Democratic Socialist Republic of Sri Lanka
Ceylon Electricity Board

Data Collection Survey on Electricity Supply System Efficiency in Democratic Socialist Republic of Sri Lanka

FINAL REPORT

DECEMBER 2012

Japan International Cooperation Agency (JICA)

Nippon Koei Co., Ltd.
Tokyo Electric Power Services Co., Ltd.
Sojitz Research Institute, Ltd.

4R
JR
12 - 050

Democratic Socialist Republic of Sri Lanka
Ceylon Electricity Board

Data Collection Survey
on
Electricity Supply System Efficiency
in
Democratic Socialist Republic of Sri Lanka

FINAL REPORT

DECEMBER 2012

Japan International Cooperation Agency
(JICA)

Nippon Koei Co., Ltd.
Tokyo Electric Power Services Co., Ltd.
Sojitz Research Institute, Ltd.

EXECUTIVE SUMMARY

1. Objectives

The main objectives of the Survey are to:

1) Collect and organize the latest information and data on electricity supply system, including transmission and distribution losses in Sri Lanka;

2) Confirm the system efficiency program prepared by Ceylon Electricity Board (CEB) and shortlist CEB's requested projects, which will contribute to the efficiency of the electricity supply system, to be applied for Japan's Loan Aid; and

3) Prepare the project summary including conceptual design, approximate cost estimate, and simplified economic evaluation of the projects requested.

2. Issues on Transmission and Distribution Network

Through the discussions with CEB and site survey conducted, the Survey Team found the following issues on the existing transmission and distribution network;

1) Issues on the transmission network
   - i) Rapidly increasing power demand in Colombo City
   - ii) Transmission lines with old design concept
   - iii) System reliability
   - iv) Shortage of reactive power
   - v) Voltage drop at the end of the network, etc.

2) Issues on the distribution network
   - i) Overloading in primary substations
   - ii) Voltage drop
   - iii) Lack of distribution automation system (DAS)
   - iv) Lack of energy meters and data transmission
   - v) Increase of transformer loss by inadequate transformer capacity
   - vi) Distribution losses caused by long low voltage (LV) lines
   - vii) Theft of electric power
   - viii) Resistive losses at connection points on LV lines
   - ix) Aged and deteriorated facilities
   - x) Salt contamination along seaside
   - xi) Tariff for street lighting, etc.

CEB has prepared project proposals as countermeasures against the above issues and submitted them to the Survey Team in order to request support for Japan's Yen Loan.

3. Candidate Projects

The Survey Team reviewed the proposed project costs, and estimated the amount of loss reduction and economic internal rate of return (EIRR) of each project as shown in Table 1.

Table 1 Summary of Candidate Projects

Projects	Projects Costs		Loss Reduction	EIRR
Transmission Projects	MLKR	MJPY eq.	MWh/year	%
#1 Colombo City Transmission Development with 11 kV DL	21,526	12,743	23,747	18.63
#2 Construction of Kappalthurai GS	1,763	1,044	10,531	16.59
#3 Construction of GSs surrounding Colombo City				17.94
A. Kerawalapitiya 220/33 kV GS	1,294	766	11,041	
B. Kalutara 132/33 kV GS	1,289	763	1,246	
C. Battaramulla 132/33 kV GS	1,448	857	1,708	
#4 Veyangoda – Kirindiwela – Padukka 220 kV TL	5,977	3,538	21,919	16.11
Total Transmission Projects	33,297	19,711	70,192	-
Distribution Projects				
#5 Distribution Development Package in NWP of Region 1	5,271	3,121	16,309	12.92
#6 Distribution Development Package in WPN of Region 2	7,644	4,526	20,293	17.19
#7 Distribution Development Package in WPS-2 of Region 3	8,233	4,874	15,973	18.09
#8 Distribution Development Package in WPS-1 of Region 4	5,143	3,045	7,396	9.85
Total Distribution Projects	26,291	15,566	59,971	-
Grand Total	59,588	35,277	130,163	-

(Prepared by the Survey Team)

As shown in the above table, the total project cost was estimated at LKR 59,588 million (JPY 35,277 million equivalent), and total loss reduction amount was estimated at 130,163 MWh/year.

4. Environmental and Social Considerations

All candidate projects will have environmental impacts such as air pollution, noise and vibration, waste water discharge, and soil contamination. Unsanitary conditions at the workforce camp without proper treatment facility will expose the laborers to sicknesses. Moreover, accidents outside the sites could occur any time since the project may affect the traffic system as the traffic volume is anticipated to be heavier. The degrees of such impacts, however, are only small scale and temporary during construction period.

Based on the legislations of Sri Lanka and JICA Guidelines for Environmental and Social Considerations, it can be concluded that the following mitigation measures should be taken and be monitored during construction period:

Air quality: The amount of SPM has to be monitored periodically, and the construction method should be altered in case it exceeds the environmental standard.

Water quality: The amount of SS and oil has to be monitored periodically, and the construction method should be altered in case its impact exceeds the environmental standard.

Waste: Although waste generated at the construction site and disposal of construction debris will be collected regularly by the local authority, project staff has to physically observe the waste disposal condition, and improve the method of disposal in case it is done inappropriately.

Soil: Project staff has to observe the soil condition, and send the sample soil to laboratories in case there is any contamination.

Noise and vibration: Time management and appropriate work shifts for particular tasks can reduce continuous exposure to such noise and vibration.

Working condition: A tangible safety consideration should be given to laborers, such as wearing helmets, gloves, shoes, and working clothes in order to mitigate the risks of accidents. Appropriate working hours such as three-shift a day, two days off a week, etc., can keep laborers' health condition well. Treatment systems such as septic tank can be installed in order to keep a safe and hygienic working condition.

Traffic: In order not to disturb the traffic system in urban areas, in particular where projects are located, construction work in and around cities/towns can be shifted to night time or weekends. Advance information disclosure on the construction schedule will also contribute to minimizing traffic impacts.

Accidents: Project construction during night and weekend shifts can help decrease disturbance to the traffic in urban areas. Information regarding the construction schedule should be disclosed in advance so that the locals will be aware and mitigate the risks of traffic accidents. Installation of 'keep out' sign boards at locations where construction works are ongoing can keep passers-by away from accidents.

5. Economic Evaluation

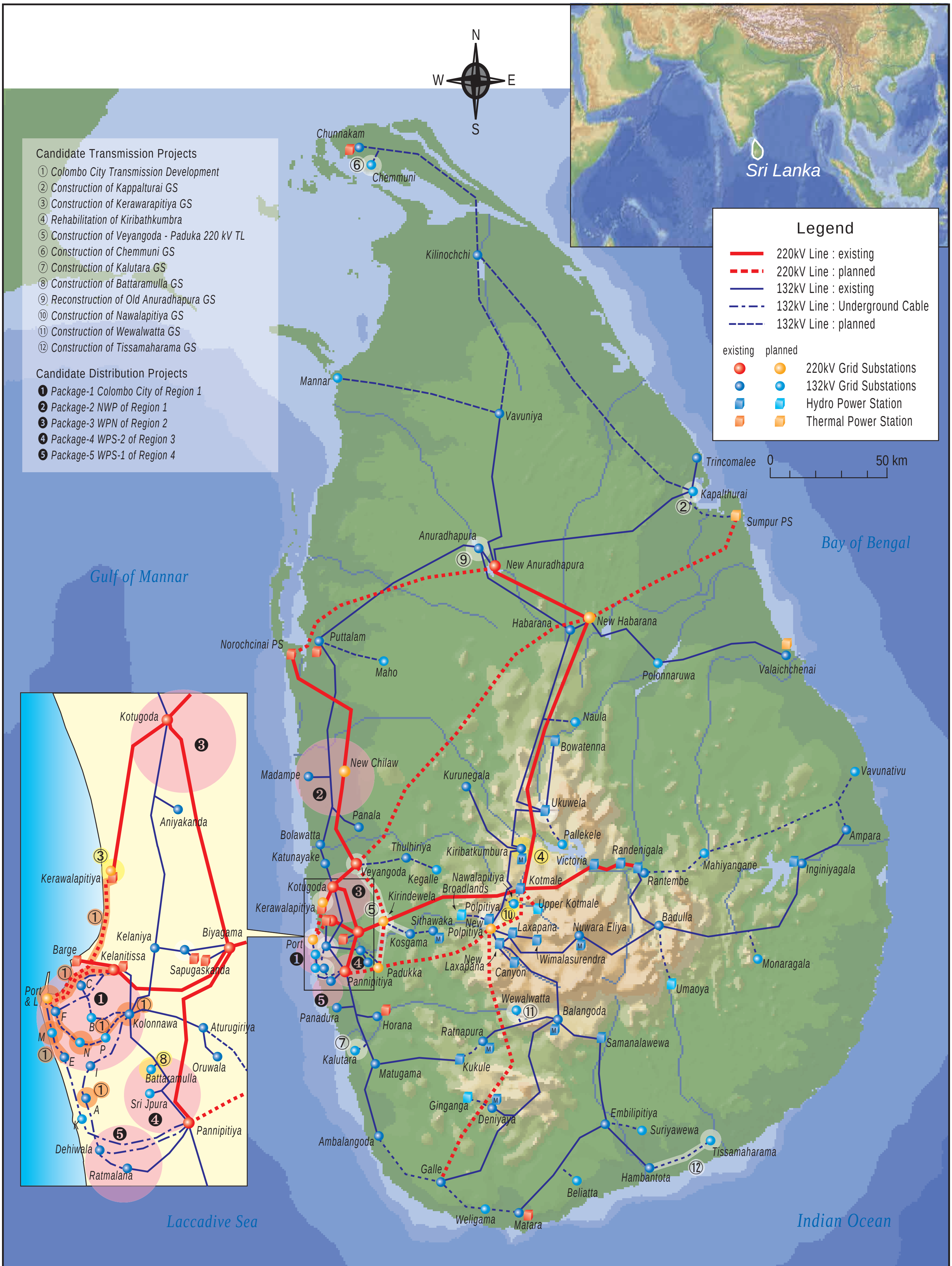
The results of the economic analysis in terms of the benefit cost (B/C) ratio and EIRR of each candidate project under the base case and sensitivity analysis case (under the condition of a 30% increase of the total project cost) are shown in Table 2.

Table 2 B/C ratio and EIRR of the Candidate Projects

Name of Project	B/C ratio		EIRR	
	base	sensitivity	base	sensitivity
#1 Colombo City Transmission Development Project	1.59	1.22	18.63%	14.68%
#2 Construction of Kappalthurai 132/33 kV GS with related TL	1.62	1.25	16.59%	13.37%
#3 Construction of Grid Substations surrounding Colombo City	1.93	1.48	17.94%	14.95%
#4 Construction of Veyangoda - Kirindiwela - Padukka 220 kV TL	1.51	1.16	16.11%	13.59%
#5 Distribution Project for North Western Province of Region 1	1.13	0.87	12.92%	8.87%
#6 Distribution Project for Western Province North of Region 2	1.42	1.09	17.19%	12.37%
#7 Distribution Project for Western Province South-2 of Region 3	1.48	1.14	18.09%	13.09%
#8 Distribution Project for Western Province South-1 of Region 4	0.93	0.71	9.85%	6.28%

(Prepared by the Survey Team)

Table 2 shows that the B/C ratio ranges from 0.93 to 1.93 for the base case and 0.71 to 1.48 under the sensitivity analysis case. Thus, it can be said that the candidate projects will bring benefits, with the exception of Project #8, since its B/C ratio is below 1.0 for both cases. As for the EIRR, it ranges from 9.85% to 18.63% for the base case and 6.28% to 14.95% for the sensitivity analysis case. With the exception of Project #5 and Project #8, under the sensitivity analysis case, the results indicate that the candidate projects shall deliver economic benefits. Thus, from an economic perspective, since most projects yield satisfactory B/C ratio and EIRR under both cases, the candidate projects may proceed.



Project Location Map

(Source:The Map of Sri Lanka Transmission System in Year 2020 prepared by CEB)

FINAL REPORT
for
Data Collection Survey
on
Electricity Supply System Efficiency
in
Democratic Socialist Republic of Sri Lanka

CONTENTS

ATTACHMENTS

ANNEX

TABLES

FIGURES

Abbreviations

ACSR	:	Aluminum Conductor Steel Reinforced
ADB	:	Asian Development Bank
AEA	:	Atomic Energy Authority
AFD	:	Agence Française de Développement (French Development Agency)
AMI	:	Advance Meter Infrastructure
AMR	:	Automatic Meter Reading
BBC	:	Back Bone Communication
BSC	:	Breaker Switched Capacitors
B/C	:	Benefit Cost (ratio)
CAGR	:	Compounded Annual Growth Rate
CCCC	:	Colombo City Control Center
CCD	:	Coast Conservation Department
CCEDD	:	Colombo City Electricity Distribution Development
CEA	:	Central Environmental Authority
CEB	:	Ceylon Electricity Board
CIF	:	Cost Insurance Freight
CPP	:	Coal Power Plant
DAS	:	Distribution Automation System
DCC	:	Domestic Control Center
DER	:	Department of External Resources
DGM	:	Deputy General Manager
DL	:	Distribution Line
DT	:	Distribution Transformer
EDBI	:	Export Development Bank of Iran
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EU	:	European Union
EUA	:	European Union Allowance
EXIM	:	Export and Import Bank of China
FC	:	Foreign Currency
FOB	:	Free on Board
GEF	:	Global Environment Facility
GIS	:	Gas Insulated Switchgear
GIT	:	Gas Insulated Transformer
GoSL	:	Government of Sri Lanka
GPRS	:	General Packet Radio Service
GS	:	Grid Substation
GSM	:	Global System for Mobile Communications
GT		Gas Turbine
HMI	:	Human Machine Interface
HPP	:	Hydropower Plant
IDA	:	International Development Association
IEE	:	Initial Environmental Examination
IPP	:	Independent Power Producer
IUCN	:	International Union for the Conservation of Nature and Natural

JBIC	:	Japan Bank for International Cooperation
JICA	:	Japan International Cooperation Agency
JPY	:	Japanese Yen
KfW	:	Kreditanstalt für Wiederaufbau (Reconstruction Credit Institute)
LAA	:	Land Acquisition Act
LAN	:	Local Area Network
LC	:	Local Currency
LCC	:	Lanka Coal Company (Pvt) Ltd
LBS	:	Load Break Switch
LECO	:	Lanka Electricity Company Ltd.
LKR	:	Sri Lanka Rupee
LOMC	:	Last One Mile Communication
LTL	:	Lanka Transformer (Pvt) Ltd
LTTDP	:	Long-Term Transmission Development Plan
LRMC	:	Long Run Marginal Cost
LV	:	Low Voltage (400 V in Sri Lanka)
MOPE	:	Ministry of Power and Energy
MV	:	Medium Voltage (33 kV and 11 kV in Sri Lanka)
NEA	:	National Environmental Act
NIRP	:	National Involuntary Resettlement Policy
NPV	:	Net Present Value
OF	:	Oil Filled
O&M	:	Operation and Maintenance
ODA	:	Official Development Assistance
PAA	:	Project Approving Agency
PAP	:	Project Affected Persons
PIA	:	Project Implementing Agency
PIU	:	Project Implementation Unit
PMU	:	Project Management Unit
PL	:	Polipto Lanka (Pvt) Ltd
PP	:	Project Proponent
PS	:	Primary Substation
PQ	:	Pre Qualification
PSS/E	:	Power System Simulator for Engineering
PUCSL	:	Public Utilities Commission of Sri Lanka
RTU	:	Remote Terminal Unit
SCADA	:	System Control and Data Acquisition
SEA	:	Sustainable Energy Authority
SCF	:	Standard Conversion Factor
SLPA	:	Sri Lanka Port Authority
SPM	:	Suspended Particular Matter
SS	:	Suspended Solid
SVR	:	Step Voltage Regulator
SwS	:	Switching Station
TA	:	Technical Assistance
TL	:	Transmission Line
TOR	:	Terms of Reference
TOQ	:	Total Quality Management

UDA	:	Urban Development Authority
UGC	:	Underground Cable
UNFCCC	:	United Nations Framework Convention on Climate Change
UNDP	:	United Nations Development Program
US$	:	United States Dollar
WAN	:	Wide Area Network
WB	:	World Bank

Exchange Rate

1 US dollar = 78.2 Japanese Yen

1 US dollar = 132.1 Sri Lankan Rupee

1 Sri Lankan Rupee = 0.592 Japanese Yen

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background and Objectives

The Japan International Cooperation Agency (JICA) has been continuously supporting the power sector of the Democratic Socialist Republic of Sri Lanka, for the efficiency of transmission and distribution facilities that will result to the stabilization of electric power supply, leading to the economic development of Sri Lanka. Especially, JICA has been assisting in the transmission and distribution lines reinforcement projects around the suburbs of Colombo City and in the rural areas since the end of the 1990s.

Following a 7% annual average economic growth rate of Sri Lanka, large-scale generating plants are needed to meet the rapidly increasing electricity demand. In 2011, the recorded electricity demand reached 2,163 MW and according to the 2020 forecast, around 4,051 MW will be required. However, the development of transmission and distribution facilities has not been expanded and resulted to 11.7% of transmission and distribution losses in 2011. Such weaknesses of the network shall be improved through the reinforcement of transmission capacity and efficient utilization of energy.

According to the "Mahinda Chintana (Mahinda Vision)", the Government of Sri Lanka will take the necessary steps to provide all households with continuous electricity supply by the end of 2012. To achieve this, the government will focus on several strategies, such as sustainable generation development, improved access to electricity supply services, efficient utilization of electric energy, and improved electricity tariff system. Among these strategies, efficient utilization of electric energy is recognized as the key strategy. Concretely, such strategies are the utilization of renewable energy, reduction of transmission and distribution losses, promotion of energy-saving equipment for electricity uses, etc. With regards to the transmission and distribution losses, the Mahinda Chintana states that "in order to minimise the transmission losses and also to introduce modern technologies, steps have already been taken to modernise and start new construction of transmission networks and substations covering all geographical areas of the country." To achieve this, the Ceylon Electricity Board (CEB) has prepared the "Long-term Transmission Development Plan 2011-2020" which is a result of several studies, including power flow calculations based on the long-term power demand forecast and generation development plan.

Under such circumstances, once again, JICA has decided to conduct a data collection survey on electricity supply system efficiency in Sri Lanka (hereinafter referred to as 'the Survey') this year. This is intended to collect and organize necessary information for realizing improved efficiency in the electricity supply system which includes the reduction of transmission and distribution losses, and for justifying the requirements for Japan's Loan Aid assistance for the loss reduction program, considering the application of Japan's system efficiency techniques. JICA has employed Japanese consulting firms, namely, Nippon Koei Co., Ltd. (NK) in association with Tokyo Electric Power Services Co., Ltd. (TEPSCO) and Sojitz Research Institute, Ltd. (SRI) (herein after referred to as 'the Survey Team') to conduct the Survey.

The main objectives of the Survey are as follows:

1) To collect and organize the latest information and data on electricity supply system, including transmission and distribution losses in Sri Lanka;
2) To confirm the system efficiency program prepared by CEB and shortlist CEB's requested projects, which will contribute to the efficiency of the electricity supply system, to be applied for Japan's Loan Aid; and
3) To prepare the project summary including conceptual design, approximate cost estimate, and simplified economic evaluation of the projects requested.

1.2 Scope of the Survey

The scope of the Survey is as follows:

1) Confirm CEB's policies and countermeasures to be taken for system efficiency;
2) Confirm the current situation of transmission and distribution network in Sri Lanka;
3) Confirm development assistance of the power sector by other international donors;
4) Prepare the shortlist of candidate projects for system efficiency to be applied for Japan's Loan Aid;
5) Conduct site visit surveys of candidate project sites;
6) Conduct power flow calculations to confirm the efficiency of the candidate projects;
7) Review environmental and social conditions of the candidate projects based on JICA's environmental guideline;
8) Consider the possibility of applying Japanese system efficiency technology to the candidate projects;
9) Prepare project summaries including conceptual design, approximate cost estimates, environmental and social considerations, simplified project evaluation, procurement and implementation plan, operation and maintenance (O&M) plan, etc.;
10) Prepare the reports listed in Section 1.3; and
11) Carry out explanations to and discussions with JICA and Sri Lankan officials.

1.3 Survey Schedule

The entire survey period is about six months: scheduled from June 2012 to December 2012. The first and second field surveys in Sri Lanka were conducted from July 4 to August 2, 2012, and from September 11 to October 13, 2012, respectively. The third survey to explain the draft final report was conducted from November 13 to November 21, 2012.

The reports to be submitted during the survey period are as follows:

1) Inception Report — beginning of July 2012
2) Progress Report 1 — end of July 2012
3) Progress Report 2 — middle of October 2012
4) Draft Final Report — middle of November 2012
5) Final Report — beginning of December 2012 (this report)

1.4 Survey Team

The Survey Team is organized through the association of NK, TEPSCO, and SRI.

The team members who carried out the Survey with assistance from CEB's counterpart personnel are shown in Table 1.4-1.

Table 1.4-1 Composition of the Survey Team

	Name	Position	Firm*
1.	Junichi FUKUNAGA	Leader / Power System Analyst	NK
2.	Fukiyoshi KOREZAWA	Transmission Line Engineer	NK
3.	Kiyotaka KATO	Distribution Line Engineer	TEPSCO
4.	Hitoshi EGAWA	Substation Engineer	NK
5.	Junko FUJIWARA	Environmental and Social Consideration Specialist	TEPSCO
6.	Michiko IWANAMI	Economist	SRI

(Prepared by the Survey Team)

Note: NK: Nippon Koei Co., Ltd.
TEPSCO: Tokyo Electric Power Service Co., Ltd.
SRI: Sojitz Research Institute, Ltd.

1.5 Concerned Personnel

During the survey period, the Survey Team met and had discussions with several concerned personnel listed in Attachment-1.

CHAPTER 2 POWER SECTOR

CHAPTER 2 POWER SECTOR

2.1 Institutions

(1) Ministry of Power and Energy (MOPE)

Formulating and implementing policies for the generation, transmission, distribution and retailing of electrical energy is the responsibility of the Ministry of Power and Energy (MOPE). The ministry's mandated roles and functions are as follows:

1) Formulation of policies, programmes and projects under the power and energy sector and all matters that come under the purview of the institutes within the ministry;
2) Directing the implementation of such policies, programmes and projects;
3) Provision of all public services that come under the purview of the ministry in an efficient and people-friendly manner;
4) Reforming all systems and procedures to ensure the conduct of business in an efficient manner, employing modern management techniques and technology while eliminating corruption;
5) Investigating, planning and development of electricity facilities throughout the island including hydropower, thermal power, mini hydro, coal and wind power;
6) Extension of rural electrification;
7) Development of a sound, adequate and uniform electricity policy for the control, regulation and utilization of normal power resources;
8) Promotion of energy efficiency; and
9) Development of indigenous renewable energy resources.

The Sri Lanka Electricity Act No. 20 of 2009 was enacted by the parliament with the sole objective of implementing the national policy for the power sector. The policy has been formulated with a view of enabling Sri Lanka to meet the expected increasing demand for electricity. The act cites provisions to regulate the generation, transmission, distribution, supply and use of electricity in Sri Lanka. In particular, the act addresses the following concerns/issues:

1) Provision of 24 hours uninterrupted electricity for all at all times;
2) Adoption of a transparent tariff policy that is acceptable to the government, consumers and utilities to ensure reasonable cost recovery;
3) Implementation of lower cost generating plants and the adoption of open competitive transparent bidding processes for the procurement of electricity by utilities, the establishment of a transparent power plant dispatch programme in 2009 and the

upgrading of management information;

4) Update of provisions that is compatible with the latest technology advances and to protect the rights and safeguard the interests of consumers; and
5) Making the Ceylon Electricity Board more efficient and effective, while being made accountable for its functions to the general public, consumers and the government.

The main entities under the purview of the MOPE are:

- Ceylon Electricity Board (CEB);
- Sustainable Energy Authority (SEA);
- Atomic Energy Authority (AEA);
- Lanka Electricity Company (Pvt) Limited. (LECO);
- Lanka Transformer (Pvt) Ltd. (LTL);
- Lanka Coal Company (Pvt) Ltd.(LCC); and
- Polipto Lanka (Pvt) Ltd. (PL)

(2) Public Utilities Commission of Sri Lanka

The Public Utilities Commission of Sri Lanka (PUCSL) was established through Act No 35 of 2002 as a multi-sector regulator to manage certain physical infrastructure industries in the country. Initially the PUCSL Act addressed regulations for electricity and water service industries. Later in March 2006, the petroleum industry was added to the list of industries to be regulated by the PUCSL.

With the enactment of the Sri Lanka Electricity Act No. 20 of 2009, PUCSL became the economic, safety and technical regulator of the electricity industry. With a view of ensuring adequate investment, greater availability, efficient supply, and improved quality of services in the electricity industry, the PUCSL regulates the generation, transmission, distribution, supply and use of electricity in Sri Lanka.

Being the regulator for the electricity industry and water services and downstream petroleum industries, the PUCSL Act identifies broad functions listed out as follows;

1) Exercise, perform and discharge the powers, functions and duties assigned to the PUCSL by the act;
2) Consult, to the extent where the PUCSL considers appropriately, any person or group who or which may be affected, or likely to be affected by the decisions of the PUCSL;
3) Advice the government on all matters concerning any industry falling within the purview of the PUCSL;
4) Collect, record, and disseminate, information concerning any public utilities industries;
5) Prepare within six months a regulatory manual containing a code of good practice which governs the functions of the PUCSL and revise when necessary;

6) Exercise licensing, regulatory and inspection functions within respect to all matters provided by any industry act;
7) Enforce the provisions of licenses, contracts and other instruments issued under the authority of any industry act;
8) Regulate tariffs and other charges levied by regulated entities when necessary;
9) Mediate disputes arising in any public utilities industry;
10) Set and enforce technical and other standards relating to the safety, quality, continuity and reliability of the public utilities industries; and
11) Undertake such other incidental or ancillary activities for the effective discharge of any of its functions.

(3) Electric Power Utilities

CEB and LECO are the only two electric power utilities in the power sector. CEB was established in terms of the Act of Parliament No.17 of 1969 as a state-owned, vertically integrated utility. CEB is responsible for power generation, transmission, and distribution. It raised 89.2% of electricity sales in Sri Lanka and served 4.7 million customers in 2011. LECO was formed in 1983 as a distribution company under the Sri Lankan Companies Act. It purchases electric power from CEB and distributed 1,216 GWh of energy to approximately 490,000 consumers in 2011 in the western and coastal belt townships between Negombo and Galle.

The power sector of Sri Lanka is struggling to meet its growing electricity demand. Economically viable hydropower potentials have already been developed, however power crises in the past drew attention to the importance of timely implementation of new generating plants to meet the growing demand. The power crises have been caused by vulnerability to rainfall. Moreover, limitations of hydropower plants during severe drought fluctuations forced load shedding to limit the daily electricity demand. Since 1996, the Government of Sri Lanka (GoSL) has allowed independent power producers (IPPs) to build, own, and operate thermal power plants to encourage private sector participation in meeting the power supply requirements. The share of electric energy from hydropower plants in the power generation ratio declined from 99.7% in 1986 to 40.1% in 2011. At present, Sri Lanka relies heavily on imported fuel for its electric energy requirements.

The total installed power generation capacity in 2011 amounted to 3,141 MW, which includes the capacity of IPPs of 1,082 MW. Of the capacity feeding the main grid, 44.6% was sourced from hydropower while the balance from thermal, except for 50 MW of new renewable energy such as wind, solar, dendro, and biomass. The peak demand in 2011 was 2,163 MW. Of the total 10,023 GWh electricity sale of CEB in 2011, domestic (households) consumers had the largest share at 33.7%, followed by the industrial sector

(31.2%), general and commercial consumers (19.2%), bulk supply by CEB to LECO (12.6%), street lighting (1.1%), and religious sector (0.5%).

Table 2.1- 1 summarizes the major indices of power sector performance.

Table 2.1-1 Power Sector Performance

	Items	2009	2010	2011	growth rate (2010-11) (%)
1.	Total installed capacity	2,684 MW	2,818 MW	3,141 MW	11.5
1.1	Installed capacity: CEB	1,758 MW	1,758 MW	2,058 MW	17.1
	Hydro	1,207 MW	1,207 MW	1,207 MW	0.0
	Thermal-Oil	548 MW	548 MW	548 MW	0.0
	Thermal-Coal	-	-	300 MW	-
	Wind	3 MW	3 MW	3 MW	0.0
1.2	Installed capacity: IPP's	926 MW	1,059 MW	1,082 MW	2.2
	Hydro	171 MW	175 MW	194 MW	10.9
	Thermal	742 MW	842 MW	842 MW	0.0
	Renewable energy	13 MW	42 MW	47 MW	11.9
2.	Gross generation	9,882 GWh	10,714 GWh	11,528 GWh	7.6
2.1	Gross generation: CEB	5,450 GWh	6,3865GWh	6,552 GWh	2.6
	Hydro	3,356 GWh	4,988 GWh	4,018 GWh	-19.6
	Thermal-Oil	2,091 GWh	1,394 GWh	1,493 GWh	7.1
	Thermal-Coal	-	-	1,038 GWh	-
	Wind	3 GWh	3 GWh	3 GWh	0.0
2.2	Gross generation: IPPs	4,432 GWh	4,329 GWh	4,976 GWh	14.9
	Hydro	525 GWh	646 GWh	604 GWh	-6.5
	Thermal	3,884 GWh	3,600 GWh	4,254 GWh	18.2
	Renewable energy	23 GWh	83 GWh	118 GWh	42.2
3.	Electricity sales	9,491 GWh	10,391 GWh	11,239 GWh	8.2
3.1	Electricity sales: CEB	8,441 GWh	9,268 GWh	10,023 GWh	8.1
	Domestic and religious	2,927 GWh	3,186 GWh	3,430 GWh	7.7
	Industrial	2,518 GWh	2,870 GWh	3,131 GWh	9.1
	General purpose and hotel	1,768 GWh	1,903 GWh	2,086 GWh	9.6
	Bulk sales to LECO	1,120 GWh	1,201 GWh	1,267 GWh	5.5
	Street lighting	108 GWh	108 GWh	109 GWh	0.9
3.2	Electricity sales: LECO	1,050 GWh	1,124 GWh	1,216 GWh	8.2
	Domestic and religious	486 GWh	510 GWh	547 GWh	7.3
	Industrial	208 GWh	229 GWh	241 GWh	5.2
	General purpose and hotel	331 GWh	364 GWh	405 GWh	11.3
	Street lighting	25 GWh	21 GWh	23 GWh	9.5
4.	Overall system Loss of CEB	14.59 %	13.50 %	13.00 %	-0.50
	TL & DL loss	13.90 %	12.97 %	11.72 %	-1.25
5.	No. of consumers: CEB+LECO ('000)	4,749	4,958	5,208	5.0
	Domestic and religious	4,207	4,392	4,610	5.0
	Industrial	46	48	51	6.3
	General purpose and hotel	496	518	542	5.7

(Source: Central Bank of Sri Lanka Annual Report - 2011 and CEB Statistical Digest 2011)

2.2 Power Sector Policies

'Mahinda Chintana (Mahinda Vision)' was formulated by the GoSL in 2006 to set out Sri Lanka's development vision for the 10-year period 2006-2016. Based on an extensive consultation process, the vision sets out a broad macroeconomic framework. It sets out 10-year policy frameworks for various sectors of the economy, including broad vision, situational analysis and strategy. It aims for an ambitious acceleration of growth through a scaling up of investment and increasing productivity.

As for the power sector policy, Mahinda Chintana focuses on infrastructure development to accelerate the country's economic growth, narrow down regional disparities, and envision sustainable development of energy resources. It also focuses on enabling electricity access to the entire population, and reliable service delivery at a competitive price through commercially viable institutions subjected to independent regulation. The framework is based on the National Energy Policy and Strategies formulated by the MOPE.

The MOPE updated this development policy framework in 2010. This provides a comprehensive sector development road map, including a long-term investment program and policy and reform measures. In particular, the strategies updated in 2010 aim to:

1) Increase supply capacity of the system to 3,470 MW by 2012 and 6,367 MW by 2020 and reduce generation cost by adding an aggregate base load capacity of about 2,000 MW from three coal-fired plants;
2) Increase share in grid energy supply from nonconventional renewable energy sources from 4.1% in 2007 to 8.5% by 2012, 10% by 2016, and 20% by 2020;
3) Increase the percentage of households connected to the grid from 88% in 2010 to 100% by 2012;
4) Reduce the total technical and commercial losses of the transmission and distribution network from 14.6% in 2009 to 14.0% by 2012, 13% by 2016 and 12.0% by 2020; and
5) Achieve energy savings of 4.3% in 2012, 6.4% in 2016, and 8.7% in 2020 from a potential consumption level through energy conservation.

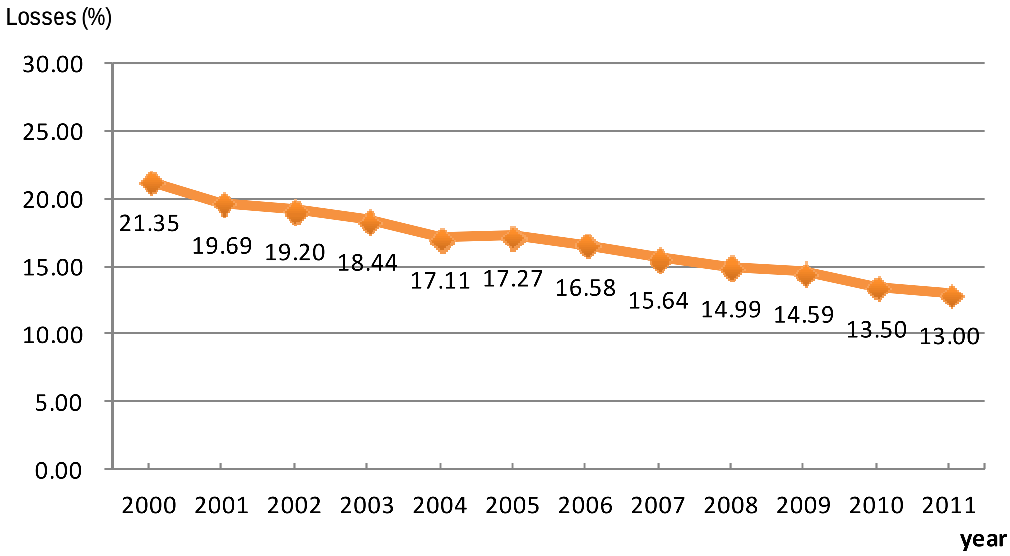
The government's main goals are to improve the quantity, quality, and cost of service delivery, and to increase electricity connections in rural areas.

The National Energy Policy and Strategies also states that "power generation and network losses will be brought down to the lowest possible levels and capacity will be improved through necessary generation, transmission, and distribution investments and efficient management of the supply systems". To achieve this, CEB has been continuously exerting utmost efforts in various ways for the reduction of transmission and distribution losses, which will be discussed in the following sections.

2.3 Current Situation and Issues

2.3.1 Transmission and Distribution Losses

Total system energy losses, including generation, transmission and distribution losses in CEB's network, are gradually being reduced over the past years as shown in Figure 2.3-1.



(Source: CEB 2009 Annual Report and Statistical Digest 2011)

Figure 2.3-1 System Energy Losses

The system energy loss in 2011 was 13.00%, of which transmission and distribution loss was 11.72% and generation loss was 1.28%. In comparison to transmission and distribution loss being 12.97% in 2010, a 1.25% reduction was achieved in 2011 as a result of CEB's reduction efforts. However, transmission and distribution losses, especially the latter, were still at a high level and countermeasures for loss reduction are to be taken continuously.

