areas now like the development master plan shown in Fig. 3.2-3, the single-sided 2 lanes road is constructed and development of a golf course, hotels, etc. is ongoing partially. In order to promote development of this area, the increase of power supply is indispensable.

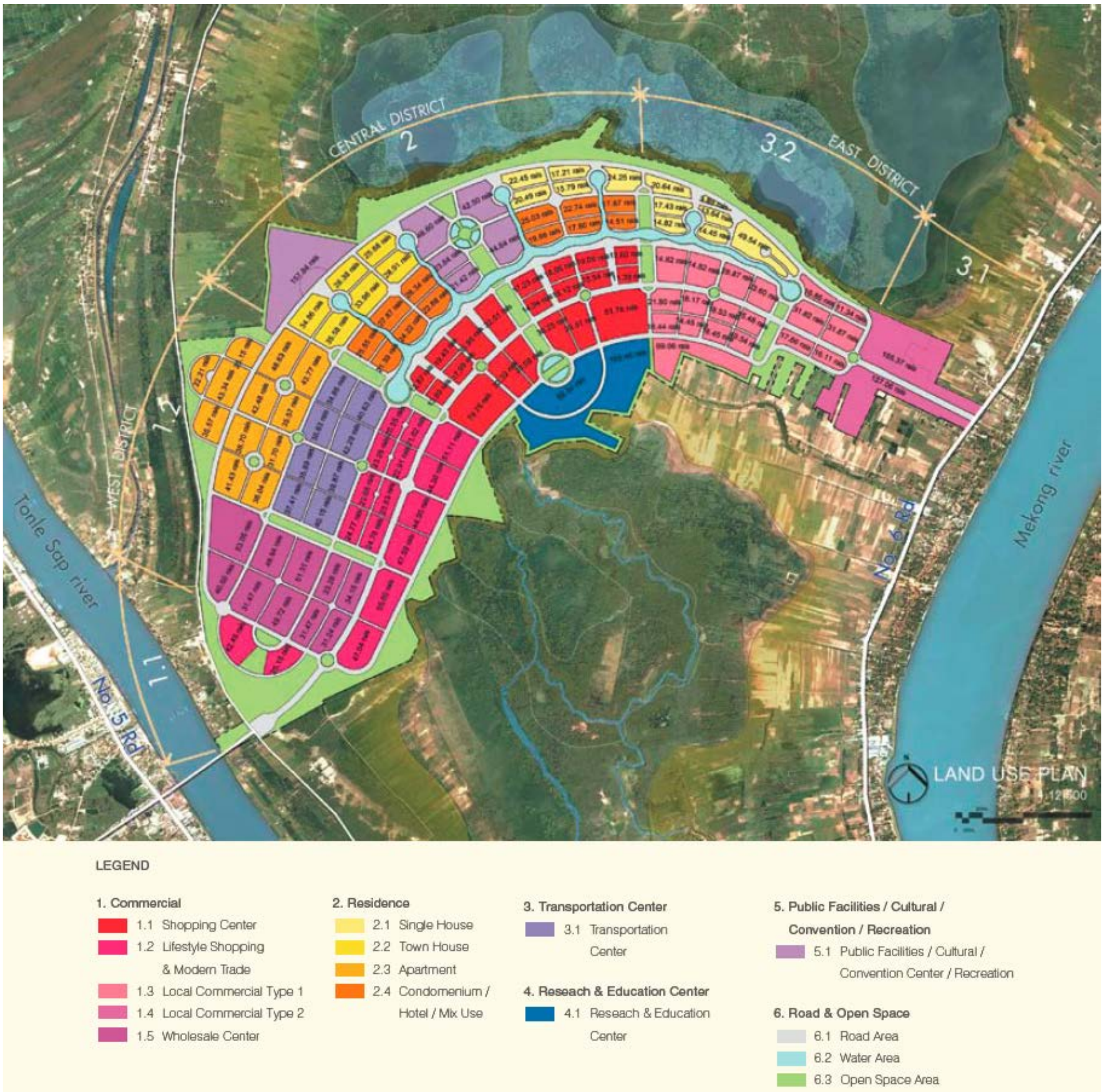


Fig. 3.2-3 Development Master Plan at Chroy Changvar Area

(2) Power supply method to Chroy Changvar Area

As a power supply system to Chroy Changvar Area, the technical study was carried out on the basis that an 115kV substation would be constructed in Chroy Changvar Area as a power supply base to this area and the substation is connected to GS5 by 115kV transmission line.

Points specifically to be considered are the location of new substation and the crossing method of the line over the Tonle Sap River.

1) Location of substation newly constructed

The following alternatives are considered as the candidate sites of the new substation in Chroy Changvar.

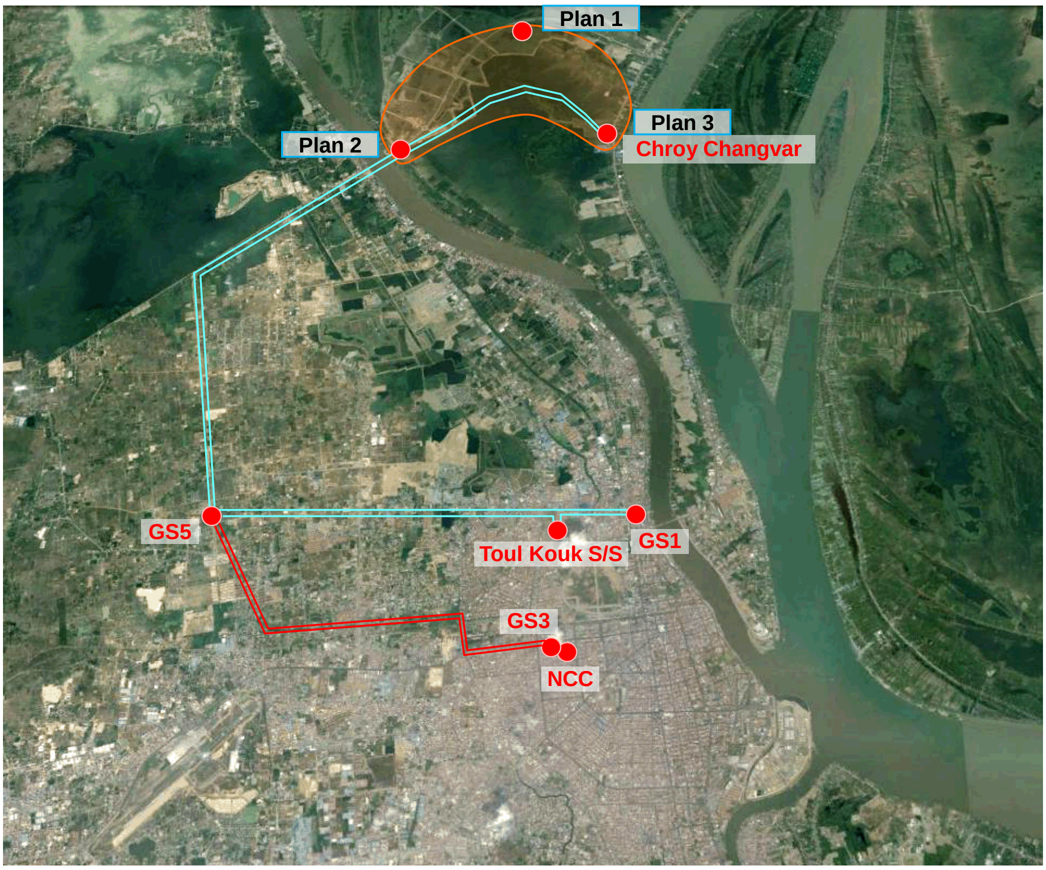
- Plan 1 North central part of development area
- Plan 2 Just near the east side of The Garden City Bridge
- Plan 3 East end of development area

Locations of the respective alternatives are shown in Fig. 3.2-4 and the result of comparison is shown in Table 3.2-3.

Table 3.2-3 Result of Comparison of Substation Location Plan

	Plan 1	Plan 2	Plan 3
Advantage	- Cheap - More Flexibility for Future Plan	- Cheap	- Flexibility for Future Plan
Disadvantage	----	- Less Flexibility for Future Plan - Flooding Area - Difficulty for land acquisition	- Difficulty for land acquisition - Expensive for installation cost

Source: JICA Study Team



©2014 google Source: JICA Study Team

Fig. 3.2-4 Location Plan of Substations Newly Constructed

Plan 1: It is easy to cope with the future development plans of northern area of Chroy Changvar and EDC,

Plan 2: Construction of the overhead transmission line inside the large scale development area is not required and the construction cost of transmission line will be smaller. However, as it is located in the flooding area, the countermeasure will be necessary. In addition, in case the development is extended toward the north area, the construction cost of distribution line and additional substation facility may be required in the north part of Chroy Changvar.

Part 3: There is a possibility to be requested by the developer of Chroy Changvar to use the underground cable for transmission line inside the development area. Compared to Plan 1 and Plan 2, the length of underground transmission line becomes longer.

The power supply to this development area is done by 22kV distribution line without any problem. Besides, transmission loss and construction cost of distribution system are considered to be practically equal in each plan.

The candidate site of Plan 3 is located in the major traffic artery road. Therefore, the land price is soaring. For this reason, it is considered difficult to acquire the land. On the other hand, Plan 3 site is higher in its elevation compared to Plan 2 site, therefore, it is considered that the countermeasure on flooding is relatively easy. And also it is advantageous for flexibility to the future system expansion.

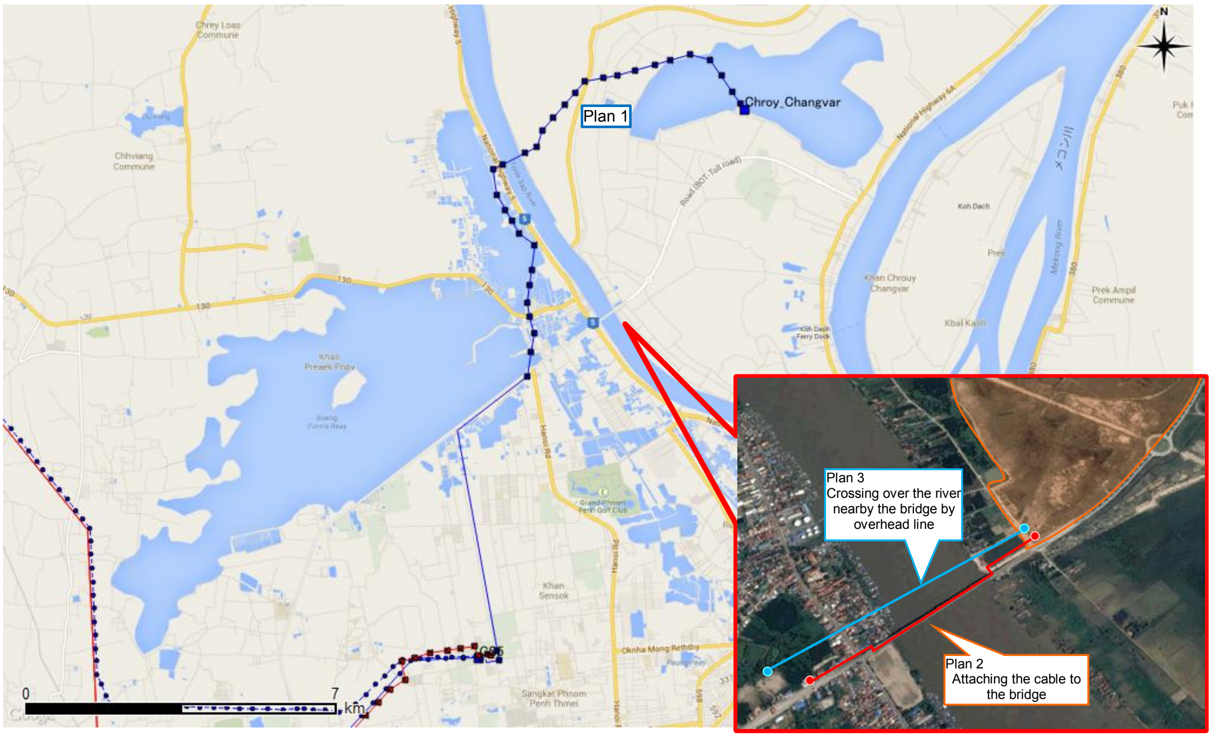
As mentioned above, although there is superiority or inferiority by the respective plans, there is no decisive difference and the respective plans are technically possible. Therefore, in the case of any plans, it is considered that the acquisition of the substation site by deliberations with a developer becomes an important selection factor. From the result of comparison, Plan 1 is recommended as optimal plan.

2) Connection method of the power system with new substation

The following plans are considered as the connection method of power system with new substation.

Plan 1: Crossing over the Tonle Sap River in the upstream by overhead line
Plan 2: Crossing the river by attaching the cable to The Garden City Bridge
Plan 3: Crossing the river by overhead line

Locations of the respective plans are shown in Fig. 3.2-5 and the result of comparison is shown in Table 3.2-4.



 Source: JICA Study Team

Fig. 3.2-5 River Crossing Method Plan for System Connection with the New Substation

Table 3.2-4 Result of Comparison of System Connection with Newly Constructed Substation

	Plan 1 [OH T/L at north side of bridge]	Plan 2 [Cable]	Plan 3 [OH T/L near bridge]	Remarks
Construction Cost	[0]	[-]	[+]	
Smooth Construction	[+]	[0] (gateway of bridge inside)	[+]	
Maintenance	[+]	[0] (gateway of bridge inside)	[+]	
Land Acquisition	[0] (Checked by EDC)	[+]	? (Checked by EDC)	Land for steel tower
Environment (including compensation)	[++]	[0]	[+]	

Source: JICA Study Team

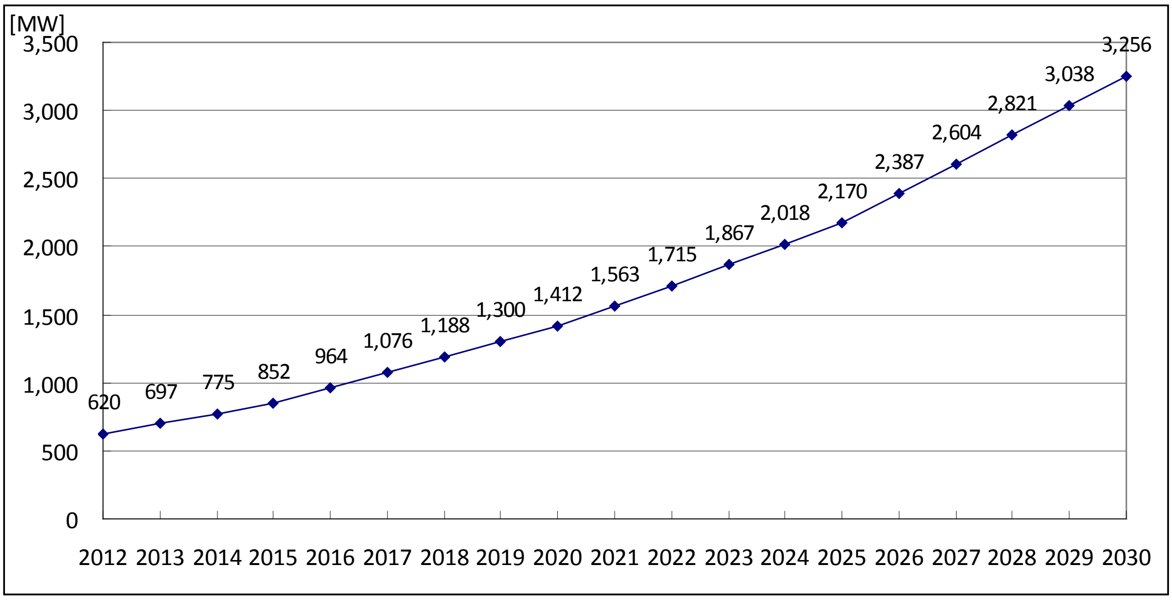
JICA Study Team recommends Plan 1 from the viewpoints of difficulty in land acquisition, reduction of construction cost, easiness of future expansion of the system, etc.

3.2.4 Demand Forecast

(1) Methodology of demand forecast

Currently, according to the Power Development Planning Revision work, Cambodian Government is conducting demand forecast. Methodologies of demand forecast are MAED (Model for Analysis of Energy Demand) which is provided by IAEA (International Atomic Energy Agency) and macro method for the whole country demand and GEO SIM Planning Tool which is provided by France and micro method for rural area.

Demand forecast by MAED is referred to increase rate of GDP (Gross Domestic Product), population increase rate, electrification rate, transmission and distribution loss and so on. The result of base case until 2030 under GDP annual increase rate of 7% was issued and is shown in Fig. 3.2-6.



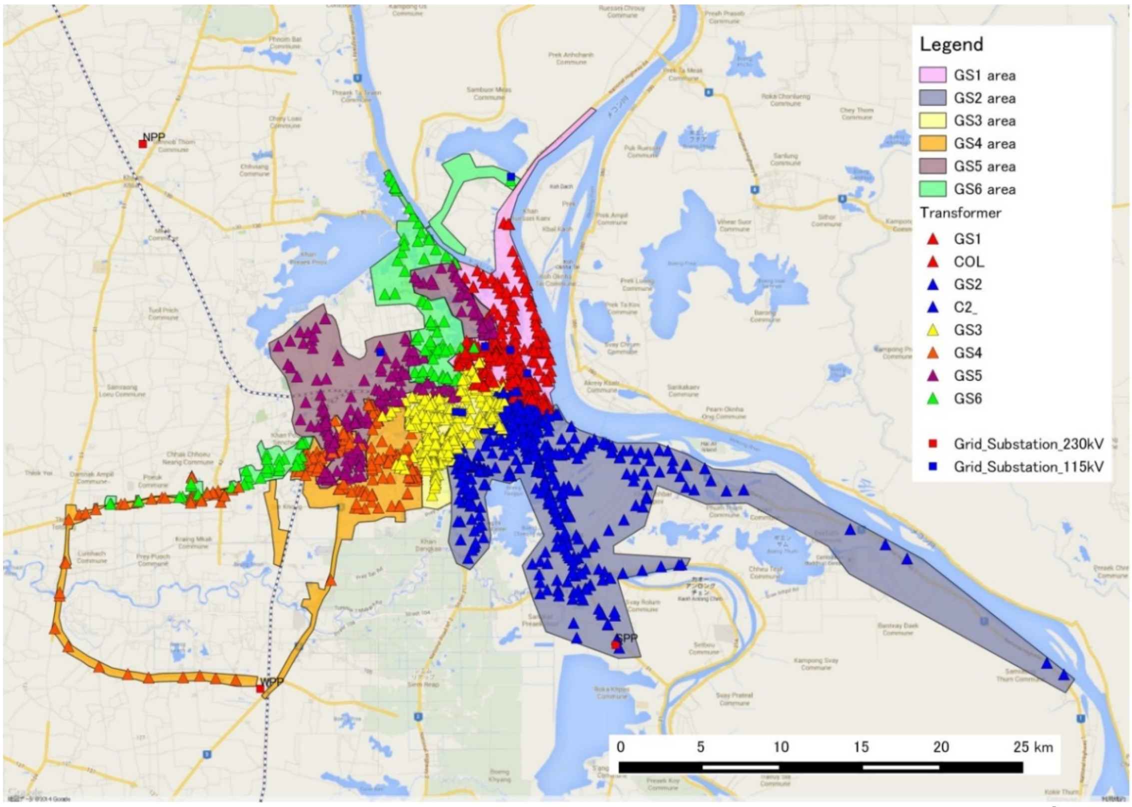
Source: EDC

Fig. 3.2-6 Demand Forecast Result in Cambodia (Base Case)

(2) Demand forecast in Phnom Penh System

a) Current situation and peak demand in Phnom Penh system

Supply area of each grid substation as of March 2014 is shown in Fig. 3.2-7.



©2014 google

Source: JICA Study Team

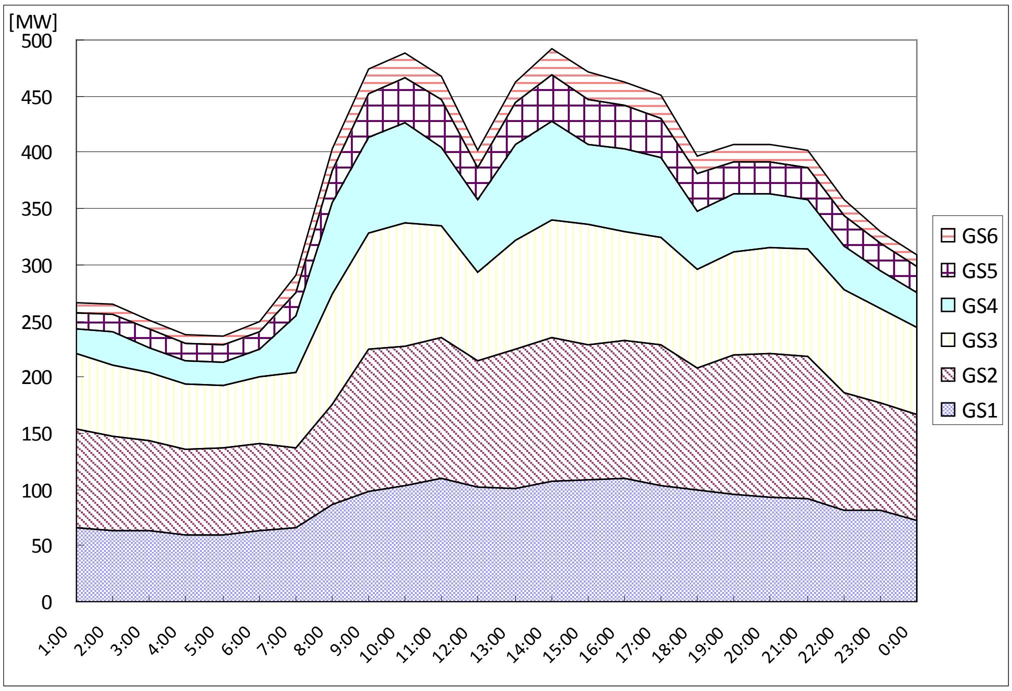
Fig. 3.2-7 Supply Area of Each Grid Substation (March 2014)

The load of each substation on March 31, 2014 which is recording the maximum load in National Grid at the end time of March, 2014 is shown in Table 3.2-5 and Fig. 3.2-8. The load in the 10:00 time on March 31, 2014 which is recording the maximum load is 488.2 MW.

Table 3.2-5 Record of Demand of Each Grid Substation in Phnom Penh System (Monday, March 31, 2014)

	GS1	GS2	GS3	GS4	GS5	GS6	Total
1:00	65.9	87.5	67.0	22.9	13.7	8.6	265.6
2:00	63.7	83.3	63.3	29.6	15.7	8.6	264.2
3:00	62.7	81.2	60.8	21.6	16.0	8.4	250.7
4:00	59.4	76.7	57.2	21.3	15.7	7.9	238.2
5:00	60.0	76.4	55.7	21.6	15.0	8.2	236.9
6:00	63.0	78.3	58.3	25.4	15.3	9.1	249.4
7:00	65.7	70.9	67.5	50.7	19.8	15.6	290.2
8:00	86.9	88.3	98.9	81.4	27.8	20.4	403.7
9:00	98.3	126.8	103.6	84.3	39.7	22.0	474.8
10:00	103.6	123.4	109.6	89.2	40.1	22.3	488.2
11:00	110.0	125.6	98.5	70.5	41.9	21.8	468.2
12:00	102.2	112.6	78.9	64.5	28.2	15.1	401.5
13:00	101.3	123.6	97.2	84.4	37.4	19.2	463.2
14:00	107.3	128.0	104.9	87.5	41.1	23.1	491.9
15:00	108.9	119.7	107.6	70.9	40.4	23.8	471.3
16:00	109.5	123.2	96.8	73.2	38.6	20.7	462.1
17:00	103.4	125.2	96.2	71.0	34.6	20.2	450.6
18:00	98.9	109.4	87.0	52.3	32.9	16.0	396.5
19:00	95.7	124.3	92.0	50.7	28.8	15.4	406.9
20:00	92.5	128.1	94.2	48.3	28.4	16.0	407.5
21:00	91.5	127.1	95.3	43.9	28.8	14.6	401.2
22:00	80.9	104.9	91.7	38.5	27.6	13.6	357.3
23:00	81.0	95.7	84.3	33.6	24.6	10.7	329.9
0:00	72.0	95.2	76.4	31.7	22.9	10.1	308.2

Source: EDC



Source: EDC

Fig. 3.2-8 Demand of Each Grid Substation in Phnom Penh System (Monday, March 31, 2014)

b) Current situation of big development projects in Phnom Penh system

And information about big development projects in Phnom Penh system collected from local newspaper and broadcasted information is shown in Table 3.2-6. Represented by Camko City, most of big projects extend duration of project period according to the economic situation and completion year is undetermined.