2.3.2 Transmission Network

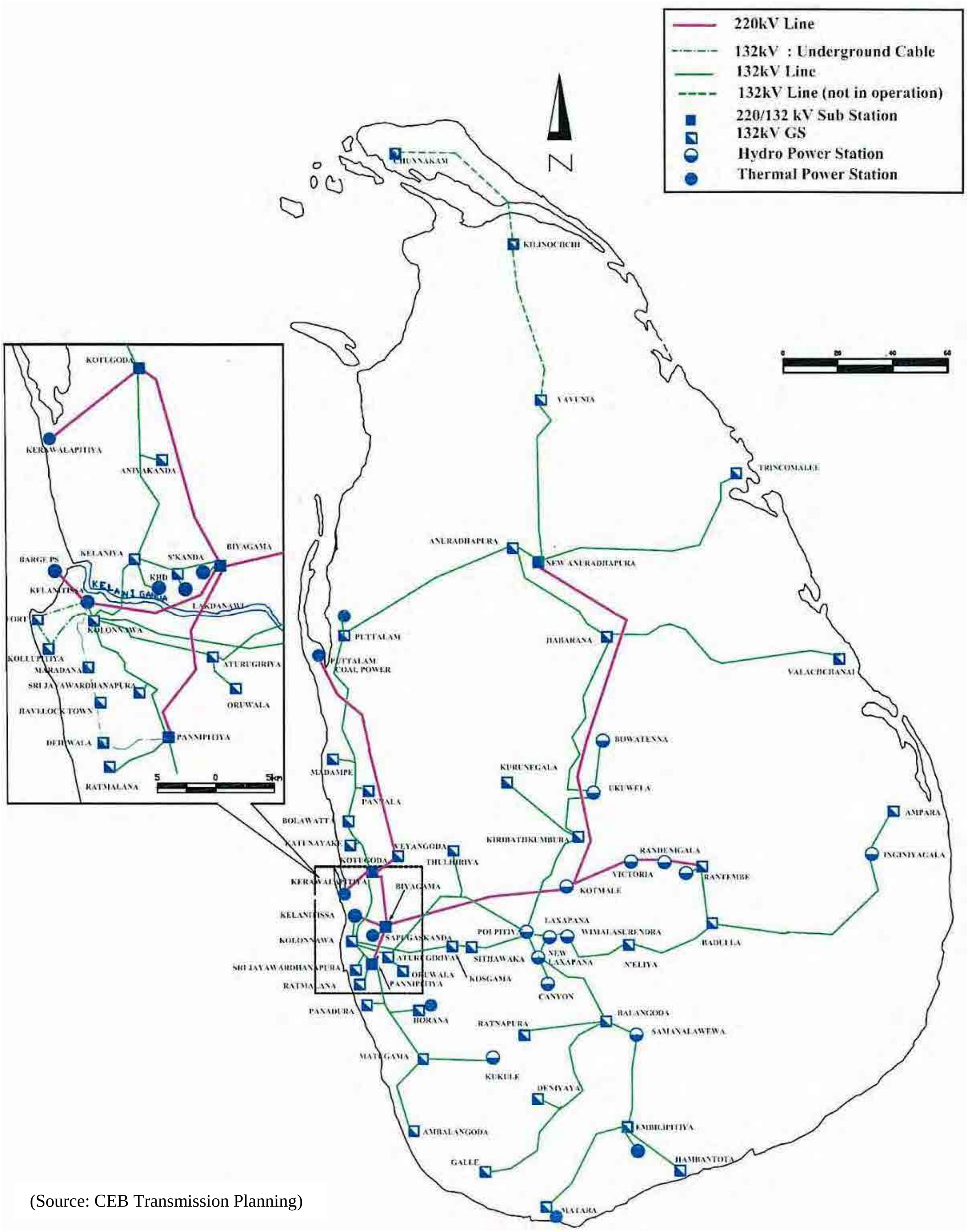
(1) Current Situation

The present transmission system in Sri Lanka consists of a nationwide network of 220 kV and 132 kV transmission lines (TLs) which feed several 220/33 kV and 132/33 kV grid substations (GSs). Table 2.3-1 shows the summary of the existing TLs and GSs. Figure 2.3-2 shows the existing transmission network of Sri Lanka.

Table 2.3-1 Existing Transmission Lines and Grid Substations

Length of Existing TLs			Numbers and Capacities of Existing GSs			
	Transmission Lines	Length(km)		Grid Substations	Number	Capacity(MVA)
1	220 kV overhead line	483	1	220/132/33 kV	5	2,100/500
2	132 kV overhead line	1,724	2	220/132 kV	2	405
3	132 kV underground cable	50	3	132/33 kV	44	2,874
			4	132/11 kV	4	306

(Source: CEB Statistical Digest 2011)



(Source: CEB Transmission Planning)

Figure 2.3-2 Existing Transmission Network as of 2011

As shown in Figure 2.3-2, there are three major 220 kV transmission corridors transmitting bulk power generated from large-scale generating plants to major load centers as follows:

1) From hydropower plants in Mahaweli Complex in the Central Province to Biyagama GS in the Western Province
2) From Kotmale HPP in the Central Province to New Anuradhapura GS in the North Central Province
3) From Norochcholai Coal Thermal Power Plant in the North Western Province to Kotugoda GS in the Western Province

The 132 kV transmission lines are constructed nationwide. Other medium- and small-scale power plants and grid substations are connected through these lines. Most of the 220 kV and 132 kV transmission lines are overhead lines, except for the 132 kV underground cable lines in Colombo City with gas-insulated switchgear (GIS).

(2) Issues on the Transmission Network

As a result of the review and discussions about the system analysis conducted by the CEB Transmission Planning, the Survey Team found the following issues on the existing transmission network.

1) Power supply to Colombo City

The electricity demand of Colombo City is rapidly increasing much faster than expected. This is due to emerging investments and developments such as hotels, commercial complexes, and port expansions after the end of the civil war in May 2009. Table 2.3-2 shows CEB's demand forecast for Colombo City for the period from 2012 to 2032.

Table 2.3-2 Colombo City Demand Forecast (unit: MVA)

Grid Substations	2012	2015	2020	2032
Colombo-A	54.4	61.1	62.6	38.2
Colombo-B	-	29.9	57.0	72.1
Colombo-C	22.9	28.7	33.1	69.8
Colombo-E	59.5	63.0	69.2	56.3
Colombo-F	52.6	45.7	60.4	19.5
Colombo-I	36.8	43.7	49.2	100.0
Colombo-K (new)	-	-	12.3	43.5
Colombo-L (new)	-	32.0	100.0	29.0
Colombo-M (new)	-	51.8	43.5	36.0
Colombo-N (new)	-	-	29.0	65.5
Colombo-P (new)	-	-	36.0	67.4
Kelanitissa	23.7	28.3	60.2	72.0
Kolonnawa	68.2	55.5	62.7	67.4
Total	318.1	439.7	675.2	736.6

(Source: CEB Transmission Planning)

The existing transmission network in Colombo City mainly consists of 132 kV underground cables with several 132/11 kV GSs such as Colombo-A, Colombo-C, Colombo-E, Colombo-F and Colombo-I, and 132/33 kV Kolonnawa and Kelanitissa GSs. In addition to the above, CEB plans to construct new GSs (as shown in Table 2.3-2) and install additional main transformers in the existing GSs to meet the rapidly increasing electricity demand with a new 132 kV underground cable network.

However, old and small-sized 132 kV oil filled (OF) cables of the following sections exist in the Colombo City transmission network;

1) Kelanitissa – Colombo-F, OF 500 mm^2, 4.9 km
2) Colombo-F – Colombo-E, OF 350 mm^2, 2.7 km
3) Colombo-E – Kolonnawa, OF 500 mm^2, 5.4 km

The above cables sometimes leak insulation oil (as shown in the right photograph) which may cause serious accidents. In addition, small-sized cables produce transmission losses. To avoid accidents and transmission losses, old cables shall be replaced with more reliable and large-sized cables.


Oil leak from OF cables at Colombo-E

2) Old design concept

There are many sections of 132 kV transmission lines, which were designed using old design concepts in the existing transmission network as shown in Table 2.3-3.

Table 2.3-3 Transmission Line Sections with Old Design Concept

No.	Section	Conductor	Length (km)	Circuit (cct)	Max. Operation Temp. (°C)	Completion Year
1	Kolonnawa – Pannipitiya	Lynx	12.9	2	54	1971
2	Bolawatta – Madampe (T)	Lynx	22.6	2	54	1963
3	Madampe (T) – Puttalam	Lynx	61.4	2	54	1963
4	Kolonnawa – Athurugiriya – Thulhiriya (T) – Polpitiya	Lynx	78.0	2	54	1959
5	Athurugiriya – Oruwala	Lynx	3.4	2	54	1963
6	Thulhiriya (T) – Thulhiriya	Lynx	23.9	2	54	1971
7	Kolonnawa – Kosgama (T) – Sithawaka (T) – Polpitiya	Lynx	66.3	2	54	1971
8	Panipitiya – Ratmalana	Lynx	6.9	2	54	1971
9	Polpitiya – Laxapana – Wimalasurendra	Lynx	13.4	2	54	1963
10	Polpitiya – New Laxapana – Laxapana	Lynx	8.9	2	54	1960
11	New Laxapana – Canyon	Lynx	10.0	1	54	1983
12	Polpitiya – Kiribathkumbra – Ukuwela – Habarana	Lynx	164.2	2	54	1971
13	Habarana – Anuradhapura	Lynx	48.9	2	54	1971
14	Ukuwela – Bowatenna	Lynx	30.0	1	54	1983
15	Kiribathkumbra – Kurunegala	Lynx	34.6	2	54	1963
16	New Anuradhapura – Trincomalee	Lynx	103.3	2	54	1978
17	New Laxapana – Balangoda	Lynx	43.9	2	54	1963
18	Balangoda – Deniyaya – Galle	Tiger	101.5	2	54	1964
19	Badulla – Inginiyagala	Oriole	79.9	1	54	1963

(Source: CEB Transmission Planning)

These sections were designed for small conductors such as Aluminum Conductor Steel

Reinforced (ACSR) Lynx (183.4 mm^2), Oriole (170.5 mm^2), and Tiger (131.1 mm^2) with 54°C maximum operation temperature, even though CEB now applies ACSR Zebra (428.9 mm^2) as the standard conductor size for new transmission lines with 75°C maximum operation temperature.

Some of the above sections, such as Item 4 "Kolonnawa – Athurugiriya – Thulhiriya (T) – Polpitiya", Item 7 "Kolonnawa – Kosgama (T) – Sithawaka (T) – Polpitiya", and Item 12 "Polpitiya – Kiribathkumbra – Ukuwela – Habarana", are important 132 kV transmission lines, which carry bulk power flow. However, the limitation of the current carrying capacity remains a serious obstacle for system operation due to the maximum operation temperature rations on the power flow. In addition, small conductors produce transmission losses.

3) System Reliability

The 220 kV Kotmale–Biyagama transmission line is one of the most important lines to carry bulk power generated from hydropower stations in Mahaweli Complex in the Central Province to major load centers in Colombo. However, since the Kotmale–Biyagama line passes through a relatively frequent lightning area, lightning sometimes strikes the line and causes severe faults such as nationwide blackouts.

To avoid such huge blackout and still have a reliable system, augmentation of the transmission network, such as construction of diversion transmission lines, is needed.

4) Shortage of reactive power

Electricity demand in Colombo has been rapidly increasing since the end of the civil war. Reactive power supply cannot meet the system requirements to keep the system voltage within an appropriate level. To meet the reactive power demand in Colombo, diesel generators in Sapgaskanda are operated only for the reactive power supply. This is an emergency measure but a costly alternative. Reactive power compensation equipment such as static capacitors shall be urgently installed in the existing grid substations in and around Colombo. This countermeasure also contributes to transmission loss reduction.

5) Voltage drop

CEB defines the permitted voltage deviation at 132 kV busbars as ±10% in the system planning criteria. However, voltage drops exceeding the permissible range are sometimes recorded at substations which are located in rural areas as well as at the end of the transmission network such as Galle, Valachchenai, and Ampara GSs. These drops are due to the long distance and small conductor transmission lines. Voltage drops also increase transmission losses.

To improve such situation, countermeasures such as the construction of a new GS, reconstruction and augmentation of transmission line, together with the installation of static capacitors are to be taken.

2.3.3 Distribution Network

(1) General

Recently, remarkable overloading on the distribution facilities of CEB's network is observed, especially on the medium voltage (MV) lines from 132 kV GSs to 33 kV primary substations (PS). This causes distribution losses.

The CEB's Statistical Digest 2011 shows that the household electrification ratio to be 91.0% in 2011. Although the electrification ratio in urban areas is generally high, it is very low in rural areas, especially in the Northern Province. Since electricity demand density of consumers is very thin in the rural area, distribution lines become very long, causing large resistive losses on the distribution lines. More than 10% of the voltage drops have been observed in rural areas. Some components of the distribution system are old which may cause failures due to poor quality of equipment. In addition, it is necessary to establish an underground cable system in urban area surrounding Colombo City because of the difficulty to reinforce the overhead distribution lines.

The distribution system does not provide a sufficient energy metering facilities to measure the coming and sending of electric power energy. At this moment, there is no energy metering provided even at the distribution transformers. Thus, it is essential to provide energy metering to accurately measure energy losses.

In 2012, Colombo City has completed the installation and commissioning of the System Control and Data Acquisition (SCADA) System under the Colombo City Electricity Distribution Development (CCEDD) Project funded by JICA. It can control the switchgear up to 11 kV PSS from the Colombo City Control Center (CCCC), but other regions/areas do not have the SCADA system like Colombo City. CEB has been developing the SCADA system and some of these are already under operation at this moment. CEB has developed several simplified SCADA systems, one of which is the simplified distribution automation system (DAS) named 'Micro SCADA' in the North Western Province in Region 2. This can operate and monitor switchgear in the network using communication links thru General Packet Radio Service (GPRS) on public mobile telephone network. However, it is not a real time control and monitoring of the system. A similar type of simplified SCADA system is provided in the Central Province. However CEB has recently developed a new SCADA system in Kandy, which can monitor the system in real time. In other areas, the switchgear in the network are still manually operated by an electrician with telephone communication, but not by remote control.

In the Medium Voltage (MV) Distribution Development Study 2010 – 2019 (MV Development Study) prepared by each distribution region or any other information from the CEB, a proposal/statement regarding a 'Smart Grid System' has not yet been proposed. However, CEB has the target to proceed with the electrification and rectification of several problems such as overloading and voltage drop, and has started to provide automatic reading of energy meter at retail distribution transformers, which will herald the Smart Grid System in Sri Lanka. It now seems possible to apply the technique of 'Smart Meter' to the remote monitoring of energy meters, which was proposed by the CEB in a letter to the MOPE.

Based on the above information collected during the site survey, the current status of CEB's distribution system was evaluated/analyzed and reported as follows.

(2) Current Status of CEB's Distribution System

1) Boundary of transmission and distribution

The boundary of responsibility between the transmission branch and distribution branches is the MV gantries of GS. The distribution branches are responsible for the allocation of facilities from the gantries to consumers. The proposals issued by the distribution branches cover MV distribution lines (33 kV and 11 kV), PS, distribution substations and low voltage (LV) lines, but do not include facilities such as capacitor banks or voltage controllers in GS. When the distribution branches need to provide such facilities to solve problems on distribution system, the transmission branch will propose the provision of any necessary equipment.

2) Growth of electricity power demand

The growth of peak demand of each region reported in the MV Development Study is shown in Table 2.3-4.

Table 2.3-4 Peak Power Demand in Distribution System (unit: MW)

Regions	2011	2012	2013	2014	2015	2016	2017	2018	2019
Region 1	272	297	330	355	382	407	431	456	478
Region 2	720	775	838	906	952	1,003	1,054	1,111	1,165
Region 3	490	543	548	586	645	686	703	741	772
Region 4	379	417	447	477	551	568	596	613	637
Total	1,861	2,032	2,163	2,324	2,530	2,664	2,784	2,921	3,052
Increase ratio	-	9.2%	6.4%	7.4%	8.9%	5.3%	4.5%	4.9%	4.5%

(Source: CEB MV Development Study)

Note: Total is summation of peak demand in each Region, actual peak demand of CEB overall shall be slightly different because peak time is different in each Region/Area.

As shown in the table, total peak demand is increasing between 5% to 9% every year in each region and overall CEB. Also, the growth of power energy demand in satellite town surrounding Colombo City is very remarkable.

3) Electrification

According to the instruction from the GoSL, CEB intends to increase the electrification ratio to 100%. However, the electrification ratio in rural areas is lower than that of urban areas as shown in Table 2.3-5 below.

Table 2.3-5 Electrification of CEB Distribution

Province	Land Area (Sq.km)	Population (Million)	Households	Electrified Households	Electrification Ratio	Demand Density (kW/Sq.km)
North West	7,756	2.32	667,000	594,899	89%	24.9
North Central	10,472	1.25	447,000	295,924	66%	8.9
Northern	8,847	1.17	224,000	143,611	64%	6.1
Colombo City	37	0.74	155,000	154,268	100%	6,811
Region 1 Total	27,112	5.00	1,493,000	1,188,702	80%	12.6 (excl CC)
Western P N	1,421	2.50	492,878	465,010	94%	290
Central	4,600	2.26	659,340	600,000	91%	36
East	9,780	1.82	453,531	322,253	71%	13
Region 2 Total	15,801	6.58	1,605,749	1,387,263	86%	45
West-south 2	1,200	0.80	341,000	334,436	98%	187
Sabaragamuwa	8,350	1.45	353,000	346,000	98%	26
Uva	5,053	2.39	394,000	386,035	98%	13
Region 3 Total	14,603	4.64	1,088,000	1,066,471	98%	226
West-south 1	1,230	1.44	419,190	375,980	90%	120
Southern	5,497	2.90	669,667	650,446	97%	36
Region 4 Total	6,727	4.34	1,088,857	1,026,426	94%	51
CEB Total	64,243	20.35	5,092,468	4,217,391	83%	32

(Source: CEB MV Development Study)

In rural areas, the electrification level in the Southern Provinces is larger than in the Northern Provinces. It is striking that the electrification level in the Northern Province is only 42%, as some islands in the province are neither connected to a transmission network nor an independent generating system such as diesel generators. Moreover, they are not synchronized with the main transmission network of CEB.

4) Current status of distribution lines

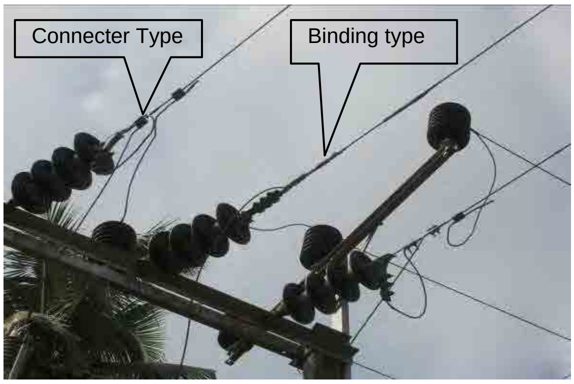
CEB's distribution system uses two kinds of ACSR conductors. One is ACSR Lynx (37/2.79 mm) used for 33 kV trunk lines named the backbone lines and the other is ACSR Raccoon (7/4.09 mm) used for 33/11 kV branch lines, named the pole lines. As far as the specifications of the conductors used for distribution lines, no problem or inadequacy were seen, despite the fact that long distribution distance may have caused most of the distribution losses.

Table 2.3-6 shows the network components of CEB's distribution system.

Table 2.3-6 Network Components in Distribution System

Province	Number of Grid SS	33kV lines (km)	Number of PS	11kV lines (km)	Number of LV SS	LV lines (km)
North West	6	3,497	19	283	3,227	17,628
North Central	3	3,087	5	258	1,739	8,397
Northern	2	903	4	176	617	3,205
Colombo City	4	48	5	572	1,318	804
Region 1 Total	15	7,534	33	717	6,901	30,034
Western P N	11	2,029	16	143	2,546	8,121
Central	6	3,188	3	130	2,781	12,288
East	5	1,846	20	373	1,552	6,448
Region 2 Total	22	7,063	39	646	6,879	26,857
West-south 2	6	1,059	9	16	1,657	5,040
Sabaragamuwa	2	2,727	0	0	1,452	10,438
Uva	4	2,680	5	54	1,572	8,878
Region 3 Total	12	6,466	14	70	4,681	22,042
West-south 1	4	793	17	72	1,148	3,175
Southern	5	3,612	17	209	2,649	18,394
Region 4 Total	9	4,405	34	281	3,797	21,569

(Source: CEB MV Development Study)



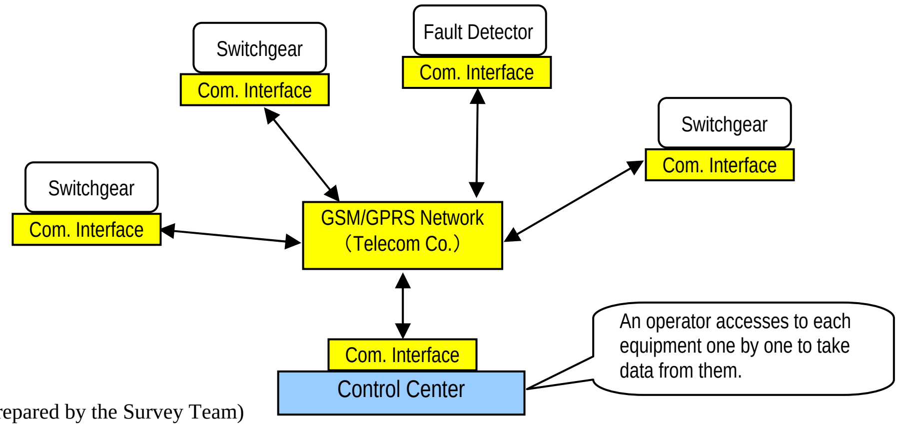
As shown in the above table, the length of the distribution line is quite long compared with the total lengths of distribution lines and the quantity of distribution substations. Actually, the length to the most distant consumer is 1.8 km and the total lengths of LV lines connected to one distribution substation is 8 km on the average and 15 km at maximum. In addition, substandard connections of wires were observed during site inspection, which may have caused the resistive losses at connection points. As shown in the above photograph, the winding connection and connector connection are on a single pole. This may cause the connection to become loose because of the mechanical characteristic of aluminum which can be deformed by continuous stress in a long duration.

All distribution lines are underground cables in Colombo City, using 11 kV cables instead of 33 kV cables due to cost difference. Although losses on the 11 kV distribution lines in Colombo City are not so large, their lengths are very short. In the CCEDD project, the existing old 33 kV underground cables have been replaced with 132 kV cables.

5) Distribution automation system (DAS)

The SCADA system is provided in Colombo City by the CCEDD project. However, other regions/areas still have no full scale SCADA system, except the North Western Province (NWP) of Region 1, Western Province North, Central Province and Kandy City. NWP in Region 1 applies a simplified DAS, which can control and indicate the status of the switchgear from a remote control center through a mobile telephone network. However, the status indication is not updated since it uses GPRS and Global System for Mobile (GSM) Communications. It also does not communicate the status periodically. When an operator accesses a remote station, he/she should first confirm the present status of the switchgear and operate it next. The Central Province also provides similar system as the simplified system of Region 1 and the same type is also provided in the Central Province of Region 2 as shown in the right photograph.

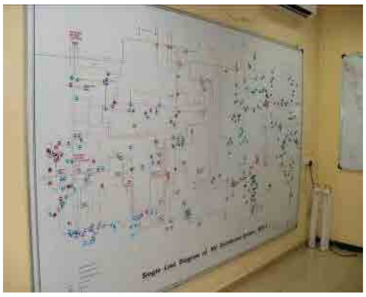
Recently, Region 2 developed a new SCADA system which applies cyclic data acquisition from local equipment and data logging. In Region 3, an identical DAS in Kandy City is under development and will be completed in 2013. The system configuration of Micro SCADA is shown in Figure 2.3-3.



(Prepared by the Survey Team)

Figure 2.3-3 Communication method of Micro SCADA

Western Province South-1 (WPS-1) in Region 4 has a white board with mimic and symbol to indicate and manually change the status of the switchgear as shown in the right photograph.



CEB has applied GPRS/GMS to transmit and receive the data for DAS. Considering the cost, security and reliability of the system, it is suggested to use a dedicated line on the public telephone network or dedicated communication link such as optical fiber communication. In the latest situation in Sri Lanka, it is recommended to apply a fiber optic communication for Back Bone Communication (BBC) and radio communication such as ZIGBEE or RF Mesh system for the Last One Mile Communication (LOMC).

The specification of each system is summarized in Table 2.3-7.

Table 2.3-7 SCADA System applied in CEB Distribution System

Function	Colombo City	Region 1 NWP (Micro SCADA)	Region 2 WPN	Region 2 Kandy Control Center	Region 2 Central Province	Region 3 WPS-2 (under develop.)
Communication	O/F cable and Public tel-links	GPRS	GSM/GPRS	GSM/GPRS	GSM/GPRS	GSM/GPRS
Operated SWGR	All SWGR/TR	SWGR	SWGR	SWGR	SWGR	SWGR
Database	Provided for almost all events, status and electrical quantity	Equipment status and events	Provided for almost all events, status and electrical quantity	Provided for almost all events, status and electrical quantity	Provided for almost all events, status and electrical quantity	Provided for almost all event, status and electrical quantity
Log Report	Provided*1	Provided	Provided	Provided	Provided	Provided
Intelligent function*2	Provided	Not available	Provided	Not Provided	Not Provided	Not provided

(Prepared by the Survey Team)

Note 1: In the log report, the operation of switchgears, alarm, and fault event are recorded and reported on demand.

Note 2: In intelligent function, there are several features (e.g. the optimum recovery routine) that can be instructed to the operator.

(3) Current Status of Distribution Losses and Countermeasures

1) Non-technical losses

Non-technical losses are caused by misreading/error of energy meters, power theft, street lighting and power supply to the public sector. However, CEB cannot grasp the quantity of lost energy from LV substations because they do not have proper energy meters. Therefore CEB calculates the losses from the difference between the input energy measured at GS/PS and sold energy to consumers. In every region, it was said that the breakdown of the non-technical losses were unknown.

2) Technical losses

Technical loss is composed of MV distribution losses (about 2%) and LV distribution losses (about 10%). The MV distribution losses are reported in the MV Development Study as shown in Table 2.3-8.

Table 2.3-8 MV Distribution Losses

Province	Power Demand (MW)	Power Loss		Energy Demand (GWh/y)	Energy loss	
		MW	%		GWh/y	%
North West	193	3.8	1.9%	1,023	12.9	1.3%
North Central	93	3.0	3.2%	362	6.0	1.7%
Northern	54	1.3	2.5%	204	2.6	1.3%
Colombo City	189	1.2	0.7%	1,249	3.7	0.3%
Region 1 Total	529	9.3	1.8%	2,838	32.6	1.1%
Western P N	412	8.5	2.1%	2,068	26.4	1.3%
Central	164	6.5	4.0%	805	19.5	2.4%
East	127	9.6	7.7%	544	22.8	4.2%
Region 2 Total	703	24.6	3.5%	3,418	68.7	2.0%
West-south 2	224	3.3	1.5%	1,393	15.0	1.1%
Sabaragamuwa	132	4.2	3.1%	487	7.7	1.5%
Uva	112	5.1	4.5%	363	8.9	2.5%
Region 3 Total	468	12.5	3.0%	2,277	31.6	1.3%
West-south 1	169	4.4	2.6%	1,098	19.6	1.8%
Southern	190	4.7	2.4%	866	12.3	1.4%
Region 4 Total	359	9.1	2.5%	1,964	31.9	1.6%

(Source: CEB MV Development Study)

However, LV distribution losses were not given in the MV Development Study. CEB explained that they do not have facilities to measure the energy to input to the LV distribution line. CEB calculates the lost energy from resistance values and current values on the LV distribution lines. Accordingly, energy meters are very effective tools to measure the output energy for each LV distribution lines.

(4) Issues and Concerns to be solved in CEB's Distribution System

1) Overloading in GSS/PSS

In the CEB's distribution system, transformers and MV distribution lines do not have any operation margin in their current capacities. For instance, scheduled shutdowns are carried out in Kuriyapitiya to prevent overloading the equipment. It is very important to reinforce the GS, PS and transformers to give an increased margin in operation. CEB produces the reports on the MV Development Study only every two years. However, overloading on facilities occur every year. The followings are the unnoticed problems to be addressed in the development plan.

i) Growth of power demand is more rapidly increasing than expected.
ii) Remarkable delays in the schedule of reinforcement/installation.
iii) Expected margin of facility is too small; and
iv) Low quality of distribution facility due to aging, improper design and poor equipment quality.

It is recommended to take the soonest action to find the root causes of the problems and take the countermeasure(s) to solve the above conditions in overloading.

2) Voltage drop

Voltage drop is observed at many locations on CEB's distribution system. The root causes of voltage drop are the distribution of electric power on long distribution lines and overloading. The following three countermeasures are considered to rectify voltage drop.

i) Provide additional distribution lines and/or size up the conductors;
ii) Construct new GS to shorten the distribution lines; and
iii) Provide voltage compensation facilities such as step voltage regulator (SVR)

If the capacity of the distribution line is sufficient to feed the power to consumers, it is an economical solution to provide voltage compensation facilities. However, considering the current situation of CEB, it is recommended to take the option i) and/or ii).

3) DAS

It is recommended to provide a DAS to the distribution system. If DAS is provided, the following advantages will be realized in the distribution control and management of CEB.

i) Continuous monitoring of switchgear

It is very essential to indicate the present status of switchgear in the Domestic Control Center (DCC). Under the present system, the call center received the claim from consumers and confirms the status of equipment. If DAS is provided in the DCC, the following activities can be available automatically.

- 24 hours monitoring (no call center)
- Indication of status of switchgear and live/dead conditions of line section
- Support system to instruct fault locations on a map and failed equipment identification.

ii) Remote control of equipment

Under the present system, the call centers receive the information from consumers and the control center instructs the operators to visit the site and change the status of the switchgear. It takes a long time to changeover the switchgear and to minimize the shut-down section. After the changeover of the switchgear, the control center may instruct maintenance electricians to repair the failed equipment. If DAS is provided, it is possible to changeover the switchgear without visiting the site and the shut-down section can be minimized. In addition to remote control, it is possible to provide software to control the switchgear automatically or give suitable instructions to the operators in accordance to a pre-determined routine. Also, DAS can monitor the power factor on the system and control the reactive power by switching-in capacitors.

However, it is essential to provide the operating mechanism in the switchgear in order to control these by remote signal.

iii) Continuous monitoring for disturbance and control

It is not possible to measure the electric current on each distribution line under the present system. The DAS can monitor all information on the distribution lines and it can acknowledge the abnormality on the distribution line even if it is given by a complicated calculation. For example, in the case of overloading of a distribution line, DAS automatically detects the changeover of the switchgear status will be done to even the load current on each line.

iv) Database and reporting

Currently, operators record the status and/or disturbance on a log book or manually input the record to a PC database. The DAS has the routine function of recording into the database and can issue a report of any information automatically or on request. It can also eliminate any human error in recording and reporting.

v) Intelligent DAS functions

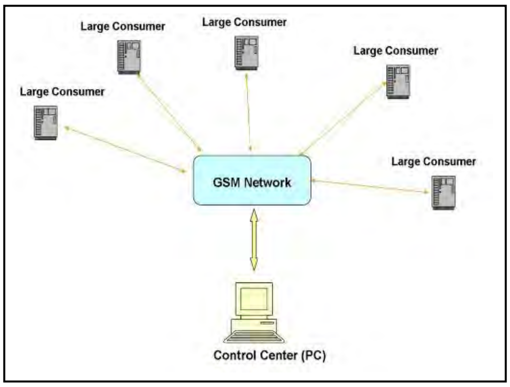
At present, operators monitor the distribution system and make decisions to control the switchgear through their own skills and knowledge. Intelligent functions can be provided with the DAS by adding an optional software. For example, it is possible to issue an alarm easily by an output of calculation, even if it can be calculated only through a complicated process or equation.

vi) Communication for DAS

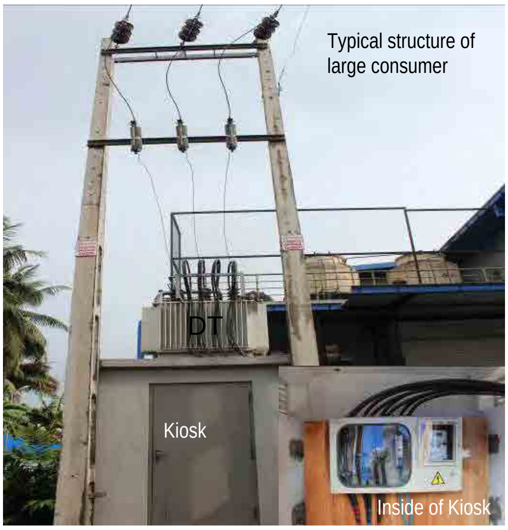
At this moment, CEB uses GSM/GPRS for DAS. However, it is not a suitable communication system for the control of electric power system because of cost, reliability and security reasons.

4) Provision of energy meters and data transmission

CEB has the static energy meters (Class 1.0) with remote reading facilities for large consumers through GSM network as shown in the right figure. Also typical structure of large consumer is shown in the photographs below. An operator remotely accesses the energy meters once a month to take consumption data one by one.



However, in some distribution substations, energy meters are not provided, or old fashioned mechanical types (induction disk-type meters with class 2.0) are used. Consequently, it is not possible to measure energy on LV lines and it takes time to read the meter indication on site. To analyze the distribution losses, energy meters are an effective tool to measure the losses.



In case of resistive losses on distribution lines, it is possible to calculate the losses by impedance of the conductor and the load current on a line. Even if meters are to be provided at distribution substations, operators need a lot of work to go to the sites and read the meters due to the large numbers of energy meters; more than 1,000 sets are to be installed at distant place in one local area office. To save time and manpower to read meters, it is important to add a remote data monitoring system to send the reading of a meter to the Control Center. In addition to the energy meter reading at a distribution transformer, it is recommended to provide smart metering at each consumer location in the future.

5) Increase of transformer loss due to inadequate transformer capacity
CEB has standard series of DT capacity of 100 kVA, 160 kVA and 250 kVA. If the power demand in rural areas is very small at the distribution substation, the minimum rating of 100 kVA transformers is used for the substation. In this case, no-load loss (iron loss) is very large because of the too-large transformer rating comparing with the power demand. If a transformer with adequate capacity such as 30 kVA is used for a small-demand substation, it is possible to reduce the no-load loss of the transformer. If a small single phase transformer is applied to the LV feeder with small load, further reduction of no-load loss is possible.

In addition, if low-loss transformers with the latest technique such as 'Top Runner Transformer' with appropriate capacities are to be applied in the system, these are expected to remarkably reduce transformer losses.

6) Distribution losses caused by long LV lines
It was confirmed that the length of the LV line to the most distant consumer is 1.8 km and the total lengths of LV lines connected to one distribution substation are on the average, 8 km and at maximum, 15 km. The LV lines seem too long and produce large distribution losses. It is therefore an effective countermeasure to provide additional LV distribution substations to reduce the lengths of LV lines and accordingly, decrease the distribution losses.

7) Theft of electric power
Most modus operandi of power theft is hanging a hook on a bare LV wire, because the density of population is very thin in rural areas and therefore, it is very difficult to notice such an activity in a wide area. Under the current distribution system of CEB, it is difficult to discover power theft because electrical energy is not exactly monitored on the LV line. Therefore, it is recommended to provide energy meters on every LV line to monitor the branched energy by theft.

8) Resistive losses at connection points on LV lines
It was observed that LV distribution wires were connected by a connector or a manual winding connection. There are two reasons of connection loss on an LV line. One is manual connection by an unskilled electrician; it is very difficult to control the skill and check the connection on site. A worker climbs on the pole alone and carries out the connection work without appropriate examination. The other reason is the connection by screw connector; aluminum can be deformed at the screw connector in long duration and therefore causes improper contact, which results in heating loss by contact

resistance at a connection point. A thermal imaging camera can observe heating at the connection.

It is necessary to use hydro-compression tools by which proper compression clamp connection can be done without long-term experience. It is also recommended to properly train the workers to eliminate defective connection.

9) Rehabilitation of aged facilities

Some existing 11/0.4 kV transformers were manufactured more than 70 years ago and are still working at 11 kV substations. Considering the current technique level, it is possible to reduce transformer losses by applying the recent technology. Rehabilitation/reinforcement of aged facilities is thus one of the options to reduce distribution losses.

10) Salt contamination along the seaside

Since salt contamination is observed on overhead lines along the seaside, the CEB applied 33 kV insulators for 11 kV distribution lines to increase the creepage distance of insulators. As a drastic measure to solve salt contamination, cables should be adopted to distribution lines instead of overhead conductors. It is effective to reduce distribution losses through provision of new small unmanned GS or PS to which 132 kV or 33 kV cable will be connected from 132 kV or 33 kV network to minimize lengths of 11 kV overhead lines.

11) Applicability of low loss transformers

Almost all DTs are supplied in accordance with standard specification of LTL. The Survey Team has investigated and confirmed whether LTL can supply the DTs with directional silicon iron core. However, it is very difficult to apply amorphous iron core for DTs because the design of the amorphous transformers are completely different from the directional silicon iron core and large changes in production line is required. In order to be produced amorphous transformer by LTL, technical assistance shall be required by Japanese manufacturers.

12) Safety issues for site works

Site work for distribution lines is very dangerous. Normally CEB workers are climbing on the top of poles by ladders and carrying out the work.


Vehicle and ladder for


Site work at pole

(5) Others

1) Street lighting

The power for street lightings is fed from an LV distribution line. Tariff for street lighting is not paid to the CEB. To reduce the demand, CEB proposes energy saving activities to the departments concerned in Colombo City.

2) Capacity building

When the Survey Team visited the CEB Training Center, the Deputy General Manager (DGM) of the Training Center explained that the 'SynerGEE' (USA) software has been used for distribution planning for more than ten years. Extension of the license is made every year and each regional office has the license. It is considered that to support to provide other software for distribution planning is not necessary because CEB is accustomed to and satisfied with SynerGEE. Meanwhile the DGM of the Training Center requested the Survey Team to supply hydro compression tools for connecting distribution conductors and to train electricians how to correctly use the tools to reduce distribution loss. The Survey Team supposes that it is very effective for loss reduction.

3) Billing system to consumers

CEB has several area offices in each province. Meter readers of CEB visit each consumer once every month to read energy meters and issue the bills to CEB's billing center. The billing center mails official bills to consumers in due course. Each consumer pays the bill by several methods such as direct payment at CEB area office, at super market or by bank account. If consumer does not pay the bill, CEB issues the "Red Notice" to the consumer and may stop electricity when he does not pay the bill within the decided time.

Almost all meters for small consumers are electro-magnetic type with accuracy class 2.0. CEB does not accurate the meters periodically then they only goes to consumer when they send claim to the service center or a meter reader find a problem during meter reading. The Survey Team has found the several problems in current billing system as follows;

- Failure of energy meters produces lots of non-technical losses.
- Poor accuracy class of energy meter may produce much non-technical losses.
- It is difficult to find the problems in energy meters until it shows remarkable error.

2.4 Development Plans

2.4.1 Long-Term Transmission Development Plan

The Transmission Planning of CEB has been preparing the Long-term Transmission Development Plan (LTTDP) 2011-2020. The objectives of the LTTDP 2011-2020 are:

1) To formulate the required transmission development to ensure a reliable and stable power system for the period year 2011 – 2020 and the planned implementation dates.
2) To estimate the investment cost of the transmission development within the period from year 2011 to 2020.

The LTTDP 2011-2020 has been prepared as a result of power system analysis, considering the current issues described in Sub-section 2.3.2, and based on the national power and energy demand forecast as well as the long-term generation expansion plan.

Chapter 5 of the LTTDP 2011-2020 includes transmission expansion proposals with the following three categories:

1) Uncommitted transmission development proposals
   The transmission network expansion proposals, which are identified as a result of the system analysis done by CEB Transmission Planning, include two kinds of project lists; one is the list of already committed and being implemented projects, and the other is the list of uncommitted projects.

2) Power plant connection proposals
   This includes transmission system development required for power plant developments.

3) Other transmission development proposals
   Apart from the above transmission system expansion and reinforcement proposals, other proposals include minor system improvements or renewal needs to enhance the operational and maintenance aspects of the transmission system.

Among the proposals mentioned above, the Survey Team agreed with CEB to take the list of uncommitted projects of transmission development proposal as the long list for the candidate subprojects for Japan's Loan Aid as shown in Table 2.4-1.

Table 2.4-1 Transmission Expansion Proposals

ID	Projects	Comm. year	Base Cost (MLKR) FC	LC	Expected Funding
1	Installation of 100 MVar capacitor bank at Pannipitiya GS	2012	206.3	13.0	GoSL
2	Construction of Colombo-B 132/11 kV GS with single in/out connection from Colombo-C - Kolonnawa 132 kV UG cable	2013	908.0	133.8	JICA
3	Augmentation of Sri J'pura GS	2013	389.5	59.6	GoSL
4	Augmentation of Hambantota GS	2013	369.8	59.6	GoSL
5	Construction of Suriyawewa 132/33 kV GS	2013	808.9	197.9	GoSL
6	Construction of Kegall 132/33 kV GS with Thulhiliya-Kegall Zebra, 132 kV 14 km 2-cct TL and TL bays at Thulhiliya GS	2013	994.4	252.7	ADB*1
7	Construction of Kerawalapitiya 220/33 kV GS	2013	880.8	140.3	JICA
8	Augmentation of Colombo-A GS	2013	203.8	39.1	JICA
9	Construction of Kappalturai 132/33 kV GS with double in/out connection from New Anuradhapura - Trincomalee 132 kV TL	2013	742.9	145.0	JICA
10	Construction of Kalutara 132/33 kV GS with single in/out connection from Panadura - Mathugama 132 kV TL	2013	728.4	155.7	JICA
11	Installation of 2nd 220/132 kV, 105 MVA inter-bus ATR at Rantambe PS	2013	287.1	67.2	GoSL
12	Installation of 3rd 220/132/33 kV, 150 MVA inter-bus ATR at New Anuradhapura GS	2013	303.8	67.7	N/A
13	Installation of reactive power compensation devices at Kurunegala GS (30 MVar)	2013	116.2	8.4	N/A
14	Reconstruction of Polpitiya-Kiribathkumbra-Ukuwela-Habarana 132 kV, 164 km 2-cct TL (from Lynx to Zebra)	2014	2,652.8	1,384.3	N/A
15	Replacement of 132 kV 500 mm^2 OF cables between Colombo-E and Colombo-F	2014	184.3	13.1	JICA
16	Construction of Vauniya-New Anuradhapura Zebra, 132 kV, 55 km 2-cct TL	2014	889.6	464.3	ADB*1
17	Construction of Thulhiliya-Veyangoda Zebra, 132 kV, 28 km, 2-cct TL with 2 TL bays at Veyangoda GS	2014	645.6	304.7	N/A
18	Construction of Pannipitiya-Ratmalana Zebra, 132 kV, 7 km, 2-cct TL	2014	113.2	59.1	N/A
19	Reconstruction of 132 kV TL with Zebra, Bolawatta-Pannala-New Chilaw	2014	372.0	194.1	N/A
20	Augmentation of Madampe GS	2014	318.7	56.4	N/A
21	Construction of Mannar 132/33 kV GS with Vavuniya-Mannar Zebra, 132 kV, 75 km, 2-cct TL and 2 TL bays at Vauniya GS	2014	1,749.1	747.7	ADB*1
22	2^{nd}-cct stringing of 132 kV Habarana – Valachchenai TL, Zebra, 100 km	2014	293.0	11.0	N/A
23	Augmentation of Kelaniya GS	2014	321.0	53.9	N/A
24	Construction of Kirindiwela GS with related 220 kV and 132 kV TL and 2X132 kV TL bays at Kosgama GS	2014	1,518.0	291.5	JICA
25	Construction of New Polpitiya GS with Polpitiya - New Polpitiya 2xZebra, 132 kV, 10 km, 2-cct TL	2014	1,436.7	298.3	ADB*1
26	Construction of Padukka GS with Athurugiriya - Padukka 2xZebra, 132 kV, 12.5 km 2-cct TL	2014	1,577.0	323.3	ADB*1
27	Construction of New Polpitiya - Padukka - Pannipitiya 2xZebra, 220 kV, 58.5 km, 2-cct TL	2014	1,987.4	779.2	N/A
28	Construction of Athurugiriya - Kolonnawa 2xZebra, 132 kV, 15 km, 2-cct TL	2014	320.1	158.3	N/A
29	Installation of 3rd 220/132/33 kV, 250 MVA inter-bus ATR at Pannipitiya GS	2014	340.9	68.4	N/A
30	Construction of Colombo-K 132/11 kV GS with single in/out connection from Dehiwala - Colombo-A 132 kV UG cable	2014	777.7	138.5	JICA
31	Augmentation of Aniyakanda GS	2014	234.6	48.3	N/A
32	Installation of reactive power compensation devices at 8 GS	2014	1,084.2	78.6	ADB*1
33	Construction of Upper Kotomale - New Polpitiya 2xZebra, 220 kV, 25 km, 2-cct TL with 2 TL bays at Upper Kotomale PS	2014	909.9	333.4	N/A
34	132 kV TL upgrades with Zebra for 6 sections	2015	1,172.7	612.0	N/A
35	Construction of Weligama 132/33 GS with double in/out connection from Galle - Matara 132 kV TL	2016	729.5	130.4	N/A

36	Installation of reactive power compensation devices at Valachchenai GS (20 MVar) and Matara GS (20 MVar)	2016	154.9	11.2	N/A
37	Construction of New Habarana - Veyangoda 2xZebra, 220 kV, 142 km, 2-cct TL and New Habarana GS with double in/out connection from Kotomale-New Anuradhapura 220 kV TL	2016	6,268.9	2131.3	JICA*2
38	Augmentation of Chunnakam GS	2016	207.0	29.1	N/A
39	Construction of New Polpitiya - Galle 2xZebra, 220 kV, 115 km, 2-cct TL with 2 TL bays at New Polpitiya GS	2017	3,804.6	1,524.4	N/A
40	Upgrade Galle GS to install 220 kV ATR	2017	799.6	151.3	N/A
41	Installation of reactive power compensation devices at Colombo-A GS (20 MVar)	2017	77.4	5.6	N/A
42	Augmentation of Maho 132/33 kV GS with 2nd cct stringing of Puttalam-Maho, Zebra 132 kV, 42 km TL and TL bay at Puttalam GS	2017	1,049.7	480.5	N/A
43	Construction of Veyangoda-Kirindiwela 2xZebra, 220 kV, 17.5 km, 2-cct TL with 2 TL bays at Veyangoda GS and 2 TL bays at Kirindiwela GS	2018	774.4	246.2	JICA
44	Construction of Kirindiwela - Padukka 2xZebra, 220 kV, 20 km, 2-cct TL with 2 TL bays at Padukka GS and 2 TL bays at Kirindiwela GS	2018	854.8	279.2	JICA
45	Reconstruction of 132 kV Balangoda – Deniyaya – Gall TL, Zebra, 101 km	2018	1,633.7	852.5	N/A
46	Installation of reactive power compensation devices at Padukka GS (100 MVar)	2018	187.7	12.7	N/A
47	Augmentation of Pannala GS	2019	234.6	48.3	N/A
48	Augmentation of Athurugiriya GS	2019	234.6	48.3	N/A
49	Construction of Kappalturai - Kilinochchi Zebra, 132 kV, 140 km, 2-cct TL with 2 TL bays at Kappalturai GS and 2 TL bays at Kilinochchi GS	2019	2,359.3	1,199.3	N/A
50	Augmentation of Dehiwala GS	2020	234.6	48.3	N/A
51	Augmentation of Kilinochchi GS	2020	207.0	29.1	N/A
-	Rehabilitation of Kiribathkumbra 132/33 kV GS	2016	782.0	91.0	JICA*3
-	Rehabilitation of Anuradhapura 132/33 kV GS	2012	698.8	147.0	JICA*3

(Source: Long Term Transmission Development Plan 2011-2020, CEB Transmission Planning)

Note *1: Projects are included Clean Energy and Network Efficiency Improvement Project to be funded by ADB

Note*2: Project was already committed by JICA.

Note *3: Project is originally included in Other Transmission Development Proposals in LTTDP 2011-2020

It should be noted that "GoSL" and "ADB" shown in "Expected Funding" column in the table means "not yet committed but probably to be funded by GoSL/ADB", and "JICA" means CEB's initial request with project proposal (PP) numbers for Japan's Loan Aid to be described in Section 3.1 of Chapter 3.

2.4.2 Distribution Line Development Plans

The CEB plans several MV distribution projects in the MV Development Study, which are prepared by each distribution region and issued every two years. However, any development plan for low voltage distribution system is not included in the MV Development Study. The MV Development Study include the construction of new PSs and MV distribution lines, augmentation and rehabilitation of the existing system to reduce the distribution losses and improve reliability of the distribution system.

1) Methodology of Planning

CEB plans several development projects to be evaluated by computer based modeling using the planning software SynerGEE ver. 3.52/36 in the following process.

Step 1 Data collection of network and load data

Step 2 Modeling of existing distribution network and analysis of existing system

Step 3 Network load assessments and load forecasting

Step 4 Modeling of future loads and simulation of various MV network enhancement option to select optimum techno-economic solution, analysis of simulated network

The development plans are formulated according to the load and power forecasting based on computer-aided planning.

2) MV Development Study

After forecasting future system analysis and planning, followed by referring planning criteria, the proposal will be produced. Upon economic evaluation of candidate projects, the final project proposals are selected.

Table 2.4-2 shows the MV development projects proposed by each regional office.

Table 2.4-2 MV Development Projects

Description	Type	Region 1	Region 2	Region 3	Region 4
Backbone Lines (km)	Lynx DC Tower	342	544	69	171
	Lynx SC Tower	0	113	124	17
	Lynx DC Pole	272	0	14	0
	Lynx SC Pole	239	105	58	28
	Racoon DC Pole	12	-	-	-
	Racoon SC Pole	82	-	26	-
	Racoon	-	40	-	-
	Racoon Pole	-	-	-	3
Distribution Gantries (Nos)	DBB Tower Gantry	18	32	1	-
	SBB Pole Gantry	6	22	9	-
	4 Pole Gantry	11	-	-	-
	Gantry	-	-	-	11
MV Line Conversion (km)	11 kV to 33 kV	101	159	-	-
Reconductoring Lines (km)	Racoon Pole	196	-	-	0
	Elm/Lynx Pole	21	-	-	-
	Elm/Lynx Tower	22	-	7.5	-
	Elm	-	-	-	36
	Weasel → Racoon	-	10	27	12
	Weasel/Racoon → Lynx	-	15	29	4
New Primaries (Nos)	Manned Primaries	4	-	3	-
	Unmanned Primaries	12	5	-	-
	Primaries	-	-	-	21
New Substations (Nos)	Radial Substations	4	-	-	-
	Ring Substations	1	-	-	-
Re-Distribution SS		1	-	-	-
PSS Augmentations (Nos)		8	4	-	7
Installation (Nos)	Voltage Regulator	3	-	-	-
	Capacitor Bank	2	-	-	-
33kV/11kV Underground Cable		4		-	3
Others	Conversion 33 kV to 11kV(km)	-	-	10	2
	Change Line Tapping	-	-	-	1
	UG Cables(km)	-	-	4.5	-

(Prepared by the Survey Team based on the MV Development Study)

2.5 Other Donors' Assistance

(1) Asian Development Bank (ADB)

Since 1998, ADB's assistance in Sri Lanka's power sector has focused on expanding the infrastructure as well as strengthening CEB and LECO, while providing complementary support for power reforms. For example, ADB has supported CEB in strengthening its transmission and distribution systems and expanded rural electrification.

The power sector strategies of ADB are based on Sri Lanka's development policy framework (namely, Mahinda Chintana), with the recent one being in 2010. The framework provides a comprehensive sector development road map, including long-term investment programs, policies, and reform measures. The goal of Sri Lanka's power sector is to provide improved service delivery to the entire population by the end of 2012, such as by providing reliable services and reducing the cost of service delivery. On such basis, ADB's assistance focuses on renewable energy development (including wind and other clean energy sources), energy efficiency improvement, improving the efficiency of transmission and distribution systems, and improving energy access for lagging regions. ADB will work with the government in reducing system losses through improved metering efficiency and better management systems. ADB will also help the government in creating an enabling environment for clean power development through sector reforms and PPPs. Table 2.5-1 below shows the strategy of ADB for the energy sector in Sri Lanka.

Table 2.5-1 ADB Strategy for the Energy Sector

2. Energy (Strategy 2020 Core Area 1: Infrastructure)			
Sustainable development of energy resources, conversion facilities, and delivery systems to enable access to and use of energy services by the entire population Safe, reliable delivery of such energy services at a regionally competitive price, through a commercially viable institution subjected to independent regulation	Improved provision of electricity: (i) System supply capacity increased to 3,470 MW by 2012 and 6,367 MW by 2020 (2010 baseline: 2,891 MW) (ii) Electrification ratio increased from 88% (2010) to 100% by 2012	Electrical power transmission; electrical power distribution; energy efficiency; Wind, solar, and hydro power generation	$170 million from 2012 to 2014, 19% of CPS, of which: ENV = 100% GEN + EGM = 100% PSD = 100% RCI = 0%

(Source: ADB Country Partnership Strategy: Sri Lanka 2012-2016)

Legend: EGM: effective gender mainstreaming, ENV: environmental sustainability, GEN: gender equity, PSD: private sector development, RCI: regional cooperation and integration.

The latest project approved was the Clean Energy and Network Efficiency Improvement Project, of which structure is as detailed below.

1) TA: Clean Energy and Network Efficiency Improvement Project (Approved) (formerly Power Sector Strengthening Project)
   Technical Assistance Special Fund: US$ 1.0 million

2) Clean Energy and Network Efficiency Improvement Project (for approval in 2012)
   2-1) TA: Clean Energy and Network Efficiency Improvement Project
   Technical Assistance Special Fund: US$ 900,000
   Clean Energy Fund – Multi-donor: US$ 1.5 million

2-2) Loan: Clean Energy and Network Efficiency Enhancement (Transmission)
Ordinary Capital Resources: US$ 100.0 million

2-3) Loan: Clean Energy and Network Efficiency Improvement Project (Transmission)
Asian Development Fund: US$ 30.0 million

(2) World Bank

The World Bank (WB) is currently implementing 13 projects totaling US$ 1.068 billion. In the power sector, WB has contributed to increasing the availability of electricity in rural areas and energy supply from renewable sources. For example, access to electricity in rural areas has expanded with the support of the Renewable Energy for Rural Economic Development Project[1].

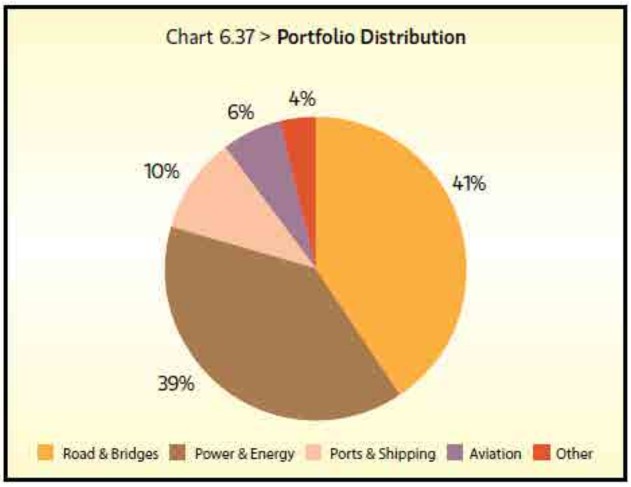
The WB will support the government's efforts to address the challenges for achieving its vision by: (i) facilitating sustained private and public investment through improving the investment environment and increasing fiscal space and public spending efficiency, (ii) supporting structural changes of the economy through assistance for a knowledge-based economy, and increased internal and international integration and competitiveness, and (iii) promoting improved living standards and social inclusion by improving the quality of services, reducing malnutrition and promoting social inclusion.

(3) China

Since the end of the civil war in 2009, there has been a noticeable increase in Chinese lending, with almost US$ 6.5 billion being invested primarily in infrastructural projects, making China a major player in Sri Lanka's development. China's loans to Sri Lanka are neither at preferential rates nor as grants-in-aid, but offers a grace period of 4-5 years for repayment.

According to the Annual Report 2011 from the Ministry of Financing and Planning of Sri Lanka, the total project portfolio funded by China in 2011 was US$ 2,522 million. The power and energy sector was the second largest amount of the total portfolio, being 20 % of the total. Also in 2011, the China Development Bank Corporation agreed to provide US$ 1.5 billion over a three year period for roads, power plants and irrigation schemes.

[1] By this project, 139,241 new rural households have access to electricity (committed amount US$ 75 million).



(Source: Annual Report 2011, Ministry of Financing and Planning of Sri Lanka)

Figure 2.5-1 Chinese Assistance to Sri Lanka 2011

In addition to the above, China is expected to contribute about US$ 10 billion, which is almost half the amount that Sri Lanka is expected to spend during 2012-2015 for infrastructure development.

In power generation, China National Machinery and Equipment Corporation constructed the first phase of the 900 MW plant (three 300 MW coal power plant) in the Norochcholai area, which was under a LKR 51,415 million loan from China's Export and Import (EXIM) Bank.

Moreover, approval has been given to proceed with the construction of Broadlands Hydropower Project. This is a 35 MW hydropower project in the Kelani River, located in the Central and Sabaragamuwa Provinces. The estimated construction cost was US$ 103 million but a Chinese contractor, China National Electric Equipment Ltd, has undertaken the project cost for US$ 82 million and is scheduled to be completed in 2014. According to the Ceylon Electricity Board, this project will minimize the carbon dioxide emission to the environment, decreasing it by 80,000 tons per annum, earning for the country US$ 2.4 million in carbon trading.

(4) Iran

Iran has been funding a number of infrastructure development projects in Sri Lanka. For example, it shall provide assistance in doubling the capacity of the Sapugaskanda Oil Refinery, the creation of a 100 MW hydropower project, and to the Uma Oya Multipurpose Development Project[2].

In the power sector, Iran has expressed its stance to continue financial and technical aid for rural electrification projects to strengthen the electricity supply to remote villages of Sri Lanka.

[2] Construction of two dams across two main tributaries of Uma Oya at Welimada and Dyraaba and a 23 km long trans basin diversion tunnel with an underground power station at Randeniya.

These projects, also called the Rural Electrification Project–8 scheme, will electrify a thousand villages in eleven CEB provinces: North West, Central, Western North, Eastern, West South, West South–II, Sabaragamuwa and Southern Provinces. The expected completion date of the project is June 2012 and the total estimated cost is US$ 106.5 million. The proposed contractor for this project is Sunir Co. of Iran and supplies all the materials except the RC pre-stressed poles, which will be procured by CEB. The project is expected to bring benefits to about 180,000 rural households.

(5) India

The National Thermal Power Corporation Limited (NTPC), the largest thermal power generation utility of India and CEB signed the joint venture and shareholder agreement to set up Coal Thermal Power Plant at Sampur in September 2011. The power plant at Sampur has a total capacity of 500 MW with two generating units of 250 MW each. The project is a fifty-fifty joint venture between CEB and NTPC. The power plant at Sampur with a total investment being US$ 500 million, would be Sri Lanka's second coal-fired power plant.

The Government of Sri Lanka has allocated a 500 acre land in Sampur for the site and will construct the coal unloading jetty and install related equipment. The Government of India has offered a concessional line of US$ 200 million to Sri Lanka to expedite the construction.

It is expected that the issuance of tenders for construction will be made by the end of 2012 and completion will be by the end of 2016.

(6) Other countries and summary

Table 2.5-2 shows the committed or on-going transmission and distribution projects, and Table 2.5-3 shows the assistances for generating plants and others.

Table 2.5-2 Assistance for Transmission and Distribution Projects

No	Projects	Project Cost	Fund	Comm. year
1	Colombo City Distribution Development Project	JY 5,959 mil	JICA	completed
2	Clean Energy & Access Improvement Project		ADB	2012
	3.1 Construction of new system control center	LKR 2.528 mil		
	3.2 Lot A1 - Augmentation of grid substations	LKR 918 mil		
	3.3 Lot A2 - Transmission system strengthening GS	LKR 3,567 mil		
	3.4 Lot B - Construction of transmission lines	LKR 2,203 mil		
	3.5 Augmentation of GS for absorption of renewable energy	LKR 2,240 mil		
	3.6 Transmission system Strengthening in the Eastern Province	LKR 2,852 mil		
3	Vauniya - Kilinochchi Transmission Project	JY 1,422 mil JY 1,278 mil	JICA	2012
4	Kilinochchi - Chunnakam Transmission Project	US$ 28.7 mil	ADB	2012
5	Sustainable Power Sector II Project	US$ 95.4 mil LKR 29 mil	ADB	2013
6	Procurement of materials for the Power Sector Development Programme in Northern Province	US$ 31.7 mil	EXIM Bank of China	(committed in 2010)
7	Rural Electrification Project -8 (Northern and Eastern Provinces)	Euro 77.1 mil	EDB of Iran	2012
8	Rural Electrification Scheme		EXIM Bank of China	2012
	- in North Central Province	US$ 57.9 mil		
	- in Trincomalee and Batticoloa Districts	US$ 60 mil		
	- in Badulla and Monaragala Districts under Uva Udanaya project	US$ 34 mil		
	- in Jaffna, Vavuniya, Mannar, Mullathivu and Killinochchi districts under Uthuru Vasanthaya project	US$ 34 mil		
9	New Habarana – Veyangoda Transmission Project	JY 9,573 mil	JICA	2016
10	Clean Energy and Network Efficiency Improvement Project		ADB	(committed in 2012)
	- Transmission infrastructure strengthening in the Northern province	US$ 41.8 mil		
	- Transmission and distribution network efficiency improvement	US$ 118.3mil		
	- Solar rooftop power generation	US$ 2.8 mil		

(Source: Prepared by the Survey Team referring to the data from CEB, DER and JICA)

Table 2.5-3 Assistance for Generating Plants and Others

No	Projects	Project Cost	Fund	Comm. year
1	Norochcholai (Puttalam) Coal Power Plant Project (900 MW)	US$ 891 mil	EXIM Bank of China	Ph-1 (300 MW) completed, Ph-2&3 (600 MW) 2014
2	Uma Oya Multipurpose Development Project including Uma Oya HPP (120 MW)	US$ 529 mil	EDB of Iran (85%) GoSL (15%)	2012
3	Upper Kotomale Hydropower Project (150 MW)	JY 4,552 mil JY 33,265 mil JY 1,482 mil	JICA	2011
4	Rehabilitation of Old Laxapana HPP (50 MW)	US$ 32.5 mil	Uni-Credit Bank of Austria AG	(committed in 2010)
5	Rehabilitation of Wimalasurendra (50 MW) and New Laxapana HPPs (100 MW)	US$ 55.2 mil	AFD	2013
6	Trincomalee Coal Power Project (1,000 MW)	LKR 60,000 mil	Government of India and GoSL	2017
7	Renewable Energy for Rural Economic Development	US$ 115 mil US$ 8 mil	IDA GEF (grant)	2011
8	Trincomalee integrated Infrastructure Development Project (electricity distribution portion)	Euro 58.2 mil (Euro 2.45 mil)	AFD	2011

(Source: Prepared by the Survey Team referring to the data from CEB, DER and JICA)

CHAPTER 3
TRANSMISSION LINE PROJECTS

CHAPTER 3 TRANSMISSION LINE PROJECTS

3.1 General

CEB submitted the following list to the Survey Team which is required for the Japan's Loan Aid. The list was prepared by selecting sub-projects from the long list entitled Long Term Transmission Development Plan which was described in Sub-section 2.4.1. The order of the projects is in the order of CEB's priority.

Table 3.1-1 CEB's Priority Projects

No.	Projects	Base Costs (MUS$)
PJT-1	Colombo City Transmission Development	145
PJT-2	Construction of Kappalturai 132/33 kV GS	10
PJT-3	Construction of Kerawalapitiya 220/33 kV GS	10
PJT-4	Rehabilitation of Kiribathkumbura 132/33 kV GS	8
PJT-5	Construction of Veyangoda–Kirindiwela–Padukka 220 kV TL	37
PJT-6	Construction of Chemmuni 132/33 kV GS	10
PJT-7	Construction Kalutara 132/33 kV GS	8
PJT-8	Construction of Battaramulla 132/33 kV GS with related TL	9
PJT-9	Reconstruction of Anuradhapura 132/33 kV GS	10
PJT-10	Construction of Nawalapitiya 132/33 kV GS with related TL	8
PJT-11	Construction of Wewalwatta 132/33 kV GS with related TL	7
PJT-12	Construction of Tissamaharama 132/33 kV GS with related TL	13
	Total	275

(Source: CEB Transmission Planning)

Together with the list above, CEB has compiled proposals for each project. On the basis of the submitted proposals, the Survey Team carefully studied the development plan proposed by CEB and evaluated them based on the degree of their contribution to the improvement and reliability of transmission systems in Sri Lanka. Distribution projects proposed by CEB are examined in Chapter 4.

3.2 Proposed Transmission Projects

This section describes the contents of the project proposals submitted by CEB. Project scopes and costs, which are modified and adjusted by the Survey Team, are described in Chapter 7.

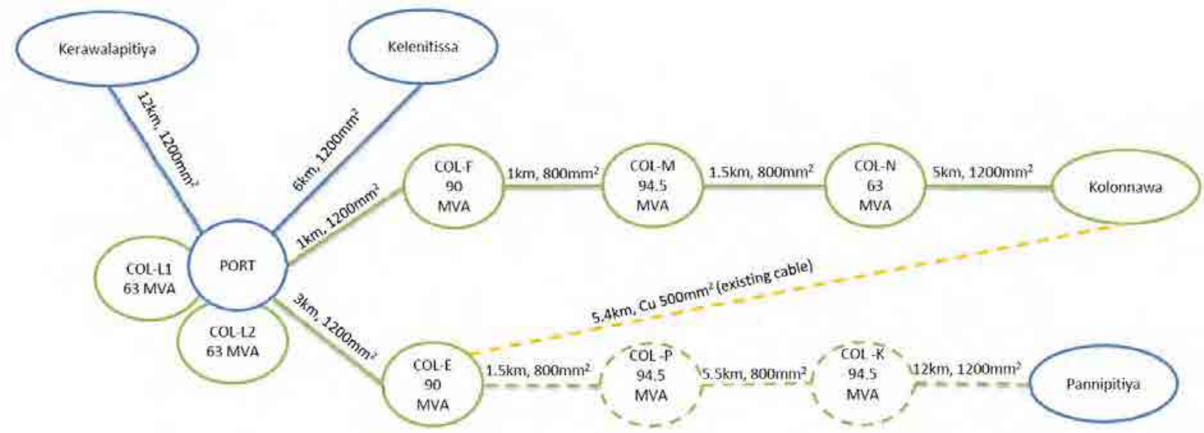
3.2.1 Colombo City Transmission Development (PJT-1)

(1) Objective

At present, electric power in Colombo City is supplied by Colombo A (Havelock Town), Colombo C (Kotahena), Colombo E (Kollupitiya), Colombo F (Fort), Colombo I (Maradana), 132/11 kV GSs and Kolonnawa and Kelenitissa 132/33 kV GSs. The present demand for the GSs is approximately 318 MVA in total. However, it is expected that there are some urban development plans which require larger power demand in Colombo City in the near future.

According to the demand forecast prepared by CEB, of which extract is shown in Table 2.3-2 of Chapter 2, approximately 120 MVA demand is to be added to the Colombo City network by 2015 and 357 MVA demand is to be added by 2020. Therefore, the transmission network development for Colombo City needs to be implemented to meet the demand growth. In addition, it is expected to realize improved quality and reliability of power supply in Colombo City.

Figure 3.2-1 shows outline of the project proposed by CEB.

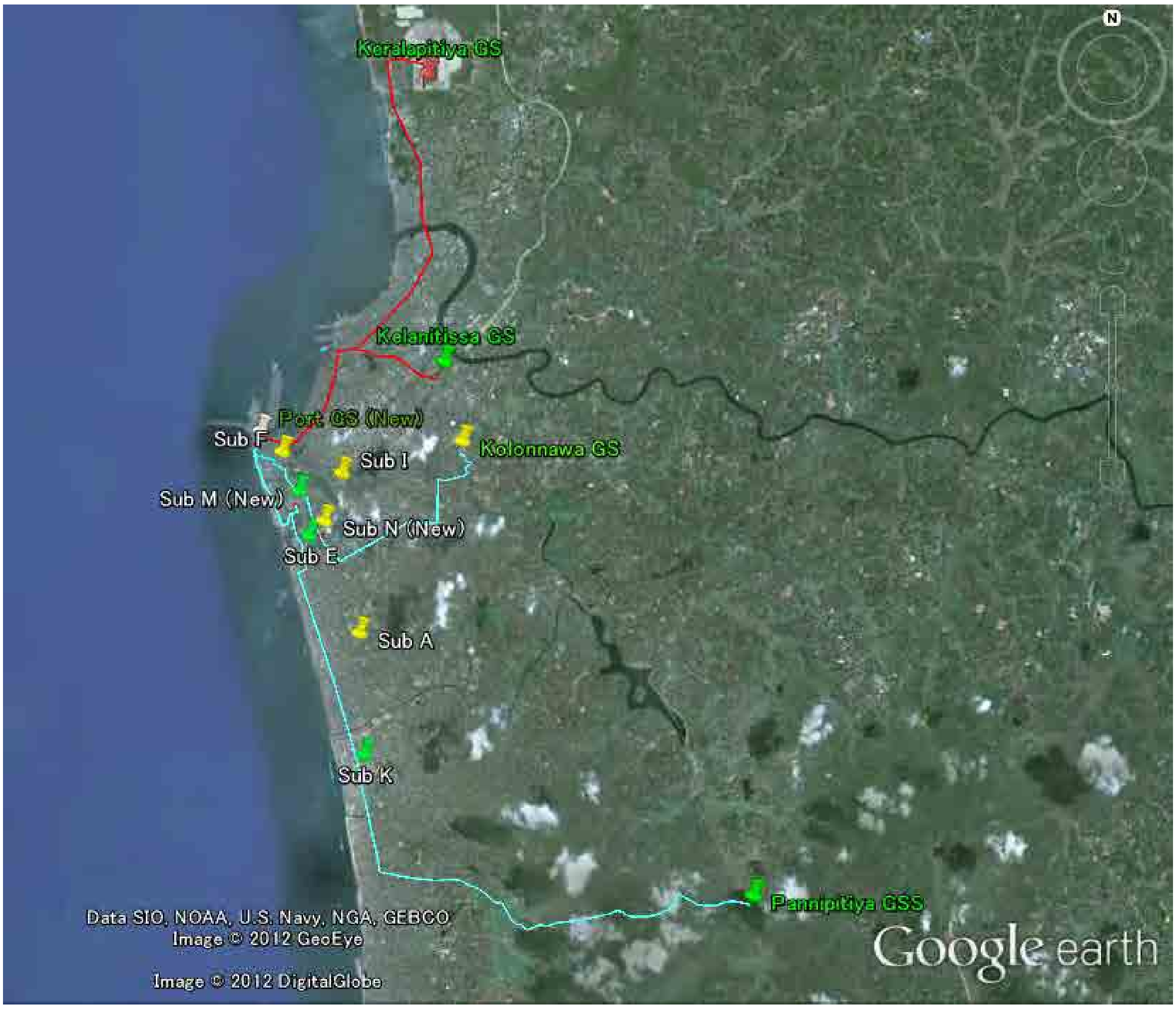


(Source: Project Proposal, CEB Transmission Planning)

Figure 3.2-1 Outline of Colombo City Transmission Development

According to CEB's proposal, the project is planned to be implemented in two phases. The green colored dotted line shows the second phase of development. It is further proposed to use the existing oil-filled copper 500 mm^2 cables to ensure N-1 reliability to Colombo E GS until the second phase is completed.

At present, the aforementioned existing 132/11 kV GSs are supplied with electric power by Kelanitissa and Pannipitiya 220 kV GSs. At present, inter-bus transformers with the capacity of 2x150 MVA and 2x250 MVA are installed at Kelanitissa and Pannipitiya GSs, respectively. To meet the rapidly increasing demand forecasted in the future, it is further planned that another 220/132 kV, 2x250 MVA GS will be introduced at Colombo Port where major part of the expected future demand of Colombo City is concentrated. Moreover, it is proposed to connect Kerawalapitiya and Kelanitissa Power Plants to the proposed Port GS to enhance the reliability of the Colombo City supply. Figure 3.2-2 shows the planned cable line route under the project.



(Source: Google earth Pro)

Figure 3.2-2 Location of Colombo City Transmission Development

(2) Scope of the Project

Major scope of the project is as follows;

1) Construction of Port 220/132/33 kV GS
   - 2x250 MVA, 220/132/33 kV main tie-transformers
   - 2x220 kV double busbar transformer bay
   - 2x220 kV indoor single busbar cable bay
   - 1x220 kV bus section bay
   - 2x132 kV indoor double busbar cable bay
   - 2x132 kV double busbar transformer bay
   - 1x132 kV bus coupler bay
   - 2x33 kV transformer bay
   - 1x33 kV indoor bus section bay with single busbar arrangement

2) Construction of Colombo L (Port) GS
   - 4x31.5 MVA, 132/11 kV main transformers

- 4x132 kV indoor single busbar transformer bays
- 4x11 kV indoor single busbar transformer bays
- 18x11 kV indoor cable bays
- 1 x 11 kV indoor bus section bays with single busbar arrangement

3) Construction of Colombo M (Slave Island) GS
    - 3x31.5 MVA, 132/11 kV main transformers
    - 3x132 kV indoor single busbar transformer bays
    - 3x11 kV indoor single busbar transformer bays
    - 18x 11 kV indoor cable bays
    - 2x 132 kV single busbar indoor cable bays
    - 1x 132 kV indoor bus section bay with single busbar arrangement
    - 2X11 kV indoor bus section bays with single busbar arrangement

4) Construction of Colombo N (Hunupitiya) GS
    - 2x31.5 MVA, 132/11kV main transformers
    - 2x132 kV indoor single busbar transformer bays
    - 2x11 kV indoor single busbar transformer bays
    - 12x 11 kV indoor cable bays
    - 2x 132 kV single busbar indoor cable bays
    - 1x 132kV indoor bus section bay with single busbar arrangement
    - 1 x 11 kV indoor bus section bays with single busbar arrangement

5) Augmentation of Colombo A GS
    - 1x31.5 MVA, 132/11kV main transformer
    - 1x132 kV indoor single busbar transformer bays
    - 1x11 kV indoor single busbar transformer bays
    - 6x 11 kV indoor cable bays
    - 1x 132kV indoor bus section bay with single busbar arrangement
    - 1 x 11 kV indoor bus section bays with single busbar arrangement

6) Augmentation of Colombo I GS
    - 1x31.5 MVA, 132/11kV main transformer
    - 1x132 kV indoor single busbar transformer bays
    - 1x11 kV indoor single busbar transformer bays
    - 6x 11 kV indoor cable bays
    - 1x 132kV indoor bus section bay with single busbar arrangement
    - 1 x 11 kV indoor bus section bays with single busbar arrangement

7) Construction of underground cable
    - 220 kV, Cu (XLPE) 1,200 mm^2, 6 km cable between Kelenitissa and Port GSs
    - 220 kV, Cu (XLPE) 1,200 mm^2, 12 km cable between Kerawalapitiya and Port GSs

- 132 kV, Cu (XLPE) 1,200 mm^2, 1 km cable between Port and Colombo F GSs
- 132 kV, Cu (XLPE) 800 mm^2, 1 km cable between Colombo F and Colombo M GSs
- Construct 132 kV, Cu (XLPE) 800 mm^2, 1.5 km cable between Colombo M and Colombo N GSs
- 132 kV, Cu (XLPE) 1,200 mm^2, 5 km cable between Colombo N and Kolonnawa GSs
- 132 kV, Cu (XLPE) 1,200 mm^2, 3 km cable between Port and Colombo E GSs

(3) Estimated Base Cost

CEB has preliminary estimated the project cost using the standard unit prices quoted by the previous projects as shown in Table 3.2-1. The estimated total project cost (base cost) is LKR 12,250.3 million (Foreign Currency: FC) and LKR 1,547.2 million (Local Currency: LC).