Table 3.2-6 Summary of Big Projects in Phnom Penh System

Name	Developer	Project cost [MillionUS$]	Place	Area	Completion	Remarks
Garden City Project	LYP Group		Chroy Changva commnue	1,000ha	Unknown	
Chroy Chang Va Development Zone (Chroy Changva City)	Oversea Corporation Investment of Cambodia (OCIC) (subsidiary of Canadian Bank)	1,600	3 Sangkats, Sangkat Chroy Chang Va, Prek Leap and Prek Ta Sek of Russey Keo District	387ha	Unknown	Botanic Garden 60ha, Stadium 40ha, Conference 45ha, housing etc. 162ha
AZ satellite city			Cheoung Ek Lake	290.4ha	Unknown	50.7MW for total
Booyoung Town	Booyoung Group (South Korea)	1,100		270ha	2020 later	40 apartments and 7 complexes, 17,760 units
Grand Phnom Penh International City	YLP Gr. (Local) And Ciputra Gr. (Indonesia)	600	Kmounh commnue, Russei Keo District	260ha	Unknown	70ha Golf course, 4,000 units of house
Olympia City	OCIC	250	Olympic Stadium	8ha	2016 (15Fx5, Shopping Mall)	13 skyscrapers (55F, 36Fx2, 20Fx5, 15F (358 units, 390 units) x 5), Olympia Plaza 7F
Phnom Penh City Center (Boeung Kok Lake Development)	Shukaku Inc.	1,500	Daun Penh District and Toul Kok District	133ha	Unknown	
Camko City	World City Company (South Korea)	2,000	Boeung Pong Development zone, Russei Keo District	119ha	Unknown	1300 units for the 1st and 2nd phase, 140 villas and 386 units for 3rd
Koh Pich Diamond Island City	OCIC	300	Tonle Bassac River, Chamkarmon District	100ha	Unknown	168 units for the first phase
Vattanak Capital	Vattanak Bank		next to Freedam park		2014	39F
Hongkong Land project	Hongkong Land		next to Freedam park		17F(2018), 27F(2016), 37F(2020)	17F, 27F, 37F
Casa Meridian Condo	OCIC				2017	33Fx2 (188 units and 16 shops per each)
the Bridge	Oxley Holdings (Singapore), World Bridge Land (Cambodia)	300	south of Australian embassy in Tonle Bassac commune, Chamkarmon district	1.5ha	2018	45Fx2 (700 units, 4F super market, offices)
Parkson	Parkson Holding Bhd (Malaysia)		opposite side of Phnom Penh International Airport	70,000m^2	2017	
Aeon Phnom Penh Mall	Aeon (Japan)	205	Sothearos Blvd.	68,000m^2	June of 2014	5 malls more in Phnom Penh
Times Centre	Taiwan and local		near Olympic Stadium at the west end of Sihanouk Blvd.	8,557m^2	2017	38Fx2, 40F (1,583 units, etc.)

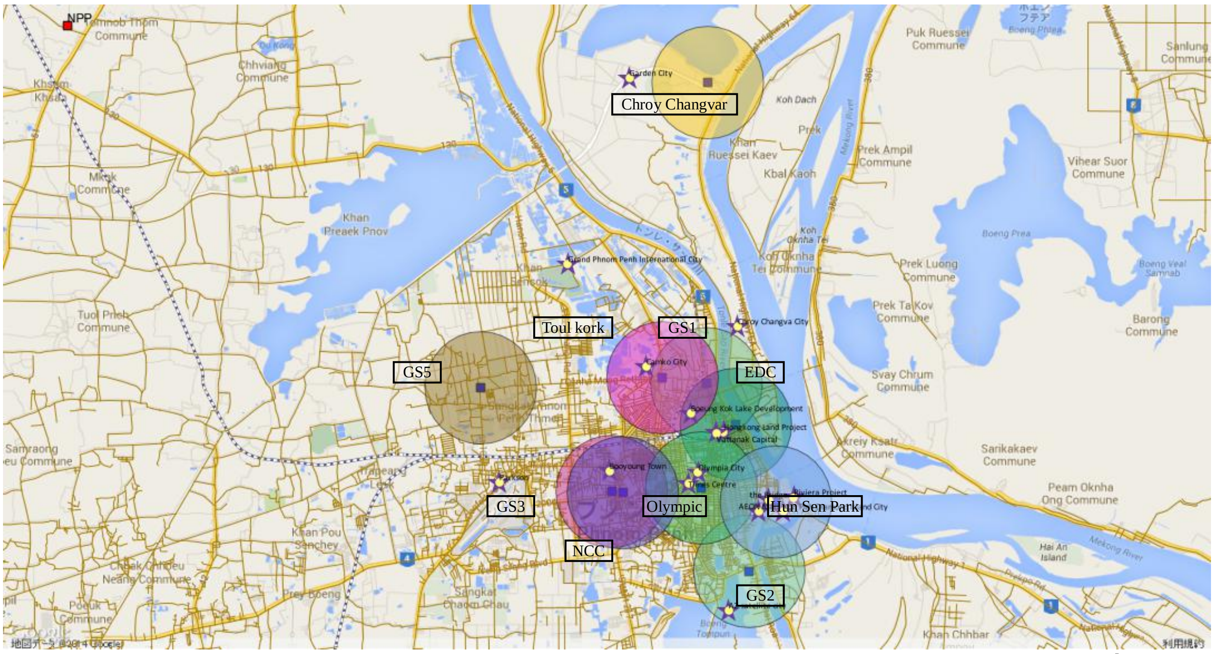
Source: JICA Study Team

Therefore, demand of each big development projects is forecasted by the example of AZ Satellite City, which was studied by "Study on the Environment-Friendly Smart Community in Phnom Penh, the Kingdom of Cambodia, Feasibility Study for Promotion of International Infrastructure Projects in FY 2011, November 2011", and development area. And it was forecasted under the condition that the project will complete in 2030. And demand of high-rise building and skyscraper is defined by the record of Canadian Tower (30F) which is around 3MW peak except fixed demand. Therefore 3MW per each building will be supplied in the completion year. According to the above result, demand forecast result until 2020 for big development projects and supply grid substation by Fig. 3.2-9 is shown in Table 3.2-7.

Table 3.2-7 Demand Forecast Result until 2020 for Big Development Projects

Name	Final Demand [MW]	Supplying GS	2015	2016	2017	2018	2019	2020
Garden City Project	174.6	Chroy Changvar	10.9	21.8	32.7	43.6	54.6	65.5
Chroy Changvar Development Zone (Chroy Changvar City)	67.6	Chroy Changvar	4.2	8.4	12.7	16.9	21.1	25.3
AZ Satellite City	50.7	GS2	3.2	6.3	9.5	12.7	15.8	19.0
Booyoung Town	47.1	NCC	2.9	5.9	8.8	11.8	14.7	17.7
Grand Phnom Penh International City	45.4	Toul Kork	2.8	5.7	8.5	11.3	14.2	17.0
Olympia City	39.0	Olympic Stadium		15.0	15.0	18.0	21.0	24.0
Phnom Penh City Center (Boeung Kok Lake Development)	23.2	Toul Kork	1.5	2.9	4.4	5.8	7.3	8.7
Camko City	20.8	Toul Kork	1.3	2.6	3.9	5.2	6.5	7.8
Koh Pich Diamond Island City	17.5	Hun Sen Park	1.1	2.2	3.3	4.4	5.5	6.5
Vattanak Capital	10.0	EDC	10.0	10.0	10.0	10.0	10.0	10.0
Hongkong Land Project	9.0	EDC		3.0	3.0	6.0	6.0	9.0
Casa Meridian Condo	6.0	Hun Sen Park			6.0	6.0	6.0	6.0
the Bridge	6.0	Hun Sen Park				6.0	6.0	6.0
Parkson	6.0	GS5			6.0	6.0	6.0	6.0
Aeon Phnom Penh Mall	5.8	Hun Sen Park	6.0	6.0	6.0	6.0	6.0	6.0
Times Centre	4.1	Olympic Stadium			4.1	4.1	4.1	4.1
Total			**43.9**	**89.9**	**133.8**	**173.8**	**204.7**	**238.6**

Source: JICA Study Team



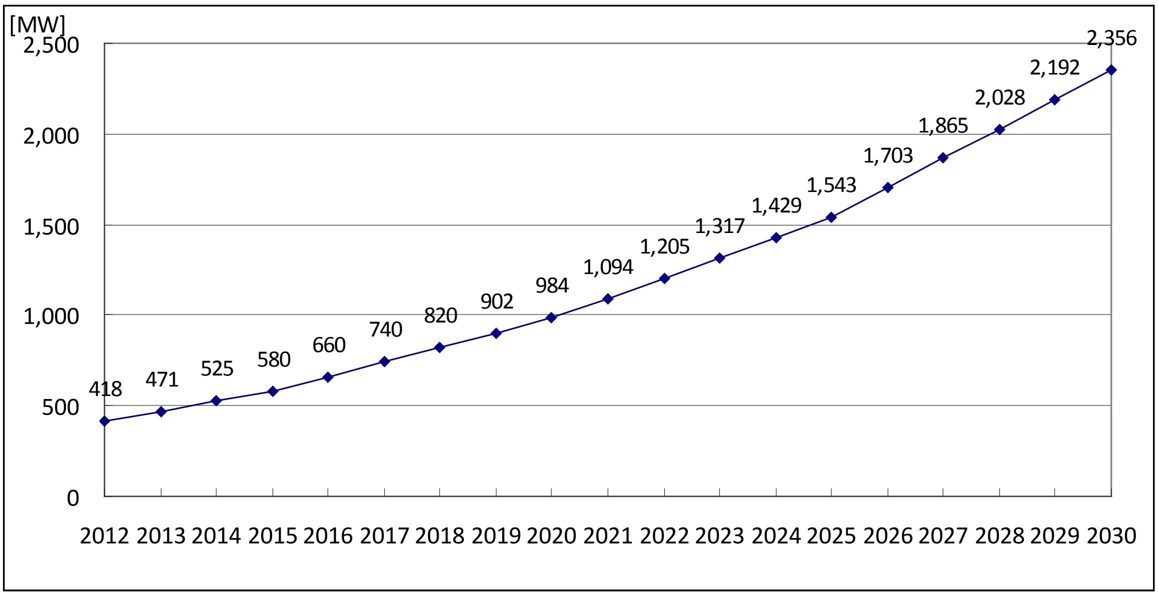
Source: JICA Study Team

* Circle shows radius 2km from each grid substation.

Fig. 3.2-9 Grid Substation and Big Project Location in Phnom Penh

c) Demand forecast result in Phnom Penh system in the power development plan

Demand forecast result at base case in Phnom Penh system including Phnom Penh City and Kandal Province is shown in Fig. 3.2-10.



Source: EDC

Fig. 3.2-10 Demand Forecast Result at Base Case in Phnom Penh System (Base Case)

Demand forecast result is demand for generation side. Therefore it should be deducted by 3% transmission loss rete as commonly used for each grid substation's demand. Demand forecast result for each grid substation in Phnom Penh system until 2030 is shown in Table 3.2-8. It is referred to big development projects and capacity of transformers.

Table 3.2-8 Peak Demand of Each Grid Substation in Phnom Penh System

Name	Current status	Transformer Capacity	2014 (March 31)	Divided demand	2020	2025	2030
National Demand			699.5		1,412	2,170	3,256
GS1	Existing	75MVAx2	103.6	28.7	86	134	205
GS2	Existing	50MVAx3	123.4	87.0	106	166	254
GS3	Existing	50MVAx3	109.6	77.2	103	161	246
GS4 (WPP)	Existing	50MVAx2	89.2	79.0	86	135	206
GS5 (SWS)	Existing	50MVAx2	40.1	40.1	78	123	188
GS6 (NPP)	Existing	50MVAx2	22.3	22.3	44	68	104
GS7 (SPP)	Under construction	50MVAx1		10.2	20	31	48
EDC HQ	Phase 1 project	75MVAx2		49.7	84	131	201
Hunsen Park	Under preparation	75MVAx2		16.5	76	120	183
Olympic Stadium	Phase 1 project	75MVAx2		16.3	60	94	144
NCC	Phase 2 project	75MVAx2*		30.0	57	89	136
Toul kork	Phase 2 project	75MVAx2*		20.8	57	90	138
Chroy Changvar	Phase 2 project	75MVAx2*		10.6	98	153	234
		*tentative capacity	488.2		954	1,496	2,285

Source: JICA Study Team

In 2020, which is the target year for this project, supply capacity including the new grid substation studied in this survey is enough. But in 2025, 1,496MW as the peak demand will be over total capacity of transformers as 1,475MVA (in the case of only one 75MVA transformer at NCC, Toul Kork and Chroy Changvar GS) in Phnom Penh system. Therefore the new grid substation or the additional transformers have to be considered.

3.3 SYSTEM ANALYSIS OF THE PHNOM PENH SYSTEM

3.3.1 Analysis Conditions

In consideration of the demand forecast by 2020 in Phnom Penh described previously, system analysis of the Phnom Penh system is carried out for study and evaluation of the transmission and substation facility expansion plan which is the target of a preliminary design of the Phnom Penh Transmission and Distribution System Expansion Project which is the purpose of this Preparatory Survey. PSS®E (made by SIEMENS) which is the system analysis software currently used also in EDC is used for system analysis.

In this Preparatory Survey, it is assumed that the new facilities already planned and all the new facilities planned with this project are operated by the peak season in 2020 and the year for study of system analysis is set to 2020.

Generally, since the power flow conditions of a system differ in an aspect by a peak time and an off-peak one, system analysis is also carried out to both time. However, since a peak time is assumed to be the severest heavy power flow conditions from the following special situations in the case of Phnom Penh, in this Preparatory Survey, only a peak time is made applicable to study. That is, there are CEP and KEP which are the IPP plants using heavy oil in Phnom Penh in the city, and when a high-water season and cheap import power can be procured, such IPP plants are stopped from the reason of economic efficiency. The power demand in Phnom Penh is then supplied by 230kV or 115kV transmission line from the surrounding area. Therefore, if IPP plant stops at the peak period of the power demand in Phnom Penh, power flow conditions will be in the severest state. The power supply from the surrounding area is divided roughly into the supply from the northern part in Phnom Penh, and the supply from the southern part. That is,

- Southern part: Import power from Vietnam, coal-fired power plants which are due to be developed in the Sihanoukville area.

- Northern part: Hydropower plants which are due to be developed in the mid-west of Cambodia.

Although output adjustment of the northern part power supply and the southern part power supply is possible in a high-water season, it is forced to depend on the southern part power supply and most flexibility of adjustment is lost in a dry season. Therefore, in this Preparatory Survey, the dry season is made target for this Study.

3.3.2 Reliability Conditions

The reliability criteria applied by this Study are shown in Table 3.3-1.

Table 3.3-1 Reliability Criteria

Normal System Conditions	◊ Power flow does not exceed the rated capacity of facilities. ◊ Voltage is maintained properly.
Contingency Conditions (N-1)	◊ Power flow does not exceed the emergency capacity of facilities.

Source: JICA Study Team

The voltage proper range at the normal system conditions is determined as within the limits of ±10% of reference voltage by EDC. However, it is reported by "Final Report of Data Collection Survey on Electric Power Sector in Cambodia", JICA, March 2012" that the voltage of 115kV and 22kV system is within the limits of ±5% of reference voltage in general as a track record but the voltage of a 230kV system is shifting lowness since the reference voltage of Vietnam is 220kV. Therefore, in this Preparatory Survey, the 115kV system voltage at the normal system conditions is set as the value in the range about 115kV ± 5%. Besides, since the voltage of a 230kV system is lower at the normal system conditions, as a reliability criterion at the contingency conditions, a voltage variation is carried out the outside of the target.

The emergency capacity of facilities (overhead transmission lines, underground transmission lines and transformers) is made into 150% of each rated capacity.

3.3.3 System Composition Plan

The Project component is mainly divided into the following two objectives.

- Measure for power demand increase in Phnom Penh City
- Power supply to the development area

(1) Measure for power demand increase in Phnom Penh City

As the result of system analysis at the time of 2020 in The Preparatory Survey Project Phase 1, several system composition plans and power flow patterns were compared. As shown in Fig. 3.3-1 as an example, it is reported that the transmission line (250MVA) between GS2 and Hun Sen Park is overloaded at all times. As a countermeasure, introduction of 230kV system to the center of Phnom Penh is proposed.

Construction of 230/115/22kV GIS substation (planned to be constructed inside NCC) and 230kV overhead transmission line and underground cable (π junction) between the middle point of NPP/WPP and NCC proposed in this Project is the countermeasure (Alternative 1). On the other hand, as an alternative plan, expansion of GS5 to 230/115/22kV substation and alternative route of 230kV transmission line (construction of double circuit overhead transmission line (π junction) between the middle point of NPP/WPP and GS5 and a single circuit underground cable between GS5 and NCC substation) are indicated (Alternative 2).

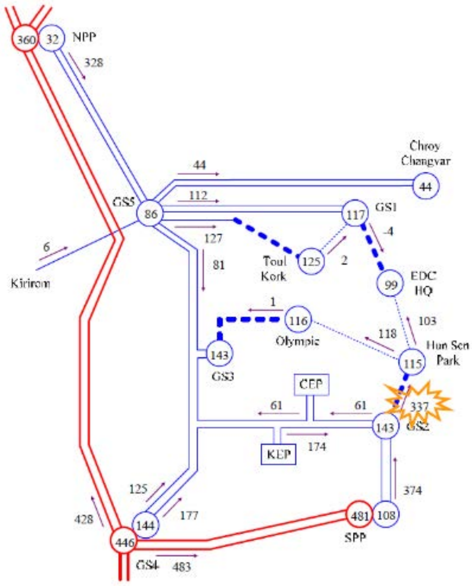
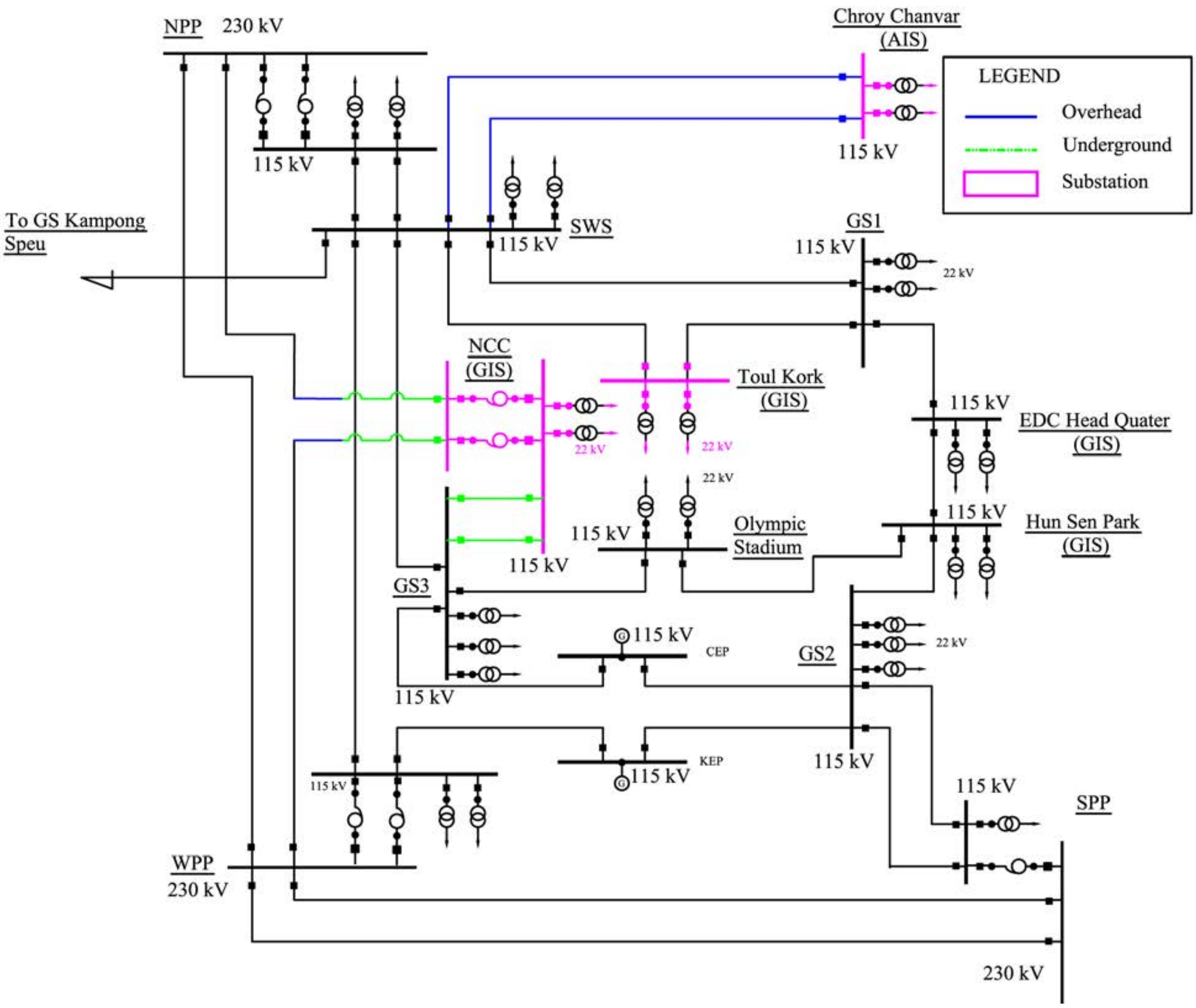


Fig. 3.3-1 Example of Effective Power Flow (2020)

Source: JICA Study Team

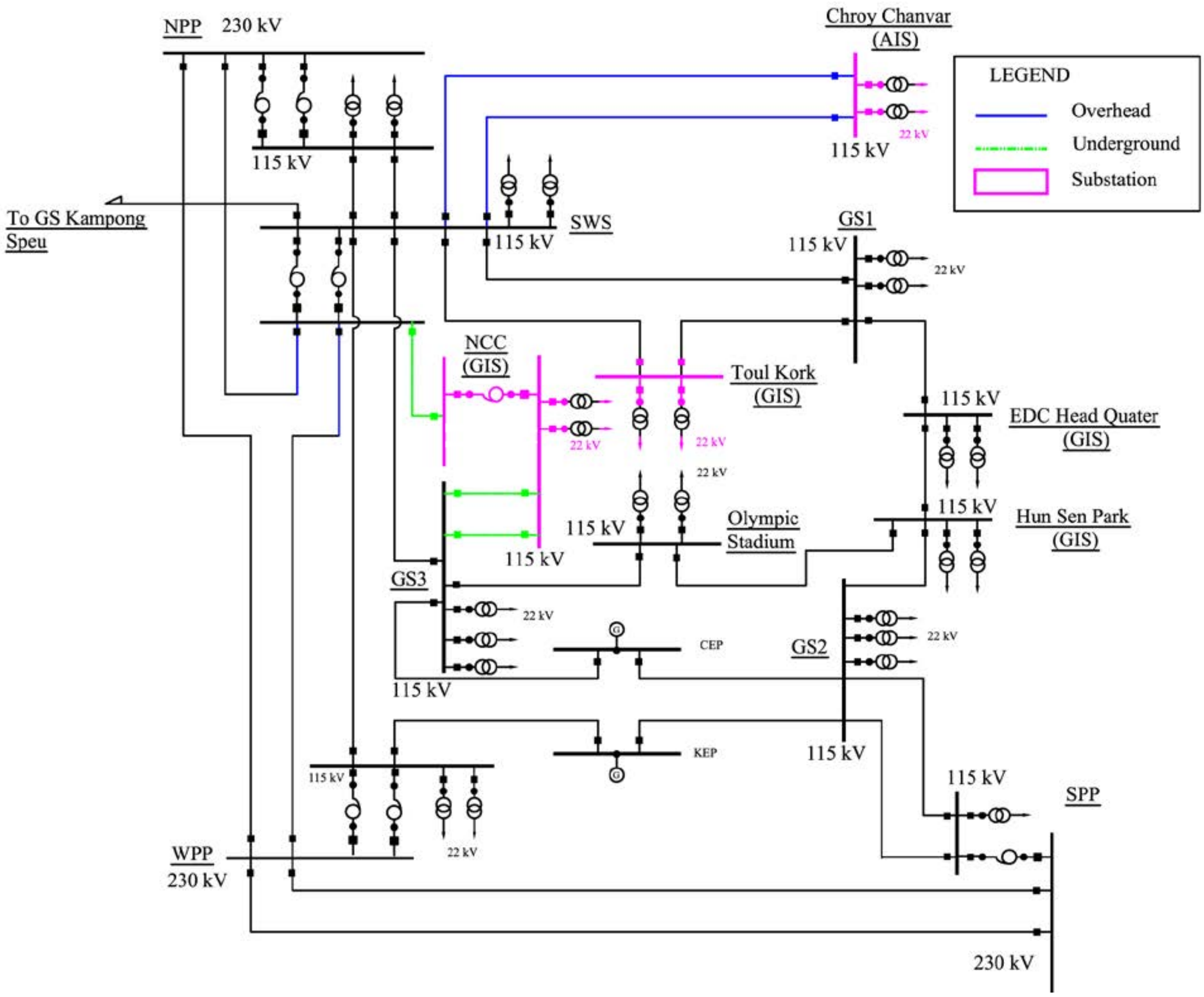
Besides, based on discussion with EDC, in the case of Alternative 1, NCC is 2 bank operation, but in the case of Alternative 2, it is considered as 1 bank operation.