Table 3.2-1 Cost of Colombo City Transmission Development Project

Sub-projects	Total Cost (MLKR)	
	FC	LC
1) Construction of Port 220/132 kV GS	1,695.5	198.1
2) Construction of Colombo L (Port) GS	1,027.0	222.5
3) Construction of Colombo M (Slave Island) GS	1,044.8	142.7
4) Construction of Colombo N (Hunupitiya) GS	817.0	127.0
5) Augmentation of Colombo A	261.1	37.6
6) Augmentation of Colombo I	261.1	37.6
7) Additional cable bays of Kerawalapitiya and Kelenitissa	178.5	8.4
8) Cable between Kelenitissa and Port	1,685.0	187.0
9) Cable between Kerawalapitiya and Port	3,370.0	374.0
10) Cable between Port and Kolonnawa via F-M and N	1,383.8	153.8
11) Cable between Port and E	526.5	58.5
Total	12,250.3	1,547.2
Total (FC+LC)		13,797.5

(Source: Colombo City Transmission Development Proposal, CEB Transmission Planning)

(4) Effect of Transmission Loss Reduction studied by CEB

CEB has calculated loss reduction values on assumptions that load of the proposed GSs (Colombo L, M and N) were transferred to the existing GSs (Colombo E, F, B, C and Kelenitissa) by 2015 and by 2020 in the case without the project. Loads considered for Colombo B, C, E, F and Kelenitissa GSs in the case without the project are shown in Table 3.2-2.

Table 3.2-2 Load Conditions for Loss Reduction Calculation

	2015		2020	
GSs	MW	MVar	MW	MVar
Colombo B	25.4	15.8	91.0	56.2
Colombo C	24.4	15.1	70.6	43.7
Colombo E	81.4	48.9	83.5	47.8
Colombo F	84.3	48.9	76.5	42.3
Kelanitissa	24.2	14.8	99.2	56.8

(Source: CEB Transmission Planning)

Table 3.2-3 shows the energy loss savings from the project calculated by CEB.

Table 3.2-3 Energy Loss Savings by PJT-1

	Unit	2015	2020
Transmission losses with project	MW	41.41	78.98
Transmission losses without project	MW	43.87	83.26
Loss savings	MW	2.46	4.28
Loss load factor		0.408	0.408
Energy loss saving per year	GWh/year	8.8	15.3

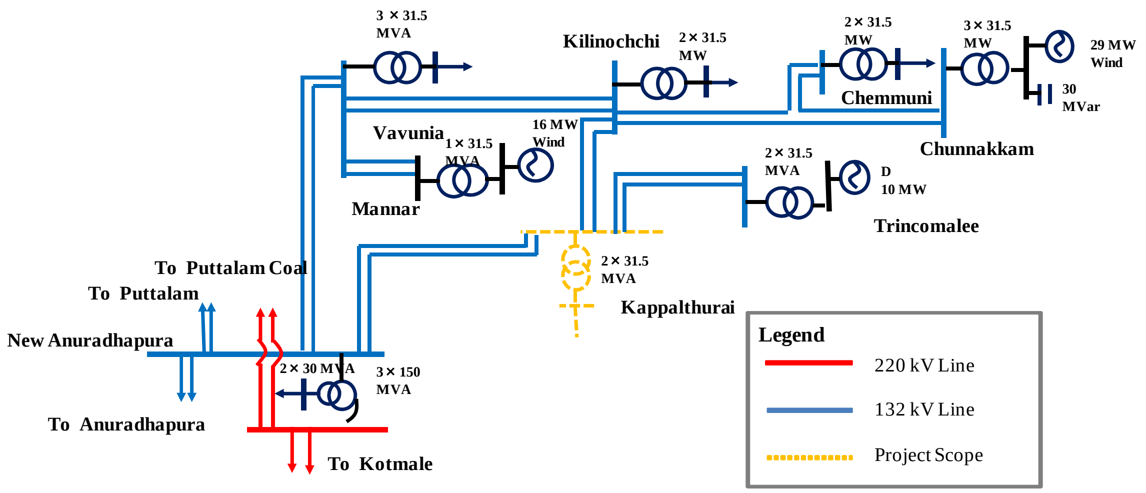
(Source: CEB Transmission Planning)

3.2.2 Construction of Kappalthurai GS (PJT-2)

(1) Objective

At present, the capacity of the Trincomalee GS is 63 MVA. According to the demand forecast, Trincomalee GS shall be augmented to 94.5 MVA by 2013 and to 126 MVA by 2020. However, it is difficult to augment the existing GS due to the limitation of space.

Therefore, in order to meet the growing demand in Nilaweli and Kappalthurai areas and the proposed Kappalthurai special economic zone, it is proposed to construct a new GS at Kappalthurai with two 31.5 MVA transformers and eight 33 kV feeders in 2014 to relieve the loading of Trincomalee GS. The proposed GSs will also improve the voltage profile of 33 kV distribution systems and therefore improve the quality of supply in and around the areas. This new GS is proposed to connect to the existing New Anuradhapura-Trincomalee 132 kV line using double in and out connection as shown in Figure 3.2-3.



(Prepared by the Survey Team)

Figure 3.2-3 Transmission Network around Kappalthurai GS

(2) Scope of the Project

1) Construction of Kappalthurai GS
- 2 × 31.5 MVA 132/33 kV transformers
- 4 × 132 kV double busbar transmission line bays
- 2 × 132 kV double busbar transformer bays
- 1 × 132 kV double busbar arrangement with bus coupler
- 2 × 33 kV transformer bays
- 8 × 33 kV feeder bays
- 1 × 33 kV single bus bar including bus section

2) Double in and out connection to Kappalthurai GS from New Anuradhapura – Trincomalee 132 kV TL (2 cct., 1.0 km, Zebra)

3) Provision for 2 × 132 kV double busbar transmission line bays to connect Kilinochchi-Kappalthurai 132 kV TL

4) Provision for development of a 220/132 kV substation at Kappalthurai with Stage II of the Trincomalee Coal Power Plant Project.

(3) Estimated Base Cost

Table 3.2-4 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 767.7 million (FC) and LKR 169.6 million (LC).

Table 3.2-4 Cost of Kappalthurai 132/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Kappalthurai 132/33 kV GS		FC	LC	FC	LC
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	2 sets	71.8	8.8	143.6	17.6
132 kV double busbar transformer bay	2 sets	28.0	5.1	56.0	10.1
132 kV line bay double busbar	4 sets	24.5	5.2	98.1	20.8
132 kV double busbar arrangement with bus coupler	1 sets	42.6	3.9	42.6	3.9
33 kV transformer bay	2 sets	13.3	0.1	26.5	0.3
33 kV feeder bay	8 sets	12.8	0.1	102.3	0.9
33 kV single busbar incl. bus section	1 set	14.4	0.1	14.4	0.1
Common items for 2 × 31.5 MVA 132/33 kV grid	1 set	156.6	86.6	156.6	86.6
Substation Automation for GS	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			47.4	9.3
			Total	734.8	150.6
2) Construction of double in & out connection					
132 kV, 2 cct Zebra	2 km	16.5	9.5	32.9	19.0
			Total 1)～2)	767.7	169.6
			Total (FC+LC)	937.2	

(Source: CEB Transmission Planning)

3.2.3 Construction of Kerawalapitiya GS (PJT-3)

(1) Objective

At present, the electricity demand in the Wattala, Handala and Kerawalapitiya areas is 81

GWh in total and the estimated load growth is 7 %. These areas are mainly fed by Kotugoda GS. Considering the load demand forecast in the 33 kV distribution systems in these areas, the loading of Kotugoda GS will be 90 % in 2011 and also 181 % under outage of one transformer. Furthermore Kotugoda GS is expected to reach 126 % load under outage of a 60 MVA transformer by 2017 even after the expansion of the GS in 2012.

Since Kotugoda GS is located at a highly industrialized area, it has to be able to cater to the demand under outage of one unit. Therefore, it is proposed to construct a new GS at Kerawalapitiya with 2x35 MVA transformers and eight 33 kV feeders in terms of improving reliability of the regional distribution system and meeting the growing demand in 2014.

(2) Scope of the Project

1) Construction of Kerawalapitiya GS
- 2 × 35 MVA 220/33kV transformers
- 2 × 33 kV GIS transformer bays
- 8 × 33 kV GIS feeder bays
- 1 × 33 kV GIS single busbar arrangement including bus section

2) Installation of 20 MVar (4 × 5 MVar) breaker switched capacitor banks at 33 kV busbar

(3) Estimated Base Cost

Table 3.2-5 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 801.1 million (FC) and LKR 148.2 million (LC).

Table 3.2-5 Cost of Kerawalapitiya 220/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Kerawalapitiya 220/33 kV GS		FC	LC	FC	LC
Transformers 220/33 kV, 35 MVA & E.Tr. & Aux.Tr	2 sets	162.5	20.0	325.0	39.9
33 kV transformer bay (indoor)	2 sets	15.7	0.1	31.5	0.3
33 kV feeder bay	8 sets	12.8	0.1	102.3	0.9
33 kV single busbar arrangement incl.bus section (indoor)	1 set	14.41	0.13	14.4	0.1
Common items for 220/33kV grid	1 set	157.4	90.9	157.4	90.9
Substation Automation for GS	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			47.4	9.3
			Total	724.5	141.9
2) Installation of 20 MVar breaker switched capacitors at Kerawalapitiya	4 sets	19.1	1.6	76.6	6.3
			Total 1)～2)	801.1	148.2
			Total (FC+LC)	949.3	

(Source: CEB Transmission Planning)

3.2.4 Reconstruction of Kiribathkumbura 132/33 kV GS (PJT-4)

(1) Objective

Kiribathkumbura GS commissioned in 1986 was the first 33 kV GIS substation of CEB. In 2003, the substation was expanded by adding a third 31.5 MVA transformer and 4x5 MVar capacitor banks. At present, 3x31.5 MVA Kiribathkumbura GS feeds electric power to many important government and commercial establishments in the Kandy area. According to statistical data, the anticipated load growth rate of the area is 5.0 %.

It is reported that all 132 kV bays of the substation have operational problems, except for No.1 of Kurunegala line bay, No.2 of Ukuwela line bay and No.3 of the transformer bay. The number of operations of 33 kV switchgears has exceeded the recommended 10,000 operations. In addition, 11 units of 33 kV GIS switchgear have already exceeded their service life of 25 years which is 2.5 times of the recommended service life (10 years). Hence, these switchgear units need overhauling according to the operation and maintenance (O&M) manual. Furthermore, the price quoted by the manufacturer for inspection and overhauling was excessive according to the O&M Branch of the CEB Transmission Division. In addition, the existing protection system which comprises electromagnetic type of relays has many operational problems. Furthermore, aging equipment and unavailability of spare parts have caused the low reliability of Kiribathkumbura GS.

After an assessment of the condition, the Asset Management Branch of the Transmission Division has recommended the rehabilitation of Kiribathkumbura GS. Therefore, it is proposed to rehabilitate Kiribathkumbura GS in order to improve the quality and reliability of the electricity supply.

(2) Scope of the Project

1) Reconstruction of Kiribathkumbura 132/33 kV GS
- Installation of 1×31.5 MVA 132/11 kV main transformer
- Installation of 3×132 kV S/B transformer bays
- Installation of 4×132 kV S/B transmission line bays
- Installation of 1×132 kV S/B bus section bays
- Installation of 4×33 kV transformer bays
- Installation of 12×33 kV line feeder bays
- Installation of 4×generator feeder bays
- Installation of 2×33 kV capacitor bank bays
- Installation of 1×33 kV bus coupler bays

(3) Estimated Base Cost

Table 3.2-6 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 782.2 million (FC) and LKR 91.1 million (LC).

Table 3.2-6 Cost of Kiribathkumbura GS Reconstruction Project

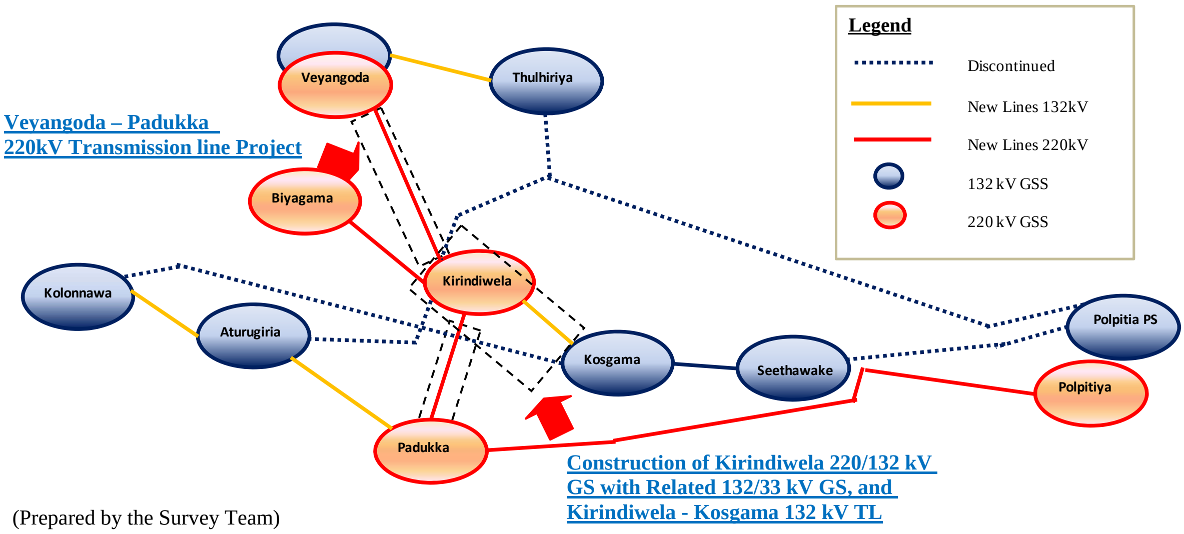
Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
		FC	LC	FC	LC
1) Transformers / 132/33 kV /31.5 MVA & E.Tr & Aux Tr	1 set	71.8	8.8	71.8	8.8
2) 132 kV S/B transformer bay	3 sets	25.6	4.5	76.7	13.6
3) 132 KV S/B Line bay	4 sets	23.7	4.7	94.8	18.7
4) 132 kV S/B inc. Bus section bay	1 set	23.4	3.6	23.4	3.6
5) 132 kV protection and control panels for line bays	2 sets	8.6	0.1	17.1	0.1
6) 132 kV protection and control panels for transformer bays	1 set	7.4	0.2	7.4	0.2
7) 33 kV transformer bay	4 sets	15.7	0.1	63.0	0.6
8) 33 kV feeder bay	14 sets	12.8	0.1	179.0	1.5
9) 33 kV generator bays	4 sets	14.9	0.1	59.5	0.5
10)33 kV Bus coupler bay including double bas bar arrangement	1 set	14.4	0.1	14.4	0.1
11) Common items for 132/33 kV grid	1 set	77.3	36.9	77.3	36.9
12) Substation Automation	1 set	46.6	0.5	46.6	0.5
13) Spare parts (7 %)	1 lot			51.2	6.0
			Total 1)～13)	782.2	91.1
			Grand Total		873.3

(Source: CEB Transmission Planning)

3.2.5 Construction of Veyangoda – Kirindiwela - Padukka 220 kV TL (PJT-5)

(1) Objective

In the future, the electric power generated at Puttalam and Trincomalee Coal Power Plants (CPPs) will be delivered to the Veyangoda GS in the Western Province. In order to make possible for power to be received at Veyangoda GS, new transmission lines and substations need to be developed.



(Prepared by the Survey Team)

Figure 3.2-4 Planned Transmission Network around Kirindiwela GS

In the proposed project, a Switching Station (SwS) at Kirindiwela is to be constructed under the Kotmale-Biyagama 220 kV transmission line. Veyangoda, Padukka, Kotmale and Biyagama GSs are to be connected to Kirindiwela SwS. In the future transmission system, Kirindiwela SwS would be the power receiving station generated at Mahaweli Complex whereas Padukka GS would be the power receiving station for that generated at Laxapana Complex. New lines will be constructed from Veyangoda to Padukka via Kirindiwela connecting three stations as shown in Figure 3.2-4. This arrangement will enhance the power supply capacity to the Colombo area and will improve system reliability.

(2) Scope of the Project

1) Construction of Kirindiwela 220/132 kV GS

- 2 × 150 MVA 220/132 kV tie-transformers
- 1 × 220 kV double busbar arrangement including bus coupler
- 2 × 220 kV double busbar transformer bays
- 8 × 220 kV double busbar transmission line bays
- 2 × 31.5 MVA 132/33 kV transformers
- 4 × 132 kV single busbar transformer bays
- 1 × 33 kV single busbar arrangement including bus section
- 2 × 33 kV single busbar transformer bays
- 8 × 33 kV feeder bays

2) Installation of 10 MVar at 33 kV busbar

- Installation of 10 MVar (2x5 MVar) breaker switched capacitors at 33 kV busbar

3) Construction of Kirindiwela - Kosgama 132 kV TL

- Construction of 132 kV Kirindiwela - Kosgama Zebra, 10 km, double-circuit TL
- Kosgama GS: 2x 132 kV TL bays with single busbar arrangement

4) Construction of Veyangoda - Kirindiwela - Padukka 220 kV TL

- Construction of 220 kV Veyangoda - Kirindiwela 2xZebra, 17.5 km, double-circuit TL
- Construction of 220 kV Kirindiwela - Padukka 2xZebra, 20 km, double-circuit TL
- Veyangoda GS: 2x220 kV double busbar TL bays
- Padukka GS: 2x220 kV double busbar TL bays
- Double in & out connection from Biyagama – Kotmale 220 kV TL

(3) Estimated Base Cost

Table 3.2-7 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 3,487.7 million (FC) and LKR 953.0 million (LC).

Table 3.2-7 Cost of Veyangoda – Kirindiwela - Padukka 220 kV TL Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Kirindiwela 220/132/33 kV GS		FC	LC	FC	LC
Transformers 220/132 kV, 150 MVA & E.Tr.	2 sets	154.5	11.1	308.9	22.2
Transformers 132/33 kV 2 × 31.5 MVA	2 sets	70.5	7.9	141.0	15.8
132 kV single busbar Transformer bay	4 sets	25.6	4.5	102.4	18.0
220 kV double busbar transformer bay	2 sets	42.1	4.4	84.1	8.8
132 kV single busbar line bay	2 sets	23.7	4.7	47.4	9.4
220 kV double busbar line bay	8 sets	53.8	4.3	430.6	34.6
132 kV single busbar arrangement inc. bus section	1 set	38.4	3.6	38.4	3.6
220 kV double busbar arrangement inc. bus coupler	1 set	55.7	4.3	55.7	4.3
33 kV single busbar transformer bay	2 sets	13.3	0.1	26.5	0.3
33 kV single busbar feeder bay	8 sets	12.8	0.1	102.3	0.9
33 kV bus section bay including BB	1 set	14.4	0.1	14.4	0.1
Common items for 220/132 kV GS	1 set	212.9	119.5	212.9	119.5
Substation automation for GS	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			112.8	16.7
			Sub-total	1,724.0	254.7
2) 10 MVar at Kirindiwela 33 kV BB					
5 MVar including. BSC bay	2 sets	19.1	1.6	38.3	3.2
3) Kirindiwela – Kosgama 132 kV TL					
132 kV Zebra 2 cct.	10 km	16.5	9.5	164.6	94.8
Kosgama GS 132 kV single busbar line bay	2 sets	23.7	4.7	47.4	9.4
Kosgama GS 132 kV single busbar arrangement	1 lot	38.4	3.6	38.4	3.6
			Sub-total	85.8	13.0
4) Veyangoda - Kirindiwela - Padukka 220 kV TL					
Veyangoda - Kirindiwela 220 kV TL 2 × Zebra 2 cct.	17.5 km	32.7	14.8	572.9	259.3
Kirindiwela – Padukka 220 kV TL, 2 × Zebra 2 cct.	20 km	32.7	14.8	654.0	296.0
220 kV D/B line bay in Veyangoda GS	2 sets	53.8	4.3	107.7	8.6
220 kV D/B line bay in Padukka GS	2 sets	53.8	4.3	107.7	8.6
Double in & out connection from Biyagama–Kotmale	1.0 km	32.7	14.8	32.7	14.8
			Sub-total	1,475.0	587.3
			Total 1)～4)	3,487.7	953.0
			Total (FC+LC)		4,440.7

(Source: CEB Transmission Planning)

(4) Effect of Loss Reduction studied by CEB

Energy losses are reduced through implementation of the project. Transmission losses in year 2015 under two generation scenarios; hydro maximum and thermal maximum and two load scenarios; day peak and night peak without the lines and with lines are tabulated in Table 3.2-8.

Table 3.2-8 Loss Reduction Calculation of PJT-5 by CEB

Scenarios	Transmission Losses (MW) Night Thermal	Night Hydro	Day Thermal	Day Hydro
Without Veyangoda - Kirindiwela- Padukka 220 kV TL	73.29	68.33	40.80	40.98
With Veyangoda - Kirindiwela- Padukka 220 kV TL	72.28	67.80	38.81	40.79
Loss Reduction Value (MW)	1.01	0.53	1.99	0.19
Loss Reduction Ratio (%)	1.4	0.8	4.9	0.5

(Source: CEB Transmission Planning)

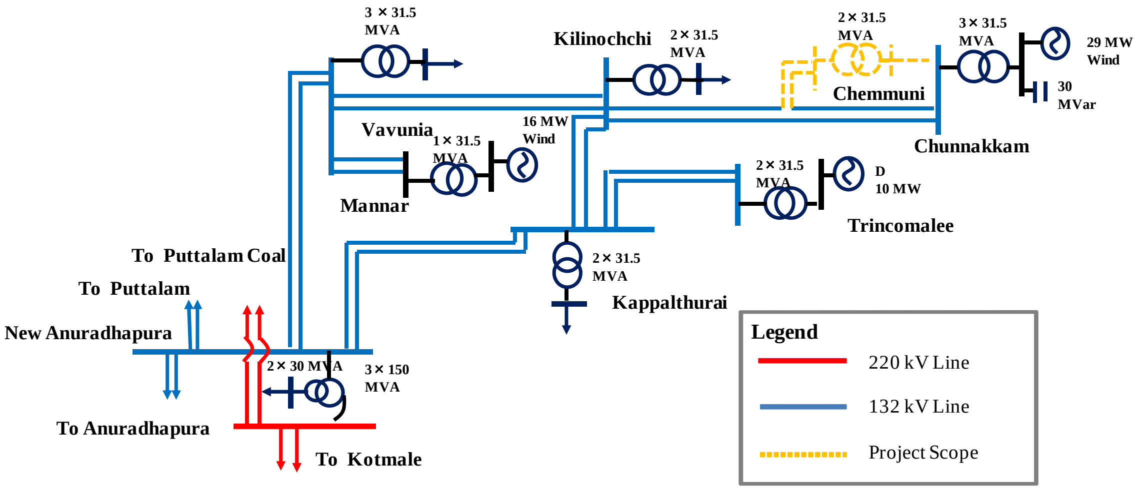
The result shows that the line loss reduction ratio, which could be brought about by the construction of the transmission line, will approximately be 4.9 % in the Day Thermal case at the highest value.

3.2.6 Construction of Chemmuni GS (PJT-6)

(1) Objective

Since the Jaffna Peninsula is presently isolated from the national grid, electric power to Jaffna Peninsula is supplied by CEB and privately owned generators. Due to the inadequacy of the present generation, power supply in Jaffna is partly interrupted during the peak hours. To overcome this situation, a new 2x31.5 MVA 132/33 kV GS at Chunnakam and a 67 km, 132 kV transmission line from Kilinochchi to Chunnakam are under construction.

The objective of this project is to meet the growing electricity demand in Vaddukkodda, Chavakachcheriya, Kankasanthurai, Point Pedro and Jaffna areas by providing quality and reliable supplies and to connect the proposed Chemmuni GS to the national grid as shown in Figure 3.2-5.



(Prepared by the Survey Team)

Figure 3.2-5 Transmission Network around Chemmuni GS

(2) Scope of the Project

1) Construction of Chemmuni GS

- 2 × 31.5 MVA 132/33 kV transformers
- 2 × 132 kV single busbar transformer bays
- 2 × 132 kV single busbar transmission line bay
- 1 × 132 kV busbar including a bus section bay
- 2 × 33 kV transformer bay
- 8 × 33 kV feeder bays

- 1 × 33 kV busbar including a bus section bay

2) Construction of 10 km 2 cct 132 kV TL with Zebra conductor as a single in and out connection from Kilinochchi – Chunnakam TL

(3) Estimated Base Cost

Table 3.2-9 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 836.2 million (FC) and LKR 236.4 million (LC).

Table 3.2-9 Cost of Chemmuni GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Chemmuni 132/33 kV GS		FC	LC	FC	LC
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	2 sets	71.8	8.8	143.6	17.6
132 kV single busbar transformer bay	2 sets	25.6	4.5	51.1	9.0
132 kV single busbar line bay	2 sets	23.7	4.7	47.4	9.4
132 kV single busbar inc. bus section bay	1 set	38.4	3.6	38.4	3.6
33 kV transformer bay	2 sets	13.3	0.1	26.5	0.3
33 kV feeder bay	8 sets	12.8	0.1	102.3	0.9
33 kV bus section bay including BB	1 set	14.41	0.13	14.4	0.1
Common items for 132/33 kV grid	1 set	157.4	90.9	157.4	90.9
Substation automation for GS	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			43.9	9.3
			Total	671.6	141.6
2) Single in & out connection from Kilinochchi – Chunnakam					
132 kV, Zebra 2 cct.	10 km	16.5	9.5	164.6	94.8
			Total 1)～2)	836.2	236.4
			Total (FC+LC)	1,072.6	

(Source: CEB Transmission Planning)

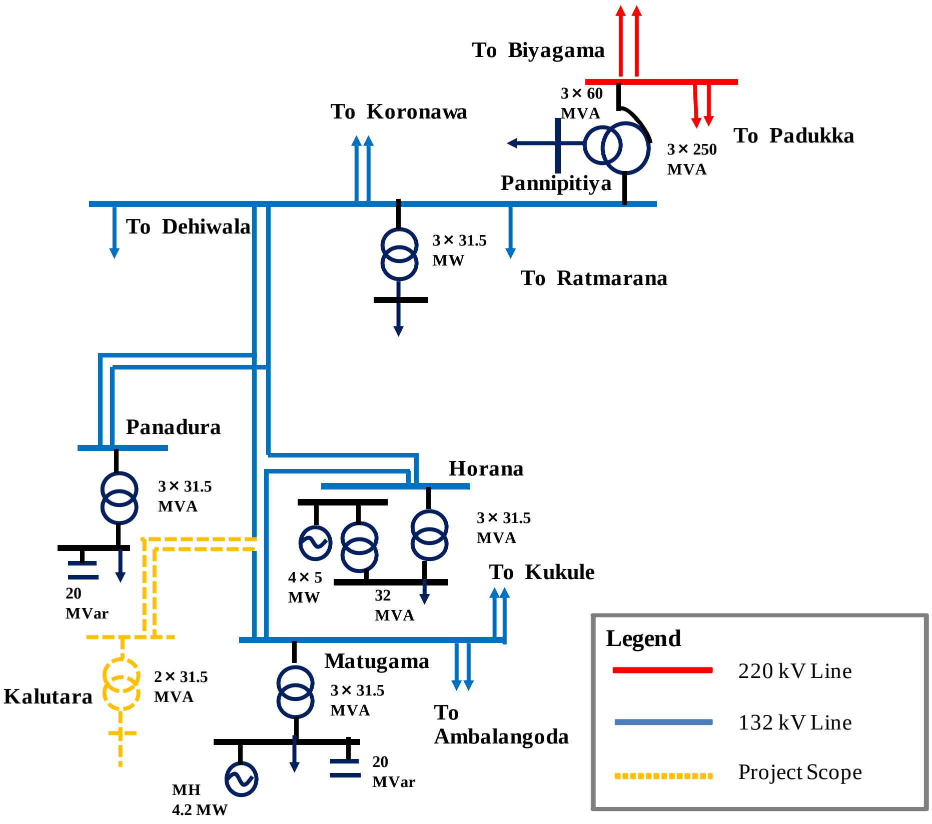
3.2.7 Construction of Kalutara GS (PJT-7)

(1) Objective

Kalutara area is mainly fed by Panadura and Matugama GSs with long distance 33 kV distribution lines, which cause high distribution losses. According to the demand forecast, the loading of Panadura GS will be 90 % in 2014 and also 128 % under outage of one transformer. Panadura GS will be overloaded by 2016 even after the expansion of the GS. On the other hand, the loading of Matugama GS will be 94 % in 2014 and also 134 % under outage of one transformer and it will be further overloaded by 2016. In order to meet the growing electricity demand while minimizing distribution losses and relieve loading of Panadura and Matugama GSs, it is proposed to construct a new GS at Kalutara with two 31.5 MVA transformers and eight 33 kV feeders.

Proposed GSs will improve the voltage profile of the 33 kV distribution system and reduce distribution losses and therefore improve the quality of supply in and around the Kalutara areas. This new GS is proposed to connect to the existing Pannipitiya – Matugama 132 kV

TL using single in and out connection as shown in Figure 3.2-6. This project will reduce losses, improve the reliability of the system and meet the growing demand in the area.



(Prepared by the Survey Team)

Figure 3.2-6 Transmission Network around Kalutara GS

(2) Scope of the Project

1) Construction of Kalutara GS
- 2×31.5 MVA 132/33 kV transformers
- 2×132 kV single busbar transformer bays
- 2×132 kV single busbar transmission line bays
- 1×132 kV single busbar including bus section
- 2×33 kV transformer bays
- 8×33 kV feeder bays
- 1×33 kV single bus bar including bus section

2) Construction of 132 kV single in and out connection from Pannipitiya – Matugama 132 kV TL to connect Kalutara GS (2 cct., 6 km, Zebra)

(3) Estimated Base Cost

Table 3.2-10 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 769.6 million (FC) and LKR 193.9 million (LC).

Table 3.2-10 Cost of Kalutara 132/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
		FC	LC	FC	LC
1) Construction of Kalutara GS					
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	2 sets	71.8	8.8	143.6	17.6
132 kV single busbar transformer bay	2 sets	25.6	4.5	51.1	9.0
132 kV line bay single busbar	2 sets	23.7	4.7	47.4	9.4
132 kV bus section bay inc.S/S	1 sets	38.4	3.6	38.4	3.6
33 kV transformer bay	2 sets	13.3	0.1	26.5	0.3
33 kV feeder bay	8 sets	12.8	0.1	102.3	0.9
33 kV bus section bay incl. BB	1 sets	14.4	0.1	14.4	0.1
Common items for 2×31.5 MVA 132/33 kV grid	1 set	156.6	86.6	156.6	86.6
Substation Automation for GS	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			43.9	9.0
			Total	670.8	137.0
2) Construction of single in & out connection from Pannipitiya – Mathugama TL					
132kV, Zebra 2 cct.	6 km	16.5	9.5	98.8	56.9
			Total 1)～2)	769.5	193.9
			Total (FC+LC)	963.4	

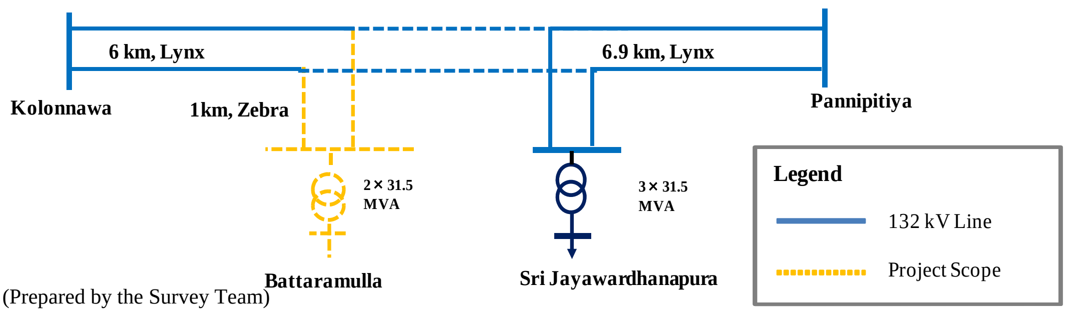
(Source: CEB Transmission Planning)

3.2.8 Construction of Battaramulla GS (PJT-8)

(1) Objective

At present Sri Jayawardhanepura Kotte demand, which is approximately 50 MVA, is mainly fed from Sri Jayawardhanepura 132/33 kV GS. There is a future development plan around the Battaramulla area. CEB has projected the required demand for the development plan as 114 MW in 2025. As a result of the study for the development, CEB has proposed to implement augmentation of the existing Sri Jayawardhanepura GS and the construction of a new Battaramulla GS in the vicinity of the existing GS. The capacity of Sri Jayawardhanepura GS is to be increased to 94.5 MVA. In the meantime, the capacity of the new Battaramulla GS is to be planed as 63 MVA. These capacities can meet the rapidly increasing demand by 2017.

Sri Jayawardhanepura GS is presently fed from Kolonnawa - Pannipitiya 132 kV Lynx line by double "T" connection. Since Battaramulla GS is proposed in the same area, it can be connected to the same line by opening the existing connection as shown in Figure 3.2-7.



(Prepared by the Survey Team)

Figure 3.2-7 Transmission Network around Battaramulla GS

(2) Scope of the Project

1) Construction of Battaramulla GS
   - 2×31.5 MVA 132/33 kV transformers
   - 2×132 kV indoor single busbar transformer bays
   - 1×132 kV bus section with single busbar arrangement
   - 2×33 kV indoor single busbar transformer bays
   - 8×33 kV indoor cable bays
   - 1×33 kV indoor bus section bays with single busbar arrangement
2) Construction of 132 kV, Zebra connection to existing Kolonnawa – Panipitiya line

(3) Estimated Base Cost

Table 3.2-11 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 865.3 million (FC) and LKR 154.4 million (LC).

Table 3.2-11 Cost of Battaramulla 132/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Battaramulla GS		FC	LC	FC	LC
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	2 sets	71.8	8.8	143.6	17.6
132 kV single busbar transformer bay (GIS)	2 sets	52.8	1.3	105.6	2.7
132 kV line bay (GIS)	2 sets	53.1	1.5	106.3	2.9
132 kV single busbar (including bus section) (GIS)	1 set	54.9	1.7	54.9	1.7
33 kV transformer bay	2 sets	15.7	0.1	31.5	0.3
33 kV bus section bay incl. BB (GIS)	1 set	14.4	0.1	14.4	0.1
33 kV feeder bay (GIS)	8 sets	12.8	0.1	102.3	0.9
Common items for 132/33 kV grid	1 set	157.4	90.9	157.4	90.9
Substation Automation	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			53.4	8.2
			Total	815.9	125.9
2) Construction of Battaramulla – Kolonnawa TL					
132kV, Zebra 2 cct.	3 km	16.5	9.5	49.4	28.5
			Total 1)～2)	865.3	154.4
			Total (FC+LC)	1,019.7	

(Source: CEB Transmission Planning)

3.2.9 Reconstruction of Old Anuradhapura GS (PJT-9)

(1) Objective

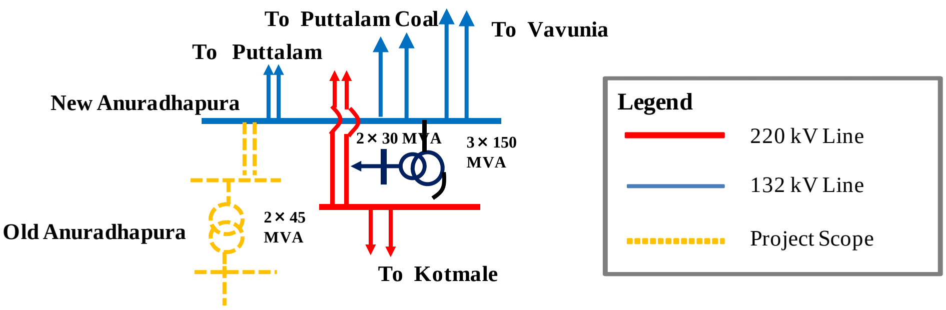
Old Anuradhapura GS is situated in the North Central Province. Annual energy demand of the GS is 138 GWh and the estimated load growth is 4.7%. At present, Old Anuradhapura GS feeds power to Nochchiyagama, Periyankulama, Horowpathana, Medawachchiya and Mihintale areas and some parts of the Vavuniya area.

Old Anuradhapura GS consists of 2x10 MVA transformers which were commissioned in 1969 and 1975, and a 31.5 MVA transformer which was commissioned in 1996. At present, Old Anuradhapura GS is connected to New Anuradhapura, Habarana and Puttalam GSs with 132 kV double circuit transmission lines. No rehabilitation or any augmentation work has been carried out at this GS since 1996.

It is reported that Old Anuradhapura GS has many operational problems. Almost all of the equipment in the GS is now 40 years old and spare parts are not available. After a complete condition assessment, the Asset Management Branch and the Operation & Maintenance Branch of the Transmission Division of CEB have recommended to augment Old Anuradhapura GS.

Furthermore, it has been planned to transfer connections of Puttalam and Habarana 132 kV transmission lines to New Anuradhapura GS and to rearrange Old Anuradhapura GS. Hence, in the future, Old Anuradhapura GS will be fed from New Anuradhapura GS by 132 kV double circuit transmission line. Further, to cater the increasing demand in and around Anuradhapura City it has been decided to augment Old Anuradhapura GS with 2x45 MVA transformers.

Therefore, it is proposed to augment Old Anuradhapura GS in order to ensure the quality and reliability of the electricity supply and to cater the growing demand.



(Prepared by the Survey Team)

Figure 3.2-8 Transmission Network around Old Anuradhapura GS

(2) Scope of the Project

1) Augmentation of Old Anuradhapura GS
- 2×45 MVA 132/33 kV transformers
- 2×33 kV GIS transformer bays
- 6×33 kV GIS feeder bays
- 2×33 kV GIS generator bays
- 1×33 kV GIS SB arrangement including bus section

2) Augmentation of New Anuradhapura 220/132/33 kV GS
- 4×132 kV double bus transmission line bays

(3) Estimated Base Cost

Table 3.2-12–shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 698.9 million (FC) and LKR 147.0 million (LC).

Table 3.2-12 Cost of Old Anuradhapura 132/33 kV GS Reconstruction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Reconstruction of Anuradhapura GS		FC	LC	FC	LC
Transformers 132/33 kV, 45 MVA & E.Tr. & Aux.Tr	2 sets	102.6	12.6	205.1	25.2
33 kV transformer bay (GIS)	2 sets	15.7	0.1	31.5	0.3
33 kV feeder bay (GIS)	6 sets	12.8	0.1	76.7	0.7
33 kV generator bay(GIS)	2 sets	14.9	0.1	29.8	0.3
33 kV bus section bay incl. BB (GIS)	1 set	14.4	0.13	14.4	0.1
Common items for 132/33 kV grid	1 set	157.4	90.9	157.4	90.9
Substation Automation	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			39.3.4	8.3
			Total	600.7	126.2
2) Augmentation of New Anuradhapura 220/132/33 kV GS					
132kV, D/B line bay	4 sets	24.5	5.2	98.1	20.8
			Total 1)～2)	698.8	147
			Total (FC+LC)		845.8

(Source: CEB Transmission Planning)

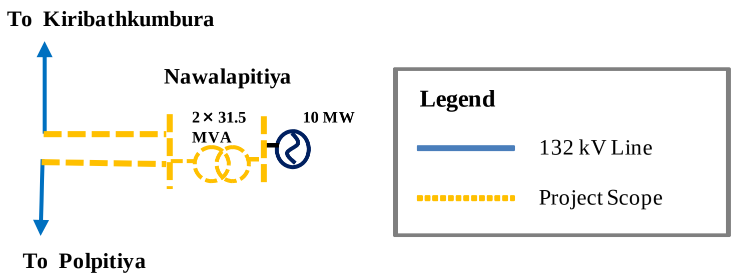
3.2.10 Construction of Nawalapitiya GS (PJT-10)

(1) Objective

In Sri Lanka, there is a policy target of obtaining 20% of energy from non conventional renewable energy resources by 2020. In this context, mini-hydro power plants play a key role. A large part of mini-hydro potential of Sri Lanka exists in the Central Hills and a large number of mini-hydro projects have been identified in Nawalapitiya, Kotmale, Galaha and Ginigathhena areas. However, the GSs existing in the area; Nuwara Eliya and Wimalasurendra are unable to send power from any new projects because the GS capacities have already been exceeded. Therefore, the requirement of a GS at Nawalapitiya is urgent and important to accommodate new mini-hydro power plants.

At present, Nawalapitiya area is fed from Kiribathkumbura GS which is approximately 30 km away. To meet the increasing demand, Nawalapitiya GS is required to be constructed by 2017. This will relieve the loading in Kiribathkumbura GS and high losses in the distribution network. Nawalapitiya GS will also improve the voltage profile of the 33 kV distribution system in and around Nawalapitiya area and thereby improve the quality of supply in the area.

Hence, the construction of Nawalapitiya GS is important in order to accommodate renewable energy, to meet the growing demand, and to improve the quality of supply in and around Nawalapitiya area.



(Prepared by the Survey Team)

Figure 3.2-9 Transmission Network around Nawalapitiya GS

(2) Scope of the Project

1) Construction of Nawalapitiya GS

- 2×31.5 MVA 132/33 kV transformers
- 2×132 kV single busbar transformer bays
- 2×132 kV single busbar transmission line bays
- 1×132 kV busbar including a bus section bay
- 2×33 kV transformer bay
- 8×33kV feeder bays
- 1×33kV busbar including a bus section bay

2) Construction of single in and out transmission connection from 132 kV Polpitiya – Kiribathkumbura TL (4 km, 2 cct., Zebra)

(3) Estimated Base Cost

Table 3.2-13 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 736.6 million (FC) and LKR 175.0 million (LC).

Table 3.2-13 Cost of Nawalapitiya 132/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Nawalapitiya GS		FC	LC	FC	LC
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	2 sets	71.80	8.82	143.60	17.64
132 kV single busbar transformer bay	2 sets	25.56	4.52	51.12	9.04
132 kV line bay	2 sets	23.70	4.69	47.41	9.37
132 kV single busbar (including bus section)	1 set	38.38	3.65	38.38	3.65
33 kV transformer bay	2 sets	13.25	0.13	26.51	0.25
33 kV bus section bay incl. BB	1 set	14.41	0.13	14.41	0.13
33 kV feeder bay	8 sets	12.79	0.11	102.31	0.87
Common items for 132/33 kV grid	1 set	156.57	86.57	156.57	86.57
Substation Automation	1 set	46.56	0.5	46.56	0.51
Spare parts (7 %)	1 lot			43.88	8.96
			Total	670.8	137.0
2) Single in and out connection from Polpitiya – Kiribathkumbura TL					
132kV, Zebra double cct.	4 km	16.5	9.5	65.9	37.9
			Total 1)～2)	736.6	175.0
			Total (FC+LC)		911.6

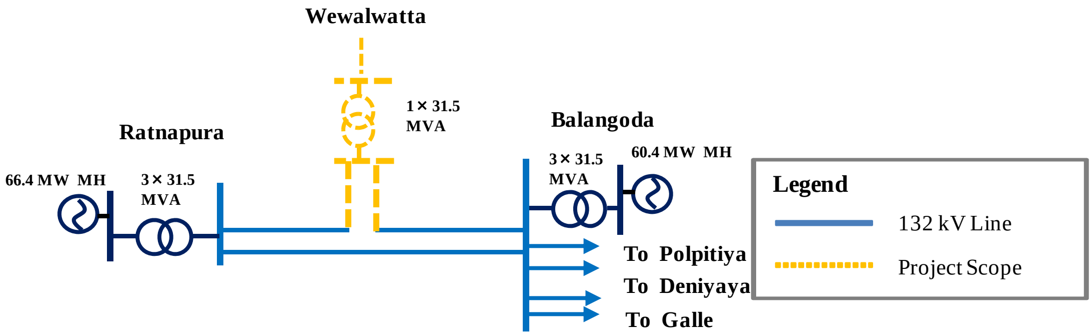
(Source: CEB Transmission Planning)

3.2.11 Construction of Wewalwatta GS (PJT-11)

(1) Objective

There is a large potential of mini-hydro capacity that can be harnessed in and around the Balangoda and Ratnapura areas. At present existing Ratnapura and Balangoda GSs are both being augmented to 3 x 31.5 MVA so as to send capacity of 150 MW generated by mini-hydro which can be harnessed around the area.

According to information provided by CEB, Ratnapura and Balangoda GSs will exceed their allowable connection capacity by 2016 even after their augmentations. Because there is capacity limitation in the existing GSs, grid interconnection of mini-hydro projects is restricted in these areas. Therefore, construction of a new GS has been proposed in this area. Wewalwatta area has been identified as a potential site for the interconnection of about 25 MW of mini-hydro power plants and is located between Ratnapura and Balangoda GSs close to the existing 132 kV Balangoda - Ratnapura transmission line. The new GS can be connected to the existing Balangoda - Ratnapura 132 kV transmission line.



(Prepared by the Survey Team)

Figure 3.2-10 Transmission Network around Wewalwatta GS

(2) Scope of the Project

1) Construction of Wewalwatta GS
- 1 × 31.5 MVA 132/33 kV transformers
- 1 × 132 kV single busbar transformer bays
- 2 × 132 kV single busbar transmission line bays
- 1 × 132 kV busbar including a bus section bay
- 1 × 33 kV transformer bay
- 4 × 33 kV feeder bays

2) Construction of single in and out transmission connection from 132 kV Balangoda – Ratnapura TL (5 km, 2 cct., Zebra)

(3) Estimated Base Cost

Table 3.2-14 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 557.9 million (FC) and LKR165.7 million (LC).

Table 3.2-14 Cost of Wewalwatta 132/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Nawalapitiya GS		FC	LC	FC	LC
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	1 set	71.80	8.8	71.8	8.8
132 kV single busbar transformer bay	1 set	25.6	4.5	25.6	4.5
132 kV line bay	2 sets	23.7	4.7	47.4	9.4
132 kV single busbar (including bus section)	1 set	38.4	3.6	38.4	3.6
33 kV transformer bay	1 set	13.3	0.1	13.3	0.1
33 kV feeder bay	4 sets	12.8	0.1	51.2	0.4
Common items for 132/33 kV grid	1 set	150.3	83.1	150.3	83.1
Substation Automation	1 set	46.6	0.5	46.6	0.5
Spare parts (7 %)	1 lot			31.1	7.7
Total				475.5	118.3
2) Single in and out connection from Balangoda – Ratnapura TL					
132 kV, Zebra double cct.	5 km	16.5	9.5	82.3	47.4
Total 1)～2)				557.9	165.7
Total (FC+LC)					723.6

(Source: CEB Transmission Planning)

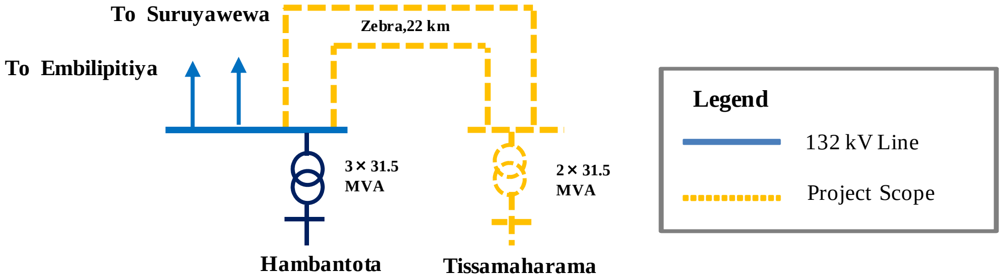
3.2.12 Construction of Tissamaharama GS (PJT-12)

(1) Objective

Tissamaharama GS is planned to be constructed in the Southern Province. The annual energy demand of the Southern Province is 760 GWh. The Tissamaharama and Katharagama areas are presently fed from Hambantota GS, with an alternative supply from Embilipitiya GS via Thanamalvila. However, these distribution lines are very long and the load of Katharagama is connected at the end of the distribution line. Hence, these areas experience serious voltage drops. The situation may become critical with the load growth in the areas in the near future.

Tissamaharama GS will relieve overloads of Hambantota GS, where the load growth in the area is considerably high due to the development activities planned in the area. These development activities include the Hambantota Harbor, Mattala Airport, Mirijjawila Industrial Park, Mirijjawila salt- based industries, and Mirijjawila oil refinery.

In accordance with the forecasted demand to be increased in the area by 2025, it has been proposed to construct a new GS at Tissamaharama in 2016 to overcome the critical voltage drop issues at the Tissamaharama and Katharagama areas and to relieve loads of Hambantota GS. Tissamaharama GS is proposed to connect to the national grid at Hambantota GS using double circuit 132 kV transmission line.



(Prepared by the Survey Team)

Figure 3.2-11 Transmission Network around Tissamaharama GS

(2) Scope of the Project

1) Construction of Tissamaharama GS

- 2×31.5 MVA 132/33 kV transformers
- 2×132 kV single busbar transformer bays
- 2×132 kV single busbar transmission line bays
- 1×132 kV bus section bay including busbar
- 2×33 kV transformer bay
- 1×33 kV bus section bay including bus bar
- 8×33 kV feeder bays

2) Construction of 132 kV Hambantota – Tissamaharama TL (22 km, 2 cct., Zebra)

3) Augmentation of Hambantota GS (2×132 kV single busbar transmission line bays)

(3) Estimated Base Cost

Table 3.2-15 shows the project cost estimated by the CEB Transmission Planning. The estimated total project cost (base cost) is LKR 1,080.4 million (FC) and LKR 361.4 million (LC).

Table 3.2-15 Cost of Tissamaharama 132/33 kV GS Construction Project

Description	Q'ty	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Tissamaharama GS		FC	LC	FC	LC
Transformers 132/33 kV, 31.5 MVA & E.Tr. & Aux.Tr	2 sets	71.80	8.82	143.6	17.64
132 kV single busbar transformer bay	2 sets	25.56	4.52	51.12	9.04
132 kV line bay	2 sets	23.70	4.69	47.41	9.37
132 kV single busbar (including bus section)	1 set	38.38	3.65	38.38	3.65
33 kV transformer bay	2 set	13.25	0.13	26.51	0.25
33 kV bus section bay incl. BB	1 set	14.41	0.13	14.41	0.13
33 kV feeder bay	8 sets	12.79	0.11	102.31	0.87
Common items for 132/33 kV grid	1 set	156.57	86.57	156.57	86.57
Substation Automation	1 set	46.6	0.5	46.56	0.51
Spare parts (7 %)	1 lot			31.1	7.7
			Total	670.8	137.0
2) Construction of Hambantota – Tissamaharama TL					
132 kV, Zebra double cct.	22 km	16.5	9.5	362.2	208.7
3) Augmentation of Hambantota GS					
132 kV single busbar line bays	2 sets	23.7	4.7	47.4	9.4
			Total 1)～3)	1,080.4	355.0
			Total (FC+LC)		1,435.4

(Source: CEB Transmission Planning)

3.3 Selection of Candidate Project for Japan's Loan Aid

The Survey Team has evaluated the proposed projects based on the following criteria:

1) CEB's development priority

   3 points: PJT1 – PJT4

   2 points: PJT5 - PJT8

   1 point: PJT9 -

2) Commissioning year in LTTDP

   3 points: - Year 2013

   2 points: Year 2014 - 2015

   1 point: Year 2016 -

3) Requirements from distribution development

   3 points: 132 kV GS construction projects

   2 points: 132 kV GS augmentation and TL projects

   1 point: 220 kV TL and GS construction projects

4) Environmental and social considerations (existence of IEE report)

   3 points: existing IEE report or GS augmentation projects (no IEE is needed)

   2 points: GS land acquired/selected and TL route selected

   1 point: No GS land acquired/selected and no TL route selected (no IEE report)

5) Applicability of Japan's technology

   3 points: 220 kV TL projects

   2 points: 132 kV TL and/or GIS GS construction projects

   1 point: AIS GS and GS augmentation projects

6) Contribution to TL and DL loss reduction

   3 points: TL and DL loss reduction

   2 points: DL loss reduction

   1 point: No loss reduction

7) Population density of the project site[1] (persons per sq. km)

   3 points: 3,000 -

   2 points: 600 – 2,999

   1 point: - 599

Table 3.3-1 shows the result of the evaluation.

[1] Source: Population of Sri Lanka by District by Department of Census and Statistics

Table 3.3-1 Result of Evaluation

No.	Sub-projects	1)	2)	3)	4)	5)	6)	7)	Score
PJT-1	Colombo City Transmission Development	3	2	3	2	3	3	3	19
PJT-2	Construction of Kappalturai 132/33 kV GS	3	3	3	2	1	2	1	15
PJT-3	Construction of Kerawalapitiya 220/33 kV GS	3	3	3	2	2	2	3	18
PJT-4	Rehabilitation of Kiribathkumbura 132/33 kV GS	3	1	2	3	1	1	2	13
PJT-5	Construction of Veyangoda – Padukka 220 kV TL	2	2	2	1	3	3	2	15
PJT-6	Construction of Chemmuni 132/33 kV GS	2	1	3	2	1	2	2	13
PJT-7	Construction Kalutara 132/33 kV GS	2	3	3	2	1	2	2	15
PJT-8	Construction of Battaramulla 132/33 kV GS	2	1	3	1	2	2	3	14
PJT-9	Reconstruction of Anuradhapura 132/33 kV GS	1	1	2	3	1	1	1	10
PJT-10	Construction of Nawalapitiya 132/33 kV GS	1	1	3	1	1	2	2	11
PJT-11	Construction of Wewalwatta 132/33 kV GS	1	1	3	1	1	2	1	10
PJT-12	Construction of Tissamaharama 132/33 kV GS	1	1	3	1	1	2	1	10

(Prepared by the Survey Team)

As a result of the discussion with CEB considering the result of the evaluation, the following project components were selected as the candidate projects:

1) Colombo City Transmission Development (PJT-1)
2) Construction of Kappalturai 132/33 kV GS (PJT-2)
3) Construction of Kerawalapitiya 220/33 kV GS (PJT-3)
4) Construction of Veyangoda – Kirindiwela – Padukka 220 kV TL (PJT-5)
5) Construction of Kalutara 132/33 kV GS (PJT-7)
6) Construction of Battaramulla 132/33 kV GS with related TL (PJT-8)

The selected candidate projects have scored more than 14 points in total. As these projects are regarded as worth developing, they shall be carefully evaluated in the following chapters. Projects that scored less than 10 points are not regarded as important to be studied by CEB and thus the Survey Team also has not conducted further studies.

Regarding project packaging, it is reasonable and feasible to combine PJT-3, PJT-7 and PJT-8, since each project area is in the vicinity of Colombo City and thus, is expected to add increased benefit due to their combination.

As a result, the Survey Team proposed to further study the feasibility of the following projects:

1) Colombo City Transmission Development (PJT-1)
2) Construction of Kappalturai 132/33 kV GS (PJT-2)
3) Construction of Kerawalapitiya 220/33 kV GS (PJT-3)
   Construction of Kalutara 132/33 kV GS (PJT-7)
   Construction of Battaramulla 132/33 kV GS with related TL (PJT-8)
4) Construction of Veyangoda – Kirindiwela – Padukka 220 kV TL (PJT-5)

CHAPTER 4
DISTRIBUTION LINE PROJECTS

CHAPTER 4 DISTRIBUTION LINE PROJECTS

4.1 General

The Survey Team has received project proposals for the development of distribution lines including MV, LV and DAS/AMR projects, which were prepared by each distribution region of CEB. In addition, the Survey Team has investigated further requirements through interviews with each regional office. As a result of the discussion with CEB concerning the proposals, plans, and requirements, the Survey Team has nominated the following sub-projects that will contribute to loss reduction.

1) New LV Substation (LV scheme)

   The density of consumers is very thin in Sri Lanka, resulting in making LV lines long, Thus causing major distribution losses. It would be very effective to provide additional LV substations to reduce distribution losses. Details of the location and quantity of LV substations shall be carefully studied and then selected. Basically, this activity shall be considered into Distribution Loss Reduction Project. Additional loss reduction can be obtained by using low loss type transformers for distribution transformers (DTs).

2) Single-phase to Three-phase Conversion

   When single-phase circuit is converted to three-phase circuit, the maximum distributed power can be three times than that of the single-phase circuit, and thus the load current can be reduced by a third. Accordingly, the resistive loss can be reduced to a sixth considering three wires for three-phase distribution lines. It is necessary to design the consumer's connections to balance the load current on each phase in order to make it effective.

3) Auto Meter Reading (AMR)

   At this moment, CEB does not have an automatic meter reading at DTs. CEB has energy meters for large bulk consumers only. These energy meters have remote monitoring facilities using Global System for Mobile (GSM) communications. CEB has planned to provide the energy meters at the DTs to monitor the energy flow. The technical losses of the distribution system cannot be reduced by providing energy meters, but it can increase the ability to measure the distribution losses such as technical and non-technical losses. It is possible to grasp the non-technical losses on the distribution system and reduce power theft by monitoring and comparing input energy to consumers billing. In the future, all energy meters will be provided at each consumer as smart metering.

   GRPS/GSM communications system is applied to the existing DAS system and CEB planned to apply the same system for AMR. However, considering its reliability, the Survey Team recommends to apply fiber optic communication as the “Back Bone Communication” and radio communication such as Zigbee or RF Mesh for the “Last One Mile Communication”.

4) New 33/11 kV PS and Reinforcement of Distribution Line

Construction of new 33/11 kV PS and reinforcement of MV distribution lines, which may contribute to distribution loss reduction, are to be recommended. The major contribution is resistive loss reduction by decreasing the load current and upgrading the system voltage, and rectification of overloading to balance the load current on each MV line. As a supplemental effect, reliability of the distribution system will improve and lead to the reduction of overloading and blackouts. The final nomination of projects will be done in a later stage after detailed analysis and evaluation.

5) Distribution Automation System (DAS)

Although DAS is not mentioned in MV Development Plan, the Survey Team found the need through the project proposals and meetings with Regions 2 and 3.

DAS is a convenient tool to control the load current on distribution systems, to select the best operation options, and to minimize distribution losses. DAS has intelligent functions, for example, it is possible to know the latest distribution losses, which are calculated from energy meters. Also, DAS has several supplemental advantages, such as savings on labor, minimizing shut-down area, increasing reliability and automatic logging and reporting.

New simplified DAS developed by CEB has remarkable progress from the existing fully manual operation. It can monitor the switchgear status, alarm and current/voltage, power factor and other control data obtained through simplified DAS. The so called “Full-scale DAS” produced by major manufactures have superior functions in accessibility, reliability, security and maintainability. Here, in the next step from simplified “Mini SCADA” or “Micro SCADA” system, the Survey Team strongly recommends to provide “Full scale DAS” for CEB. In addition, it is economical and functional to combine the DAS and AMR system, for it is possible to use the same communication links together.

On the other hand, the Survey Team has the subject to provide communication links between the remote terminal units (RTUs) and the distribution control center. CEB has used GSM/GPRS network in a very low cost of about US$ 3.0/month per terminal. Communication links can be realized with a combination of the public telephone network and GSM/GPRS network. However, CEB has already experienced that there are several inconveniences and problems in GSM/GPRS communication system.

6) Specialized Vehicles

At present, CEB's maintenance staff use normal trucks and wooden radars for site works at the top of the pole. They also use normal trucks and cranes to install distribution poles at road sides. This is very dangerous and ineffective and therefore, if the staff uses insulation bucket trucks and pole installation trucks for site works, safe and efficient work can be assured. Therefore, the Survey Team suggests supplying such trucks as shown in the following photographs.

To maximize the loss reduction effects, the distribution projects were mainly selected in collaboration with the transmission projects as mentioned in Chapter 3 and may be grouped to one distribution project including DAS and AMR, switchgear and MV lines to make them effective as total system. The final proposal is described in Section 4.2 after detailed investigation, discussions with CEB, and technical and economic studies.

4.2 Proposed Distribution Projects

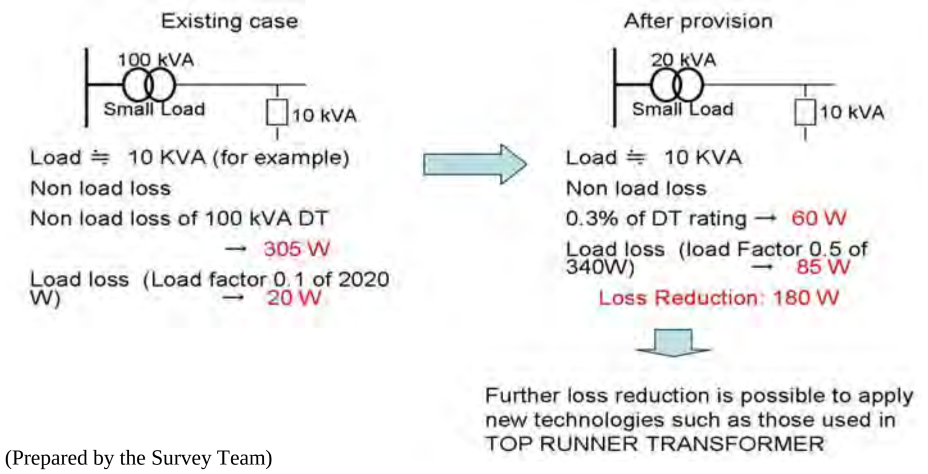
4.2.1 New LV Schemes

(1) Small Capacity Distribution Transformers

1) Present situation of loading on DTs

DTs step down MV (33 or 11 kV in Sri Lanka) to LV (415 V). DTs on overhead lines are of the single-pole or double-pole mounted type. Pole mounted DTs have a series of capacities of 100 kVA, 160 kVA, 250 kVA, 400 kVA, and others up to 1,000 kVA, with power fuses, lightning arresters, disconnectors and energy meters. LV lines from DTs have the length from several hundred meters to 1.8 km to the most distant consumers.

On the other hand, in Japan, the DTs are only single-pole mounted type and smaller in capacity than Sri Lankan DTs, such as 10 kVA to 100 kVA, and the length of the LV line is shorter than that of CEB. In addition, if Japan's technologies such as "Top Runner Transformers" are to be applied, further loss reduction can be realized.



(Prepared by the Survey Team)

Figure 4.2-1 Loss Reduction by Small Transformers

2) Project scope of small DT installation

CEB has a series of standard capacities of DTs of which the minimum capacity is three phase 100 kVA. However, a bigger capacity is used for smaller loads in some cases. It may cause much no-load (iron) losses as pointed out in Region 3. If it is replaced by a small sized single-phase transformer, it may be possible to reduce no-load losses. On the other hand, load-losses on LV lines shall not be changed substantially because such a small loaded feeder is almost single-phase. Heavily loaded single-phase lines shall be converted to three-phase lines, and small sized single-phase DTs can be used for small loaded single-phase lines without increasing much losses.

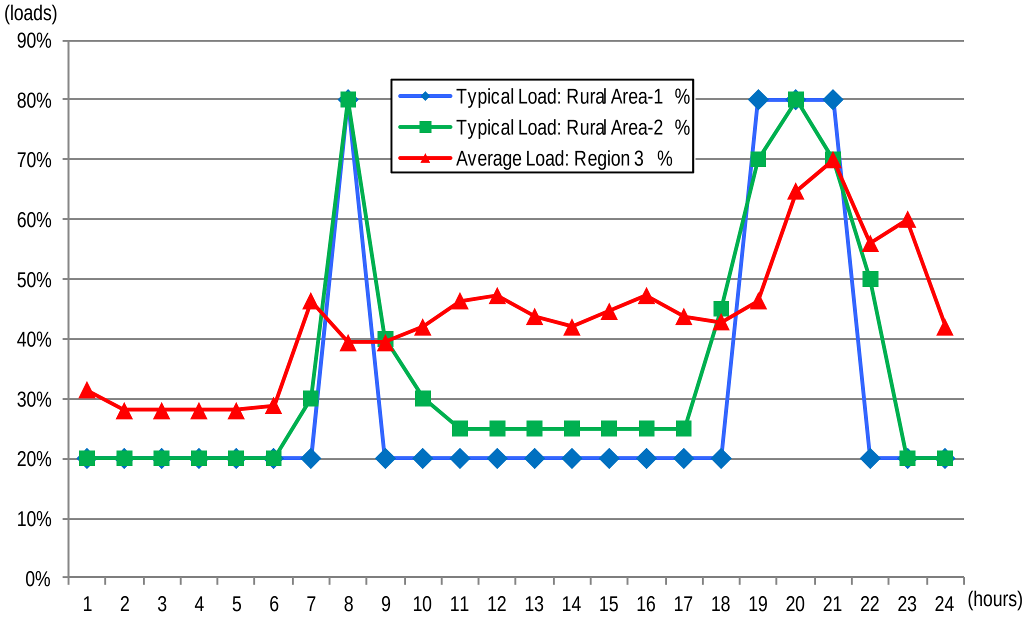
(2) Addition of LV Scheme

1) Present situation of LV distribution substation (LV Scheme)

In rural areas, the length of the LV distribution line is very long beyond determined maximum length by CEB. It is very effective to provide one new LV Scheme between the existing substations in order to shorten the LV lines and reduce the losses. Typical daily load curves of rural areas and average load curve of Region 3 are shown in Figure 4.2-2.

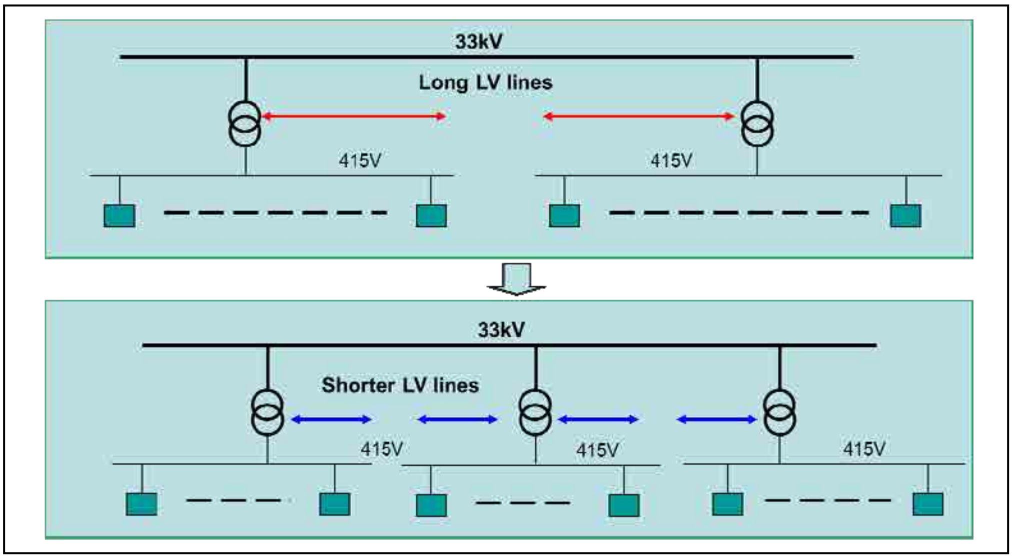
2) Project of additional LV Scheme installation

It is possible to reduce the losses by installing LV Scheme as shown in Figure 4.2-3. In case the lengths of LV line up to the end consumers are longer than determined lengths, it should be selected to add new LV schemes as shown in Table 4.2-1. Although Regions 2 and 3 of CEB proposed the project for LV schemes as shown in the table, the Survey Team assumed the latent demand of LV schemes in other regions.



(Source: CEB MV Develop Plan)

Figure 4.2-2 Typical Load Curves of Rural Areas and Region 3



(Prepared by the Survey Team)

Figure 4.2-3 Loss Reduction by Additional LV Schemes

Table 4.2-1 Proposed Additional LV Schemes

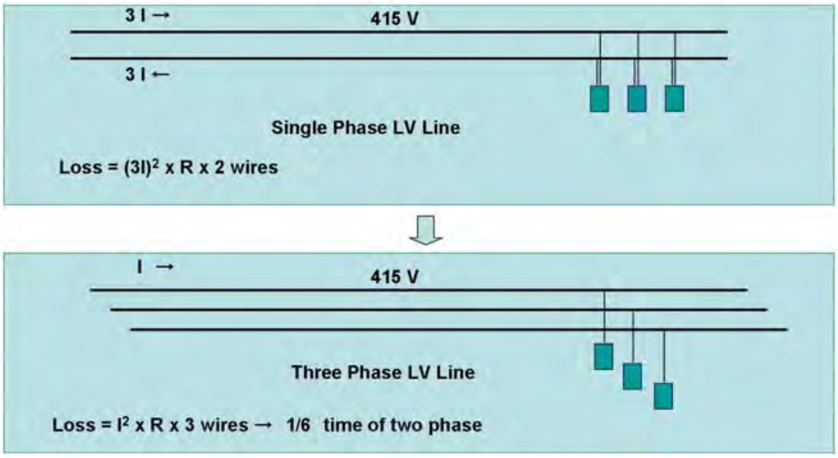
Region	Area	Required Q'ty
Region 1	-	N/A
Region 2	WPN	75
	Central	300
	Eastern	170
Region 3	WPS-2	75
	UVA	90
	Sabaragamuwa	125
Region 4	-	N/A
	Total	835

(Source: CEB Project Proposals of Region-1, -2,-3 and -4)

4.2.2 Single-phase to Three-phase Conversion

(1) Present Situation of LV Lines

In Sri Lanka, three-phase four wire system is adopted for LV lines, but many single-phase two wire systems still remain in rural areas. The conversion from single-phase to three-phase is being carried out one by one at this moment, thus it may take substantial time to convert a single-phase line to three-phase line. The losses on LV lines can be reduced to 1/6 times as shown in Figure 4.2-4.



(Prepared by the Survey Team)

Figure 4.2-4 Three-phase Conversion

(2) Project Scope for Single-phase to Three-phase Conversion

It is possible to reduce the losses by converting the existing single-phase lines to three-phase lines. The Survey Team assumed that this measure is to be adopted in WPN, CP and eastern of Region-2, and WPS-2, UVA and Sabaragamuwa of Region-3. However, the Survey Team believed there is latent demand in Regions 1 and 4.

Table 4.2-2 Proposed Single-phase to Three-phase Conversion

Region	Area	Required Q'ty (km)	Project Cost (MLKR)
Region 1	-	N/A	0
Region 2	WPN	100	50
	Central	850	425
	Eastern	420	210
Region 3	WPS-2	400	200
	UVA	700	350
	Sabaragamuwa	700	350
Region 4	-	N/A	0
	Total	3,170	1,585

(Source: CEB Project Proposals of Region-1, -2,-3 and -4)

4.2.3 Provision of Automatic Meters Reading (AMR)

(1) Present Situation

The existing mechanical type energy meter on site and the electronic energy meter, which are currently used are shown in the following photographs for reference. At this stage, the energy meters have no remote monitoring facilities except for large bulk consumers. The communication used for remote monitoring of large bulk consumers is GSM/GPRS.

(2) Requirement of AMR

Although only Region 4 has submitted the proposal of AMR at DTs, the Survey Team has confirmed the needs of AMR at DTs through discussions with other regions. The proposal and latent demand are shown in Table 4.2-3.

Table 4.2-3 Proposed AMR

regions	areas	project scope	Remarks
Region 1	North Western Province	New AMR	Confirmed in discussion
Region 2	Western Province North	New AMR	Confirmed in discussion
	Central	New AMR	Confirmed in discussion
Region 3	Western Province South II	New AMR	Confirmed in discussion
Region 4	Western Province South I	Proposed New AMR for DTs 2660 sets	In proposal

(Source: CEB Project Proposals of Region-4 and discussion with each region)

(3) Future Provision of “Smart Meter”

If smart meters can be provided at each consumer site, all information of energy flow can be identified by CEB. Technical and non-technical losses can be monitored, especially, power theft can be detected instantaneously and prevented completely.