Each Alternative is shown in Fig. 3.3-2 and Fig. 3.3-3.



Source: JICA Study Team

Fig. 3.3-2 Alternative 1



Source: JICA Study Team

Fig. 3.3-3 Alternative 2

(2) Power supply to the development area

There is a large scale development plan of the new city such as stadium and housing estate plan in Chroy Changvar area. Therefore, fundamental measure for power supply is required as there are only two 22kV distribution lines extended to this area at present. As a part of the Project component, construction of 115/22kV AIS substation in Chroy Changvar and double circuit overhead transmission line between GS5 and Chroy Changvar substations are proposed.

Besides, increasing demand is expected in Toul Kork area in the future. Construction of 115/22kV GIS substation in Toul Kork and double circuit overhead transmission line (π junction) between the middle point of GS1/GS5 and Toul Kork substations, are planned (Alternative A).

However, double circuit overhead transmission line connected to NCC substation and interconnection route with GS5 by a single circuit underground cable are indicated for Toul Kork substation as a countermeasure (Alternative B).

These two Alternatives are applied to two Alternatives shown in (1) above, and each schematic view is shown in Fig. 3.3-4 from Fig. 3.3-7.

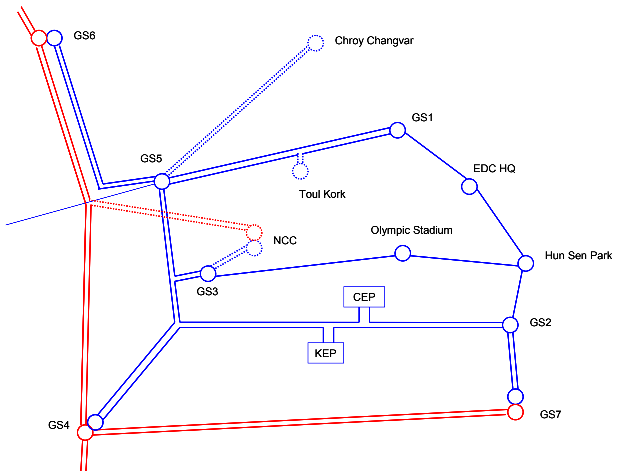


Fig. 3.3-4 Alternative 1-A

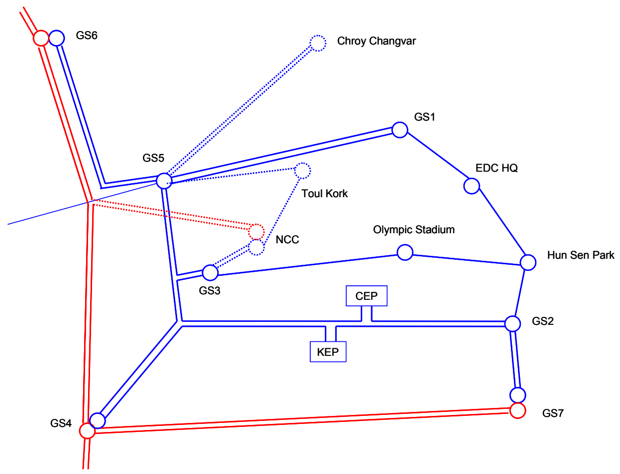


Fig. 3.3-5 Alternative 1-B

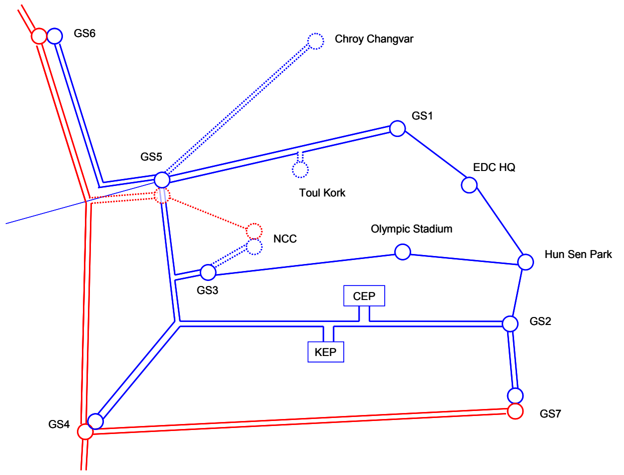


Fig. 3.3-6 Alternative 2-A

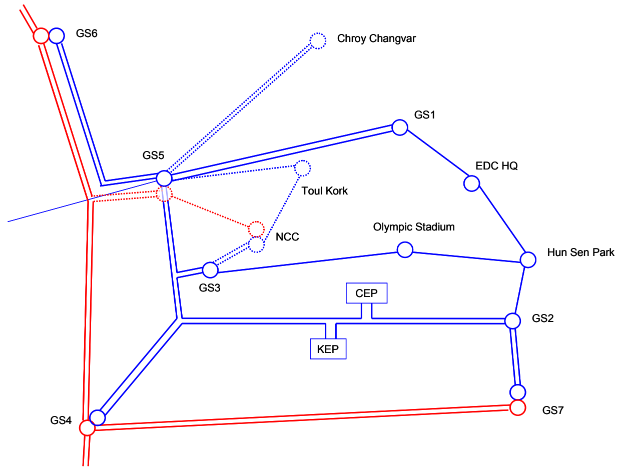


Fig. 3.3-7 Alternative 2-B

Source: JICA Study Team

(3) Power system operation

Although each system composition plan shown in this section is the composition of a loop system, it is generally employed as a radial system in a city system in many cases from the reasons of the ease of power flow and voltage control, specification of the fault range, and relay setting etc. However, based on discussion with EDC, both a loop system and a radial system are made to target for this Study.

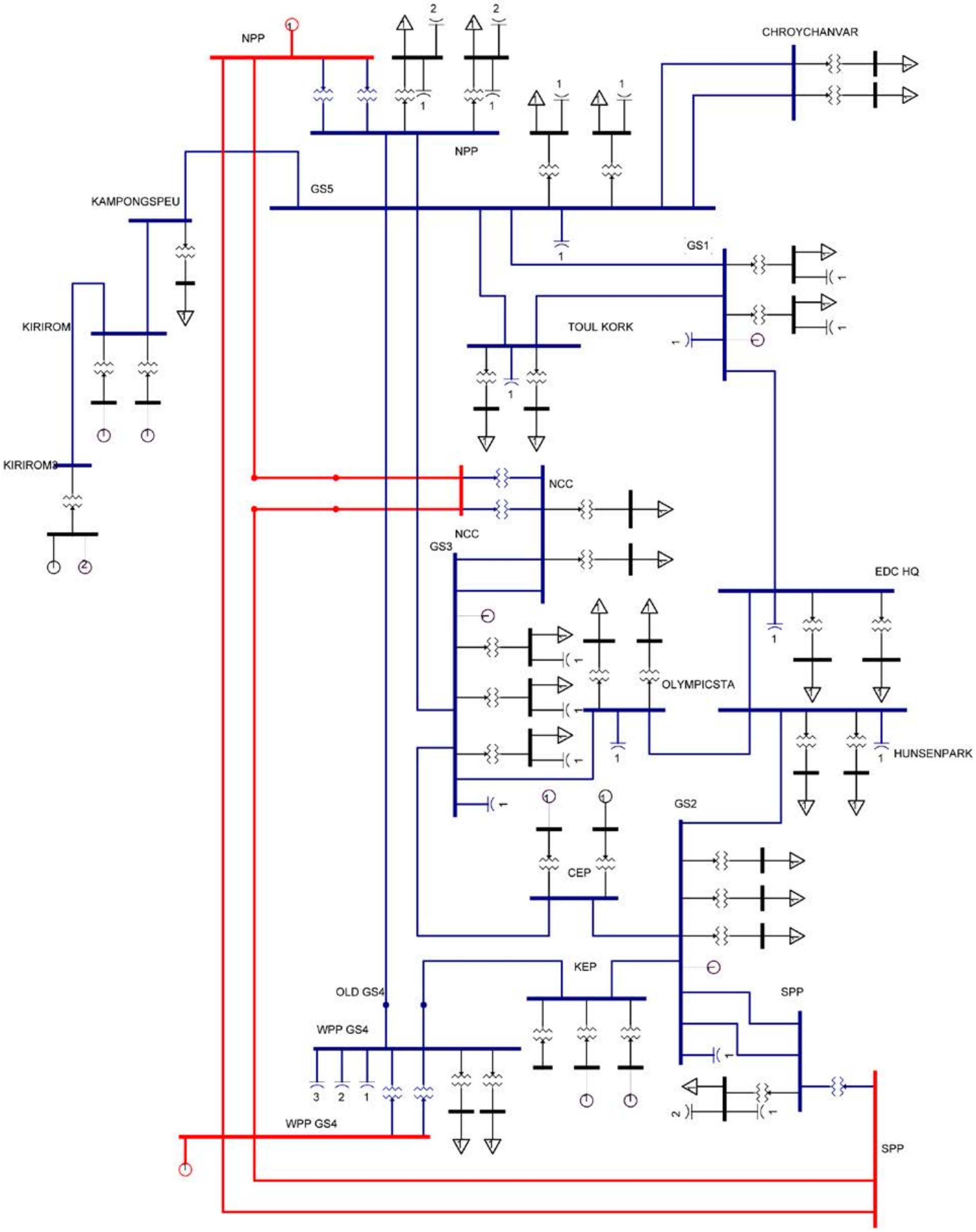
3.3.4 System Analysis Result

System analysis for contributing to determination of an optimal plan which would be described in Chapter 5 "Determination of the Project Component Targeting for Preliminary Design" was carried out to the system composition plan shown in the foregoing paragraph.

Power flow analysis and N-1 analysis were carried out and each result is shown below.

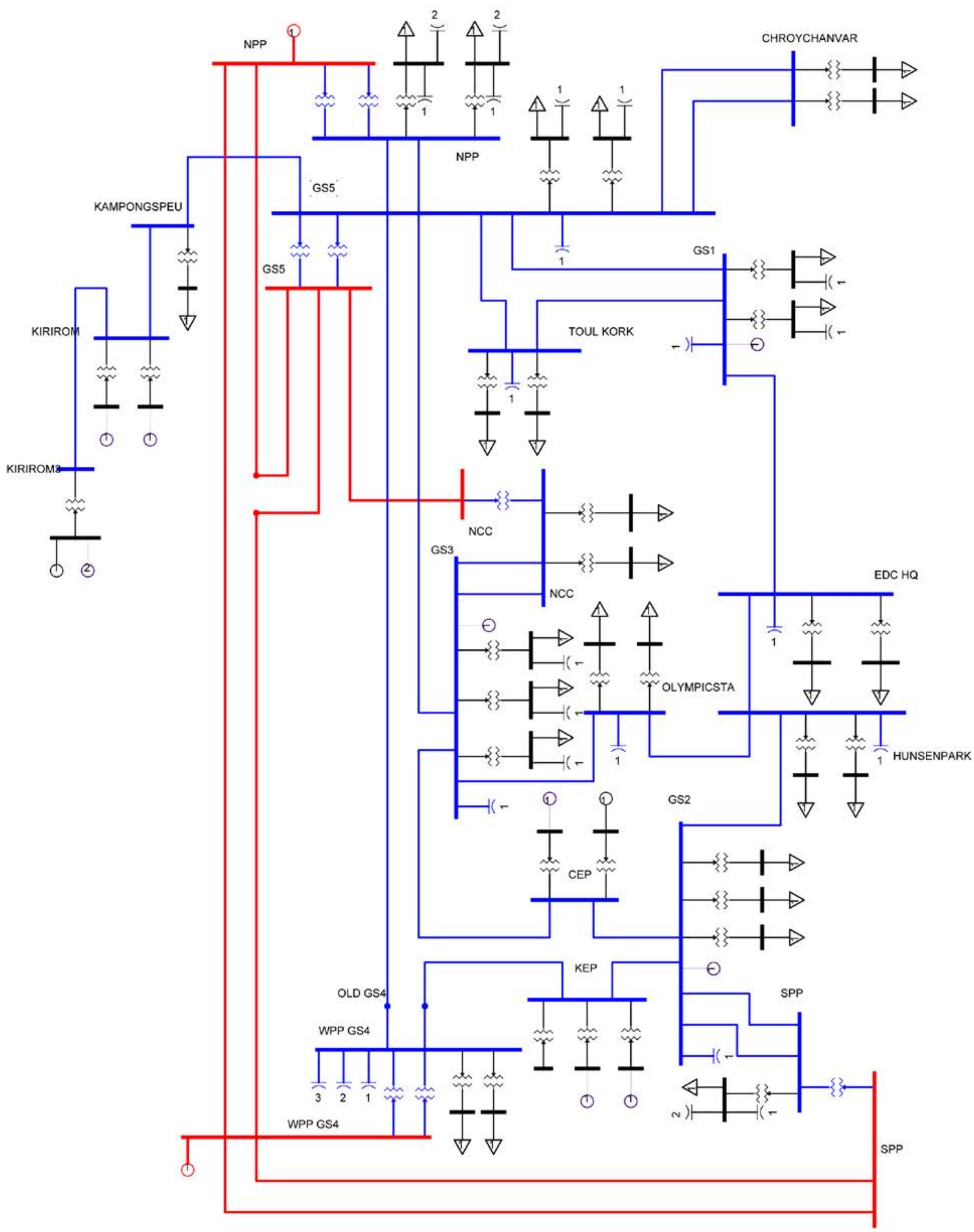
In order for system voltage to drop with the increase in demand, it is necessary to maintain voltage appropriately by SC (Shunt Capacitor). In this analysis, all existing SC was installed and SCs of 320 MVar were installed in Phnom Penh based on the result, which is described in the Final Report of "Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project", JICA, November 2013, that SC of about at least 300 MVar is needed in the city in order to maintain system voltage properly in 2020. Besides, since the distance between the substations in Phnom Penh is short, even if the amount of installation of SC to each substation is adjusted, there is no large impact.

The single line diagram of the used system model (in the case of a Loop system) is shown in Fig. 3.2-8 and Fig. 3.2-9 about Alternative 1-A and Alternative 2-A, respectively.



Source: JICA Study Team

Fig. 3.3-8 Single Line Diagram (Alternative 1-A, Loop System)



Source: JICA Study Team

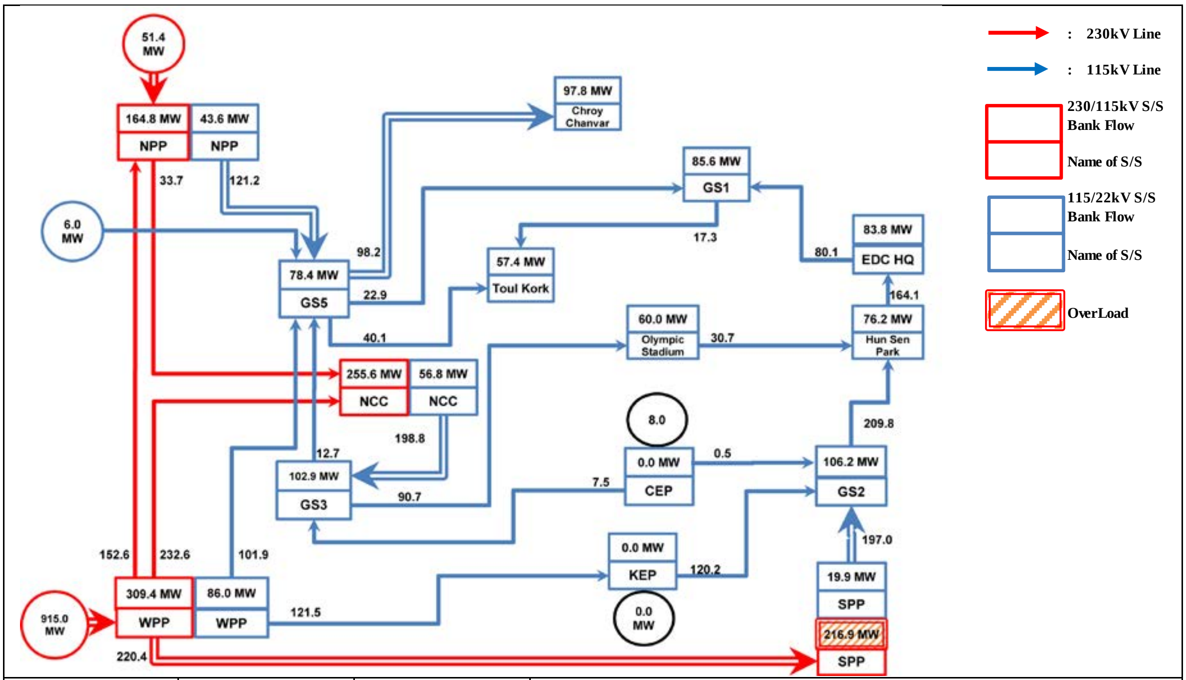
Fig. 3.3-9 Single Line Diagram (Alternative 2-A, Loop System)

(1) Loop system

The analysis result of Alternative 1 and Alternative 2 in the case of a loop system is shown in Fig. 3.2-10 and Fig. 3.3-11. In both cases, the overload occurred with the transformer of SPP at normal conditions.

(2) Radial system

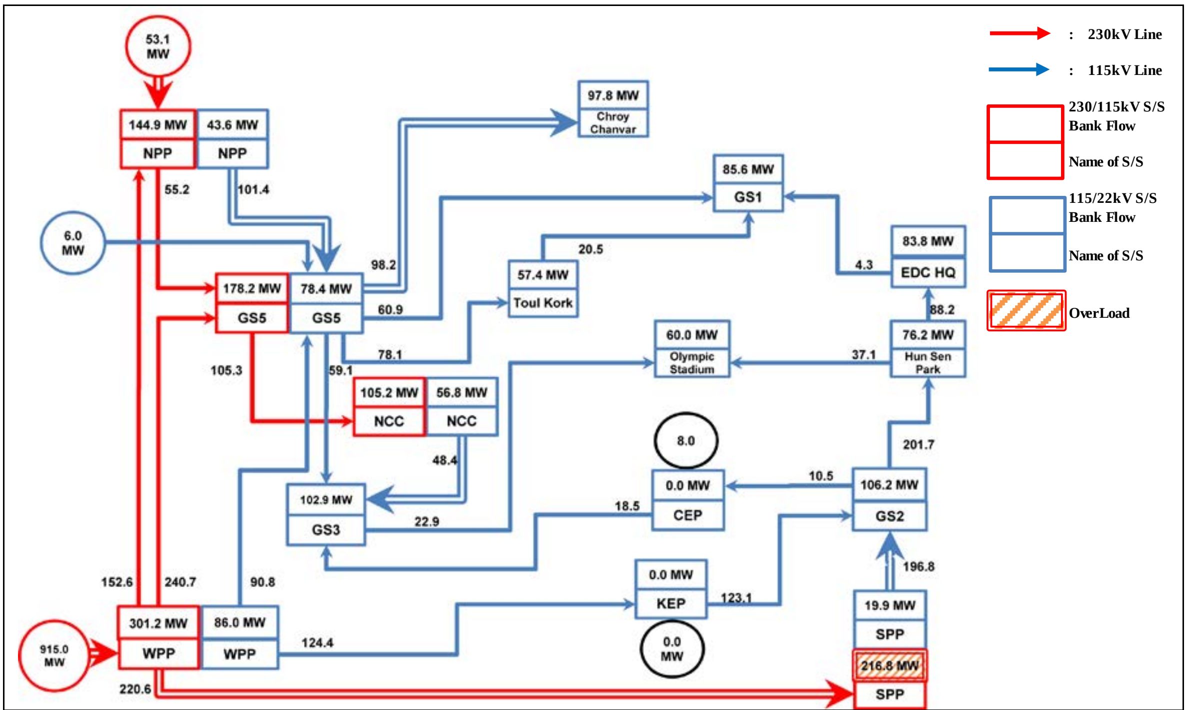
The analysis result of Alternative 1-A and Alternative 2-A in the case of a radial system is shown in Fig. 3.3-12 and Fig. 3.3-13. In the case of Alternative 1-A, the overload occurred in both the case of normal condition and N-1, but in the case of Alternative 2-A, there was no problem. Therefore, Alternative 1 has a problem in reliability. The analysis result of Alternative 2-B is shown in Fig. 3.3-14. There is also no problem in the case of Alternative 2-B.



System Loss	Reliability	Power Flow	Overloaded at SPP 230/115kV Tr. (109%, 217.5MVA)
26.18MW		N-1	---

Source: JICA Study Team

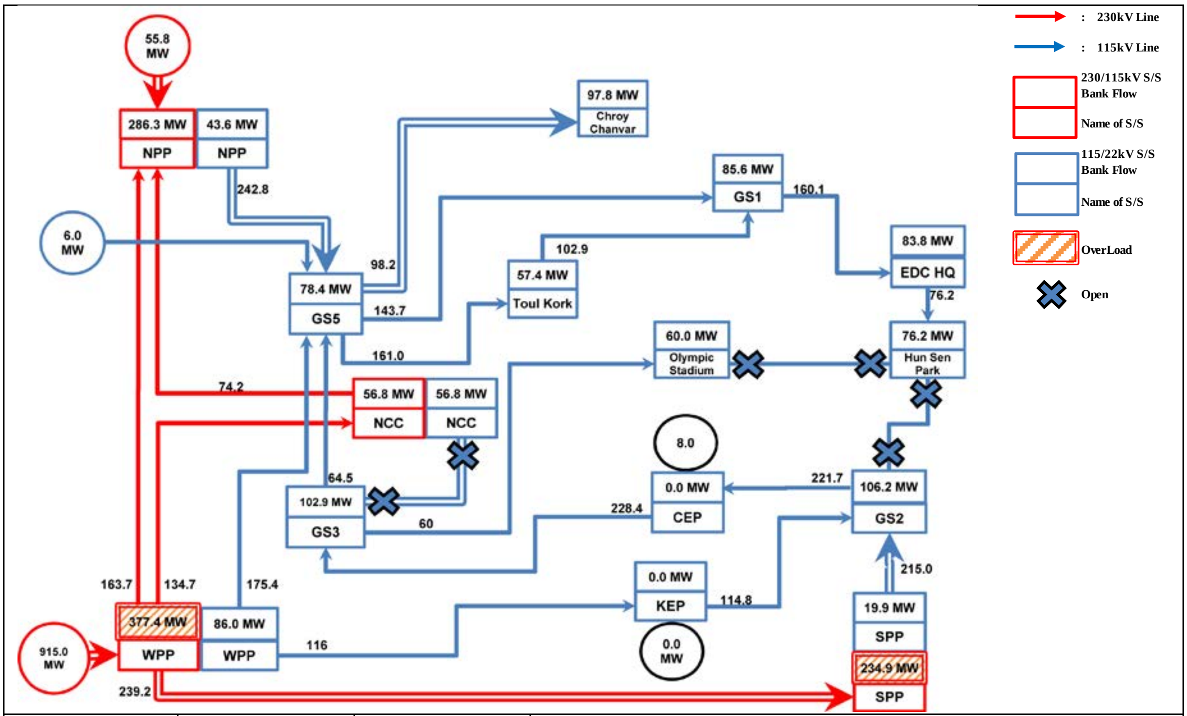
Fig. 3.3-10 Alternative 1-A, Loop System



System Loss	Reliability	Power Flow	Overloaded at SPP 230/115kV Tr. (111%, 222.1MVA)
27.62MW		N-1	---

Source: JICA Study Team

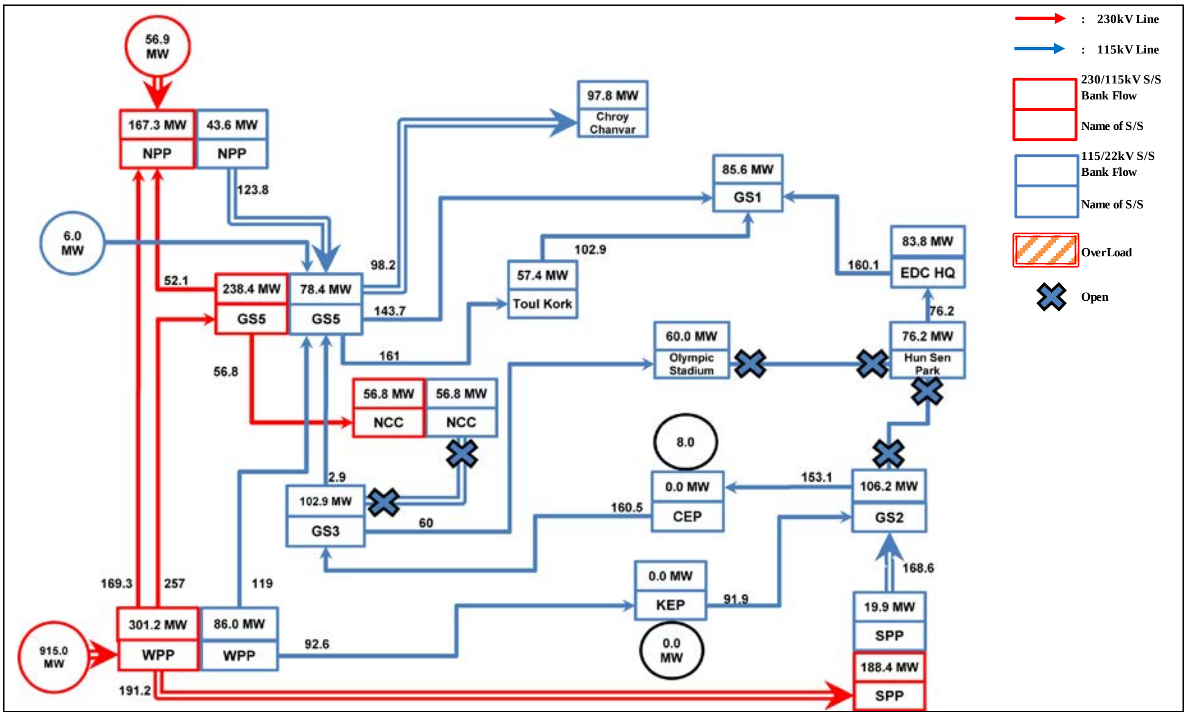
Fig. 3.3-11 Alternative 2-A, Loop System



System Loss	Reliability	Power Flow	Overloaded at SPP 230/115kV Tr. (118%, 235.9MVA)
30.29MW		N-1	Overloaded at GS4 230/115kV Tr. (160%)

Source: JICA Study Team

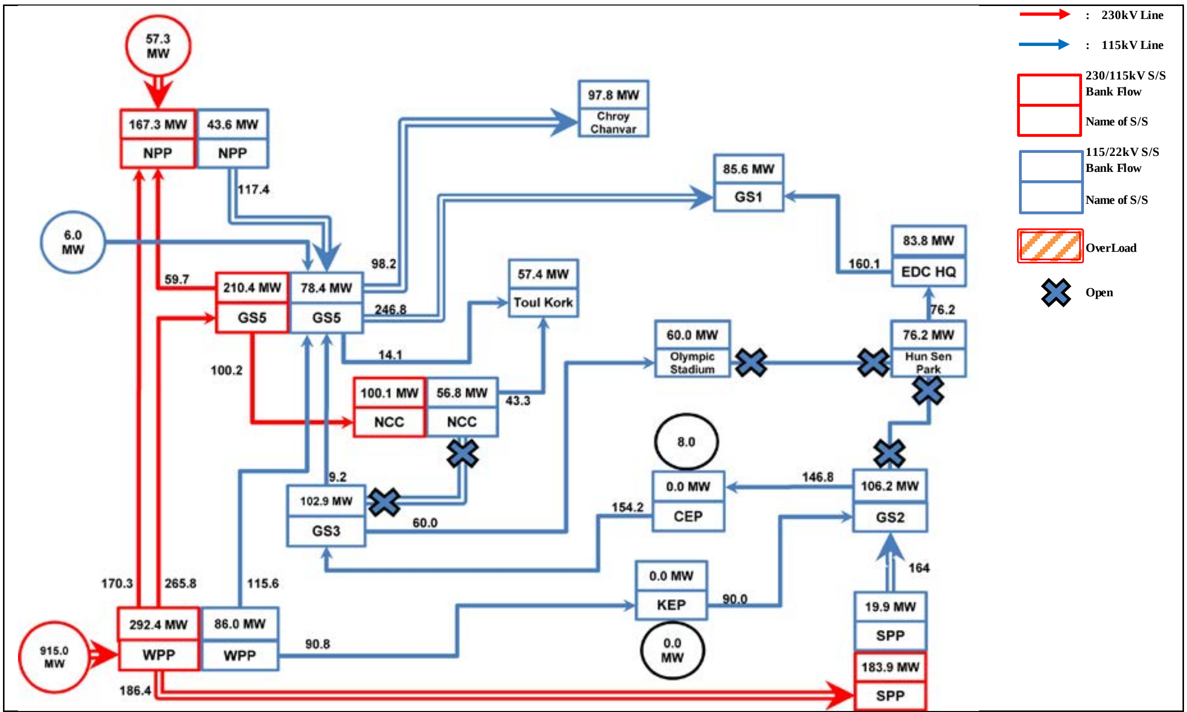
Fig. 3.3-12 Alternative 1-A, Radial System



System Loss	Reliability	Power Flow	---
31.41MW		N-1	---

Source: JICA Study Team

Fig. 3.3-13 Alternative 2-A, Radial System



System Loss	Reliability	Power Flow	---
31.75MW		N-1	---

Source: JICA Study Team

Fig. 3.3-14 Alternative 2-B, Radial System

3.3.5 Other System Analysis Results

While advancing discussion with EDC in this study, some possibilities of a different alternative plan from the fundamental system composition proposal shown until now were suggested.

The system analysis results about those alternative plans are described in this section. Besides, each case shown in this section uses as a base the loop system of Alternative 2-A shown in Fig. 3.3-9 and Fig. 3.3-11.

(1) Alternative plans

The detailed alternative plan is as follows.

(a) Route change of 230kV overhead transmission lines

It is the proposal to construct the 230kV 2cct overhead transmission lines which connect a middle point of the NPP and the WPP and the GS5 along with the route of the existing 115kV transmission line and the railway (The existing 115kV transmission line equipment is removed.). The line length of the 230kV transmission lines are shortened from 10.6km to 10.2km by this route change.

(b) Line-type change of 230kV overhead transmission lines

It is the proposal to change into TACSR[2] 610mm^2 × 2 (1,359MVA/cct) from ACSR[3]

[2] Thermal-resistant Aluminum alloy Conductor Steel Reinforced
[3] Aluminum Conductor Steel Reinforced

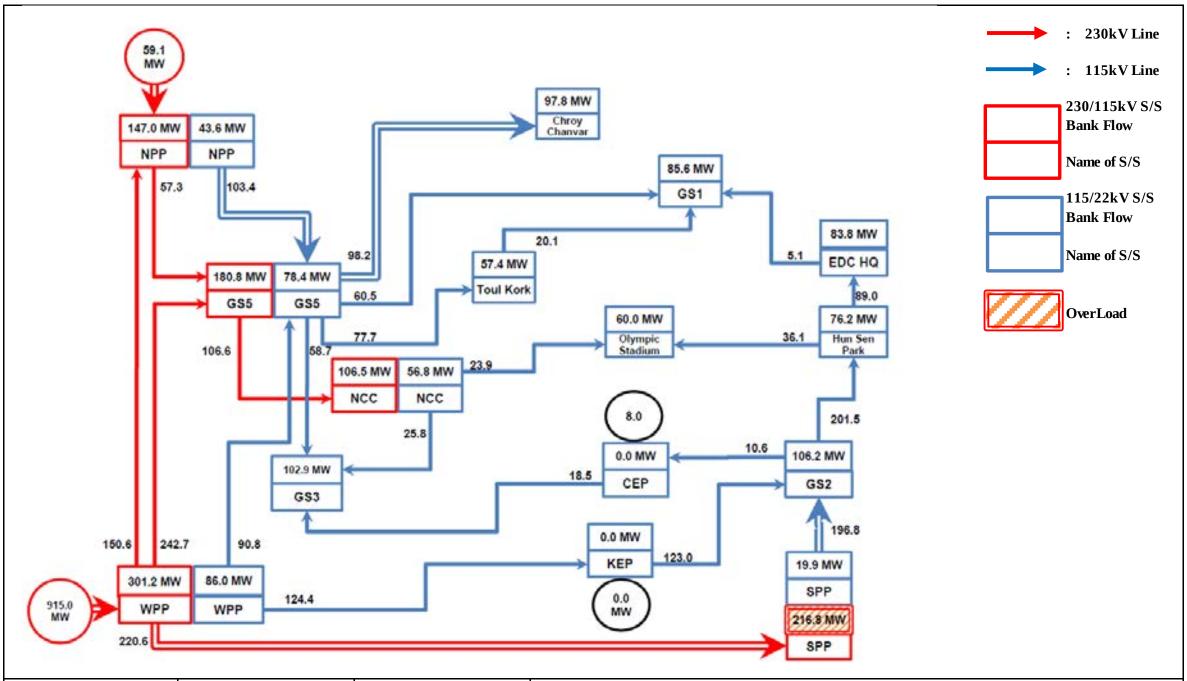
632mm^2 × 2 (861MVA/cct) the line type of the 230kV 2cct overhead transmission lines which connect a middle point of the NPP and the WPP and GS5. Since the line constants of both line types are almost the same, the data for analysis is not changed.

(c) Underground transmission cable route change between Olympic Stadium-GS3

It is the proposal to change into the route via the NCC substation the route of the underground transmission cable which connects the Olympic Stadium substation and the GS3. The cable line type shall be planned by Phase 1 and the line length between the Olympic Stadium substation and the NCC substation is set to 4km.

The analysis result of the above alternative plans is shown in Source: JICA Study Team

Fig. 3.3-15. This result shows that there is no problem regarding power flow analysis and N-1 analysis, even when the alternative plans, (a) – (c), are carried out. However, in the SPP, an overload occurs like the result shown in Fig. 3.3-11.



System Loss	Reliability	Power Flow	Overloaded at SPP 230/115kV Tr. (111%、 222.3MVA)
27.48MW		N-1	---

Source: JICA Study Team

Fig. 3.3-15 Alternative 2-A, Loop System (as an alternative plan)

(2) The maintaining voltage of the system by SC arrangement

(a) Case 1

In the analysis shown in the foregoing paragraph, all the existing SC was installed. At the same time, in order to maintain system voltage proper, in 2020 shown in the report of The Preparatory Survey Project Phase 1, based on the result that SC about 300 MVar is needed in Phnom Penh at least, an equivalent amount of SC(s) were installed in Phnom Penh. At the same time, in order to maintain system voltage proper, based on the result shown in the report of The Preparatory Survey Project Phase 1 that SC about 300 MVar is needed in

Phnom Penh at least, an equivalent amount of SC(s) were installed in Phnom Penh. Here, in order to reconfirm the necessity, the status of the system voltage with only existing SC was confirmed. Besides, it was targeted at the alternative plans shown by (1) as system composition.

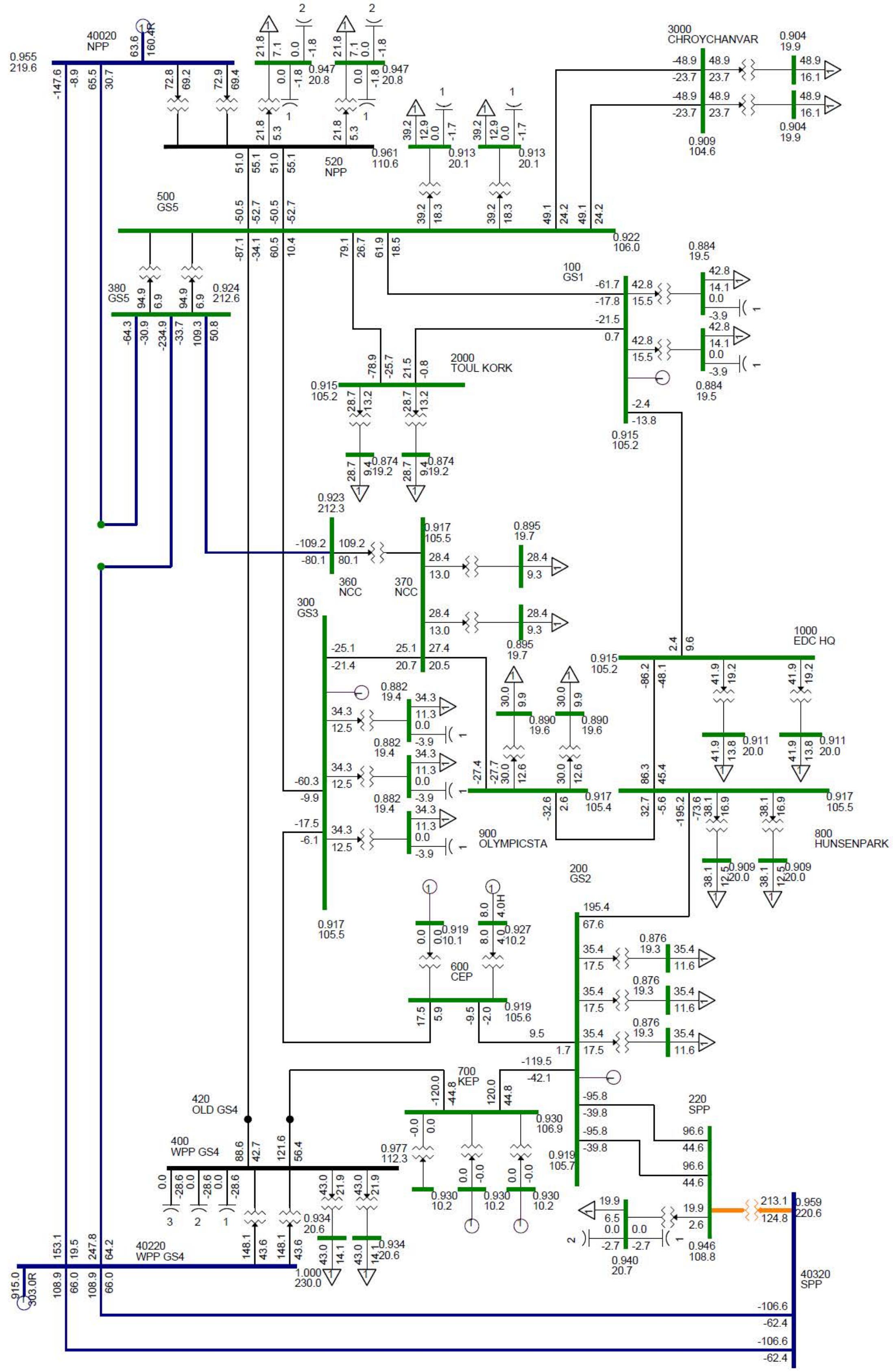
The amount of existing SC installation is shown in Table 3.3-2.

Table 3.3-2 Amount of Existing SC Installation

Substation	Shunt Capacitor (MVAR*units)	Voltage Level (kV)
Existing SC		
GS1	5*2	22
GS3	5*3	22
GS4	30*3	115
GS5	2*2	22
NPP	2*4	22
SPP	3*2	22

Source: JICA Study Team

As shown in Fig. 3.3-16, it was confirmed that voltage of each 115kV and 22kV bus is unmaintainable within ±5% of reference voltage only by existing SC.



Source: JICA Study Team

Fig. 3.3-16 Single Line Diagram and Bus Voltage (SC: Case-1, Existing SC Only)

(b) Case 2

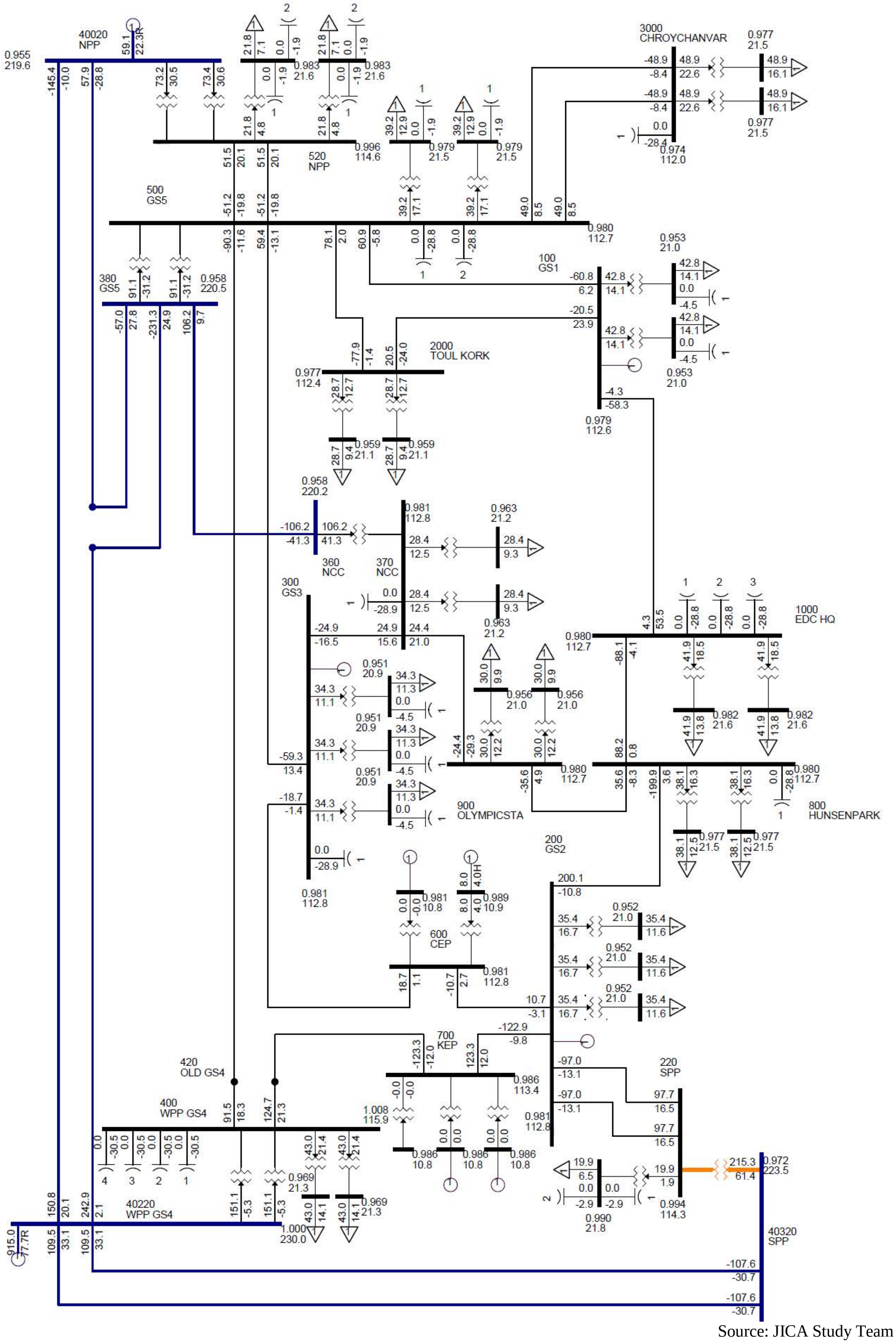
It was confirmed whether system voltage could maintain proper with the proposal regarding the point and quantity of installation of SC which are shown in Table 3.3-3.

The result confirmed that voltage of each 230kV, 115kV, and 22kV bus was maintainable within ±5% as shown in Fig. 3.3-17

Table 3.3-3 Amount of Existing and New SC Installation

Substation	Shunt Capacitor (MVAR*units)	Voltage Level (kV)
Existing SC		
GS1	5*2	22
GS3	5*3	22
GS4	30*3	115
GS5	2*2	22
NPP	2*4	22
SPP	3*2	22
New SC (Existing S/S)		
GS3	30*1	115
GS4	30*1	115
GS5 (SWS)	30*2	115
New SC (Phase 1)		
EDC HQ	30*3	115
Huns Sn Park	30*1	115
New SC (Phase 2)		
NCC	30*1	115
Chroy Changvar	30*1	115

Source: JICA Study Team



Source: JICA Study Team

Fig. 3.3-17 Single Line Diagram and Bus Voltage(SC: Case-2, Existing SC and New Installation)

3.4 PRIORITY MEASURES AGAINST SYSTEM ISSUES

The system analysis of the Phnom Penh system was described in the foregoing paragraph. An overload occurs with the transformer (200MVA) of SPP in many cases, this transformer may become a bottleneck of the Phnom Penh system in the future, and the necessity for transformer extension is high. However, the study which also combined the relation with the 230kV outer system of SPP-EPP-WPP is required.

CHAPTER 4

RESULTS OF SITE SURVEY

CHAPTER 4 RESULTS OF SITE SURVEY

4.1 OVERHEAD TRANSMISSION LINE ROUTE

Route selection of overhead transmission lines is the basics of transmission line construction, and its success has a major effect on aspects of economic efficiency, facility reliability, execution of work and maintenance as well as on difficulty of procuring land. Therefore, noted the following during the route selection process, and selected the technically and environmentally harmonized route.

① Economical route
② Route with high reliability and ease of maintenance
③ Harmonized economic efficiency and reliability
④ Harmony with local community

The list of overhead transmission line routes checked in the field survey is shown in Table 4.1-1. The field survey of each route proposal is shown in Fig. 4.1-1 to Fig. 4.1-6. As the result of this study, OHL_Route1 and OHL_Route8 were removed from this Study

Table 4.1-1 List of Overhead Transmission Line Routes

Route	Location		Voltage	Circuit	Remarks
	From	To			
OHL_Route1	Midpoint of NPP and WPP	NCC S/S	230kV	2	UG_Route2
OHL_Route3	Midpoint of NPP and WPP	GS5	230kV	2	UG_Route4
OHL_Route6	GS5	Chroy Changvar S/S	115kV	2	
OHL_Route7	Midpoint of GS5 and GS1	Toul Kork S/S	115kV	2	
OHL_Route8	GS5	Toul Kork S/S	115kV	1	

: The routes removed from this project as a result of the first field survey.

(1) OHL_Route1

OHL_Route1 is double circuit overhead transmission line which branches at the midpoint of NPP and WPP and goes to the middle of NCC (National Control Center). OHL_Route1 is connected to UG_Route2. Since the Phnom Penh International Airport is near the route. The route which is not subject to the influence of the Phnom Penh International Airport as much as possible was selected. Plan1 is a route which makes UG_Route2 shortest. Plan2 is a route which makes OHL_Route1 shortest. Plan3 is a route which goes along a road. At the result of the consultation with EDC, if this route is adopted, Plan1 shall be adopted.

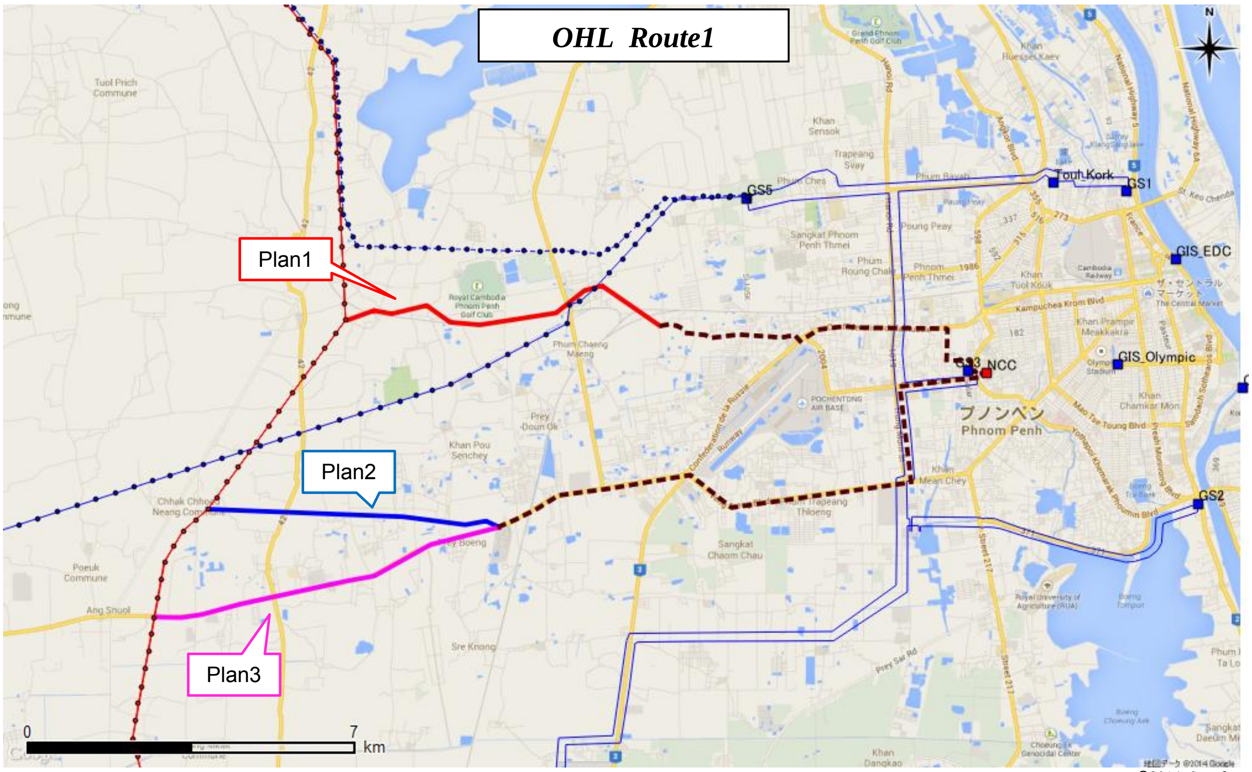


Fig. 4.1-1 Location Map of OHL_Route1

Table 4.1-2 Investigation Results of OHL_Route1

Route	Plan	Distance (UG_Route2)	Ease of Construction	Crossing house	Ease of land acquisition	Evaluation
OHL_Route1	Plan1	7.7km(8.3km)	A	A	B	A
	Plan2	6.4km(13.4km)	B	B	B	B
	Plan3	7.8km(13.4km)	C	C	C	C

*A : Recommend (Very good), B : Available (Good), C : Difficult (Bad)

(2) OHL_Route3

OHL_Route3 is double circuit overhead transmission line which branches at the midpoint of NPP and WPP and goes to GS5. Plan1 is a route which mainly goes along railway. Plan 2 is a route which goes along existing 115-kV TL. Plan3 is a route which makes distance shortest. Plan 4 is a route which utilizes the existing 115kV transmission line. In selection of a route, JICA Study Team considered the following three matters.