4.2.4 Provision of New PSs and Reinforcement of Distribution Lines

Upgrading system voltage is one of the effective measures to reduce distribution losses. If the system voltage is upgraded, it is possible to reduce load currents on the distribution lines and resistive losses on the line. Upsizing conductors or installing additional distribution lines is also one of the effective measures to reduce resistance of distribution lines. Therefore, the Survey Team selected the projects to provide new PSs and the associated new 33 kV distribution lines.

Table 4.2-4 shows the proposed MV projects from each region.

Table 4.2-4 Proposed MV Projects

projects	scope	project costs (MLKR)	contribution to loss reduction
Region 1			
Colombo City Network Development (Distribution Portion)	11 kV Under Ground Cable 400mm2 90km 11 kV Under Ground Cable 240mm2 3km 33kV Incoming and Outgoing panels and bus coupler panels at Kelanitissa 18sets 11kV Radial and RMU 86 sets RTU for SCADA 10 sets Communication Equipment 10 sets Fiber Optic Cable 15km	3,261.0	Loss reduction by shorten MV Cable length
North Central 3 3kV Distribution Lines	New A'pura GS to Kaduwela (DC Lynx Tower Line 20 km) Polonnaruwa GS to Mananpitiya (DC Lynx Tower Line 20 km) Polonnaruwa GS to Kaduruwela (DC Lynx Tower Line 3 km) Polonnaruwa GS to Janthipura (DC Lynx Tower Line 9 km) New A'pura GS to Mahaillupallama (DC Lynx Tower Line 41 km) Vavunia GS to Padaviya (DC Lynx Tower Line 35 km)	1,920.0	Loss reduction by preventing overload
North Western 33 kV Distribution Lines	Mandanpe GS to Bowatta (DC Lynx Tower Line 20 km) Maho GS to Maho Gantry (SC Con. Pole Lynx Line 3 km) Maho GS to Nikaweratiya Gantry (SC Con. Pole Lynx Line 14 km) Maho GS to Galgamuwa (DC Lynx Tower Line 23 km) Mallawapitiya GS to Udawalpola (SC Con Pole Lynx Line 4 km)	714.0	Loss reduction by preventing overload
Northern 33 kV Distribution Lines	Chemmuni GS to Ramalingam Ga. (SC ELM Pole Line 4 km) Chemmuni GS to Ramalingam Ga. (SC ELM Pole Line 2 km) Chemmuni GS to Kaithadi Ga. (SC ELM Pole Line 11.5 km)	54.3	Loss reduction by preventing overload
Region 2			
WPN 33 kV Lines	Imbulgoda to Brandriyamulla (Replace Lynx DC Tower 3.5km from Raccoon) Brandriyamulla to Dekatana (Replace Lynx DC Tower 15km from Raccoon) Veyangoda Feder 7 and 8 to Maradana(Replace Raccoon DC Tower from Cockroach) Biyagama Feeder 5 to Mabola (Same conductor) Kerawarapitiya to Maradana (Lynx SC Pole 3.7km) Kerawarapitiya to Mabola (Lynx SC Pole 8km) ABC Insulated Cable (ABC 0.5km)	1,071.4	Loss reduction by preventing overload
WPN 33 kV Primary Substation	Augmentation of two PSs with Remote Control(2x5MVA to 2x10MVA) Two new PSs (Awarakotuwara 2x5MVA, Pamunugamuwa 1x5MVA) Five gantries (Sellakanda, Siriyangani, Diulapitiya, Veyangoda, Dunagaha)	1,765.7	Loss reduction by upgrade voltage
WPN Aerial Bundle Conductor(ABC)	Conversion of Tree Phase LV bare Conductor to ABC in town area 6 x 20km)	140	Loss reduction and reliability
WPN Equipment for Loss Reduction	Portable three-phase meters testing units 14 sets Portable single-phase testing units 20 sets Three-phase phantom load Unit 1 set	37.8	
Central 33kV Primary Substation	Augument of Bogambara PS (2x10 MVA to 2x20/15 MVA) Augument of Gatambe PS (2x10 MVA to 2x20/15 MVA) Augument of Polgolla PS (2x5 MVA to 2x10 MVA) New PS (Wattarantenna 2x10 MVA)	1,639.2	Loss reduction by preventing overload
Eastern 33kV Lines	Gamadu Junc. to Inginiyanagala (Lynx DC Tower 20km) Giranturukotte to Dehiatakandiya (Lynx SC 25km) Ampara to Uhana (Lynx SC 10km) Akkaraipatthu GSS to Karathivu (Lynx DC Tower 20km)	1,067.5	Loss reduction by preventing overload
Eastern Gantry	12 DBB and 12 SBB gantries	960.0	
Eastern Equipment for loss reduction	Portable three-phase meters testing units 5 sets Portable single-phase testing units 9 sets	14.1	
Region 3			
WPS2 Conversion of OH system to UG Cable System	In Battaramulla town, existing OH distribution system will be replaced to new underground distribution system.	3,500.0	Loss reduction by decrease cable resistance and shorten length
WPS2 33/11 kV Primary Substation	2X10 MVA at Thalahena	600.0	Loss reduction by upgrade voltage

projects	scope	project costs (MLKR)	contribution to loss reduction
WPS2 33 kV UG Lines	Aurveda Junc. to Ethulkotte, Rajagiriya UD Double Circuit 3. km	350.0	Loss reduction by preventing overload
WPS2 Construction and Rehabilitation of 33 kV Lines	Reconduction Koratota to Ambatale (Lynx SC 7.5 km) Meethotamulla Ga. to Ambatale Ga. (Con. Pole Lynx SC 10 km) Authurugiriya GS to Malambe (Lynx SC 7 km) Rukmale Ga. To Makumbura Ga. (Lynx SC 8 km) Reconduction Wele Junc. To Ambathala (Raccoon SC 5 km) Reconduction Horana Ga. to Narthupana Line (Raccoon SC 2 6km) Reconduction Batuwita Junc. To Mawgama (Raccoon SC 3 km) Reconduction Horana Ga. from Ingiriya to Bope Tapping (Raccoon SC 3km)	340.5	Loss reduction by preventing overload
UVA Construction of 33 kV Lines	Mahiyangana to Girakotte (Lynx DC 16 km) with Gantry (2SSBB) Mhiyangana GS to Walapane (Lynx SC 20 km) with Gantry Mhiyangana GS to Walapane (Lynx SC 20 km) with Gantry(2SSBB) Monaragala to Wellawara Express (Lynx SC 28 km) with Gantry(2SSBB) Mahiyangana GS to Andaulpotha (Lynx SC 12 km) Ragala to Rikillagaskada (Lynx DC 24 km) with Gantry (2SSBB) Kalugakandura to Roberiya (Raccoon SC 8 km) Keerthibandarapura to Happawara (Raccoon SC 8 km) Haggala to Galahagama (Raccoon SC 6 km) Glendevon to Roberiya (Raccoon SC 4 km) Motogora to Hali Ela (Raccoon SC 4 km) Pallebowala to Hapugasdeniya (Raccoon SC 6 km) Haputale to Boralenda (Raccoon SC 6km) Reconducting to Haputale to Idalgashinna (Raccoon SC 10 km) Reconducting to Ragala to Rupaha (Raccoon SC 7 km) Reconducting to Welimada to Boraland (Raccoon SC 8 km)	1,432.5	Loss reduction by preventing overload
SAB Construction of 33 kV Lines	WPS GS to Norwood (Lynx SC 12 km) with Gantry (2SSBB) Conversion to 33 kV Emblipitiya to Panamura (Raccoon SC 10 km) Reconducting Kurivita to Ehaliyagoda from weasel line (Raccoon SC 15 km) Reconducting Kolonna to Kooppakanda from weasel line (Raccoon SC 12 km) Reconduction to Neelagama (Lynx SC 10 km) Horana GS to Heraniyawaka ABS (Lynx SC 19 km) Seethwaka GS to Daraniyagala/Nakkavia Ga. (Lynx SC 23 km) with Ga. Reconduction NAkkavita to Maliboda Estate (Lynx SC 6 km) Kotiyakumbra to Balapaththawa (Raccoon SC 10 km) Kotiyakumbra to Warawala (Raccoon SC 6 km) Pathakada to Ganegama (Raccoon SC 2.5 km) Indurana to Gonagaldeniya (Raccoon SC 2 km) Reconducting Pelamadulla Bathgangoda to Lellupitiya Junc. (Raccoon SC 6 km) Reconducting Deraniyagala to Miyanawita (Raccoon SC 6 km) Reconducting Anguruwella to Kotiyakumbra (Raccoon SC 5 km) Malwala Junc. to Palabaddala (Raccoon SC 7 km)	935.8	Loss reduction by preventing overload
Region 4			
Dehiwala Mount Laveniya Under Ground Cabling Project	New 11 kV UGC (240 sq.mm x 33 km) New 11 kV UGC (95 sq.mm x 3km) New Radial SS 12 locations Replace to ABC 200 km	2,125.0	Loss reduction by decrease resistance of cable and shorten the length
Bentota 11 kV Under Ground Network Development Project	New 11kV UGC (240 sq.mm x 4 km) New 11kV UGC (95 sq.mm x 2.25 km) New Ring Main Unit 10 locations New LV cable 7 km Other miscellaneous	160.0	Loss reduction by decrease resistance of cable and shorten the length

(Source: CEB MV Project Proposals of Region-1, -2,-3 and -4)

4.2.5 Provision of DAS

DAS is very useful to control and manage the distribution system. Although only Western Province North and Central Province of Region 2 have submitted the proposal of DAS, the Survey Team recognized additional needs through the discussion with each region. The requirements of DAS are summarized in Table 4.2-5.

Table 4.2-5　Proposed DAS

regions	project scope	remarks
Region 1		
North Western Province	New DAS	
Region 2		
Western Province North	Reinforcement of existing DAS including Auto-recloser 94sets, LBS 126 sets, Fault indicator 410 sets	Interface of GSM/ GPRS is included in each switch.
Central	Reinforcement of existing DAS, SCADA software, Auto-recloser 65sets, LBS 110, GPS instrument, GIS software	Interface of GSM/ GPRS is included in each switch.
Region 3		
Western Province South II	New DAS	
Region 4		
Western Province South I	New DAS	

(Source: CEB Project Proposals of Region-1, -2,-3 and -4)

4.2.6 Provision of Specialized Vehicles

As mentioned in Item 6) in Section 4.1, to secure safety and efficiency of installation and maintenance work of distribution lines, Regions 1 and 2 have requested specialized vehicles as shown in Table 4.2-6.

Table 4.2-6　Proposed Specialized Vehicles

Region	Vehicle	Required Q'ty	Project Cost (MLKR)
Region 1	Bucket Truck	1	42.2
	Pole Ins. Truck	1	42.2
	Cargo Cranes	1	42.2
Region 2	Bucket Truck	4	168.9
	Pole Ins. Truck	4	168.9
	Cargo Cranes	4	168.9
Region 3	-	-	-
Region 4	-	N/A	-
	Total	15	630.3

(Prepared by the Survey Team based on CEB proposal)

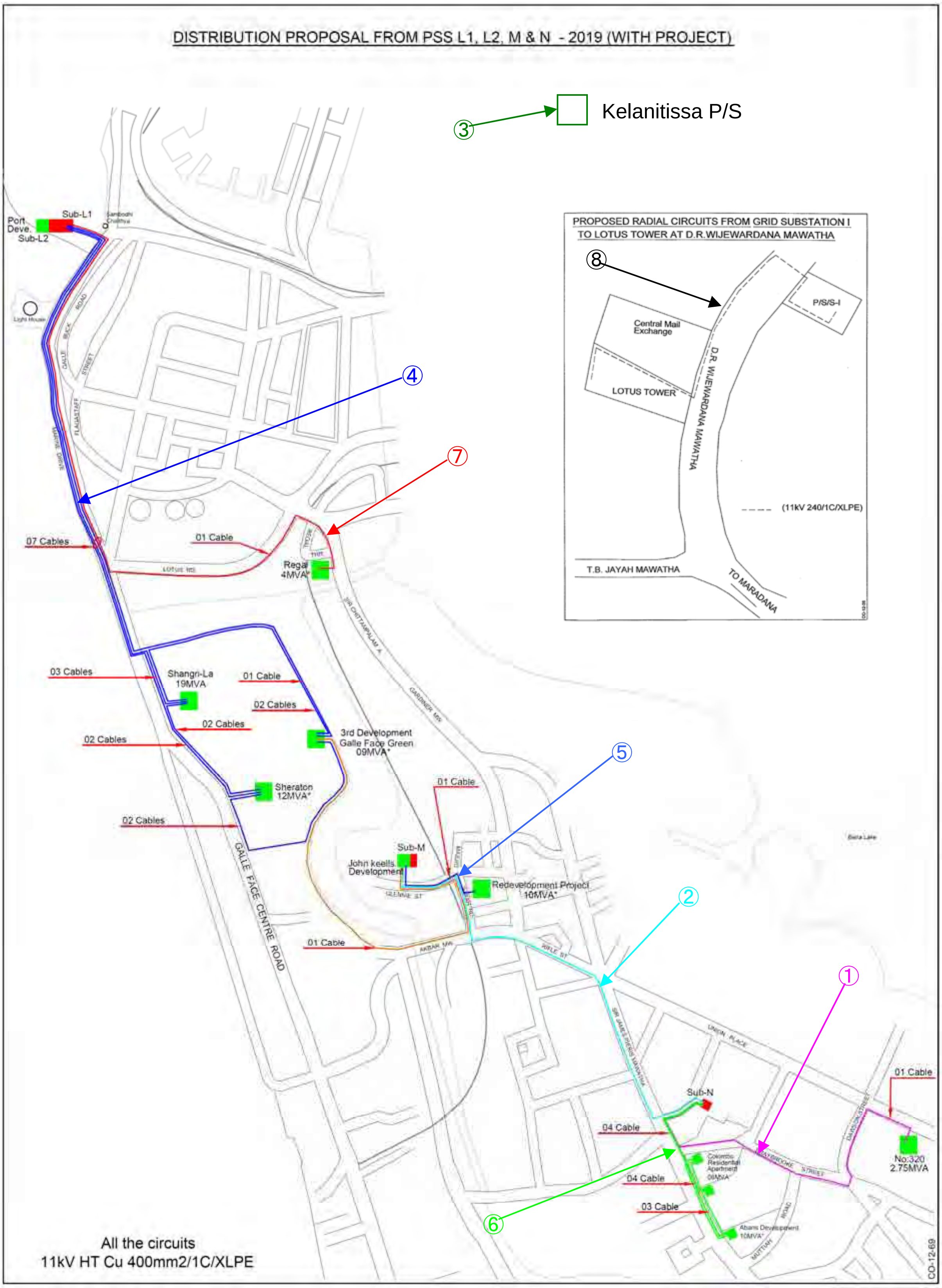
4.2.7 Colombo City 11 kV Development Project

This project is associated with Colombo City Transmission Development Project (PJT-1) and is designed to provide 11 kV underground cables and switchgear to distribute the electricity from 132 kV GSs which are reinforced by PJT-1. Table 4.2-7 shows the scope of this project and Figure 4.2-5 shows the project locations.

Table 4.2-7 Colombo City 11 kV Development Project

No.	Sub-projects	Specifications	Switchgear
1	Radial circuit from N GS to No 320, Union Place to De load Sub. E & I	11 kV UGC XLPE 400 mm^2, 4.5 km	N/A
2	Interconnection from M GS to N GS	11kV UGC XLPE 400 mm^2, 6 km	N/A
3	33 kV GIS substation at Kelanitissa	N/A	33 kV GIS panels: 18 sets
4	Galle Face Green 3 Projects: Shangri-La, Sheraton Hotels Apartment and Condominium Center	11kV UGC XLPE 400 mm^2, 50 km	11 kV RMU :33 sets
5	Re-development project, Slave Island	11kV UGC XLPE 400 mm^2, 6 km	11 kV RMU :9 sets
6	Development project at Colombo Commercial -Colombo Residential Apartment -Abans Development -Nawaloka Development	11kV UGC XLPE 400 mm^2, 15 km	11 kV RMU : 26 sets
7	Regal Theater Site	11kV UGC XLPE 400 mm^2, 7.5 km	11 kV RMU :9 sets
8	Lotus Tower	11kV UGC XLPE 240 mm^2, 3 km	11 kV RMU :9 sets
9	Construction vehicles	12 Vehicles	N/A

(Prepared by the Survey Team based on CEB proposal)



(Source: CEB Project Proposals of Region-1 Colombo City)

Figure 4.2-5 11 kV Cable Routes in Colombo City

4.3 Packaged Distribution Projects

Individual loss reduction projects have been described in the above sections. Considering the features of a distribution system, the individual projects are spread all over the country. Thus, it is difficult to control and manage the projects and moreover, the total effect of the projects cannot be measured. The Survey Team proposes to concentrate the projects into one package in one province, considering the project priority of CEB, the multiplier effect between each individual project, and its relation to the transmission project as shown in Table 4.3-1.

Table 4.3-1 Packaged Distribution Projects

Region	Package	Area	11 kV UGC	11/33 kV SWGR	DAS	AMR	MV Line & PSs	DT	3-phase Conv.	Small DT	Other Facilities
R 1	1	Colombo City	Yes	Yes	N/A	N/A	N/A	N/A	N/A	N/A	
	2	NWP	N/A	N/A	Yes	Yes	Yes	Yes	Yes	(Yes)	Construction Vehicle
R 2	3	WPN	N/A	N/A	Yes	Yes	Yes	Yes	Yes	(Yes)	Ditto
R 3	4	WPS-2	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Ditto
R 4	5	WPS-1	Yes	N/A	Yes	Yes	N/A	Yes	N/A	(Yes)	Ditto

(Prepared by the Survey Team)

Note: "Yes" in the table means latent demand in rural area assumed by the Survey Team.

Package 1 is associated with Colombo City Transmission Development (PJT-1). Other packages are independent projects in each province which surrounds Colombo City. Since electricity demand is rapidly increasing in these areas, the provision of DAS and other control systems with advanced technology, and reinforcement of the MV system are necessary.

CHAPTER 5
POWER FLOW AND LOSS REDUCTION CALCULATIONS

CHAPTER 5 POWER FLOW AND LOSS REDUCTION CALCULATIONS

5.1 General

To evaluate the effects of the candidate transmission projects as mentioned in Section 3.3, the Survey Team carried out power flow and loss reduction calculations.

Transmission line projects, such as PJT-1 and PJT-5, are intended to reduce transmission losses, which are calculated using software for power system analysis, such as PSS/E. Loss reduction values for transmission projects are calculated to compare the results between with and without project cases.

On the other hand, grid substation construction projects aim to reduce distribution losses by shortening medium voltage (MV) distribution lines. Loss reduction values of the grid substation projects are to be calculated based on the forecasted demand and supposed MV feeder line length from the related grid substations. Details of the calculations are described in the following sections.

Calculated loss reduction values are to be used for economic evaluations of the candidate projects described in Chapter 10.

5.1.1 Power Flow Calculations for Transmission Projects

The power flow calculations validate the status of the future CEB's transmission network, especially for the 220 kV and 132 kV transmission lines to be developed under the candidate projects. The active and reactive power flows on transmission lines, voltages, and phase angles at each bus in power stations and grid substations are to be simulated in the calculations. The objective of the power flow calculations is to compare the transmission loss values between with and without the candidate transmission line projects.

The Transmission Planning of CEB has provided all necessary data on the existing and future network required to calculate results in 2012, 2015, and 2020, using the PSS/E format. Such data include line constants, transformer capacities, generating conditions, substation loads, static capacitors, and shunt reactors, etc. The Survey Team has built future network models for with and without the candidate projects that are suitable to calculate results for 2015 and 2020, based on the provided data, development plans and demand forecast.

The Survey Team has carried out power flow calculations using "PSS/E™ version 33" software with the following technical criteria for transmission network planning:

1) Power Flow

Under normal operating conditions, the loading of transmission lines shall not exceed the thermal ratings calculated at a maximum operating temperature of 75 °C or 54 °C for some old lines, as shown in Table 2.3-3 in Chapter 2. In case of a single circuit fault for the interval with more than double circuits, the power flow of remaining facilities must be within the rated capacity (N-1 criteria).

Under normal operating conditions, the loading of transformers shall not exceed the rated capacity of transformers allowed by the available mode of cooling. Under N-1 contingency conditions, a short period (one hour) of overloading of up to 120% rated capacity is allowed.

2) System Voltage

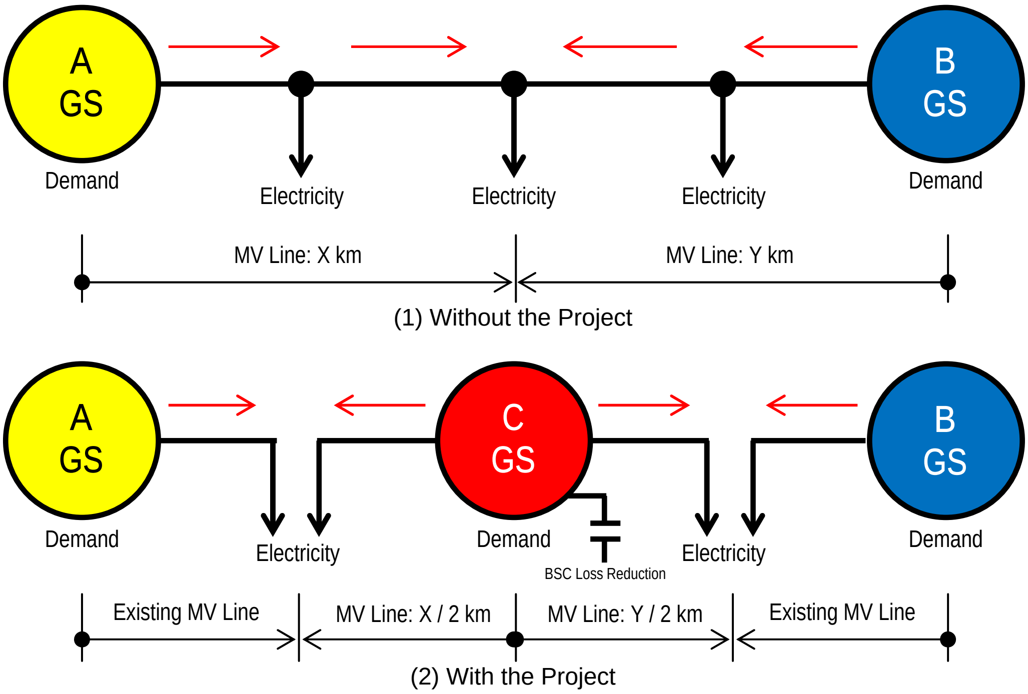
Bus voltage for power stations/substations must be in the range from 95 % to 105 % at normal operating conditions, and in the range from 90% to 110 % at N-1 condition.

5.1.2 Loss Reduction Calculations for Substation Projects

Since it is difficult to estimate loss reduction values of candidate substation projects with the power flow calculations, the Survey Team estimated the values with the following methods.

(1) Losses on MV Distribution Lines

Candidate substation projects contribute to the reduction of MV distribution losses. Figure 5.1-2 shows the concepts of the loss reduction calculation on the MV lines.



(Prepared by the Survey Team)

Figure 5.1-2 Calculation Concept

1) Demand forecasts for the existing and new substations up to 2025 are given by CEB.
2) In case that candidate substation (C GS) is not constructed in some areas, neighboring existing substations (A and B GSs) shall supply electric power to said areas via long-distance MV distribution lines (without the project case).
3) In case the candidate substation is constructed in the area as mentioned above, MV distribution lines from the existing substations can be shortened (with the project case). Loss reduction values can be calculated to examine differences in distribution losses between "with the project" and "without the project".
4) Annual MV line losses (MWh/year) can be calculated using the following formula:

Annual MV line loss = NC x L x NCC x R x I^2 x (0.3 x LF + 0.7 x LF^2) x 24 hrs x 356 days

Where: NC: Nos. of conductors/circuit
L: Line length (km)
NCC: Nos. of circuit
R: Conductor resistance (Ω/km)
I: Load current (A)
LF: Load factor = 0.55

(2) Iron and Copper Losses on Main Transformers

As described in the above cases shown in Figure 5.1-2, transformer loads in C GS shall be borne by A and B GSs in the "without the project" case. Transformer losses consist of iron (no-load) and copper (load) losses. Among these, copper loss especially increases with the increase in load. Thus, transformer loss reduction values can be calculated for comparison between "with the project" and "without the project" cases.

Annual transformer losses (MWh/year) can be calculated using the following formulas:

Annual transformer loss (MWh/year) = Annual iron (no load) loss + Annual copper (load) loss

Annual iron loss (MWh/year) = Iron loss (MW) x UF x 24 hrs x 365 days x TR nos.

Annual copper loss (MWh/year) =** Copper loss (MW)* ***x $(load/capacity)^2$ x *LF x 24 hrs x 365 days x TR nos.*

Where: UF: Utilization factor = 1.0 (TR 1 unit), 0.95 (2 units), 0.75 (3 units), and 0.65 (4 units)
LF: Load factor = 0.55

(3) Installation of Static Capacitors

In case static capacitors are to be installed in the candidate substation, annual loss reduction value (MWh/year) by the capacitors is calculated using the following formula:

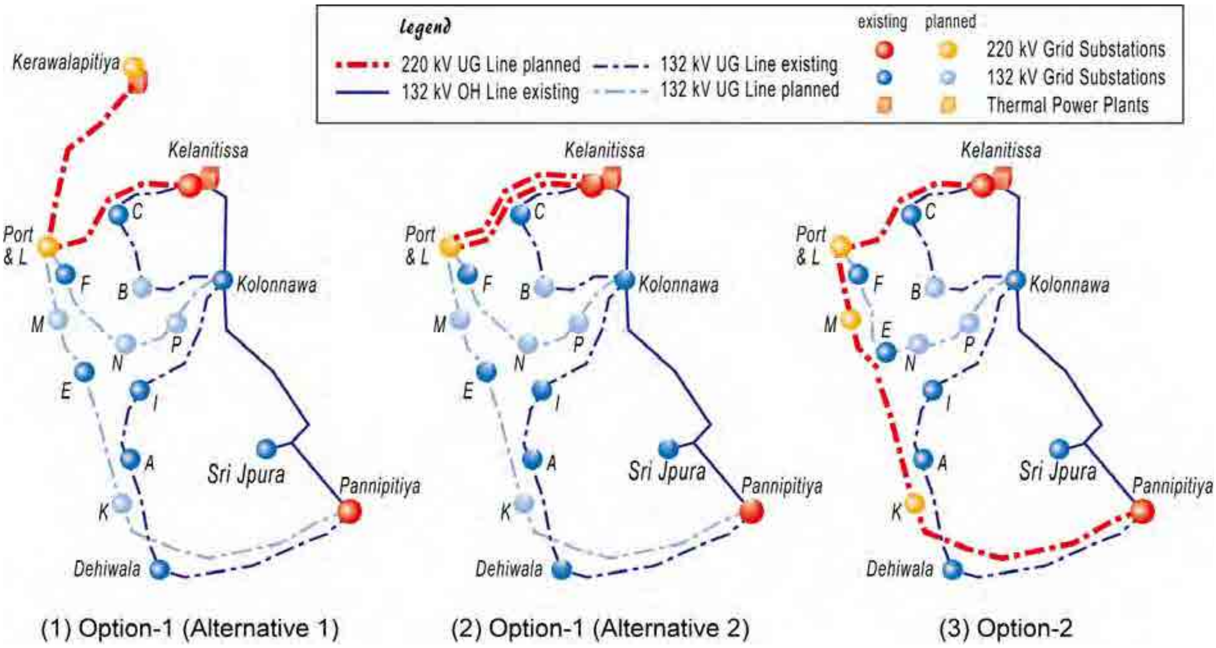
Loss Reduction (MWh/year) = (AP1 – AP2) × (1 – $(PF1 / PF2)^2$) x PF2 × LF^2 × *24 hrs* ***× UF ×*** *365 days*

Where: AP1: Apparent power (MVA) = ($(active\ power)^2 + (reactive\ power)^2$ $)^{1/2}$
AP2: Improved apparent power by capacitors (MVA)
PF1: Power factor before improvement
PF2: Improved power factor
LF: Load factor = 0.55
UF: Utilization factor = 0.4

5.2 Colombo City Transmission Development (PJT-1)

5.2.1 Study on the Project Scope

With regards to the Colombo City Transmission Development Project (PJT-1), CEB had several alternative plans considering the future system configurations, construction costs, and construction possibilities. Through discussion with CEB in order to decide the scope of the project, the Survey Team calculated the following three cases.



(Prepared by the Survey Team)

Figure 5.2-1 Calculation Cases

1) Calculation cases

Particular scope of each calculation case is as follows:

i) Option-1 (Alternative-1): almost same as the original proposal (Figure 5.2-1 (1))
- Kerawalapitiya – Port 220 kV 1,600 mm^2 XLPE cable, single-circuit, 14.9 km
- Kelanitissa – Port 220 kV 1,200 mm^2 XLPE cable, single-circuit, 7.2 km
- Port 220/132 kV GS with 220/132 kV 2 x 250 MVA tie-TR and 132/11 kV 4 x 31.5 MVA TR

ii) Option-1 (alternative-2): without Kerawalapitiya – Port line (Figure 5.2-1 (2))
- Kelanitissa – Port 220 kV 1,200 mm^2 XLPE cable, double-circuit, 7.2 km
- Port 220/132 kV GS: same as Option-1 (Alternative-1)

iii) Option-2: 220 kV links around Colombo City (Figure 5.2-1 (3))
- Kelanitissa – Port 220 kV 1,200 mm^2 XLPE cable, single-circuit, 7.2 km
- Port – Colombo M 220 kV 800 mm^2 XLPE cable, single-circuit, 7.8 km

- Colombo M – Colombo K 220 kV 800 mm^2 XLPE cable, single-circuit, 14.2 km
- Colombo K - Pannipitiya 220 kV 1,200 mm^2 XLPE cable, single-circuit, 2.6 km
- Port: 220/11 kV GS with 220/11 kV 4 x 31.5 MVA TR
- Kelanitissa: additional 220/132 kV, 150 MVA main tie-TR

2) Calculation conditions

i) GS demands (given by CEB Transmission Planning): day peak demand in 2020

3) Calculation results

Results of the calculations are summarized in Table 5.2-1.

Table 5.2-1 Results of Power Flow Calculations for Three Cases

	FROM GENERATION SYNCHRN	FROM GENERATION INDUCTN	TO INDUCTN MOTORS	TO LOAD	TO BUS SHUNT	TO BUS GNE DEVICES	TO LINE SHUNT	FROM CHARGING	LOSSES (IN MW/MVAR)
*2020 OP-1(Alt-1) Day Peak:									
	3146.9	0.0	0.0	3072.2	0.0	0.0	0.0	0.0	74.7 (2.37%)
	546.9	0.0	0.0	1436.5	-1099.0	0.0	0.0	810.7	1020.1
*2020 OP-1(Alt-2) Day Peak									
	3148.6	0.0	0.0	3072.2	0.0	0.0	0.0	0.0	76.4 (2.42%)
	612.6	0.0	0.0	1436.5	-1094.9	0.0	0.0	756.2	1027.2
*2020 OP-2 Day Peak:									
	3147.3	0.0	0.0	3072.2	0.0	0.0	0.0	0.0	75.1 (2.39%)
	605.8	0.0	0.0	1436.5	-1100.3	0.0	0.0	765.7	1035.3

(Prepared by the Survey Team)

The following figures attached at the end of this chapter also show the results:

Figure 5.2-2 (1) Power Flow Calculation: Option-1 (Alternative-1) in 2020

Figure 5.2-2 (2) Power Flow Calculation: Option-1 (Alternative-2) in 2020

Figure 5.2-2 (3) Power Flow Calculation: Option-2 in 2020

All cases satisfy voltage and system reliability criteria. As shown in Table 5.2-1, Option-1 (Alternative-1) has the lowest percentage of transmission loss (of the whole transmission network).

4) Cable size considerations

To decide on the cable sizes, especially for the sections between Kerawalapitiya and Port, and between Kelanitissa and Port, the Survey Team carried out power flow calculations with the following conditions:

- Generation capacity of Kerawalapitiya: 540 MW (+270 MW)
- Demand forecast: day peak demand in 2032 given by CEB
- System configurations: same as in 2020, but excludes outside of Colombo City
- Swing-generators (virtual-generators) are installed to 220 kV buses in Biyagama and Kotugoda for calculation purposes.

The results of calculations considering 2032 are shown in the following figures attached at the end of this chapter:

Figure 5.2-3 (1) Power Flow Calculation: Option-1 in 2032

Figure 5.2-3 (2) Power Flow Calculation: Option-2 in 2032

As a result of the calculations, the following cable sizes were found needed:

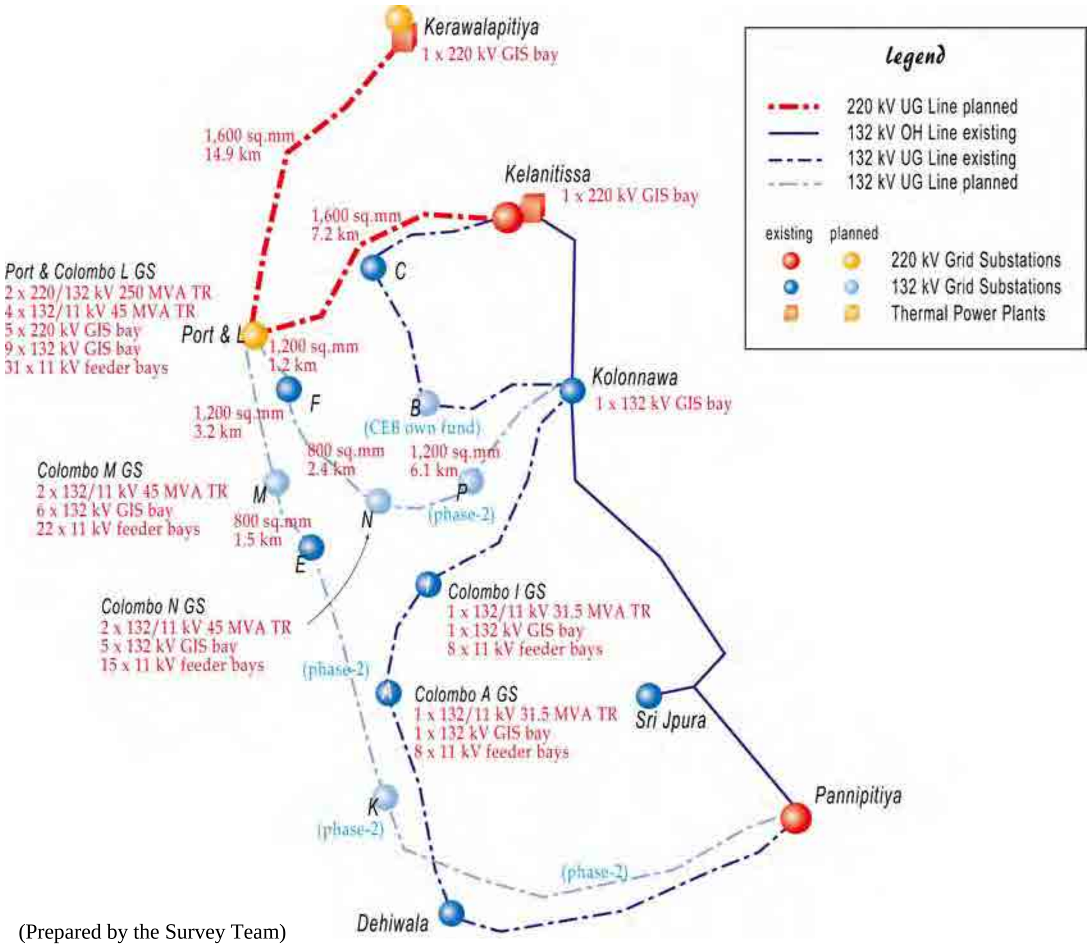
- Kerawalapitiya and Port section: more than XLPE 1,600 mm^2
- Kerawalapitiya and Kelanitissa: more than XLPE 1,600 mm^2
- Kelanitissa and Port: more than XLPE 1,200 mm^2 (considering unknown 200 MW load for 'Ocean City')

However, these results are obtained through many assumptions. It should be recalculated, when the additional generators in Kerawalapitiya are realized with the actual system configurations and substation demands.

5) Scope of the Project

Through discussions with CEB based on the above calculation results, Option-1 (Alternative-1) was selected as the scope of PJT-1. However, regarding the 220 kV cable section between Kelanitissa and Port, 1,600 mm^2 cables are to be applied since CEB required them considering power demands in the far future.

Figure 5.2-4 shows the scope of PJT-1 with full-scale development by 2020.



(Prepared by the Survey Team)

Figure 5.2-4 Colombo City Transmission Development Project (Full-scale)

Considering electricity demand forecast and system configurations in Colombo City, PJT-1 is divided into two phases: Phase-1 by 2015 (to be requested to JICA for 43rd Year Loan Package), and Phase-2 by 2020 as shown in above figure.