- There is no crossing of a residence and there are no land problems of a route as much as possible
- A branch steel tower is suitable for pi branch
- There are no problems in the foundation as much as possible

At the result of the consultation with EDC, Plan 4 shall be adopted.

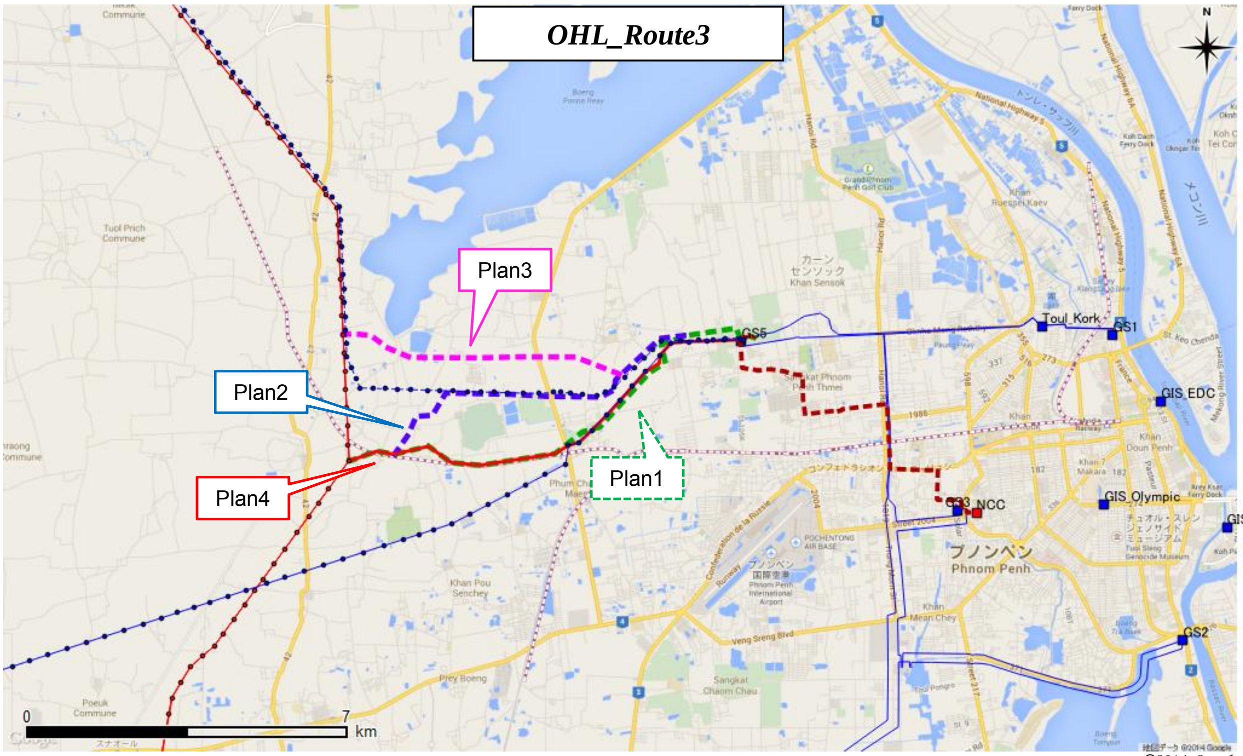


Fig. 4.1-2 Location Map of OHL_Route3

Table 4.1-3 Investigation Results of OHL_Route3

Route	Plan	Distance	Ease of Construction	Crossing house	Ease of land acquisition	Evaluation
OHL_Route3	Plan1	10.6km	A	A	B	B
	Plan2	10.2km	B	B	C	C
	Plan3	9.7km	C	B	B	C
	Plan4	10.2km	A	A	A	A

*A : Recommend (Very good), B : Available (Good), C : Difficult (Bad)

(3) OHL_Route6

OHL_Route6 is double circuit overhead transmission line which connects from GS5 to Chroy Changvar S/S. Except for existing 115kV TL crossing part, supporting structure adopts a concrete pole and a steel pipe pole from GS5 to a lake. From a lake to a Chroy Changvar S/S, supporting structure adopts a steel tower. Plan1 and Plan3 are routes which don't have a house in the crossing part of Tonle Sap River. Plan2 is a route which passes the bridge side by crossing of Tonle Sap River. Plan3 is a route of the alternatives about the part which has uncertainties by Plan1. At the result of the consultation with EDC, Plan 1 shall be adopted.

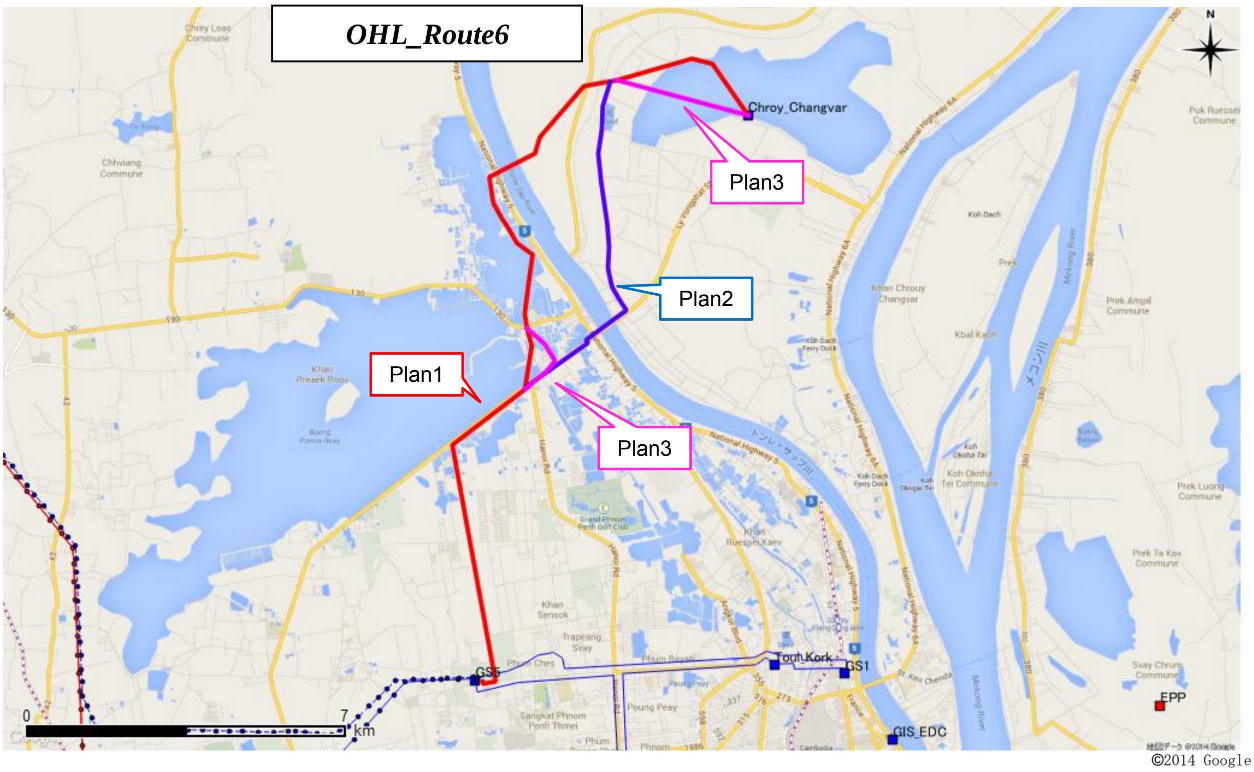


Fig. 4.1-3 Location Map of OHL_Route6

Table 4.1-4 Investigation Results of OHL_Route6

Route	Plan	Distance (km)	Ease of Construction	Crossing house	Ease of land acquisition	Evaluation
OHL_Route6	Plan1	20.2km	B	B	B	A
	Plan2	19.3km	C	C	C	C
	Plan3	20.1km	C	B	B	B

*A : Recommend (Very good), B : Available (Good), C : Difficult (Bad)

(4) OHL_Route7

OHL_Route7 is double circuit overhead transmission line which branches at the midpoint of GS5 and GS1 and goes to Toul Kork S/S. There is a concrete pole in the side of Toul Kork S/S. A steel pipe pole which design as a dead end pole shall be constructed and goes to S/S.

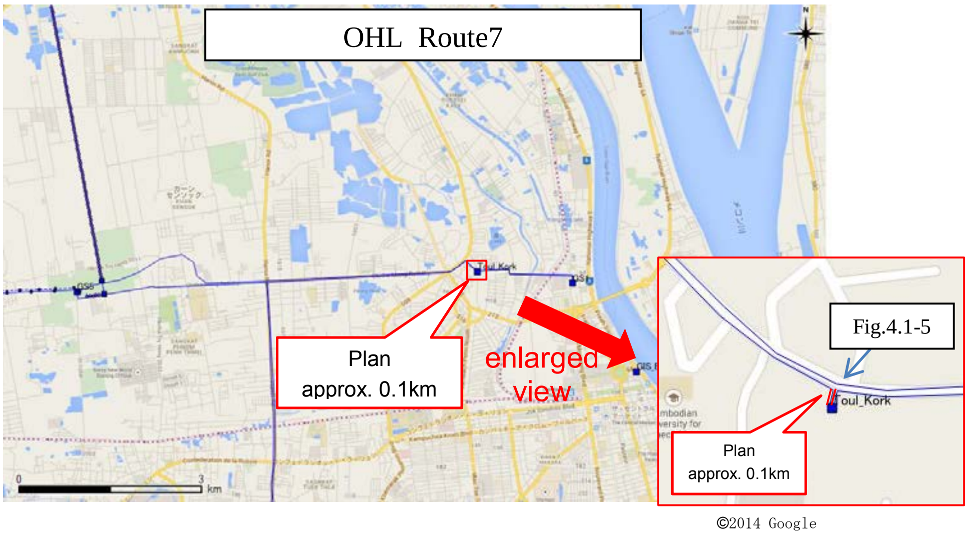


Fig. 4.1-4 Location Map of OHL_Route7

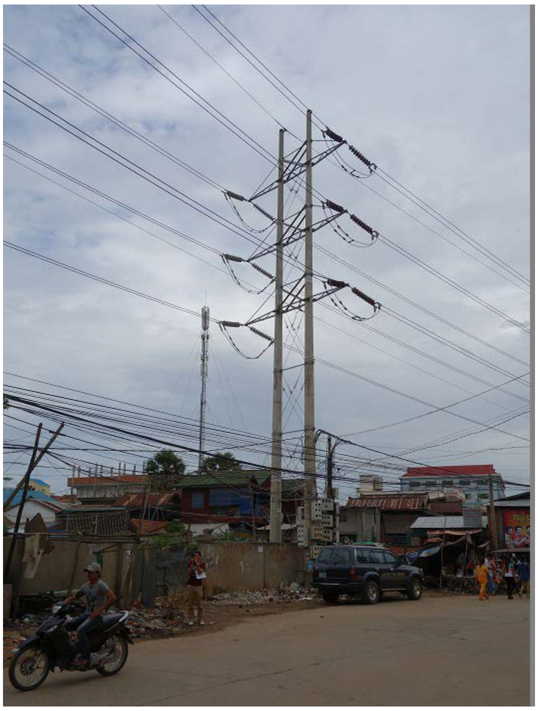


Fig. 4.1-5 Concrete Pole near Toul Kork S/S

(5) OHL_Route8

OHL_Route8 is single circuit overhead transmission line which connects from GS5 to Toul Kork S/S. Since Toul Kork S/S is in an urban area, there is no space where a concrete pole or a steel pipe pole is built newly. When carrying out this matter, it is necessary to consider electric wire re-covering of an existing transmission line, etc.

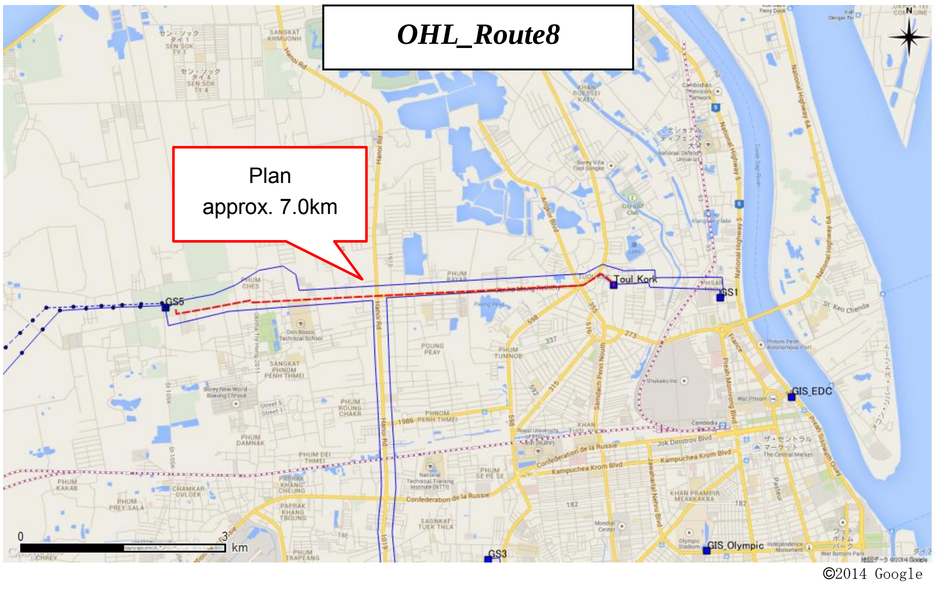


Fig. 4.1-6 Location Map of OHL_Route8

4.2 UNDERGROUND TRANSMISSION LINE

(1) Field survey of similar construction project of underground burials

During the underground transmission line construction period, various influences will be occurred. Therefore, attention shall be paid to the existing underground burials, traffic volume at the construction site and environmental consideration to the resident around construction site.

And the installation method of underground cable such as the duct bank system, the pipe jacking method, the construction during daytime or nighttime shall be studied and appropriate method shall be considered.

From the viewpoint of construction space, the installation of underground cable for over 115kV is often planned under the wide road, since the equipment sizes such as cable and joint bay is bigger compared to those of MV (22kV) underground cable.

For the purpose of studying the best solution for this underground transmission line construction, the site survey was done to collect the information on the actual situation of similar project sites.

The construction site of the underground sewage pipe works in the Phnom Penh City is shown in Fig. 4.2-1.

Fig. 4.2-1 Ongoing Construction Work of Underground Sewage Pipe

The photos taken at the sewage pipe construction sites are shown in Fig. 4.2-1. Construction was ongoing at the main road having two lanes in each side and the construction site was blocked by the protection fence.

The sewage pipe is being installed by open cut method occupying two lanes for construction works. The protection fence is temporarily removed to ease the driveway of vehicle. Heavy traffic jam is occurred as one lane is blocked for construction works during the daytime.

In case the underground transmission cable is installed on this road, the underground transmission cable will be installed on the other side of the road in principle to avoid interference with sewage pipe which was installed on the same road. However, depending on the existing burials, the pipe jacking method or the night-time open-cut construction method might be required.

(2) Field survey of underground transmission line project of Phase 1

In the final report of Preparatory Survey for Phnom Penh Transmission Line and Distribution System Construction Project (Phase 1), the installation method of 115kV underground transmission line is planned as Duct Bank method.

In Phase 2 Project, 230kV and 115kV underground transmission cable will be installed and the scale of the Project is bigger than those of Phase 1. As a reference of the route study for Phase 2 Project, the route survey of the planned underground cable route of Phase 1 Project was done.

The planned Underground Cable Route for Phase 1 at Olympic Stadium Substation (east side crossing point) is shown in Fig. 4.2-2.

Source: JICA Study Team

Fig. 4.2-2 Tentative Underground Cable Route for Phase 1
(East side crossing point of Olympic Stadium Substation)

As shown in Fig. 4.2-2, the preparation of the installation work of underground cable is done at the intersection of the main road.

In the digging yard, the existing pipes and cables are exposed, and the protection fence is carefully installed by lifting up by the crane. The construction is carried out occupying a part of intersection where a lot of traffic volume exists. Therefore, Duct Bank method during daytime seems to be very difficult judging from the congested burials and the traffic volume at the intersection. Moreover, considering the existing underground burials, the installation space of underground transmission cable may be not enough.

In such a case, the study about the intersection crossing by the jacking method is required.

(3) Routes survey for 230kV/115kV underground transmission lines

Scope of survey for 230kV/115kV Underground Transmission Lines are shown in Table 4.2-1 and the location map of underground transmission lines is shown below.

And the photographs of each underground transmission routes are shown in Appendix 1.

UG_Route 2 and UG_Route 9 were decided to be excluded from the scope of the Project by adaptation of Alternative 2-A. UG_Route 5 was decided to be excluded from the scope of work of this project following the discussion between JICA and EDC. Result of survey for 230kV Underground Transmission Line Routes are shown in Table 4.2-2.

Table 4.2-1 Scope of Survey for 230kV/115kV Underground Transmission Lines

No.	Starting point	Ending point	Voltage level	Nos. of circuit	Remarks
UG_Route2	Connection point between OHL and UG	NCC	230 kV	1	
UG_Route4	GS5	NCC	230 kV	1	
UG_Route5	NCC	GS3	115 kV	2	
UG_Route9	Toul Kork	NCC	115 kV	1	

: UG_Route 2 and UG_Route 9 were decided to be excluded from the scope of the Project by the adaptation of Alternative 2-A.

: UG_Route 5 was decided to be excluded from the scope of the Project after 3rd field survey.

Source: JICA Study Team

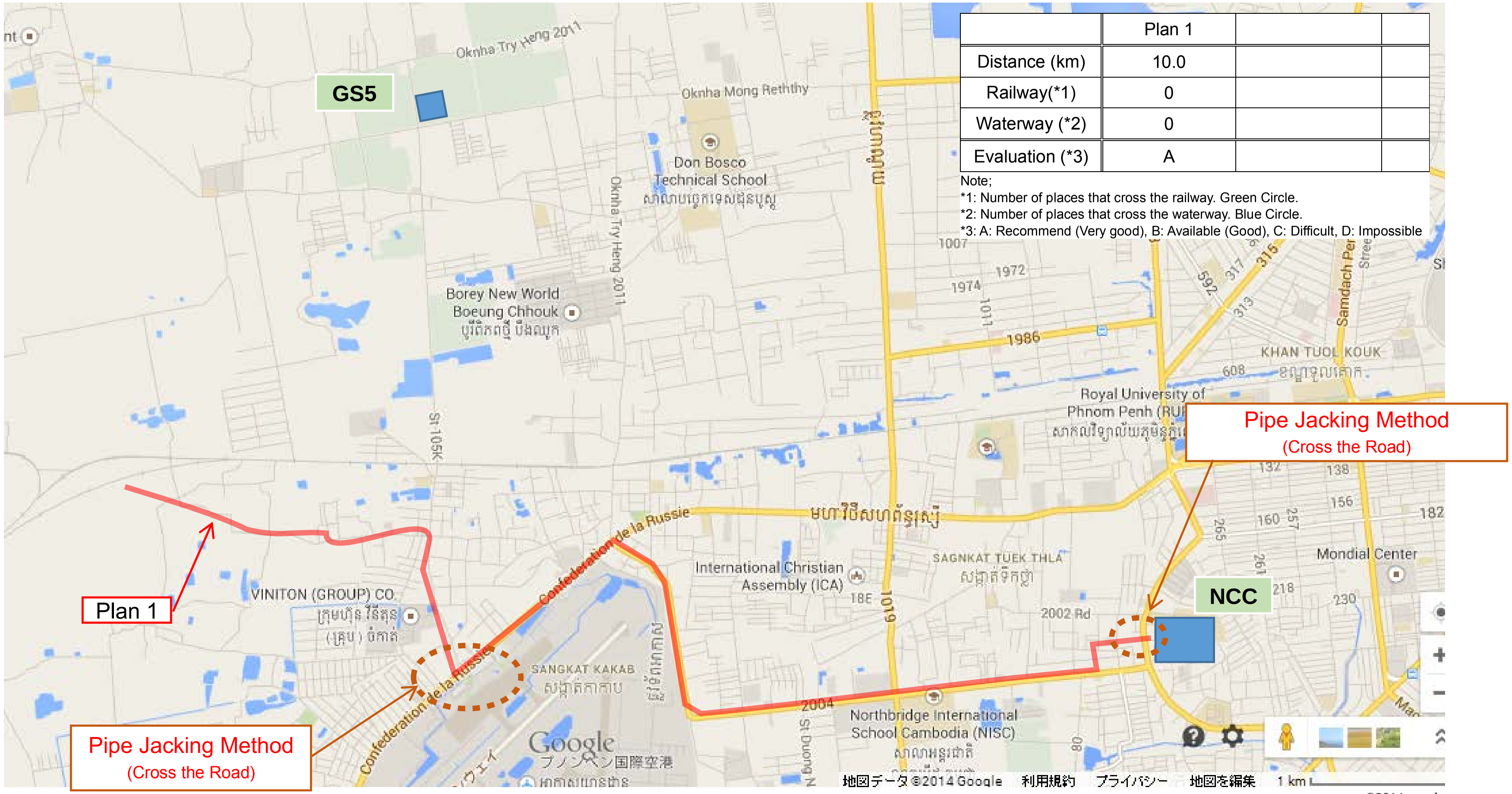
Table 4.2-2 Result of Survey for 230kV/115kV Underground Transmission Line Routes

No.	Plan	Route Length (km)	Railway (*1)	Waterway (*2)	Evaluation(*3)
UG_Route 2	Plan1	10.2	0	0	A
UG_Route 4	Plan1	10.38	1	0	B
	Plan2	**9.28**	**1**	**2**	**A**
	Plan3	10.18	1	2	B
UG_Route 5	Plan1	0.9	0	0	B
	Plan2	0.7	0	0	B
	Plan3	**0.4**	**0**	**0**	**A**
UG_Route 9	Plan1	5.4	1	0	A
	Plan2	5.6	1	0	B

Note; *1: Number of places crossing the railway. Green Circle.
*2: Number of places crossing the waterway. Blue Circle.
*3: A: Recommend (Very good), B: Available (Good), C: Difficult, D: Impossible

: UG_Route 2 and UG_Route 9 were decided to be excluded from the scope of the design by the adaptation of Alternative 2-A.
: Plan 3 of UG_Route 5 was decided to be excluded from the scope of the Project after 3rd field survey.
: Plan 2 of UG Route 4 was selected as Tentative Route.

Source: JICA Study Team



	Plan 1		
Distance (km)	10.0		
Railway(*1)	0		
Waterway (*2)	0		
Evaluation (*3)	A		

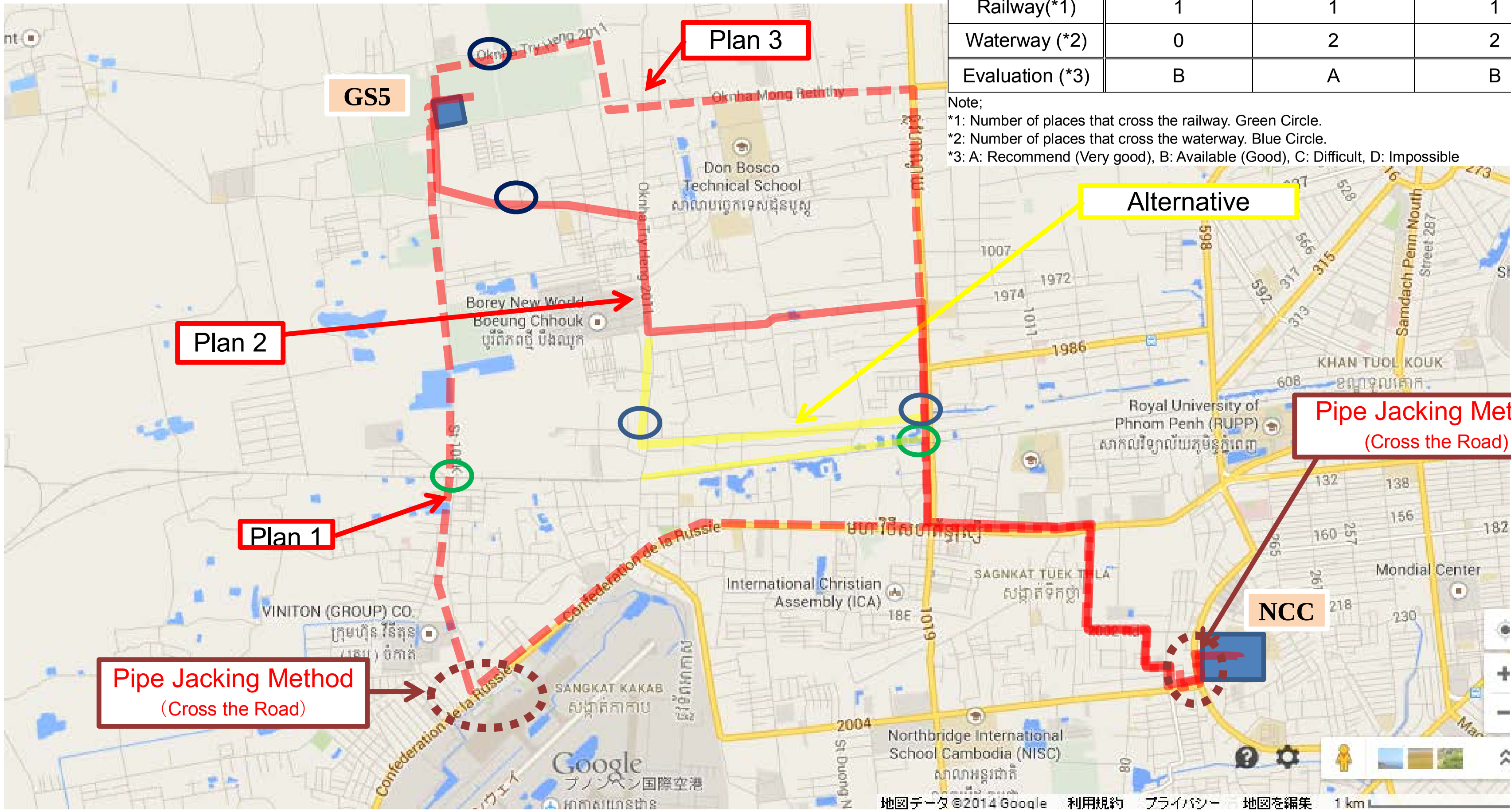
Note;
*1: Number of places that cross the railway. Green Circle.
*2: Number of places that cross the waterway. Blue Circle.
*3: A: Recommend (Very good), B: Available (Good), C: Difficult, D: Impossible

Source: JICA Study Team

Fig. 4.2-3 Location Map of UG_Route 2 (Result of Site Survey)

	Plan 1	Plan 2	Plan 3
Distance (km)	10.38	9.28	10.18
Railway(*1)	1	1	1
Waterway (*2)	0	2	2
Evaluation (*3)	B	A	B

Note;
*1: Number of places that cross the railway. Green Circle.
*2: Number of places that cross the waterway. Blue Circle.
*3: A: Recommend (Very good), B: Available (Good), C: Difficult, D: Impossible



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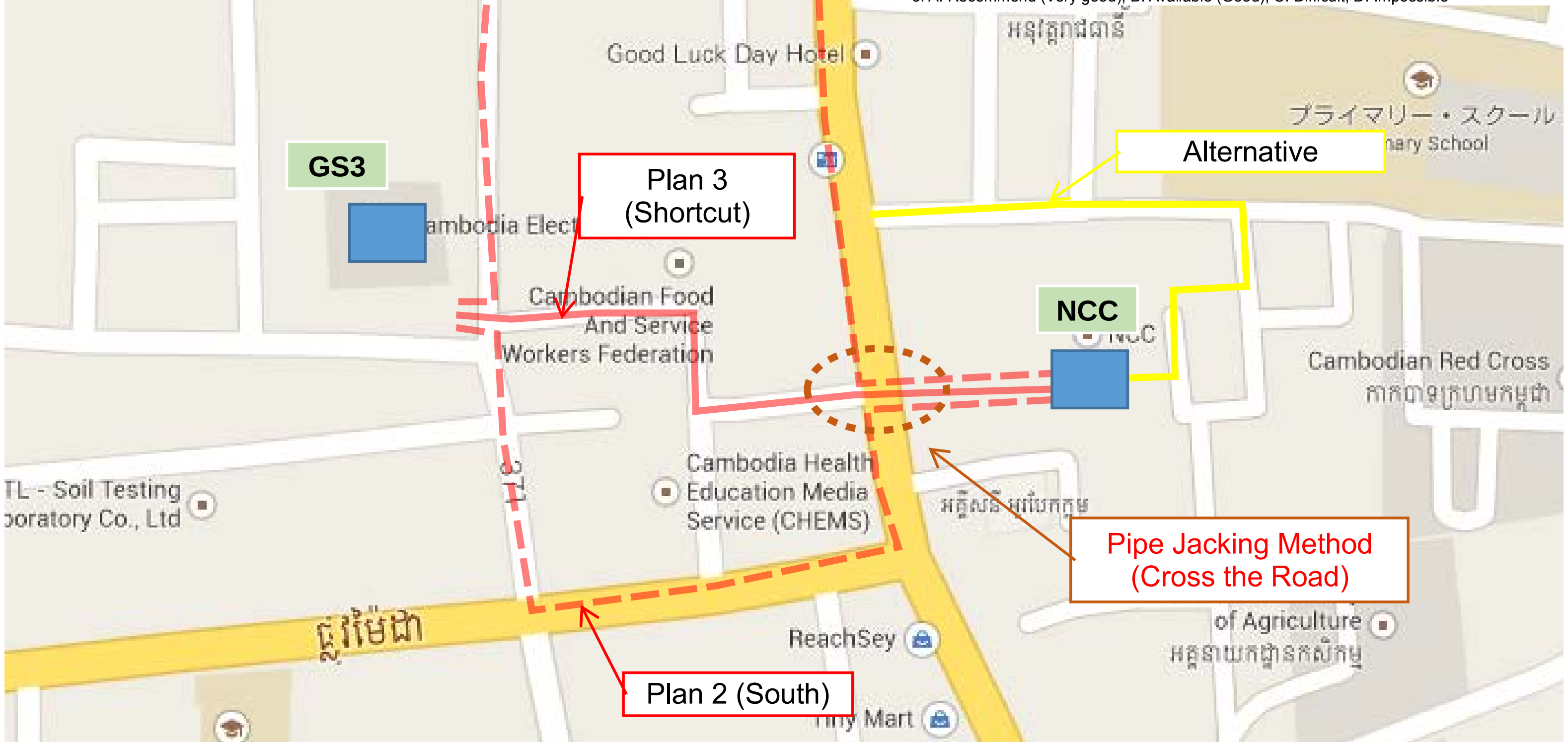
Source: JICA Study Team

Fig. 4.2-4 Location Map of UG_Route5 (Result of Site Survey)

	Plan1 (North)	Plan2 (South)	Plan3 (Shortcut)
Distance (km)	0.9	0.7	0.4
Railway(*1)	0	0	0
Waterway (*2)	0	0	0
Evaluation (*3)	B	B	A

Note;
*1: Number of places that cross the railway. Green Circle.
*2: Number of places that cross the waterway. Blue Circle.
*3: A: Recommend (Very good), B: Available (Good), C: Difficult, D: Impossible



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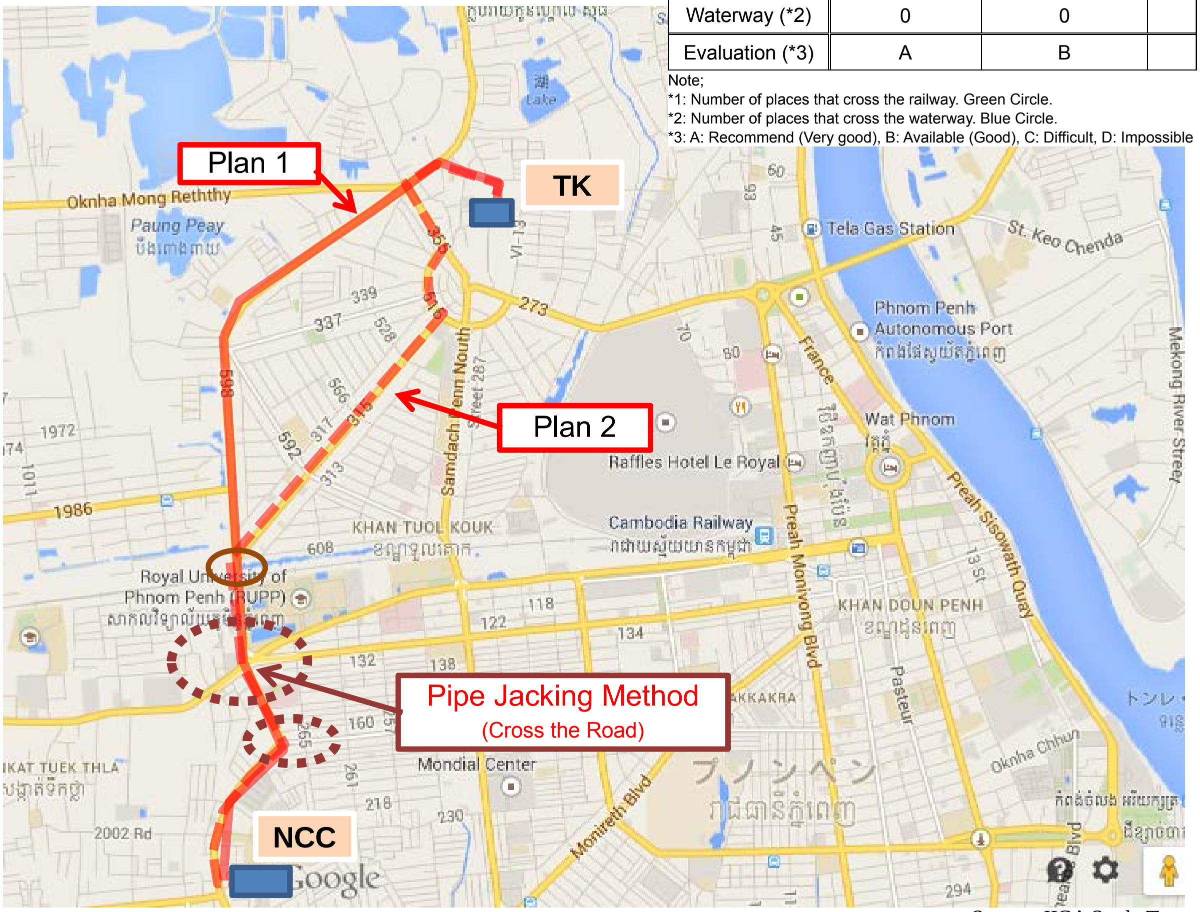
Source: JICA Study Team

Fig. 4.2-5 Location Map of UG_Route3 (Result of Site Survey)

	Plan1	Plan2	
Distance (km)	5.4	5.6	
Railway(*1)	1	1	
Waterway (*2)	0	0	
Evaluation (*3)	A	B	

Note;
*1: Number of places that cross the railway. Green Circle.
*2: Number of places that cross the waterway. Blue Circle.
*3: A: Recommend (Very good), B: Available (Good), C: Difficult, D: Impossible



 Source: JICA Study Team

Fig. 4.2-6 Location Map of UG_Route7 (Result of Site Survey)

4.3 SUBSTATION

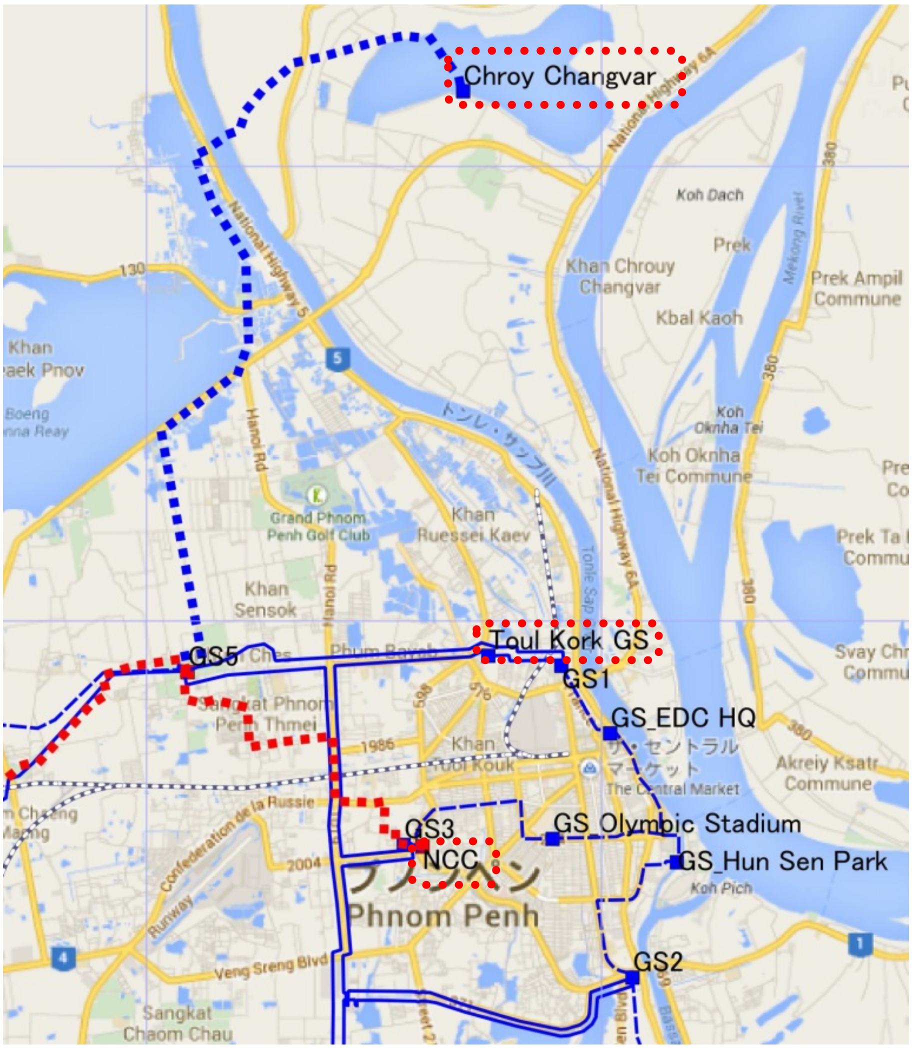
The sites of the existing substation and the candidate construction sites of the new substation are shown in Table 4.3-1 and the substation map is shown in Fig. 4.3-1.

Table 4.3-1 Existing Substation and New Substation

Existing/New	Substation	Required expansions/Facilities
Existing substation	GS3	Installation of 115kV Feeder Bays for Underground cables Installation of relay panels and telecommunication facilities Expansion of Substation Automation System and so on
	GS5	Installation of 230kV Bus (double bus) Installation of 230kV Feeder Bays Installation of 230kV/115kV interconnection transformer Modification of the 115kV Bus (Modification to double bus) Installation of 115kV Feeder Bays Installation of relay panels and telecommunication facilities Expansion of Substation Automation System and so on
New substations	NCC	Installation of 230kV GIS* Installation of 230kV/115kV interconnection Transformer Installation of 115kV GIS Installation of 115kV/22kV distribution Transformer 22kV Switchgear Installation of relay panels and telecommunication facilities Installation of Substation Automation System and so on
	Toul Kork	Installation of 115kV GIS Installation of 115kV/22kV distribution Transformer 22kV Switchgear Installation of relay panels and telecommunication facilities Installation of Substation Automation System and so on
	Chroy Changvar	Installation of the 115kV bus (single bus) Installation of 115kV Feeder Bays Installation of 115kV/22kV distribution Transformer 22kV Switchgear Installation of relay panels and telecommunication facilities Installation of Substation Automation System and so on

* GIS : Gas Insulated Switchgear

Source: JICA Study Team



Source: JICA Study Team

Fig. 4.3-1 Planned Substations Map

4.4 ROUTE SURVEY OF DISTRIBUTION LINE

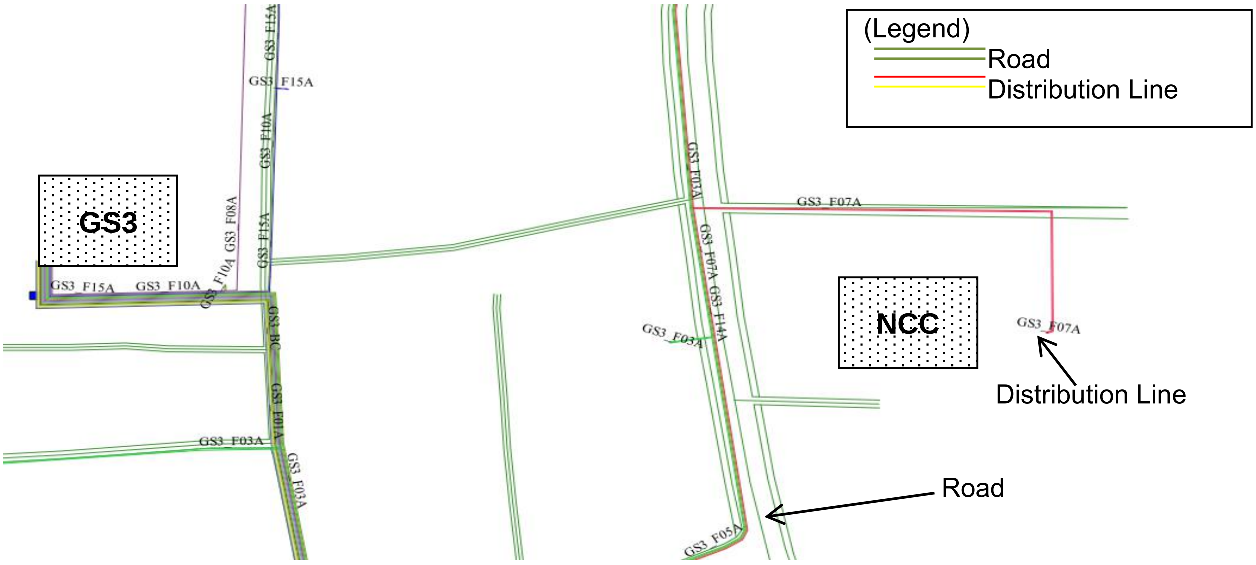
4.4.1 Candidate Sites of New Substation

(1) Around NCC

Underground distribution lines have been already laid in area of around NCC. JICA Study Team checked the route of existing distribution line by using Geographic Information System owned by EDC because JICA Study Team could not easily confirm the situation of existing distribution lines.

Source: JICA Study Team

Fig. 4.4-1 Around NCC



Source : GIS, EDC

Fig. 4.4-2 Existing Distribution Lines of around NCC

(2) Toul Kork area

There are many small buildings and houses in Toul Kork area, and overhead distribution lines are installed at the present.


Fig. 4.4-3 Toul Kork Area

(3) Chroy Changvar area

There is 1(one) overhead distribution line in Chroy Changvar area. This distribution line is crossing the Tonle Sap River by laying the cable on the Garden City Bridge connecting the center of Phnom Penh and Chroy Changvar area.

In addition, JICA Study Team confirmed that one more distribution line was under construction during the first field survey. EDC said that operation of this distribution line will be launched in June this year.

Fig. 4.4-4 Existing Cable laid on the Bridge

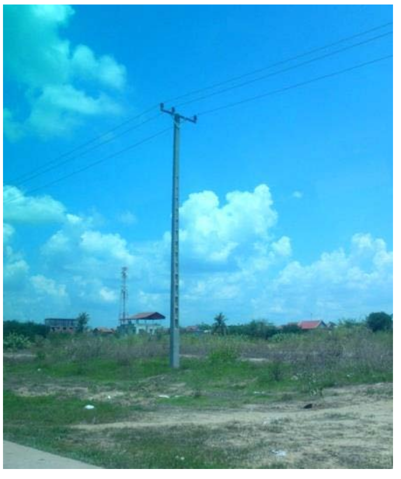
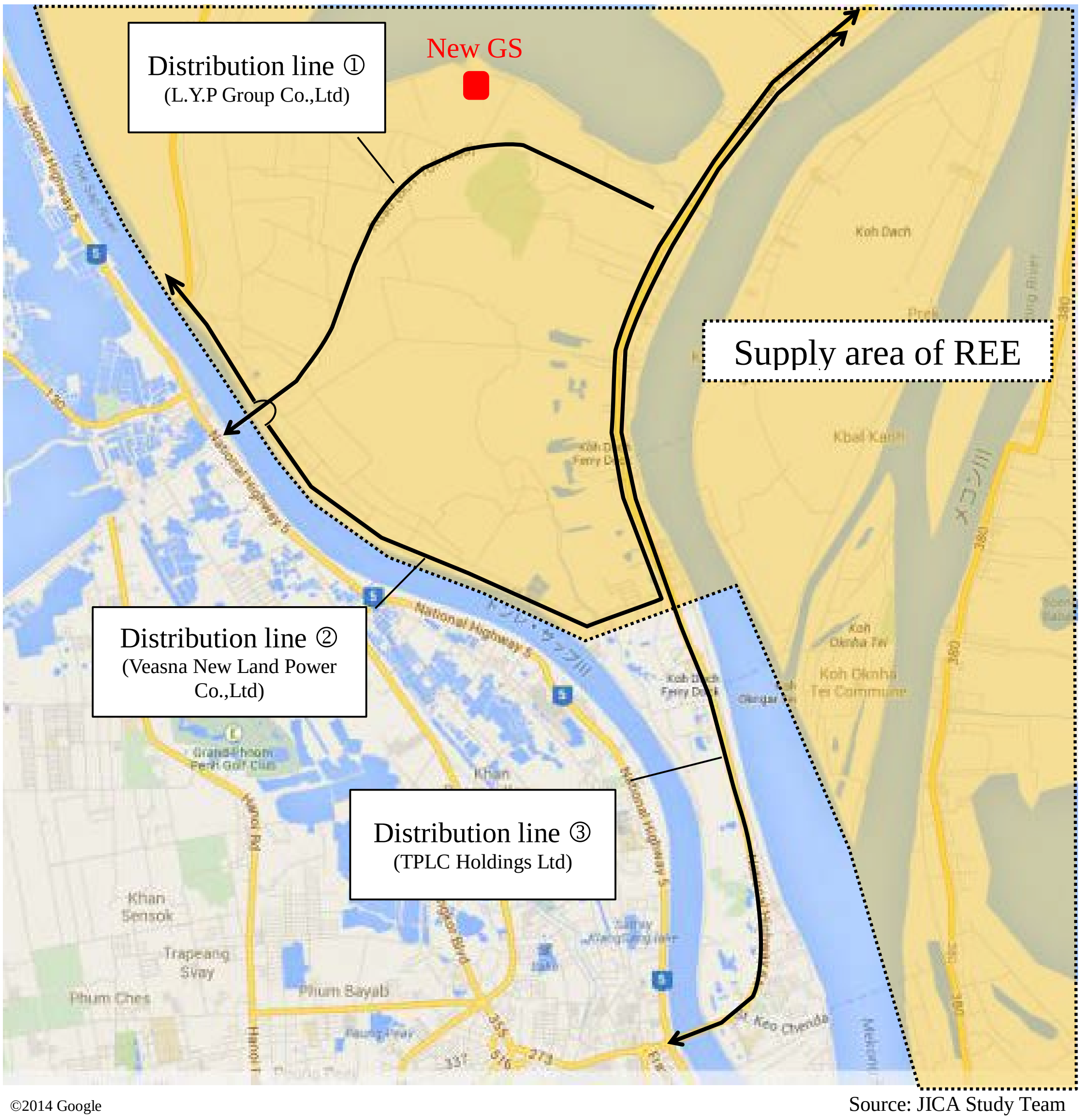


Fig. 4.4-5 Chroy Changvar Area

Source: JICA Study Team

On the other hand, an REE (Rural Electricity Enterprise) which acquired a license from EAC (Electricity Authority of Cambodia) can supply and retail electricity in this area, some distribution lines which a company except EDC owns are maintained.