5.2.2 Calculations for 2015 Network (Phase-1)

(1) Conditions

1) Cases: with and without Phase-1 Package
"Without the project" means substation demands in 2015 are to be applied for the calculation, but system configuration is the same as the existing network in 2012.

2) Basic system configurations: 2015 network data provided by CEB
The Survey Team only modified the system elements to be developed under the project.

3) Electricity demand: day peak demand in 2015 provided by CEB
Electricity demands for grid substations in Colombo City with/without the project are shown in Table 5.2-2. As for the calculation of "without the project", the following loads for new grid substations are assumed distributed to the existing grid substations considering the locations:

- 100% load of Colombo L is to be distributed to Colombo F;
- 100% load of Colombo M is to be distributed to Colombo E; and
- Each 50% load of Colombo N is to be distributed to Colombo I and Colombo B, respectively.

Table 5.2-2 Demand Forecast for Phase-1 Calculations

Grid Substations	2015 with Project		⇒	2015 without Project	
	MW	MVar		MW	MVar
Colombo A	56.82	22.46		56.82	22.46
Colombo B	25.42	15.75		34.94	19.81
Colombo C	24.40	15.12		24.40	15.12
Colombo E	54.18	32.15		80.93	48.02
Colombo F	39.76	22.53		66.96	39.39
Colombo I	40.20	17.13		49.73	21.18
Colombo K	-	-		-	-
Colombo L	27.20	16.86	F: 100%	-	-
Colombo M	26.75	15.87	E: 100%	-	-
Colombo N	19.04	8.11	I: 50%, B: 50%	-	-
Colombo P	-	-		-	-
Kelenitissa	24.06	14.91		24.06	14.91
Kolonnawa	47.18	29.24		47.18	29.24
Total	385.00	210.12		385.00	210.12

(Prepared by the Survey Team based on CEB's forecast)

4) Since this calculation aims to estimate the transmission losses, over-loadings of main transformers and transmission lines for the calculation of "without the project" are not considered.

(2) Results

Figures 5.2-5 (1) and 5.2-5 (2) (attached at the end of this chapter) show the results of the calculations for with and without Phase-1 project, respectively. As shown in Figure 5.2-5 (1), there is no serious problem in the load flow on the grid under normal operating conditions. Table 5.2-3 summarizes the results.

Table 5.2-3 Results of Calculations for Phase-1

(IN MW/MVAR)

	FROM GENERATION SYNCHRN	/ INDUCTN	TO INDUCTN MOTORS	TO LOAD	TO BUS SHUNT	TO BUS GNE DEVICES	TO LINE SHUNT	FROM CHARGING	LOSSES
With Project	2278.3	0.0	0.0	2239.1	0.0	0.0	0.0	0.0	39.2
	277.9	0.0	0.0	1051.8	-695.8	0.0	0.0	629.8	551.8
Without Project	2283.7	0.0	0.0	2239.1	0.0	0.0	0.0	0.0	44.6 (+5.4 MW)
	505.2	0.0	0.0	1045.1	-682.2	0.0	0.0	502.3	644.6

(Prepared by the Survey Team)

As shown in the above table, compared with the result of "with the project" case, active power loss of "without the project" case increased by 5.4 MW.

5.2.3 Calculations for 2020 Network (Phase-2)

(1) Conditions

1) Cases: with and without Phase-2 Package
"Without the project" means substation demands in 2020 are applied to the calculation, but the system configuration is same as the existing network in 2012.

2) Basic system configurations: 2020 network data provided by CEB

3) Electricity demand: day peak demand in 2020 provided by CEB
Electricity demands for grid substations in Colombo City for with/without the project are shown in Table 5.2-4. As for the calculation of "without the project", loads for new grid substations are assumed to be distributed to the existing grid substations considering the locations as follows:

- 100% load of Colombo K is to be distributed to Colombo A.
- Each 50% load of Colombo L is to be distributed to Colombo F and Colombo C.
- 100% load of Colombo M is to be distributed to Colombo E.
- Each 50% load of Colombo N is to be distributed to Colombo I and Colombo B.
- Each 50% load of Colombo P is to be distributed to Colombo I and Colombo B.

Table 5.2-4 Demand Forecast for Phase-2 Calculations

Grid Substations	2020 with Project MW	2020 with Project MVar	⇒	2020 without Project MW	2020 without Project MVar
Colombo A	58.22	23.01		69.66	27.53
Colombo B	48.45	30.03		78.35	42.76
Colombo C	28.14	17.44		70.64	43.78
Colombo E	59.51	35.31		96.92	57.51
Colombo F	52.55	29.78		95.05	56.12
Colombo I	45.26	19.28		75.16	32.02
Colombo K	11.44	4.52	A: 100%	-	-
Colombo L	85.00	52.68	F: 50%, C:50%	-	-
Colombo M	37.41	22.20	E: 100%	-	-
Colombo N	26.68	11.37	I: 50%, B: 50%	-	-
Colombo P	33.12	14.11	I: 50%, B: 50%	-	-
Kelenitissa	51.17	31.71		51.17	31.71
Kolonnawa	53.30	33.03		53.30	33.03
Total	590.24	324.46		590.24	324.46

(Prepared by the Survey Team based on CEB's forecast)

4) Over-loadings of main transformers and transmission lines for the calculation of "Without the Project" are to be ignored.

(2) Results

Figures 5.2-6 (1) and 5.2-6 (2) (attached at the end of this chapter) show the results of the calculations for with and without Phase-2 Project, respectively. As shown in Figure 5.2-6 (1), there is no serious problem in the load flow on the grid under normal operating conditions. Table 5.2-5 summarizes the results.

Table 5.2-5 Results of Calculations of Phase-2

(IN MW/MVAR)

	FROM GENERATION SYNCHRN	FROM GENERATION INDUCTN	TO INDUCTN MOTORS	TO LOAD	TO BUS SHUNT	TO BUS GNE DEVICES	TO LINE SHUNT	FROM CHARGING	LOSSES
With Project	3148.4	0.0	0.0	3073.9	0.0	0.0	0.0	0.0	74.5
	518.2	0.0	0.0	1433.1	-1104.4	0.0	0.0	819.4	1008.9
Without Project	3154.3	0.0	0.0	3074.0	0.0	0.0	0.0	0.0	80.3 (+5.8 MW)
	899.1	0.0	0.0	1433.2	-1077.4	0.0	0.0	672.7	1216.0

(Prepared by the Survey Team)

As shown in the above table, compared with the result of "with the project" case, active power loss of "without the project" case increased by 5.8 MW.

5.2.4 Loss Reduction Calculations

Based on the results of the power flow calculations shown in Tables 5.2-3 and 5.2-5, transmission loss reduction values are to be estimated with the following conditions:

1) Loss reduction values between 2016 and 2019 are to be determined based on

compounded annual growth rate (CAGR) calculated using the following formula:

CAGR ＝（Value of year-Y／Value of year-X）^{1／(Y－X)｝ － 1

Where: X = 2015 and Y = 2020

2) Annual loss savings are to be calculated using the following formula;

Annual loss savings = MW loss savings x 24 hours x 365 days x (0.3 x LF + 0.7 x LF^2)

Where: LF: Load Factor = 0.55

3) Annual loss savings after 2021 are assumed constant.

Table 5.2-6 shows the results of the loss reduction calculations.

Table 5.2-6 Loss Reduction Calculations for PJT-1

		unit	2015	2016	2017	2018	2019	2020
1) with Project	MW loss	MW	39.2	-	-	-	-	74.5
2) without Project	MW loss	MW	44.6	-	-	-	-	80.3
differentia 2) - 1)	MW loss saving	MW	5.4	5.5	5.6	5.6	5.7	5.8
Annual savings	MWh loss saving	MWh	17,821.8	18,078.3	18,338.5	18,602.5	18,870.3	19,141.9

(Prepared by the Survey Team)

5.3 Construction of Kappalthurai GS (PJT-2)

Table 5.3-1 shows the demand forecast for Trincomalee GS without the construction of Kappalthurai GS. A grid substation shall meet the demand taking into account a single unit outage condition without exceeding 120% loading on the other units. As shown in the forecast, loading of Trincomalee GS is expected to be 182% in 2015.

Table 5.3-1 Demand Forecast for Trincomalee GS

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Trincomalee	2×31.5	-	114.9	118.8	119.9	125.6	132.7	135.7	142.4	149.6	161.1	173.5	186.7

(Prepared by the Survey Team based on CEB's forecast)

To share the increasing needs of minimizing the MV distribution line losses, and to reduce loading of Trincomalee GS, it is proposed to construct a new GS in Kappalthurai, which will be installed with two sets of 63 MVA transformers and eight 33 kV feeders. Table 5.3-2 shows the demand forecast with the proposed new Kappalthurai GS.

Table 5.3-2 Demand Forecast for Trincomalee and Kappalthurai GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Trincomalee	2×31.5	-	27.2	29.3	29.9	32.7	36.2	37.6	41.1	45.1	47.4	48.4	49.3
Kappalthurai	-	3 x 63*	87.7	89.5	90.0	92.9	96.5	98.1	101.3	104.5	113.7	125.1	137.4

(Prepared by the Survey Team based on CEB's forecast)

Note *: Initial transformer capacity is 2 x 63 MVA, and 1 x 63 MVA transformer is to be added in 2023.

Based on the above demand forecast, the Survey Team calculated the loss reduction values on MV distribution lines and on transformers for comparison between “with” and “without” the project”.

(1) MV Line Losses

Table 5.3-3 shows the result of MV line loss calculations with the following conditions:

- MV line length: 10 km without the project, and 5 km with the project
- MV line conductor size: ACSR Goat
- Number of MV lines: single-circuit between Kappalthurai and Trincomalee GSs
- Calculation formula: as shown in Sub-section 5.1.2 (1)

Table 5.3-3 MV Line Loss Reduction by PJT-2

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (MV line 10 km)											
1) Annual MV line losses (MWh/year)	5,098.3	5,308.6	5,361.1	5,676.5	6,149.5	6,359.8	6,780.2	7,200.7	8,514.7	10,301.8	12,456.7
With project (MV line 5 km)											
2) Annual MV line losses (MWh/year)	2,522.9	2,628.0	2,680.6	2,838.2	3,048.5	3,153.6	3,363.8	3,626.6	4,257.4	5,150.9	6,254.6
Loss reduction (MWh/year) : 1) - 2)	2,575.4	2,680.6	2,680.6	2,838.2	3,101.0	3,206.2	3,416.4	3,574.1	4,257.4	5,150.9	6,202.1

(Prepared by the Survey Team)

(2) Transformer Losses

Table 5.3-4 shows the result of transformer loss calculations with the following conditions:

- Iron loss value of a typical transformer: 40.2 kW at 31.5 MVA base
  67.7 kW at 63.0 MVA base
- Copper loss value of a typical transformer: 157.0 kW at 31.5 MVA base
  270.0 kW at 63.0 MVA base
- Calculation formula: as shown in Sub-section 5.1.2 (2)

Table 5.3-4 Transformer Loss Reduction by PJT-2

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (Trincomalee)											
1) Iron loss (40.2 kW)	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1
2) Copper loss (157 kW@100%)	2,767.7	2,958.7	3,013.9	3,307.3	3,691.5	3,860.6	4,251.0	4,691.8	5,440.7	6,310.8	7,307.5
3) Total TR loss (MWh/year)	3,436.8	3,627.8	3,683.0	3,976.4	4,360.6	4,529.7	4,920.1	5,360.9	6,109.8	6,979.9	7,976.6
With Project (Trincomalee)											
4) Iron losses (40.2 kW)	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1
5) Copper loss (157 kW@100%)	155.1	180.0	187.4	224.1	274.7	296.4	354.1	426.4	471.0	491.2	509.5
6) Total TR loss (MWh/year)	824.2	849.1	856.5	893.2	943.8	965.4	1,023.2	1,095.5	1,140.1	1,160.2	1,178.6
(Kappalthurai)											
7) Iron loss (67.7 kW)	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,334.4	1,334.4	1,334.4
8) Copper loss (270 kW@100%)	693.2	721.9	730.1	777.9	839.4	867.5	925.0	984.4	776.8	940.4	1,134.4
9) Total loss (MWh/year)	1,820.0	1,848.7	1,856.9	1,904.7	1,966.2	1,994.3	2,051.8	2,111.2	2,111.2	2,274.7	2,468.8
Loss reduction (MWh/year) 3) – 6) – 9)	792.6	930.0	969.6	1,178.5	1,450.6	1,569.9	1,845.1	2,154.2	2,858.5	3,544.9	4,329.2

(Prepared by the Survey Team)

5.4 Construction of Kerawalapitiya GS (PJT-3)

Table 5.4-1 shows the demand forecast for Kotugoda GS without construction of Kerawalapitiya GS. As shown in the forecast, the loading of Kotugoda GS is expected to be 103% in 2021.

Table 5.4-1 Demand Forecast for Kotugoda GS

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Kotugoda	183*	-	123.6	133.4	140.2	153.3	166.5	175.2	188.0	201.0	201.1	217.4	234.1

(Prepared by the Survey Team based on CEB's forecast)

Note *: Initial transformer capacity is 2 x 60 MVA and 2 x 31.5 MVA.

To share the increasing needs of minimizing the MV distribution line losses and to reduce loading of Kotugoda GS, it is proposed to construct a new GS in Kerawalapitiya, which will be installed with two sets of 35 MVA transformers and eight 33 kV feeders. Table 5.4-2 shows the demand forecast with the proposed Kerawalapitiya GS.

Table 5.4-2 Demand Forecast for Kotugoda and Kerawalapitiya GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Kotugoda	183	-	94.1	102.9	109.2	121.3	133.5	141.8	130.8	143.0	141.7	156.3	171.6
Kerawalapitiya	-	3 x 35	29.5	30.5	31.0	32.0	33.0	33.4	57.2	58.0	59.4	61.1	62.5

(Prepared by the Survey Team based on CEB's forecast)

Based on the above forecast, the Survey Team calculated the loss reduction values on MV lines, on transformers, and by static capacitors for comparison between "with" and "without" the project.

(1) MV Line Losses

Table 5.4-3 shows the result of MV line loss calculations with the following conditions:

- MV line length: 10 km without the project, and 5 km with the project
- MV line conductor size: ACSR Lynx
- Number of MV lines: double-circuit between Kerawalapitiya and Kotugoda GSs
- Calculation formula: as shown in Sub-section 5.1.2 (1)

Table 5.4-3 MV Line Loss Reduction by PJT-3

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (MV line 10 km)											
1) Annual MV line losses (MWh/year)	2,155.0	2,260.1	2,365.2	2,522.9	2,680.6	2,733.1	8,041.7	8,251.9	8,672.4	9,198.0	9,618.5
With project (MV line 5 km)											
2) Annual MV line losses (MWh/year)	1,051.2	1,156.3	1,156.3	1,261.4	1,314.0	1,366.6	3,994.6	4,152.2	4,309.9	4,572.7	4,783.0
Loss reduction (MWh/year) : 1) - 2)	1,103.8	1,103.8	1,208.9	1,261.4	1,366.6	1,366.6	4,047.1	4,099.7	4,362.5	4,625.3	4,835.5

(Prepared by the Survey Team)

(2) Transformer Losses

Table 5.4-4 shows the result of transformer loss calculations with the following conditions:

- Iron loss value of a typical transformer: 40.2 kW at 31.5 MVA base
  45.0 kW at 35.0 MVA base
  67.7 kW at 60.0 MVA base
- Copper loss value of a typical transformer: 157.0 kW at 31.5 MVA base
  157.0 kW at 35.0 MVA base
  270.0 kW at 60.0 MVA base
- Calculation formula: as shown in Sub-section 5.1.2 (2)

Table 5.4-4 Transformer Loss Reduction by PJT-3

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (Kotugoda)											
1) Iron loss (40.2 & 67.7 kW)	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9
2) Copper loss (157 & 270 kW@100%)	1,032.3	1,202.7	1,328.2	1,588.1	1,873.2	2,074.3	2,388.3	2,730.3	2,732.8	3,193.9	3,703.1
3) Total TR loss (MWh/year)	2,828.2	2,998.5	3,124.1	3,383.9	3,669.1	3,870.2	4,184.1	4,526.2	4,528.7	4,989.8	5,499.0
With Project (Kotugoda)											
4) Iron losses (40.2 & 67.7 kW)	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9	1,795.9
5) Copper loss (157 & 270 kW@100%)	598.3	715.5	805.7	994.2	1,204.3	1,358.9	1,156.3	1,381.8	1,356.8	1,650.8	1,989.8
6) Total TR loss (MWh/year)	2,394.2	2,511.4	2,601.6	2,790.0	3,000.2	3,154.8	2,952.2	3,177.7	3,152.7	3,446.7	3,785.7
(Kerawalapitiya)											
7) Iron loss (45.0 kW)	749.0	749.0	749.0	749.0	749.0	749.0	749.0	749.0	749.0	749.0	749.0
8) Copper loss (157 kW@100%)	147.8	158.0	163.2	173.9	184.9	189.4	555.5	571.3	599.2	634.0	663.4
9) Total loss (MWh/year)	896.7	906.9	912.2	922.8	933.9	938.4	1,304.5	1,320.3	1,348.2	1,383.0	1,412.4
Loss reduction (MWh/year): 3) – 6) – 9)	-462.8	-419.8	-389.8	-328.9	-265.0	-222.9	-72.5	28.3	27.8	160.1	300.9

(Prepared by the Survey Team)

(3) Loss Reduction by Static Capacitors

Table 5.4-5 shows the result of loss reduction calculations by static capacitors with the following conditions:

- Capacity : 4 sets x 5 MVar
- MVar switching value: 1 MVar step
- Calculation formula: as shown in Sub-section 5.1.2 (3)

Table 5.4-5 Loss Reduction by Static Capacitors

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1) Active power (MW)	26.7	27.6	28.0	28.9	29.8	30.2	51.7	52.4	53.7	55.2	56.5
2) Reactive power forecast (MVar)	12.6	13.0	13.2	13.7	14.1	14.3	24.4	24.8	25.4	26.1	26.7
3) Apparent power (MVA)	29.5	30.5	31.0	32.0	33.0	33.4	57.2	58.0	59.4	61.1	62.5
4) Power factor	0.904	0.905	0.905	0.904	0.904	0.904	0.904	0.904	0.904	0.904	0.904
5) SC (5 MVar x 4 @ 1MVar Step)	12.0	13.0	13.0	13.0	14.0	14.0	20.0	20.0	20.0	20.0	20.0
6) Improved reactive power (MVar) = 2) - 5)	0.6	0.0	0.2	0.7	0.1	0.3	4.4	4.8	5.4	6.1	6.7
7) Improved apparent power (MVA)	26.7	27.6	28.0	28.9	29.8	30.2	51.9	52.6	54.0	55.5	56.9
8) Improved power factor	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.996	0.995	0.994	0.993
Loss reduction (MW/year)	542.5	559.8	569.4	596.2	614.0	623.4	983.1	995.3	1,000.3	1,005.2	1,007.4

(Prepared by the Survey Team)

5.5 Veyangoda – Kirindiwela – Padukka 220 kV TL (PJT-5)

5.5.1 Power Flow Calculations for 2015 Network

(1) Conditions

1) Scope of the project: as described in Section 3.2.5.
2) Basic system configurations: 2015 network data provided by CEB
3) Electricity demand: night peak demand in 2015 provided by CEB
4) Cases: with and without the project
"Without the project" means substation demands in 2015 are to be applied for the calculation, but the system configuration is same as the existing network in 2012.

(2) Results

Figures 5.5-1 (1) and 5.5-1 (2) (attached at the end of this chapter) show the results of the calculations for with/without cases, respectively. As shown in Figure 5.5-1 (1), there is no serious problem in the load flow on the grid under normal operating conditions. Table 5.5-1 summarizes the results.

Table 5.5-1 Results of Calculations for PJT-5 in 2015

	FROM GENERATION SYNCHRN	FROM GENERATION INDUCTN	TO INDUCTN MOTORS	TO LOAD	TO BUS SHUNT	TO BUS GNE DEVICES	TO LINE SHUNT	FROM CHARGING	LOSSES (IN MW/MVAR)
With Project	3106.7	0.0	0.0	3039.1	0.0	0.0	0.0	0.0	67.6
	410.7	0.0	0.0	1321.2	-998.1	0.0	0.0	599.4	687.1
Without Project	3108.4	0.0	0.0	3039.1	0.0	0.0	0.0	0.0	69.3 (+1.7 MW)
	431.2	0.0	0.0	1321.2	-996.2	0.0	0.0	587.9	694.0

(Prepared by the Survey Team)

As shown in the above table, compared with the result of "with the project" case, active power loss of "without the project" case increased by 1.7 MW.

5.5.2 Power Flow Calculations for 2020 Network

(1) Conditions

1) Basic system configurations: 2020 network data provided by CEB
2) Electricity demand: day peak demand in 2020 provided by CEB
3) Cases: with and without the project
"Without the project" means substation demands in 2020 are to be applied for the calculation, but the system configuration is same as the existing network in 2012.

(2) Results

Figures 5.5-2 (1) and 5.5-2 (2) (attached at the end of this chapter) show the results of the calculations for with/without cases, respectively. As shown in Figure 5.3-2 (1), there is no serious problem in the load flow on the grid under normal operating conditions. Table 5.5-2 summarizes the results.

Table 5.5-2 Results of Calculations for PJT-5 in 2020

	FROM GENERATION SYNCHRN	/ INDUCTN	TO INDUCTN MOTORS	TO LOAD	TO BUS SHUNT	TO BUS GNE DEVICES	TO LINE SHUNT	FROM CHARGING	LOSSES (IN MW/MVAR)
With Project	4266.5	0.0	0.0	4175.0	0.0	0.0	0.0	0.0	91.5
	1192.3	0.0	0.0	1808.7	-1120.6	0.0	0.0	739.8	1244.1
Without Project	4272.2	0.0	0.0	4175.0	0.0	0.0	0.0	0.0	97.2 (+5.7 MW)
	1217.3	0.0	0.0	1808.7	-1119.7	0.0	0.0	729.2	1257.6

(Prepared by the Survey Team)

As shown in the table above, compared with the result of "with the project" case, active power loss of "without the project" case increased by 5.7 MW.

5.3.3 Transmission Loss Reduction Calculations

Based on the results of the power flow calculations shown in Tables 5.5-1 and 5.5-2, transmission loss reduction values are estimated with the same conditions described Section 5.2.4. Table 5.5-3 shows the results of the loss reduction calculations for PJT-5.

Table 5.5-3 Loss Reduction Calculations for PJT-5

		unit	2015	2016	2017	2018	2019	2020
1) with Project	MW loss	MW	67.6	-	-	-	-	91.5
2) without Project	MW loss	MW	69.3	-	-	-	-	97.2
differentia 2) - 1)	MW loss saving	MW	1.7	2.2	2.8	3.5	4.5	5.7
Annual savings	MWh loss saving	MWh	5,610.6	7,146.5	9,102.8	11,594.8	14,768.9	18,811.9

(Prepared by the Survey Team)

5.5.4 Substation Loss Reduction Calculations

Table 5.5-4 shows the demand forecast for Biyagama GS and Kosgama GS without construction of Kirindiwela GS. As shown in the forecast, the loading of Kosgama GS is expected to be 101% in 2015, and Biyagama GS is expected to be 101% in 2021.

Table 5.5-4 Demand Forecast for Biyagama and Kosgama GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biyagama	2 x 60	-	92.4	96.8	98.4	104.6	111.7	114.8	121.1	125.6	142.7	145.8	149.0
Kosgama	2 x 31.5	1 x 31.5	64.1	66.6	67.2	70.9	75.3	77.4	81.4	88.0	101.2	107.6	114.1

(Prepared by the Survey Team based on CEB's forecast)

To share the increasing needs of minimizing the MV distribution line losses, and to reduce loading of Biyagama and Kosgama GS, it is proposed to construct a new GS at Kirindiwela, which will be installed with two sets of 31.5 MVA transformers and eight 33 kV feeders. Table 5.5-5 shows the demand forecast with the proposed new Kirindiwela GS.

Table 5.5-5 Demand Forecast for Biyagama, Kosgama, and Kirindiwela GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biyagama	2 x 60	-	74.6	78.2	79.0	84.3	90.6	92.8	98.2	99.3	108.5	110.7	113.0
Kosgama	2 x 31.5	1 x 31.5	46.3	48.0	47.8	50.6	54.2	55.4	58.5	61.7	67.0	72.5	78.1
Kirindiwela	-	3 x 31.5*	35.6	37.2	38.8	40.5	42.2	44.0	45.8	52.5	68.4	70.1	71.9

Note *: Initial transformer capacity is 2 x 31.5 MVA, and 1 x 31.5 MVA transformer is to be added in 2023.

(Prepared by the Survey Team based on CEB's forecast)

Based on the above demand forecast, the Survey Team calculated the loss reduction values on MV distribution lines, transformers, and static capacitors for comparison between "with" and "without" the project.

(1) MV Line Losses

Table 5.5-6 shows the result of MV line loss calculations with the following conditions:

- MV line length: 30 km (from Biyagama and Kosgama: each 15 km) without the project, and 15 km (7.5 km each) with the project
- MV line conductor size: ACSR Lynx
- Number of MV lines: single-circuit each
- Calculation formula: as shown in Sub-section 5.1.2 (1)

Table 5.5-6 MV Line Loss Reduction by PJT-5

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (MV line 30 km)											
1) Annual MV line 1 losses (MWh/year)	578.2	630.7	683.3	735.8	841.0	893.5	946.1	1,261.4	2,155.0	2,260.1	2,365.2
2) Annual MV line 2 losses (MWh/year)	578.2	630.7	683.3	735.8	841.0	893.5	946.1	1,261.4	2,155.0	2,260.1	2,365.2
3) Annual loss total (MWh/year) : 1) + 2)	1,156.3	1,261.4	1,366.6	1,471.7	1,681.9	1,787.0	1,892.2	2,522.9	4,309.9	4,520.2	4,730.4
With project (MV line 15 km)											
4) Annual MV line 1 losses (MWh/year)	315.4	315.4	367.9	367.9	420.5	420.5	473.0	630.7	1,051.2	1,156.3	1,208.9
5) Annual MV line 2 losses (MWh/year)	315.4	315.4	367.9	367.9	420.5	420.5	473.0	630.7	1,051.2	1,156.3	1,208.9
6) Annual loss total (MWh/year) : 4) + 5)	630.7	630.7	735.8	735.8	841.0	841.0	946.1	1,261.4	2,102.4	2,312.6	2,417.8
Loss reduction (MWh/year) : 3) -6)	525.6	630.7	630.7	735.8	841.0	946.1	946.1	1,261.4	2,207.5	2,207.5	2,312.6

(Prepared by the Survey Team)

(2) Transformer Losses

Table 5.5-7 shows the result of transformer loss calculations with the following conditions:

- Iron loss value of a typical transformer: 40.2 kW at 31.5 MVA base
  67.7 kW at 60.0 MVA base
- Copper loss value of a typical transformer: 157.0 kW at 31.5 MVA base
  270.0 kW at 60.0 MVA base

- Calculation formula: as shown in Sub-section 5.1.2 (2)

Table 5.5-7 Transformer Loss Reduction by PJT-5

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (Biyagama)											
1) Iron loss (67.7 kW)	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8
2) Copper loss (270 kW@100%)	848.4	931.2	962.2	1,086.3	1,239.8	1,309.7	1,457.4	1,566.5	2,023.6	2,111.0	2,204.8
3) Total TR loss (MWh/year)	1,975.2	2,058.0	2,089.0	2,213.1	2,366.6	2,436.5	2,584.2	2,693.3	3,150.4	3,237.8	3,331.6
(Kosgama)											
4) Iron loss (40.2 kW)	669.1	669.1	669.1	669.1	669.1	792.3	792.3	792.3	792.3	792.3	792.3
5) Copper loss (157 kW@100%)	861.4	929.8	946.8	1,052.3	1,188.6	837.2	926.1	1,081.1	1,431.4	1,616.6	1,818.0
6) Total TR loss (MWh/year)	1,530.5	1,598.9	1,615.9	1,721.4	1,857.7	1,629.5	1,718.4	1,873.5	2,223.7	2,409.0	2,610.3
With Project (Biyagama)											
7) Iron losses (67.7 kW)	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8	1,126.8
8) Copper loss (270 kW@100%)	553.1	607.7	620.1	706.2	815.7	855.7	958.2	979.8	1,169.9	1,217.7	1,269.0
9) Total TR loss (MWh/year)	1,679.9	1,734.5	1,746.9	1,833.0	1,942.5	1,982.5	2,085.0	2,106.6	2,296.7	2,344.5	2,395.8
(Kosgama)											
10) Iron loss (40.2 kW)	669.1	669.1	669.1	669.1	669.1	792.3	792.3	792.3	792.3	792.3	792.3
11) Copper loss (157 kW@100%)	449.4	483.0	479.0	536.8	615.8	428.9	478.2	532.0	627.4	734.6	852.6
12) Total loss (MWh/year)	1,118.5	1,152.1	1,148.0	1,205.9	1,284.9	1,221.2	1,270.6	1,324.4	1,419.7	1,527.0	1,644.9
(Kirindiwela)											
13) Iron loss (40.2 kW)	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	792.3	792.3	792.3
14) Copper loss (157 kW@100%)	265.7	290.1	315.6	343.9	373.3	405.9	439.8	577.8	653.9	686.8	722.4
15) Total loss (MWh/year)	934.8	959.2	984.7	1,013.0	1,042.4	1,074.9	1,108.9	1,246.9	1,446.2	1,479.1	1,514.8
Loss reduction (MWh/year) [3) + 6)] –[9) + 12) + 15)]	-227.4	-189.0	-174.9	-117.3	-45.5	-212.6	-161.8	-111.1	211.5	296.1	386.5

(Prepared by the Survey Team)

(3) Loss Reduction by Static Capacitors

Table 5.5-8 shows the result of loss reduction calculations by static capacitors with the following conditions:

- Capacity : 2 sets x 5 MVar
- MVar switching value: 1 MVar step
- Calculation formula: as shown in Sub-section 5.1.2 (3)

Table 5.5-8 Loss Reduction by Static Capacitors

Cases	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1) Active power (MW)	31.9	33.3	34.7	36.2	37.8	39.4	41.0	47.0	61.2	62.7	64.3
2) Reactive power forecast (MVar)	15.9	16.6	17.3	18.1	18.8	19.6	20.4	23.4	30.5	31.3	32.1
3) Apparent power (MVA)	35.6	37.2	38.8	40.5	42.2	44.0	45.8	52.5	68.4	70.1	71.9
4) Power factor	0.895	0.895	0.895	0.894	0.895	0.895	0.895	0.895	0.895	0.895	0.895
5) SC (5 MVar x 2 @ 1MVar Step)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
6) Improved reactive power (MVar) = 2) - 5)	5.9	6.6	7.3	8.1	8.8	9.6	10.4	13.4	20.5	21.3	22.1
7) Improved apparent power (MVA)	32.4	33.9	35.5	37.1	38.8	40.6	42.3	48.9	64.5	66.2	68.0
8) Improved power factor	0.983	0.981	0.979	0.976	0.974	0.972	0.969	0.962	0.948	0.947	0.946
Loss reduction (MW/yare)	572.7	568.1	562.4	558.8	544.6	536.2	527.6	494.0	420.6	414.8	407.6

(Prepared by the Survey Team)

5.6 Construction of Kalutara GS (PJT-7)

Table 5.6-1 shows the demand forecast for Panadura GS and Matugama GS without the construction of Kalutara GS. As shown in the forecast, the loading of Panadura GS is expected to be 80% in 2023, and Matugama GS is expected to be 83% in 2021.

Table 5.6-1 Demand Forecast for Panadura and Matugama GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Panadura	3×31.5	-	60.9	56.3	56.5	59.2	61.9	62.6	65.0	69.1	75.6	81.5	88.3
Matugama	2×31.5	-	64.0	72.3	65.7	69.0	72.8	74.5	78.0	80.4	83.9	88.0	92.0

(Prepared by the Survey Team based on CEB's forecast)

To share the increasing needs of minimizing the MV distribution line losses and to reduce loading of Panadura and Matugama GSs, it is proposed to construct a new GS in Kalutara, which will be installed with two sets of 31.5 MVA transformers and eight 33 kV feeders. Table 5.6-2 shows the demand forecast with the proposed new Kalutara GS.

Table 5.6-2 Demand Forecast for Panadura, Matugama, and Kalutara GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Panadura	3×31.5	-	60.9	50.2	50.2	52.7	55.3	55.8	58.1	60.5	64.8	69.1	73.7
Matugama	2×31.5	-	64.0	66.2	59.4	62.5	66.2	67.7	71.1	71.8	73.1	75.6	77.4
Kalutara	-	2 x 31.5	0.0	12.2	12.5	12.9	13.2	13.5	13.7	17.1	21.5	24.8	29.1

(Prepared by the Survey Team based on CEB's forecast)

Based on the above demand forecast, the Survey Team calculated the loss reduction values on MV lines and on transformers for comparison between "with" and "without" the project.

(1) MV Line Losses

Table 5.6-3 shows the result of MV line loss calculations with the following conditions:

- MV line length: 32 km (from Panadura: 12 km, from Matugama: 20 km) without the project, and 16 km (from Panadura: 6 km, from Matugama: 10 km) with the project
- MV line conductor size: ACSR Lynx
- Number of MV lines: single-circuit each
- Calculation formula: as shown in Sub-section 5.1.2 (1)

Table 5.6-3 MV Line Loss Reduction by PJT-7

Cases	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (MV line 32 km)										
1) Annual MV line 1 losses (MWh/year)	105.1	105.1	105.1	105.1	105.1	157.7	210.2	315.4	420.5	578.2
2) Annual MV line 2 losses (MWh/year)	420.5	420.5	420.5	473.0	473.0	473.0	788.4	1,208.9	1,629.4	2,260.1
3) Annual loss total (MWh/year) : 1) + 2)	525.6	525.6	525.6	578.2	578.2	630.7	998.6	1,524.2	2,049.8	2,838.2
With project (MV line 16 km)										
4) Annual MV line 1 losses (MWh/year)	52.6	52.6	52.6	52.6	52.6	52.6	105.1	157.7	210.2	315.4
5) Annual MV line 2 losses (MWh/year)	210.2	210.2	210.2	210.2	262.8	262.8	367.9	630.7	841.0	1,103.8
6) Annual loss total (MWh/year) : 4) + 5)	262.8	262.8	262.8	262.8	315.4	315.4	473.0	788.4	1,051.2	1,419.1
Loss reduction (MWh/year) : 3) -6)	262.8	262.8	262.8	315.4	262.8	315.4	525.6	735.8	998.6	1,419.1

(Prepared by the Survey Team)

(2) Transformer Losses

Table 5.6-4 shows the result of transformer loss calculations with the following conditions:

- Iron loss value of a typical transformer: 40.2 kW at 31.5 MVA base
- Copper loss value of a typical transformer: 157.0 kW at 31.5 MVA base
- Calculation formula: as shown in Sub-section 5.1.2 (2)

Table 5.6-4 Transformer Loss Reduction by PJT-7

Cases	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (Panadura)										
1) Iron loss (40.2 kW)	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3
2) Copper loss (157 kW@100%)	443.0	445.4	488.9	535.5	546.8	589.6	666.4	797.8	928.3	1,088.6
3) Total TR loss (MWh/year)	1,235.4	1,237.8	1,281.3	1,327.8	1,339.2	1,381.9	1,458.7	1,590.1	1,720.6	1,880.9
(Matugama)										
4) Iron loss (40.2 kW)	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3
5) Copper loss (157 kW@100%)	730.6	602.3	664.4	740.8	774.6	849.3	902.4	982.6	1,082.3	1,181.6
6) Total TR loss (MWh/year)	1,523.0	1,394.7	1,456.7	1,533.1	1,567.0	1,641.6	1,694.7	1,775.0	1,874.6	1,974.0
With Project (Panadura)										
7) Iron losses (40.2 kW)	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3
8) Copper loss (157 kW@100%)	352.2	352.2	388.2	427.4	435.2	471.8	511.5	586.8	667.3	759.2
9) Total TR loss (MWh/year)	1,144.5	1,144.5	1,180.5	1,219.8	1,227.5	1,264.1	1,303.9	1,379.2	1,459.6	1,551.5
(Matugama)										
10) Iron loss (40.2 kW)	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3
11) Copper loss (157 kW@100%)	612.4	493.2	546.0	612.4	640.6	706.6	720.5	746.7	798.8	837.2
12) Total loss (MWh/year)	1,404.8	1,285.5	1,338.3	1,404.8	1,432.9	1,498.9	1,512.9	1,539.1	1,591.1	1,629.5
(Kalutara)										
13) Iron loss (40.2 kW)	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1	669.1
14) Copper loss (157 kW@100%)	31.2	32.8	34.9	36.5	38.2	39.4	61.3	96.9	129.0	177.5
15) Total loss (MWh/year)	700.3	701.8	704.0	705.6	707.3	708.5	730.4	766.0	798.1	846.6
Loss reduction (MWh/year) [3) + 6)] – [9) + 12} + 15)]	-491.3	-499.4	-484.8	-469.2	-461.6	-447.9	-393.7	-319.2	-253.6	-172.8

(Prepared by the Survey Team)

As shown in the above results, although annual amounts of composite loss reduction values are negative from 2016 to 2021, these will increase from 2022.