According to interviews with EDC, there are three REE's distribution lines (L.Y.P Group Co., Ltd., Veasna New Land Power Co., Ltd., TPLC Holdings Ltd.) in this area, and these lines are connected to the Grid of EDC, then electric power meter is installed at the connection point.



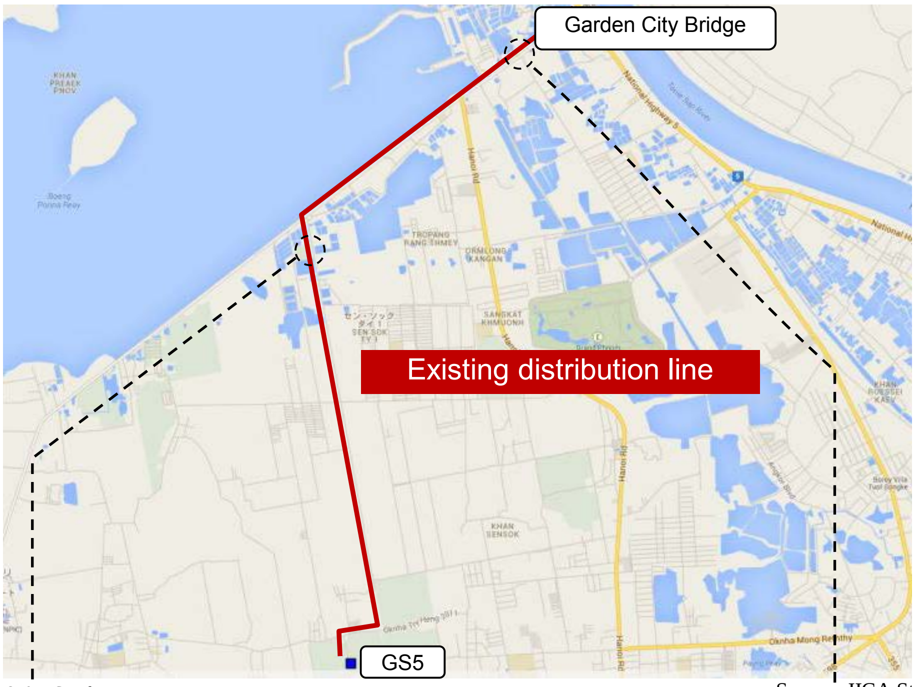
Source: JICA Study Team

Fig. 4.4-6 Existing Distribution Lines of REE

4.4.2 Effect on the Existing Distribution Line of the New Transmission Line

Result of the survey of candidate route of 115kV transmission line from GS5 to Chroy Changvar area during the first field survey, JICA Study Team found that 22kV distribution line was already installed along the route.

The route of new transmission line will be determined after agreement with EDC eventually, but if that route is the same as the route of existing distribution line, modification work of the existing distribution line will be necessary.



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Source: JICA Study Team

Fig. 4.4-7 Route of Existing Distribution Line

Fig. 4.4-8 Existing Distribution Line

CHAPTER 5

DETERMINATION OF THE PROJECT COMPONENT FOR PRELIMINARY DESIGN

CHAPTER 5 DETERMINATION OF THE PROJECT COMPONENT FOR PRELIMINARY DESIGN

5.1 FORMULATION OF OPTIMUM PLAN

5.1.1 Alternative Plans intended for Comparison

For alternative Plans intended for comparison, the following two plans as shown in Table 1.2-1 are compared. As the result of the comprehensive evaluation based on the result of site reconnaissance and system analysis, the optimum plan is formulated.

Specifically, comparison and evaluation of the system composition is studied in the following two steps.

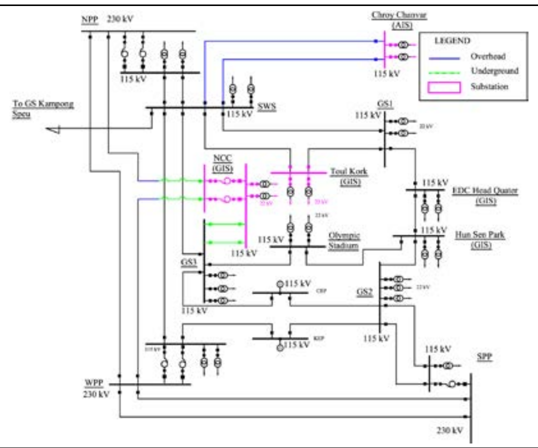
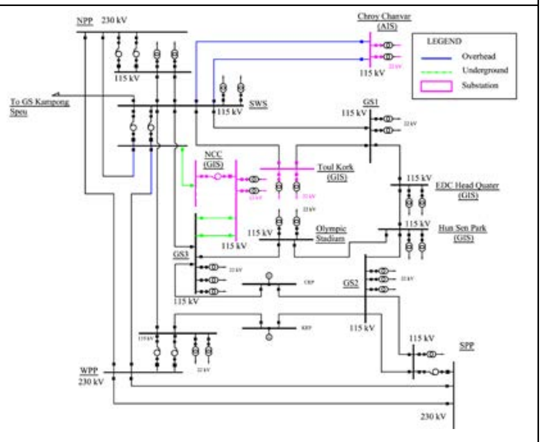
Step 1 The optimum composition of backbone system surrounding Phnom Penh City is selected based on the Alternative 1 and Alternative 2.

Step 2 The optimization is done on the interconnection system of the new Toul Kork substation to the system under the conditions of the optimum backbone system composition selected in Step 1.

[Step 1]

Qualitative and quantitative evaluation were performed to the backbone system composition plan of Alternative 1 and Alternative 2 shown in Table 5.1-1 on the evaluation criteria, such as (1) reliability, (2) system loss, (3) power flow neck, (4) construction cost, and (5) easiness of construction, and the optimal system plan was selected based on the comprehensive consideration.

Table 5.1-1 Composition Plan of Backbone System surrounding Phnom Penh City

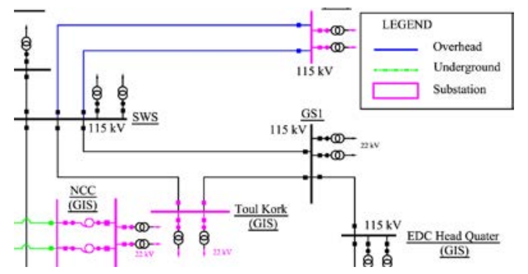
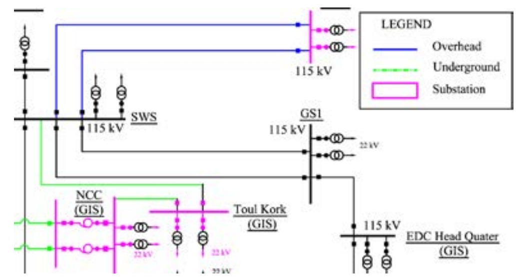
Plan	Alternative 1	Alternative 2
Characteristics	230kV system is introduced to the outskirts of Phnom Penh City and 230kV system is further extended to the center of the city. Power demand in Phnom Penh City is supplied by these systems together with the 115kV system.	230kV system is introduced to the outskirts of Phnom Penh City, and the power demand in the city is supplied by 115kV system.
System Diagram		

Source: JICA Study Team

[Step 2]

About the connection method to the system of the new Toul Kork substation in the optimal backbone system around the Phnom Penh City selected in Step 1, the optimal connection plan of the Toul Kork substation to the system was selected like Step 1 based on the comprehensive consideration after performing qualitative and quantitative evaluation on the evaluation criteria, such as (1) reliability, (2) system loss, (3) power flow neck, (4) construction cost and (5) easiness of construction.

Table 5.1-2 Connection Plan of the New Toul Kork Substation to the System

Plan	Alternative A	Alternative B
Characteristics	The new Toul Kork substation is connected to the system in the form of π connection from the nearby existing 115kV transmission line.	The new Toul Kork substation is connected by a single circuit of the new 115kV transmission line from GS5 and NCC*, respectively.
System Diagram		

* NCC : National Control Center

Source: JICA Study Team

Hereafter, the contents of detailed comparison of each evaluation criteria are described.

5.1.2 Comparison of Alternative Plans

(1) Backbone system composition around the Phnom Penh City

1) Comparison of construction cost

For Alternative 1, it is planned that 230kV overhead and underground transmission line is connected directly to NCC, the center of the city from the circumferential 230kV backbone system. Besides, for Alternative 2, it is designed that 230kV overhead transmission line is connected to GS5, located near the city load, and further 230kV transmission line is extended to NCC which is the load center. Both Alternatives consider expansion of 115kV system, and the comparison of construction cost of both Alternatives was carried out.

As conclusion, it is known that the construction cost of 230kV underground transmission line to NCC as defined in Alternative 1 is high and the construction cost of Alternative 2 is drastically lower.

2) Comparison of loss

With the plan of Alternative 1 and Alternative 2, although the number of substations (the total capacity of transformers) is different, the active power loss of transformers is considered to be the level which can be disregarded. And the active power loss of distribution line is also considered to be the same in any of the Alternatives. Therefore, only transmission loss is compared as system loss.

The estimation method of an annual system loss is divided roughly into the following two as the comparative method.

- Result of power flow analysis of typical periods (4 cases of dry and rainy seasons, and day and night time)
- Experimental formula which utilized the load factor, etc. from the annual peak power flow case

In this Study, in order to take matching with the Phase 1, the annual loss of each system was calculated using the experimental formula. The result is shown in Table 5.1-3.

Table 5.1-3 Cost Comparison of Transmission Loss

Items		Alternative 1	Alternative 2
Loss of the 2020 peak power flow (system capacity of peak time : 954.1MW)	[MW]	30.29	27.62
Annual total loss	[MWh]	146,733	133,799
Loss Cost	[million US$/ Annual]	2.07	Base

Source : JICA Study Team

Transmission loss calculated above is the result of analysis done by JICA Study Team based on the estimated power flow of the relevant system after review of demand forecast in the relevant area.

The formula and used specifications of annual loss calculation are as follows.

Formula of annual loss calculation

W = w G H [Wh]
w: Loss at maximum load

G = a F + (1-a) F2 (G: Coefficient of Loss)
H: Time of a Period [hour], a year = 8,760 [hours]
F: Load Factor = (Average load) / (Maximum load)
a: Constant Value

If calculated as a = 0.3 and F = 70%, G = 0.553

Comparing Alternative 1 and Alternative 2, both of the construction cost and transmission loss of Alternative 2 is smaller, besides, considering the easiness of construction works 230kV system to be carried out in the urban area, Alternative 2 is recommended than Alternative 1.

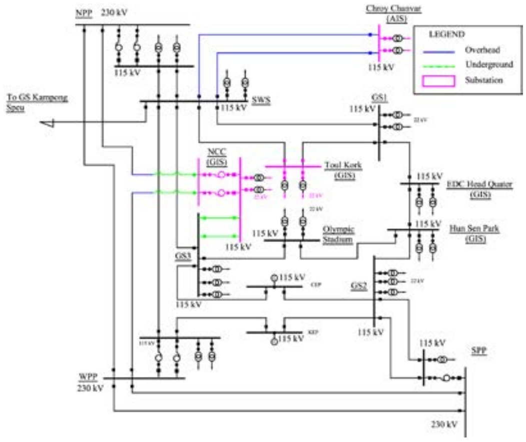
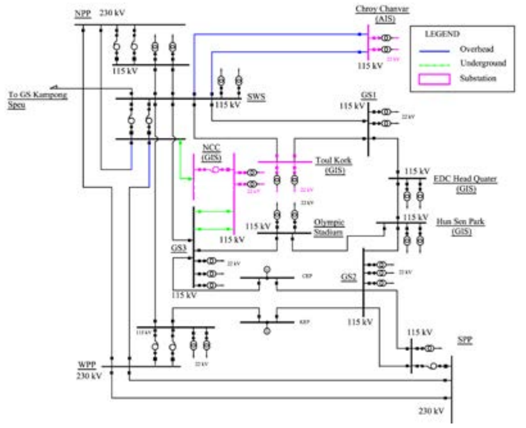
3) Comparison of supply reliability

(a) Difference of supply reliability of each Alternative

Difference of supply reliability of each Alternative in case of the fault of transmission line and distribution line is shown below.

There are not so much differences on the impact at the time of line fault of 230kV overhead transmission facility between Alternative 1 and Alternative 2. For the fault of 230kV underground transmission line between GS5 and NCC in case the Phnom Penh system is not operated in loop system, it is forecasted that blackouts occur at the new substation and NCC temporarily. However, the frequency of occurrence of line fault is very low. Therefore, there is no big difference in supply reliability of both Alternative 1 and Alternative 2.

Table 5.1-4 Supply Reliability of the Composition Plan of Backbone System surrounding Phnom Penh City

Plan	Alternative 1	Alternative 2
Characteristics	230kV system is introduced to the outskirts of Phnom Penh City and 230kV system is further extended to the center of the city. Power demand in Phnom Penh City is supplied by these systems together with the 115kV system.	230kV system is introduced to the outskirts of Phnom Penh City, and the power demand in the city is supplied by 115kV system.
System Diagram		
230kV, UG GS5~NCC	No power interruption.	Power supply of NCC is interrupted.
230kV, OH NPP~WPP	No power interruption.	No power interruption.
expectation of power supply loss	-----------------	0.5MWh

Source: JICA Study Team

(b) Line fault rate of transmission and distribution line facilities

It is very difficult to forecast these line fault rates and duration of power interruption. Table 5.1-5 shows the recent line fault record of 230 kV transmission line.

Table 5.1-5 Recent Line Fault Record of 230 kV Transmission Line

Year	Date	Duration [H]	Location	Cause	Not Supplied Power [MW]
2013	27-Oct	0.54	GS Kampong Chhnang	Tree or Something	33.05
	1-Nov	0.24	GS O'soam ~ Lower Stung Russey Chrum	Tree or Something	137.89
	3-Nov	0.22	GS O'soam ~ Lower Stung Russey Chrum	Tree or Something	40.34
	21-Nov	0.40	GS O'soam ~ GS Pursat	Un known Fault	No Load

Source: JICA Study Team

There are not many line fault related to 230 kV transmission line. From the data obtained, the line fault occurs four times per year. Most of the causes are attributed to cutting trees along the transmission lines. Considering this situation, the calculation is conducted in the following conditions here.

- Line fault of 230kV system overhead line:
  four times per year, one hour, no power interruption
- Line fault of each circuit of 230kV underground line:
  once in a 100 year, 48 hours, 100 MW of power interruption on average

Although an electric power company's track record of Japan is about 1 time/ year,·4,000km as reference and assumption of the above interruption rate of underground line is high about 2 to 3 times as compared to that in Japan, it is considered that Cambodia still has much number of times of road excavation, and it is an appropriate value.

Besides, about the power outage influence by a fault, if the restoration time to the full capacity of the facility by switching the system at the time of line fault requires 30 minutes on an average, the expectation of power supply loss in a year caused by power interruption is calculated to be 0.5MWh by simulation as shown in Table 5.1-5.

It is considered that this expectation of power supply loss will increase every year until further expansion be implemented.

Comparing the Alternative 1 and Alternative 2, although there are differences in the connection to NCC, the center of city, by way of connection of 230kV system directly from the circumferential 230kV system or by way of connection through GS5, probability of line fault is lower in the case of Alternative 2 because the line between GS5 and NCC is underground line. There is no big difference in the expectation of power supply loss by power interruption. Therefore, there will be no expectation of power supply loss by power interruption if double circuits would be adopted in this line route. Accordingly, there would be no difference in each Alternative from the view point of system reliability.

(c) Dis-benefit of power interruption

EDC does not calculate the dis-benefit caused by power interruption. However, in the Phase 1 Study Report, it is estimated that 1 US$ per kWh is the adequate level as the dis-benefit caused by power interruption from the correlation of GDP (Gross Domestic Product) in Cambodia and power sales.

For comparison of each Alternative, 1 USD per kWh is used in the evaluation of the Project under Phase 2 Study to unify the condition.

4) Comprehensive evaluation

As mentioned above, the results including evaluation of each comparison item, such as a system loss and a construction cost, of having compared the economic efficiency of each Alternative are shown in Table 5.1-6.

According to the total annual cost, Alternative 2 is more economical. Although there is a minor difference of the occurrence probability of the fault of transmission facilities, the power outage time in case of a fault and the unit price of power outage cost, it is considered that the difference of the construction cost of both Alternatives dominates the order of superiority of comprehensive year cost.

Regarding power outage cost, 1 US$ per kWh is used as the standard case as mentioned above. In Phnom Penh City, although it is assumed that the impact at the time of power outage is large, even if there is change of the unit price of power outage cost, there is little impact on total annual cost.

Table 5.1-6 Comprehensive Evaluation

	Alternative 1	Alternative 2
Cost evaluation on system reliability (power interruption)	Almost same	Base
Cost evaluation on system loss	A little high	Base
Power flow neck	Overloaded at a transformer at SPP substation	None
Capital Cost of Every Year [including the cost of environmental countermeasures]	Very high	Base
Easiness of the project construction concerned	Difficult	Easy
Total Annual Cost	Very high	Base

Source: JICA Study Team

Moreover, when based on the field survey result, long-distance underground power cable construction is needed if 230kV system is introduced to NCC located in the city center. The social and environmental impact including traffic disturbance by the construction will also be large, and it will also induce the increase in construction costs.

Considering the initial construction cost, the easiness of construction work, etc., it is considered that selection of Alternative 2 is desirable.

(2) Connection method to the system of Toul Kork Substation newly constructed

Comparative evaluation on the connection method (Alternatives 1 and 2) of the system of Toul Kork Substation which is newly to be constructed was done as follows.

1) Comparison of construction cost

In Alternative A, the system is interconnected with the nearby existing 115kV transmission line by π connection. On the other hand, in Alternative B, the system is interconnected with a single circuit newly constructed 115kV underground transmission line from GS5 and NCC, respectively.

Comparing the construction cost of both Alternatives, Alternative B requires construction of a new 115kV underground transmission line, therefore, the construction cost of Alternative B is higher than Alternative A.

2) Comparison of supply reliability

As the result of system analysis, overload of the related facilities and power interruption will not occur in both Alternatives at the time of fault at on replace. Therefore, the supply reliability of both Alternatives can be judged equal level.

3) Comparison of transmission loss

According to the result of system analysis, as the load of Toul Kork New Substation is supplied by indirect way through GS5 and NCC in Alternative B, the transmission loss is higher than Alternative A.

4) Comprehensive evaluation

Table 5.1-7 shows the result of comprehensive evaluation including evaluation of each comparison item such as transmission system loss and construction cost.

Table 5.1-7 Comprehensive Evaluation

	Alternative A	Alternative B
System reliability	No problem	
System loss	Base	High
Power flow neck	No problem	
Construction cost	Base	High
Easiness of construction work	Easy	Difficult
Comprehensive evaluation	Recommendable	---

Source: JICA Study Team

From the result of system analysis and comparative evaluation, Alternative A which is cheaper in construction cost and has no problem in supply reliability is recommended to be adopted.

CHAPTER 6

GEOLOGICAL INSPECTION

CHAPTER 6 GEOLOGICAL INSPECTION

6.1 OUTLINE OF GEOLOGICAL INSPECTION

To confirm the geological condition, especially to know the bearing capacity of the ground, for the structures such as facilities in the planned substations and planned transmission towers, geological drilling inspections by 14 drillings were implemented.

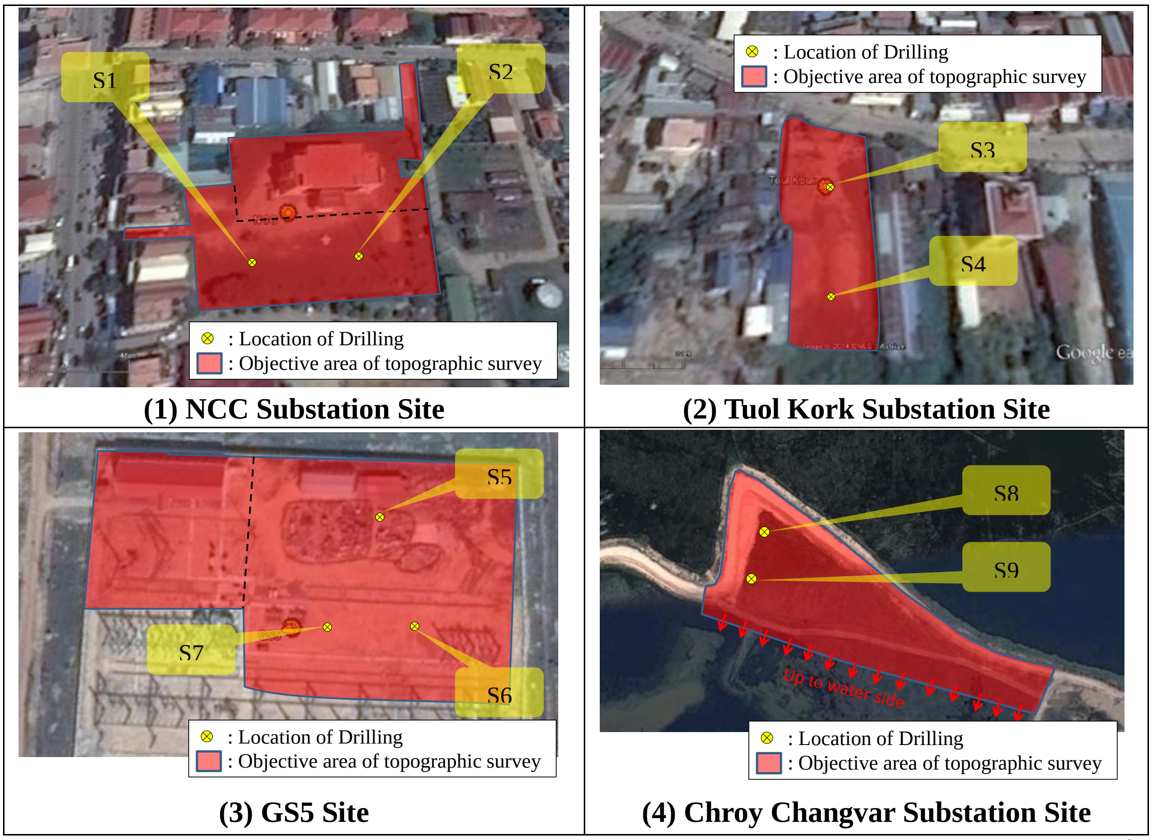
The allocations of 14 drillings are as follows.

Drilling in Substation Site··················· **9 drillings** (refer to Fig. 6.1-1 and Table 6.1-1)

- NCC (National Control Center) Substation Site...: 2 Drillings
- Tuol Kork Substation Site...: 2 Drillings
- Chroy Changvar Substation Site..: 2 Drillings
- GS5 Site...: 3 Drillings

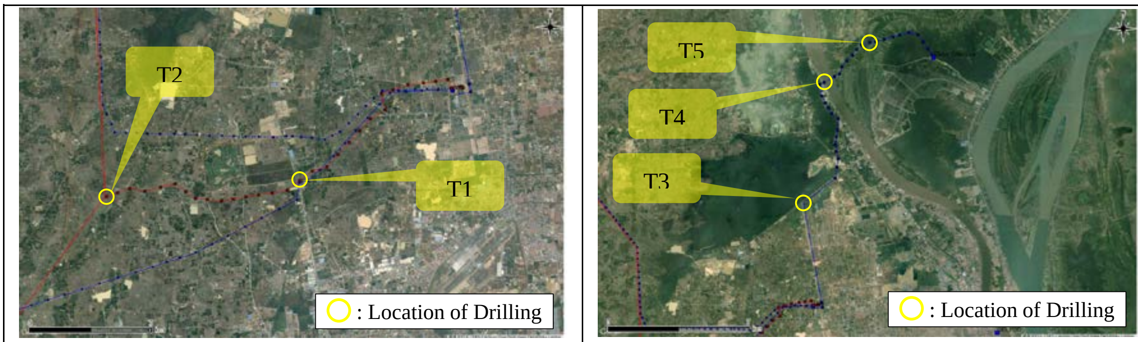
Drilling along Transmission Line Route···· **5 drillings** (refer to Fig. 6.1-2 and Table 6.1-1)

- On the 230kV Transmission Line Route (Plan 3 of Alternative 2).......................: 2 Drillings
- On the 115kV Transmission Line Route between GS5 & Chroy Changvar.........: 3 Drillings



Source: JICA Study Team

Fig. 6.1-1 Drilling Locations in Substation Site (on Google Earth Photo)



230kV Transmission Line Route | 115kV Transmission Line Route

Source: JICA Study Team

Fig. 6.1-2 Drilling Locations on Transmission Line Route (on Google Earth Photo)

Table 6.1-1 Coordinate of Drillings

No.	Borehole No.	Site	Coordination	
			Easting	Northing
1	S1	NCC Substation (O Bek Ka Orm)	487759	1277252
2	S2	NCC Substation (O Bek Ka Orm)	487801	1277255
3	S3	Toul Kork Substation	489221	1281345
4	S4	Toul Kork Substation	489221	1281305
5	S5	GS5	482764	1281059
6	S6	GS5	482780	1281019
7	S7	GS5	482743	1281016
8	S8	Chroy Changvar Substation	488653	1293456
9	S9	Chroy Changvar Substation	488633	1293386
10	T1	Transmission line 230kV Mid point WPP/NPP to GS5	478878	1278792
11	T2	Transmission line 230kV Mid point WPP/NPP to GS5	474097	1278396
12	T3	Transmission line 115kV to Chroy Changvar SS	482136	1286158
13	T4	Transmission line 115kV to Chroy Changvar SS	483190	1292173
14	T5	Transmission line 115kV to Chroy Changvar SS	485450	1294126

[Note] Coordination is by WGS-84, UTM coordination system

Source: JICA Study Team

6.2 GEOLOGICAL INSPECTION RESULT AND CONSIDERATION OF FOUNDATION TYPE

Following relations between N-value "N" and allowable bearing capacity of ground "q_a" based on experiential data* can be applied;

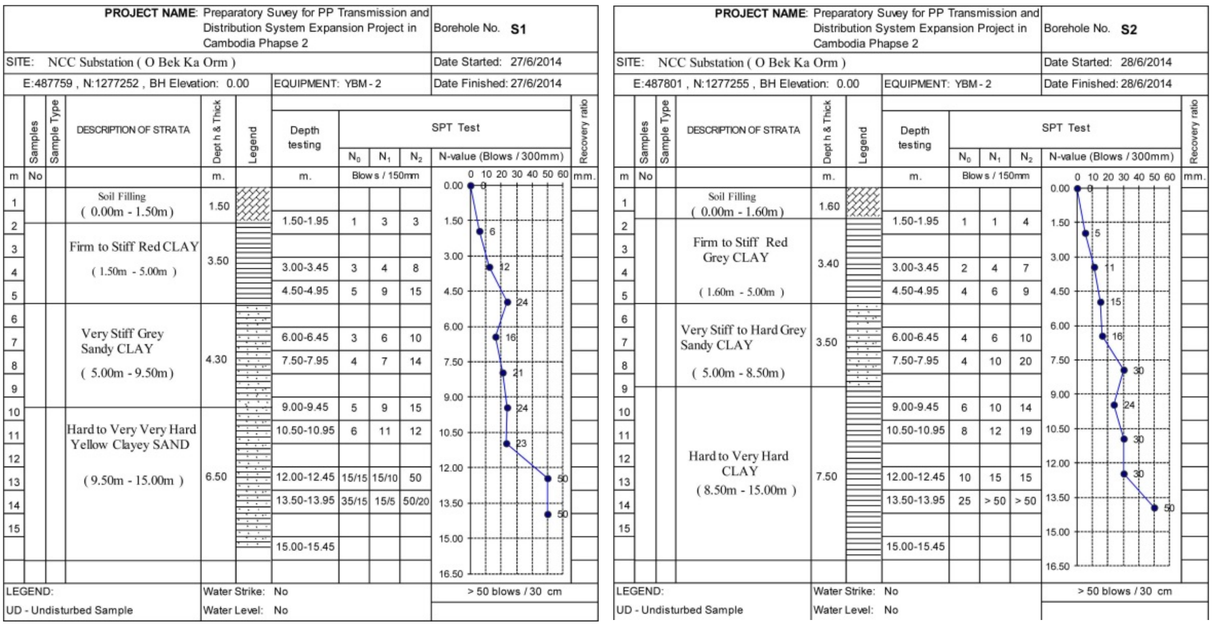
Gravel Layer: q_a = 5N [kN/m^2]
Sand Layer: q_a = 10N [kN/m^2]
Clay soil layer: q_a = (25~50)N [kN/m^2]

The applicable deepest depth of spread foundation (Pad & Chimney or Mat type foundation in case of transmission line tower foundation) is usually around 5m. And the allowable bearing capacity of 50 to 100 kN/m^2 (0.5 to 1.0 kg/cm^2) or more is usually required for the spread foundation for transmission line tower. As for the spread foundation for substation equipment, the allowable bearing capacity of 100 to 200 kN/m^2 (1.0 to 2.0 kg/cm^2) or more will be necessary for the ground considering the available area for foundation.
The application of spread foundation means that this value of allowable bearing capacity of ground can be satisfied in the depth of 5m and deeper. Otherwise, pile foundation will be applied.

In the following, the result of drillings and expected foundation type are explained. As for the detail result of drillings, refer to Appendix 2.

6.2.1 NCC Substation Site

The results of the geological inspection for NCC Substation Site are shown in Fig. 6.2-1.



Source: JICA Study Team

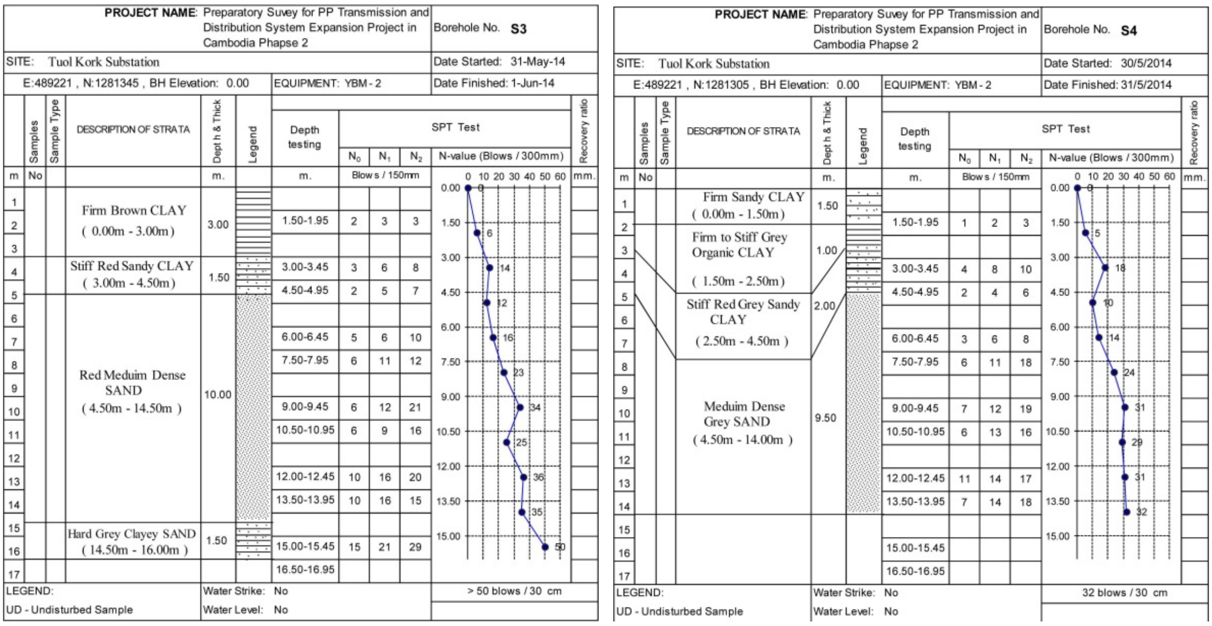
Fig. 6.2-1 Geological Inspection Result (NCC Substation Site: S1 & S2)

* : Source: Sakaguchi Satoshi: Evaluation of ground by N-value, Kisoko, Vol.10, No.6, 1982

N-value reaches 11 or 12 ($q_a \geq 270kN/m^2 = 2.7kg/cm^2$) in the clay layer with 3.5 m in depth and N-value doesn't fall below this value along with depth. So, normal spread foundation will be applicable.

6.2.2 Tuol Kork Substation Site

The results of the geological inspection for Tuol Kork Substation Site are shown in Fig. 6.2-2.



Source: JICA Study Team

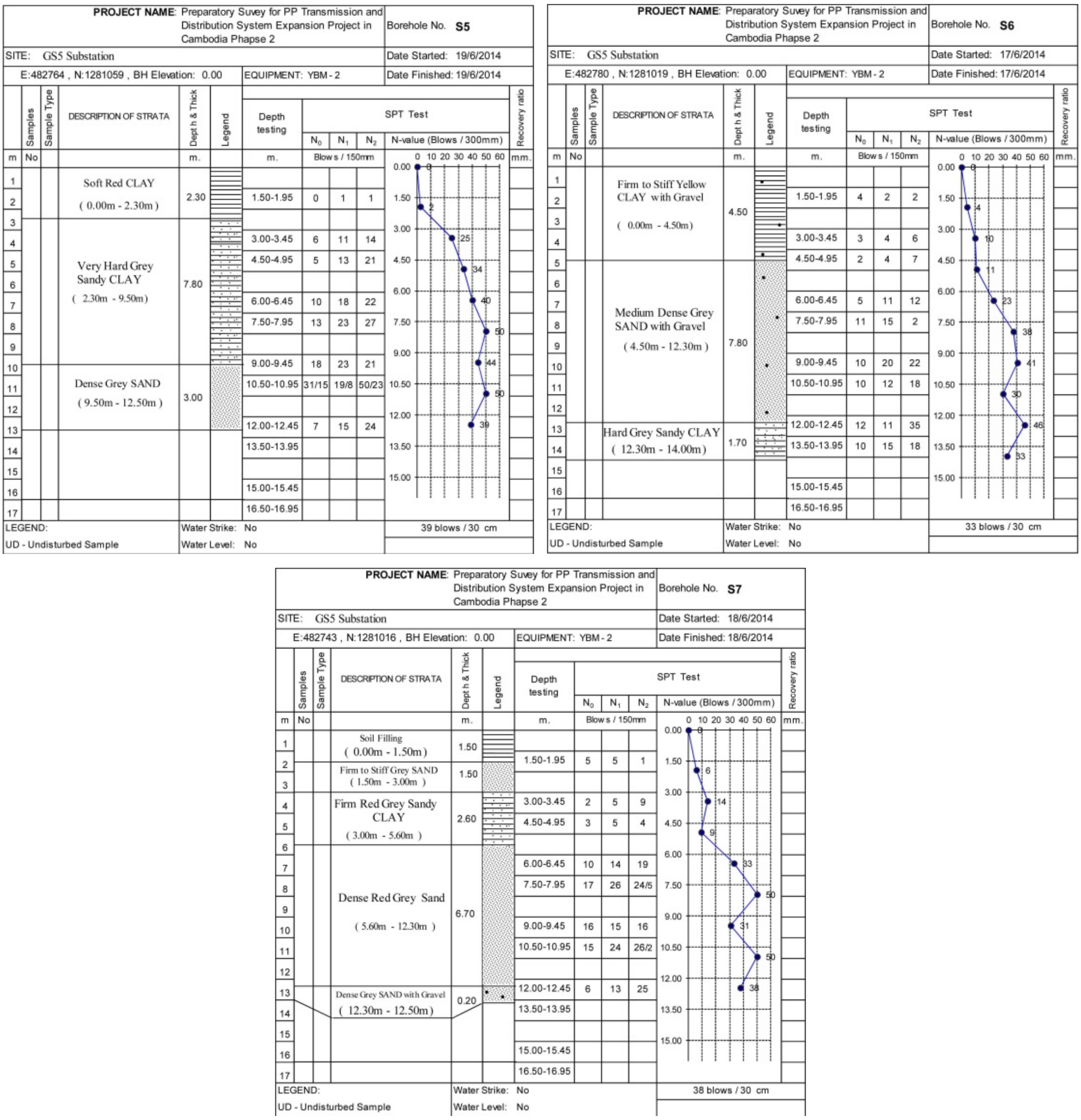
Fig. 6.2-2 Geological Inspection Result (Tuol Kork Substation Site: S3 & S4)

N-value reaches 14 or 18 in the clay layer with 3.5 m in depth and N-values secure 10 ($q_a \geq 100kN/m^2 = 1.0kg/cm^2$) although the soil becomes sandy along with depth. So, normal spread foundation will be applicable.

6.2.3 GS5 Site

The results of the geological inspection for GS5 Substation Site are shown in Fig. 6.2-3.

N-value reaches 10 or more (at least $q_a \geq 100kN/m^2 = 1.0kg/cm^2$) in the sandy clay layer with 3.5 m in depth. Although some N-values fall below 10 a little along with depth, wide spread foundation can be applied even for heavy equipment because GS5 site has enough area.



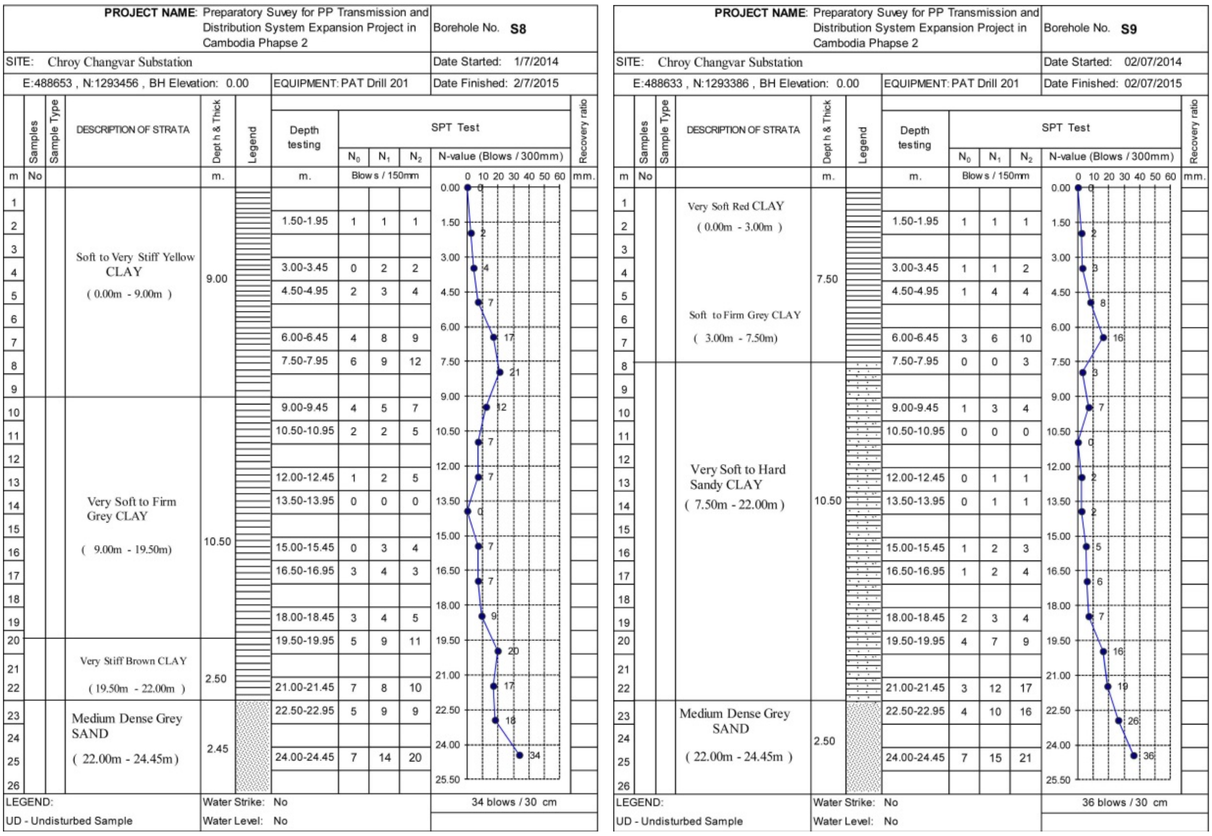
Source: JICA Study Team

Fig. 6.2-3 Geological Inspection Result (GS5 Site: S5, S6 & S7)

6.2.4 Chroy Changvar Substation Site

The results of the geological inspection for Chroy Changvar Substation Site are shown in Fig. 6.2-4.

Enough bearing layer cannot be obtained up to around 20 m in depth. Application of pile foundation will be sure.
The lengths of applied piles will depend on the weight of equipment because the capacity of pile is based on not only bearing capacity of pile bottom point but also skin friction of pile surroundings. However, transformer (heavy equipment) will require piles with around 25m (= 5m: height of site creation + 20m: depth to bearing layer) in length.



Source: JICA Study Team

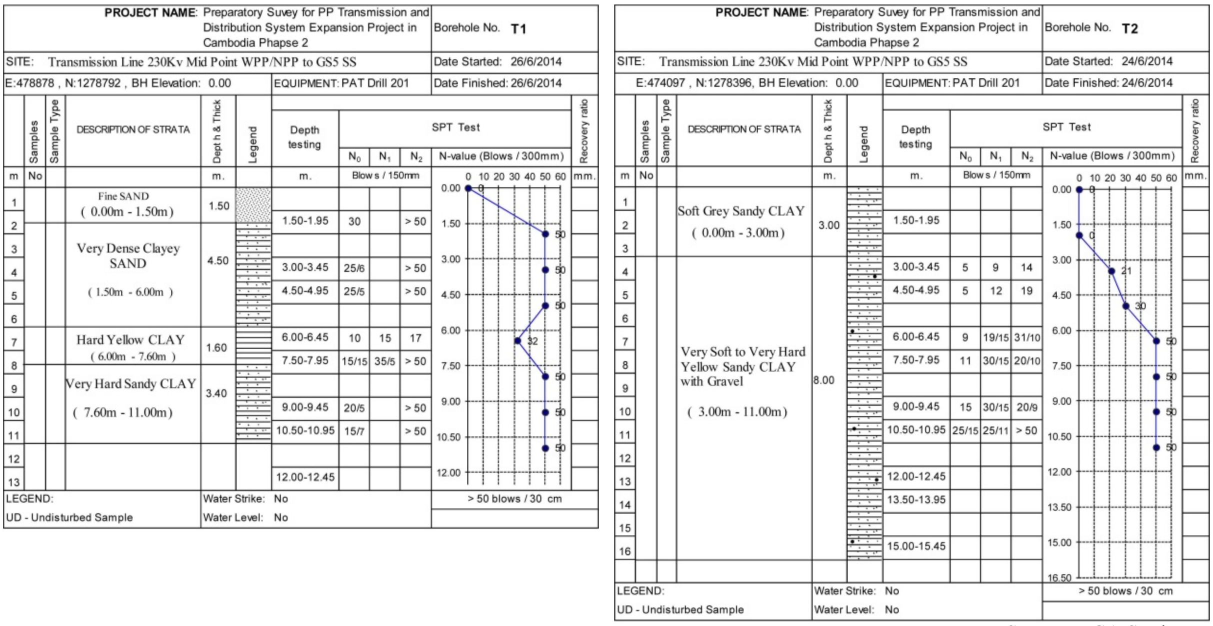
Fig. 6.2-4 Geological Inspection Result (Chroy Changvar Substation Site: S8 & S9)

The number of required piles is estimated to be two (pile arrangement will be based on the base of equipment) for each equipment except transformer and fifteen (= 150 ton / 10 ton: bearing capacity of pile is assumed to be 10 ton/pile) for transformers.

6.2.5 230kV Transmission Line Route

The results of the geological inspection for 230kV Transmission Line Route are shown in Fig. 6.2-5.

N-value reaches 21 or more (at least $q_a \geq 210kN/m^2 = 2.1kg/cm^2$) in the sandy clay layer with 3.5 m in depth and N-value doesn't fall below this value along with depth. So, spread foundation will be applicable.



Source: JICA Study Team

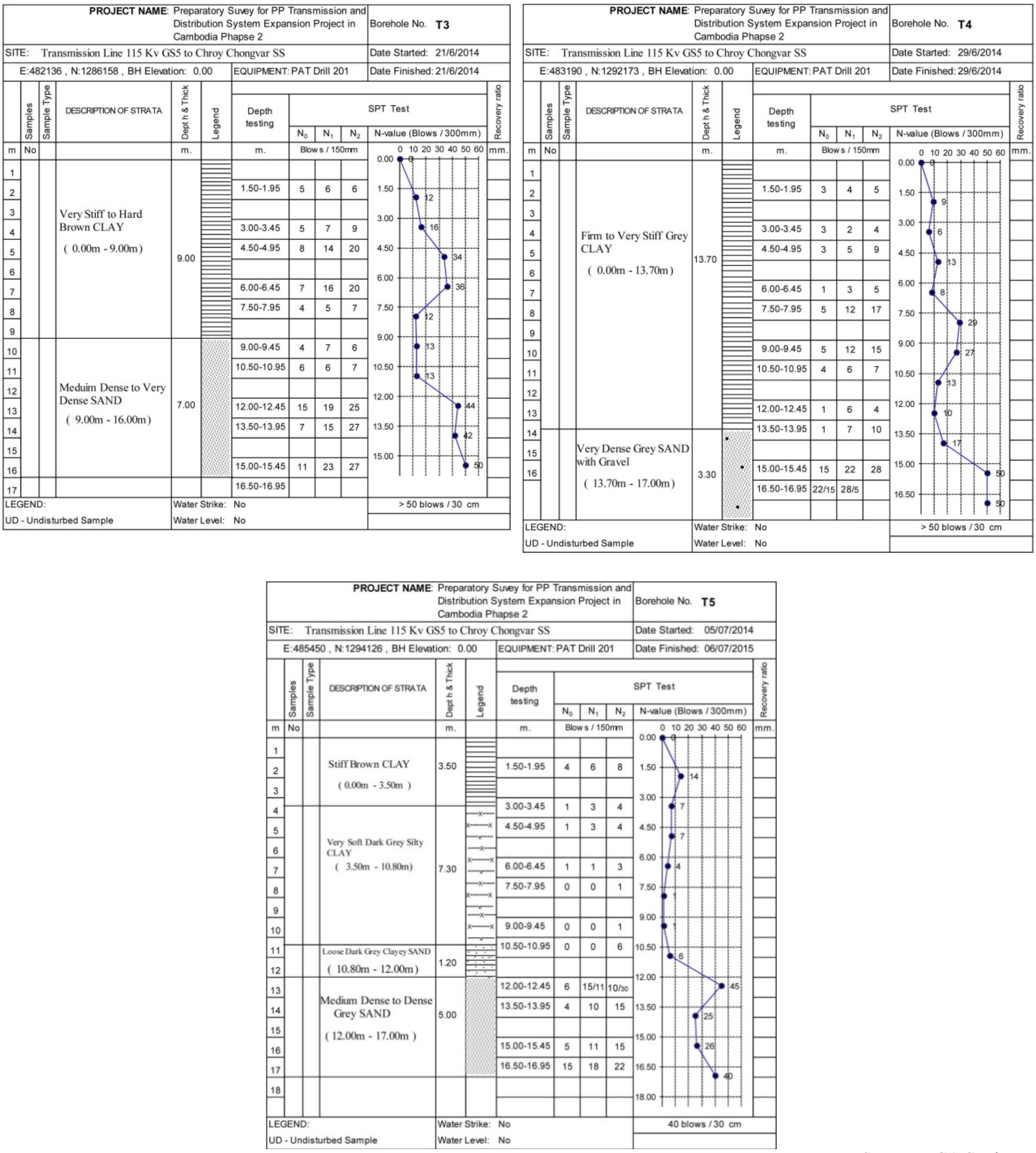
Fig. 6.2-5 Geological Inspection Result (230kV T/L Route: T1 & T2)

6.2.6 115kV Transmission Line Route

The results of the geological inspection for 115kV Transmission Line Route are shown in Fig. 6.2-6.

As for the result of T3 where the application of steel pole is expected, although enough N-value (34, $q_a \geq 850kN/m^2 = 8.5kg/cm^2$) is obtained in clay layer with 5 m in depth, the foundation type should be decided through the detail design and actual excavation, because there is a layer where N-value decreases along with depth and the location is waterside.
T4 and T5 are located along 115kV transmission line tower alignment in the right and left bank of Tonle Sap River, respectively. N-values of the ether drillings are not continuously satisfied with enough value along the depth directions. The transmission line towers in these areas will be applied with pile foundation because they are located in waterside or inundation area in rainy season in addition to the poor bearing capacity in the shallow layers.

The number of piles for one transmission line tower is estimated to be 16 to 20 because 4 to 5 piles are usually installed to each leg. Moreover, foundation of transmission line tower must be stable for uplift force by wind pressure and conductor's tension and buoyancy, and the required pile length depends on these forces.



Source: JICA Study Team

Fig. 6.2-6 Geological Inspection Result (115kV T/L Route: T3, T4 & T5)