5.7 Construction of Battaramulla GS (PJT-8)

Table 5.7-1 shows the demand forecast for Sri Jayawardhanepura GS without construction of Battaramulla GS. As shown in the demand forecast, the loading of Sri Jayawardhanepura GS is expected to be 101% in 2022.

Table 5.7-1 Demand Forecast for Sri Jayawardhanepura GS

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Sri Jayawar.	3×31.5	-	75.6	77.9	78.5	81.9	86.3	88.0	91.7	95.7	101.8	108.2	114.6

(Prepared by the Survey Team based on CEB's forecast)

To share the increasing needs of minimizing the MV distribution line losses and to reduce loading of Sri Jayawardhanepura GS, it is proposed to construct a new GS in Battaramulla, which will be installed with two sets of 45 MVA transformers and eight 33 kV feeders. Table 5.7-2 shows the demand forecast with the proposed new Battaramulla GS.

Table 5.7-2 Demand Forecast for Sri Jayawardhanepura and Battaramulla GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)										
	Present	Proposed	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Sri Jayawar.	3×31.5	-	75.6	77.9	51.5	53.9	57.1	57.5	60.0	62.6	67.4	72.3	77.3
Battaramulla	-	2 x 45	0.0	0.0	27.0	28.0	29.2	30.5	31.7	33.1	34.4	35.9	37.3

(Prepared by the Survey Team based on CEB's forecast)

Based on the above demand forecast, the Survey Team calculated the loss reduction values on MV lines and on transformers for comparison between "with" and "without" the project.

(1) MV Line Losses

Table 5.7-3 shows the result of MV line loss calculations with the following conditions:

- MV line length: 10 km without the project and 5 km with the project
- MV line conductor size: ACSR Lynx
- Number of MV lines: double-circuit between Battaramulla and Sri Jaya' GSs
- Calculation formula: as shown in Sub-section 5.1.2 (1)

Table 5.7-3 MV Line Loss Reduction by PJT-8

Cases	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (MV line 10 km)									
1) Annual MV line losses (MWh/year)	1,787.0	1,944.7	2,102.4	2,260.1	2,470.3	2,680.6	2,890.8	3,153.6	3,416.4
With project (MV line 5 km)									
2) Annual MV line losses (MWh/year)	893.5	946.1	1,051.2	1,156.3	1,208.9	1,366.6	1,471.7	1,576.8	1,734.5
Loss reduction (MWh/year) : 1) - 2)	893.5	998.6	1,051.2	1,103.8	1,261.4	1,314.0	1,419.1	1,576.8	1,681.9

(Prepared by the Survey Team)

(2) Transformer Losses

Table 5.7-4 shows the result of transformer loss calculations with the following conditions:

- Iron loss value of a typical transformer: 40.2 kW at 31.5 MVA base
  48.2 kW at 45 MVA base
- Copper loss value of a typical transformer: 157.0 kW at 31.5 MVA base
  189.0 kW at 45 MVA base
- Calculation formula: as shown in Sub-section 5.1.2 (2)

Table 5.7-4 Transformer Loss Reduction by PJT-8

Cases	2017	2018	2019	2020	2021	2022	2023	2024	2025
Without Project (Sri Jayawar.)									
1) Iron loss (40.2 kW)	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3
2) Copper loss (157 kW@100%)	861.3	937.5	1,040.8	1,082.3	1,175.3	1,280.0	1,448.2	1,636.3	1,835.5
3) Total TR loss (MWh/year)	1,653.6	1,729.9	1,833.2	1,874.6	1,967.7	2,072.3	2,240.6	2,428.6	2,627.9
With Project (Sri Jayawar.)									
4) Iron losses (40.2 kW)	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3	792.3
5) Copper loss (157 kW@100%)	370.7	406.1	455.6	462.1	503.1	547.6	634.9	730.6	835.1
6) Total TR loss (MWh/year)	1,163.1	1,198.4	1,248.0	1,254.5	1,295.4	1,340.0	1,427.2	1,523.0	1,627.5
(Battaramulla)									
7) Iron loss (48.2 kW)	802.2	802.2	802.2	802.2	802.2	802.2	802.2	802.2	802.2
8) Copper loss (189 kW@100%)	90.1	96.9	105.4	115.0	124.3	135.5	146.3	159.4	172.0
9) Total loss (MWh/year)	892.4	899.2	907.7	917.3	926.5	937.7	948.6	961.6	974.3
Loss reduction (MWh/year) 3) – 6) – 9)	-401.8	-367.7	-322.4	-297.2	-254.3	-205.4	-135.2	-55.9	26.1

(Prepared by the Survey Team)

5.8 Applicability of Japanese Technologies

(1) Gas-insulated Transformers

Conventional transformers with the latest technology such as 'top-runner transformers', which use amorphous cores, can be regarded as the recommended Japanese technology. However at present, such transformers with capacity of about 2 MVA scale can be produced in general. As far as application of Japanese technology for the conventional transformers is concerned, a special method cannot be identified for the substation facilities. However, Japanese-made transformers are generally recommended for being highly efficient, despite being more costly compared to others. This is attained not because of a special technique, but due to high quality management technique adopted such as the Total Quality Management (TQM). In this regard, the same performance can be attained in other industrial countries such as Europe and the United States of America (USA) in terms of production value, provided that detailed specifications prepared in advance are custom-made to meet manufacturers' requirements.

On the other hand, Japanese manufacturers are producing gas-insulated transformers

(GITs) that utilize the features of SF6 gas instead of insulation oil, and have coordinative ability with environmental conditions. GITs are regarded for having outstanding non-flammability characteristics, insulation effects, and safety features. Additionally, SF6 gas-insulated switchgear (GIS) incorporates the most advanced SF6 gas application technologies. Fully gas-insulated substations, adopting a combination of GITs and GIS, offer extra ease for safety assurance, accident prevention, and ease of inspection and maintenance. Concurrently, substations of this type are ideal for applications involving the needs for prevention of environmental pollution, or compactness of installation spaces.

Advantages of GITs are as follows:

1) Non-flammability
GITs using incombustible SF6 gas as insulation and cooling medium need not require installation of firefighting equipment in the transformer room.

2) Tank-explosion prevention
Pressure tank of GIT can withstand the pressure rise in case of internal fault.

3) Compactness
By directly coupling with GIS, substation area can be minimized.

4) Easy installation
Oil or liquid purifying process is not necessary.

5) Easy inspection and maintenance work
Only SF6 gas pressure shall be basically monitored during periodic inspection.

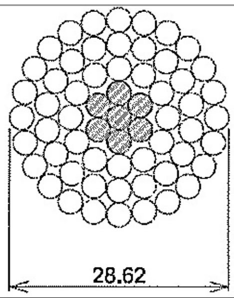
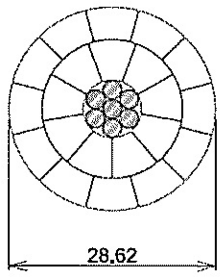
6) Environmental friendly
Use of SF6 gas eliminates the risk of oil leakage.

Port and Colombo L GSs are planned to be constructed very close to the sea under the Colombo City Transmission Development (PJT-1). Under such circumstances, it is preferred that main transformers be installed inside the substation building to prevent unpredictable accidents of transformers caused by exposure to salt. GITs can be installed inside the building as these have compact features.

(2) Low-loss Conductors

Japanese-made low-loss type conductors such as LL-ACSR/AC can be applied to both new construction and reconstruction of important overhead transmission lines. Low-loss type conductors have the same outer shape as normal ACSR conductors; however, their aluminum cross-section area can be larger by 20%–30% as shown in Table 5.8-1, if reducing electrical resistance is intended. These conductors contribute to transmission loss reduction especially on heavily loaded transmission lines.

Table 5.8-1 Specification of Conductors

items	units	ACSR Zebra	LL-ACSR/14AC 550 mm^2
Type	-	conventional ACSR	low loss type
Component of stranded wires	nos/mm	54/3.18-AL 7/3.18-St	12/TW-AL 9/TW-AL 7/2.70-14AC
Nominal diameter	mm	28.6	28.6
Cross sectional area	mm^2	Al: 428.9 St: 55.6 Total: 484.5	Al: 550.4 AC: 40.5 Total: 590.9
Nominal weight	kg/km	1,621	1,814
DC resistance at 20℃	Ω/km	0.0674	0.0519
Minimum breaking load	KN	131.9	140.9
Modulus of elasticity	GPa	78.4	69.1
Coefficient of linear expansion	/deg.C	19.5 x 10^{-6}	21.2 x 10^{-6}
Current carrying capacity (AC resistance)	A (Ω/km)	649 A (0.0854) at 75 deg.C	649 (0.0632) at 70 deg.C
Cross section	-		

(Prepared by the Survey Team)

As a case study, the Survey Team studied the situation where planned 220 kV Veyangoda – Kirindiwela (17.5 km) and Kirindiwela – Padukka (20.0 km) double-circuit transmission lines apply LL-ACSR conductors instead of ACSR Zebra, with the following assumptions:

1) Peak loads on the line in 2015 and 2020 are taken from the results of power flow calculations as shown in Figures 5.5-1 (1) and 5.5-2 (1), respectively. Loads in the other years are proportionately calculated from the obtained results.
2) Power factor: 0.85
3) Load factor: 0.55
4) Conductor resistances:
   - ACSR Zebra: 0.0814 Ω/km (at 63 ^{o}C)
   - LL-ACSR/14AC 550 mm^2: 0.0621 Ω/km (at 61 ^{o}C)
5) Formula for calculating annual loss:

Annual loss = NC x L x NCC x R x I^2 x (0.3 x LF + 0.7 x LF^2) x 24 hrs x 356 days

Where: NC: Nos. of conductors/circuit
L: Line length (km)
NCC: Nos. of circuit
R: Conductor resistance (Ω/km)
I: Load current (A)

LF: Load factor = 0.55

6) Annual loss savings after 2021 are assumed as constant.

7) Average generation cost applied for the study: 13.07 LKR/kWh (to be applied for economic analysis described in Chapter 10)

8) Conductor costs

   i) Unit prices:
      - ACSR Zebra: JPY 620,000/km
      - LL-ACSR/14AC 550 mm^2: JPY 870,000/km

   ii) Conductor costs: Veyangoda – Kirindiwela (17.5 km, 2-circuit, double-bundled)
      - ACSR Zebra: JPY 136.7 million (JPY 620,000 x 17.5 km x 12 nos. x 1.05)
      - LL-ACSR: JPY 191.8 million (JPY 870,000 x 17.5 km x 12 nos. x 1.05)
      - Cost gap: JPY 55.1 million

   iii) Conductor costs: Kirindiwela – Padukka (20.0 km, 2-circuit, double-bundled)
      - ACSR Zebra: JPY 156.2 million (JPY 620,000 x 20.0 km x 12 nos. x 1.05)
      - LL-ACSR: JPY 219.2 million (JPY 870,000 x 20.0 km x 12 nos. x 1.05)
      - Cost gap: JPY 63.0 million

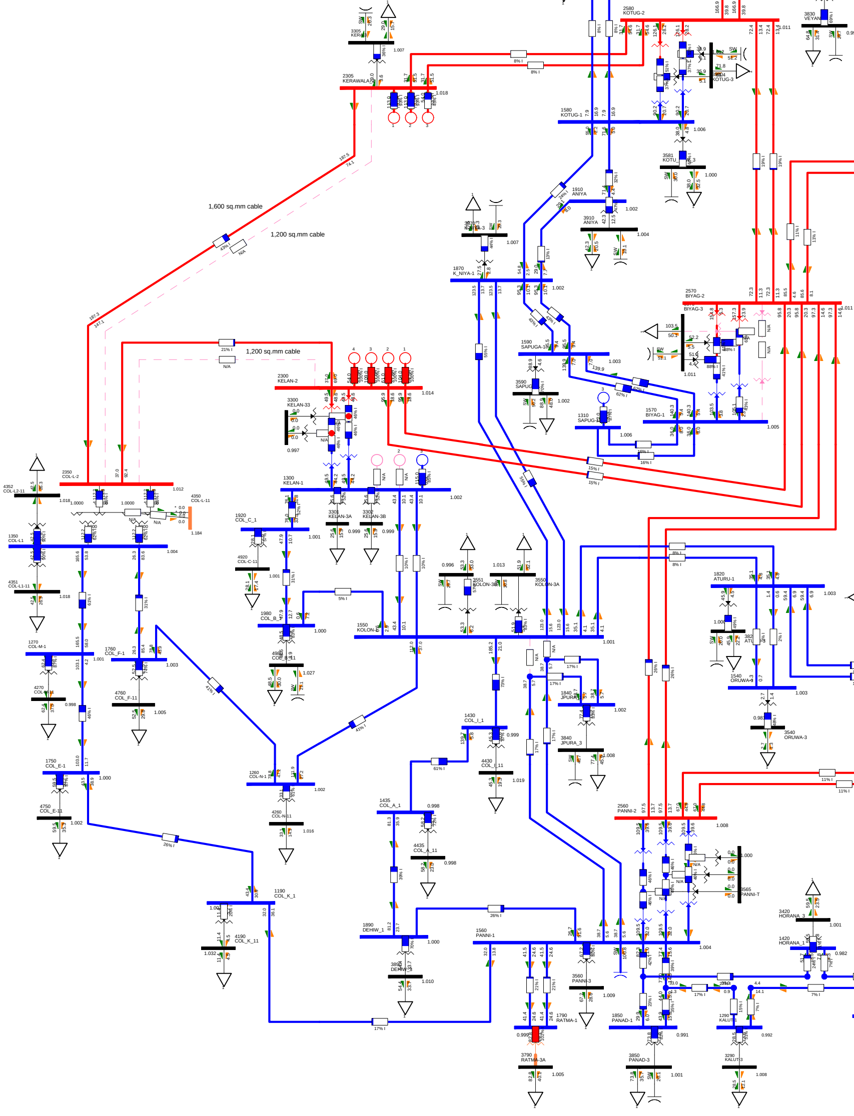
Table 5.8-2 shows the result of the case study.

Table 5.8-2 Result of Case Study

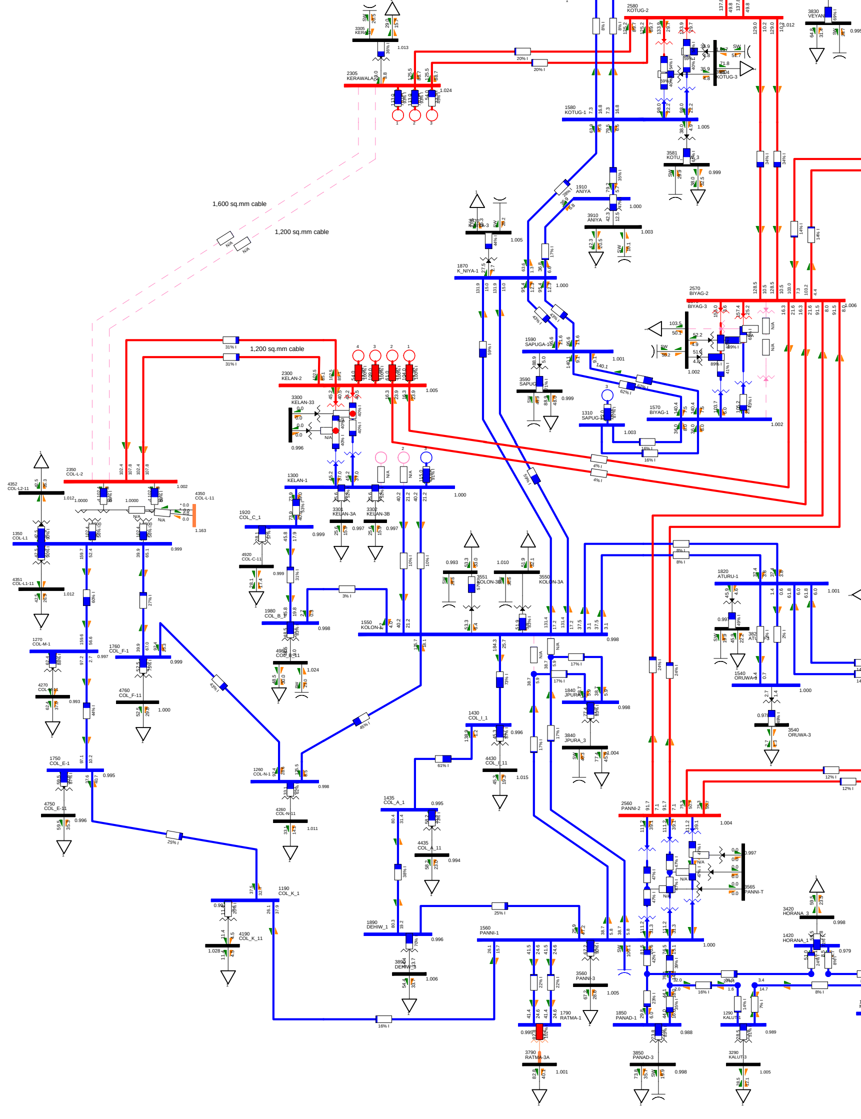
Items	unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1. Veyangoda-Kirindiwela Section												
Peak loads per cct	MW	57.8	67.7	79.3	92.9	108.8	127.5	127.5	127.5	127.5	127.5	127.5
Eq. current per cct	A	178.0	209.0	245.0	287.0	336.0	394.0	394.0	394.0	394.0	394.0	394.0
Annual Losses on Zebra (2 cct)	MWh	894.4	1,231.0	1,693.1	2,323.4	3,184.8	4,379.5	4,379.5	4,379.5	4,379.5	4,379.5	4,379.5
Annual Losses on LL-ACSR (2 cct)	MWh	683.2	940.6	1,290.4	1,772.3	2,429.0	3,339.9	3,339.9	3,339.9	3,339.9	3,339.9	3,339.9
Annual loss savings	MWh	211.2	290.4	402.6	551.2	755.8	1,039.6	1,039.6	1,039.6	1,039.6	1,039.6	1,039.6
Annual cost savings	kLKR	2,760.7	3,795.9	5,262.5	7,203.6	9,878.0	13,587.6	13,587.6	13,587.6	13,587.6	13,587.6	13,587.6
	eq.kJPY	1,634.3	2,247.2	3,115.4	4,264.5	5,847.8	8,043.9	8,043.9	8,043.9	8,043.9	8,043.9	8,043.9
Recoup the initial investment	kJPY	53,490.7	51,243.5	48,128.1	43,863.6	38,015.8	29,971.9	21,928.1	13,884.2	5,840.3	-2,203.6	-10,247.4
2. Kirindiwela - Padukka Section												
Peak loads per cct	MW	67.4	75.1	83.7	93.4	104.1	116.0	116.0	116.0	116.0	116.0	116.0
Eq. current per cct	A	208.0	232.0	259.0	288.0	321.0	358.0	358.0	358.0	358.0	358.0	358.0
Annual Losses on Zebra (2 cct)	MWh	1,396.0	1,736.0	2,161.7	2,673.3	3,323.4	4,132.0	4,132.0	4,132.0	4,132.0	4,132.0	4,132.0
Annual Losses on LL-ACSR (2 cct)	MWh	1,062.7	1,323.4	1,650.2	2,039.6	2,534.7	3,151.8	3,151.8	3,151.8	3,151.8	3,151.8	3,151.8
Annual loss savings	MWh	333.3	412.5	511.6	633.7	788.8	980.2	980.2	980.2	980.2	980.2	980.2
Annual cost savings	kLKR	4,356.7	5,391.9	6,686.0	8,282.0	10,309.3	12,811.2	12,811.2	12,811.2	12,811.2	12,811.2	12,811.2
	eq.kJPY	2,579.1	3,192.0	3,958.1	4,902.9	6,103.1	7,584.2	7,584.2	7,584.2	7,584.2	7,584.2	7,584.2
Recoup the initial investment	kJPY	60,420.9	57,228.8	53,270.7	48,367.8	42,264.7	34,680.5	27,096.2	19,512.0	11,927.8	4,343.6	-3,240.7

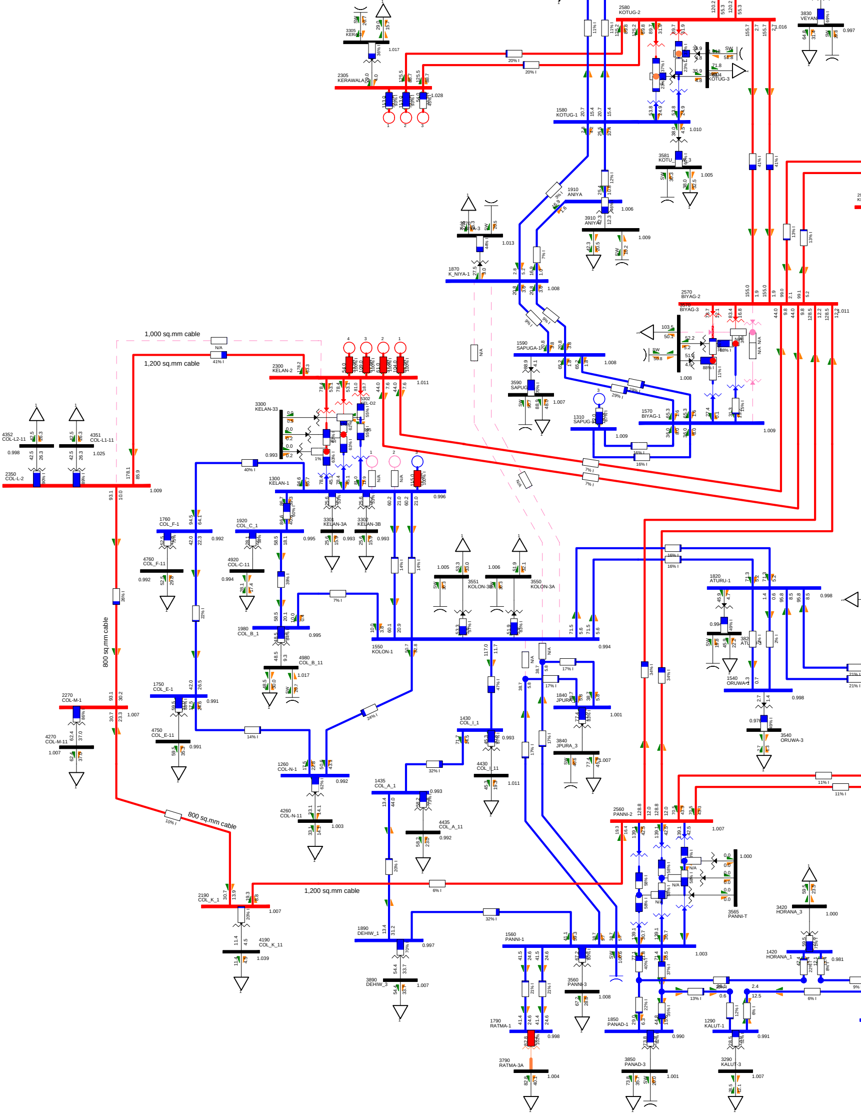
(Prepared by the Survey Team)

Although the initial cost of adopting LL-ACSR conductor is about 1.4 times that of ACSR Zebra, the initial investments for both sections can be recouped within ten years and 11 years, respectively, as shown in the above table. Therefore, it is recommended to introduce such low-loss conductors not only under the project but for planned transmission lines on which heavy loads were forecasted.

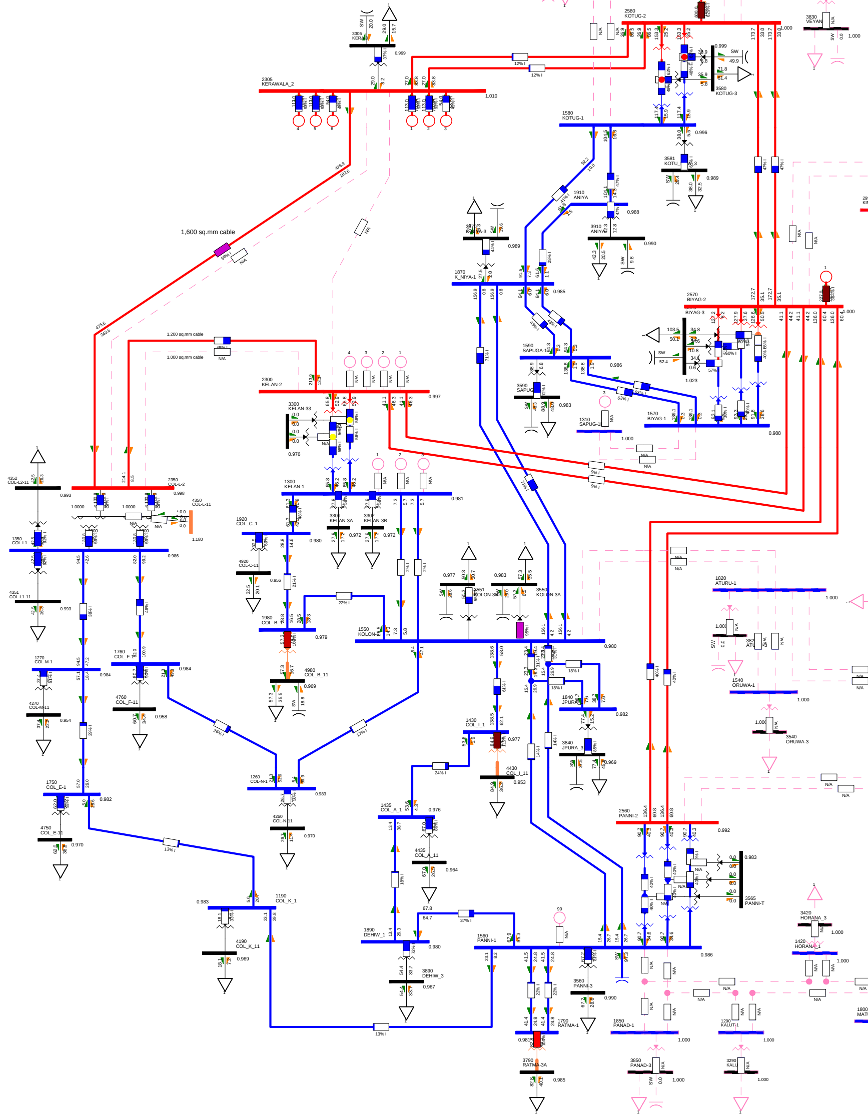


1,600 sq.mm cable
1,200 sq.mm cable
1,200 sq.mm cable
2305 KERAWALA
3305 KERA
2580 KOTUG-2
1580 KOTUG-1
3581 KOTU_3
1910 ANIYA
3910 ANIYA
1870 K_NIYA-1
3830 VEYAN
2570 BIYAG-2
BIYAG-3
1570 BIYAG-1
1590 SAPUGA-1
3590 SAPUG
1310 SAPUG-1
2300 KELAN-2
3300 KELAN-33
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
2350 COL-L-2
4352 COL-L2-11
4350 COL-L-11
1350 COL-L1
4351 COL-L1-11
1920 COL_C_1
4920 COL-C-11
1980 COL_B_1
1550 KOLON-1
3551 KOLON-3B
3550 KOLON-3A
1820 ATURU-1
1540 ORUWA-1
3540 ORUWA-3
1270 COL-M-1
4270 COL-M-11
1760 COL_F-1
4760 COL_F-11
1750 COL_E-1
4750 COL_E-11
1260 COL-N-1
4260 COL-N-11
1430 COL_I_1
4430 COL_I_11
1840 JPURA
3840 JPURA_3
1435 COL_A_1
4435 COL_A_11
1190 COL_K_1
4190 COL_K_11
1890 DEHIW_1
3890 DEHIW_3
1560 PANNI-1
2560 PANNI-2
3565 PANNI-T
3560 PANNI-3
1790 RATMA-1
3790 RATMA-3
1850 PANAD-1
3850 PANAD-3
1290 KALUT-1
3290 KALUT-3
3420 HORANA_3
1420 HORANA_1

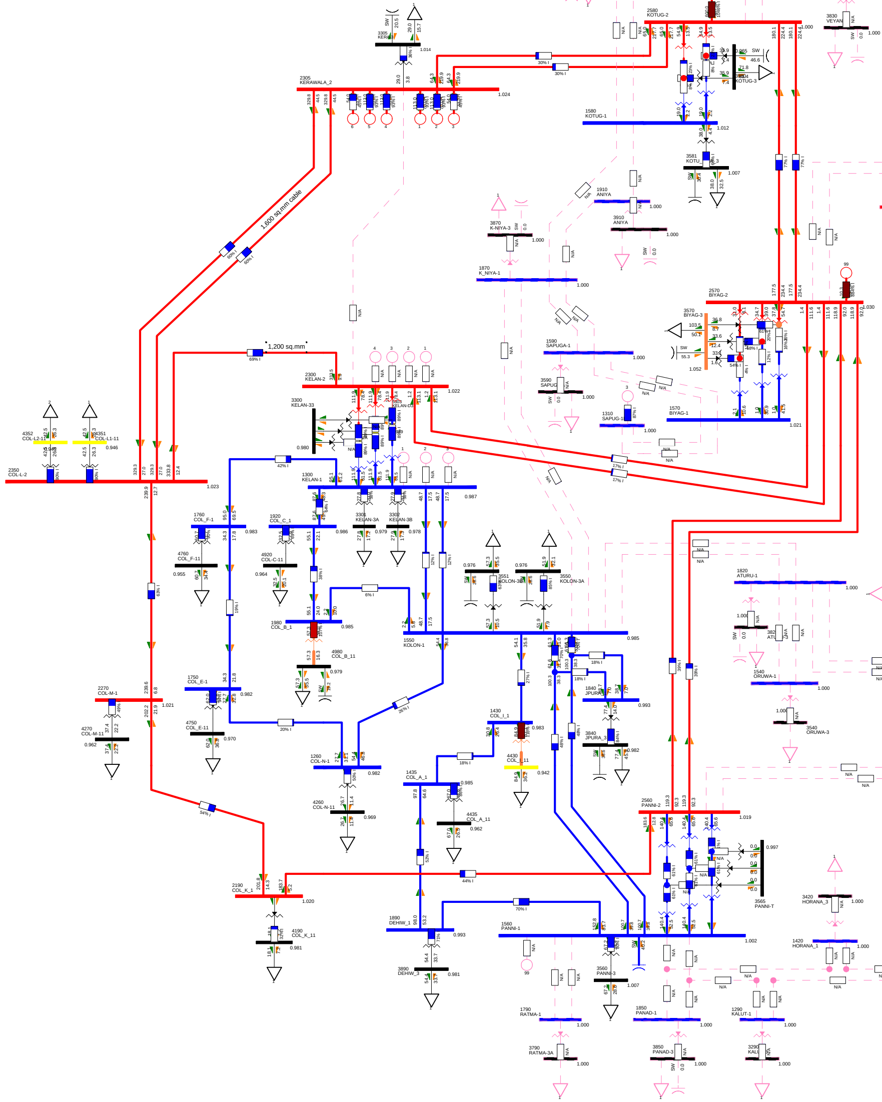

2580 KOTUG-2
3830 VEYAN
3305 KERAS
2305 KERAWALA-2
1580 KOTUG-1
3581 KOTU
3584 KOTUG-3
1910 ANIYA
3910 ANIYA
3870 K_NIYA-3
1870 K_NIYA-1
1,600 sq.mm cable
1,200 sq.mm cable
2570 BIYAG-2
BIYAG-3
1590 SAPUGA-1
3590 SAPUG
1310 SAPUG-1
1570 BIYAG-1
1,200 sq.mm cable
2300 KELAN-2
3300 KELAN-33
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
2350 COL-L-2
4352 COL-L2-11
4350 COL-L-11
1350 COL-L1
4351 COL-L1-11
1920 COL_C_1
4920 COL-C-11
1980 COL_B
4980 COL_B-11
1550 KOLON-1
3551 KOLON-3B
3550 KOLON-3A
1820 ATURU-1
1540 ORUWA-1
3540 ORUWA-3
1270 COL-M-1
4270 COL-M-11
1760 COL_F-1
4760 COL_F-11
1750 COL_E-1
4750 COL_E-11
1260 COL-N-1
4260 COL-N-11
1840 JPURA
3840 JPURA_3
1430 COL_I_1
4430 COL_I_11
1435 COL_A_1
4435 COL_A_11
2560 PANNI-2
3565 PANNI-T
1190 COL_K_1
4190 COL_K_11
1890 DEHIW_1
3890 DEHIW-3
1560 PANNI-1
3560 PANNI-3
1790 RATMA-1
3790 RATMA-3
1850 PANAD-1
3850 PANAD-3
1290 KALUT
3290 KALUT-3
3420 HORANA_3
1420 HORANA_1

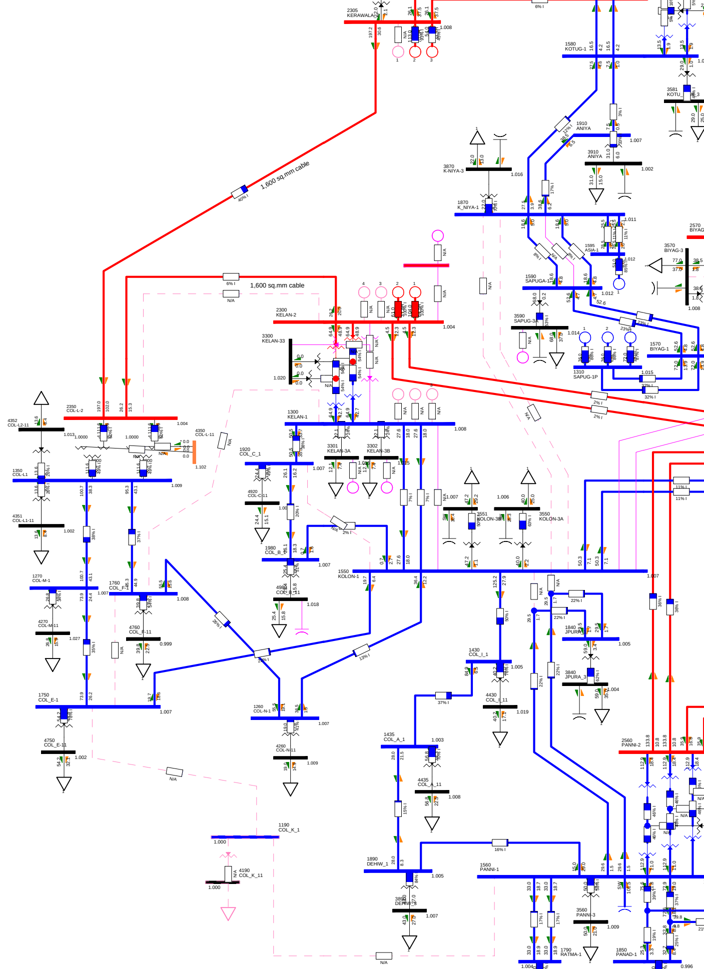


3305 KERAW
2305 KERAWALA-2
2580 KOTUG-2
3830 VEYAN
3580 KOTUG-3
1580 KOTUG-1
3581 KOTU_
1910 ANIYA
3910 ANIYA
1870 K_NIYA-1
2570 BIYAG-2
3570 BIYAG-3
1,000 sq.mm cable
1,200 sq.mm cable
2300 KELAN-2
1590 SAPUGA-1
3590 SAPUG
1310 SAPUG-1
1570 BIYAG-1
3300 KELAN-33
5302 KEL-D2
4352 COL-L2-11
4351 COL-L1-11
2350 COL-L-2
1300 KELAN-1
1760 COL_F-1
1920 COL_C_1
3301 KELAN-3A
3302 KELAN-3B
4760 COL_F-11
4920 COL-C-11
3551 KOLON-3B
3550 KOLON-3A
1820 ATURU-1
1980 COL_B_1
4980 COL_B_11
1550 KOLON-1
800 sq.mm cable
1750 COL_E-1
2270 COL-M-1
4270 COL-M-11
4750 COL_E-11
1840 JPURA
3840 JPURA_3
1540 ORUWA-1
3540 ORUWA-3
1430 COL_I_1
4430 COL_I_11
1260 COL-N-1
1435 COL_A_1
4260 COL-N-11
4435 COL_A_11
800 sq.mm cable
2560 PANNI-2
3565 PANNI-T
3420 HORANA_3
2190 COL_K_1
1,200 sq.mm cable
4190 COL_K_11
1890 DEHIW_1
1560 PANNI-1
1420 HORANA_1
3890 DEHIW_3
3560 PANNI-3
1790 RATMA-1
1850 PANAD-1
1290 KALUT-1
3790 RATMA-3A
3850 PANAD-3
3290 KALUT-3

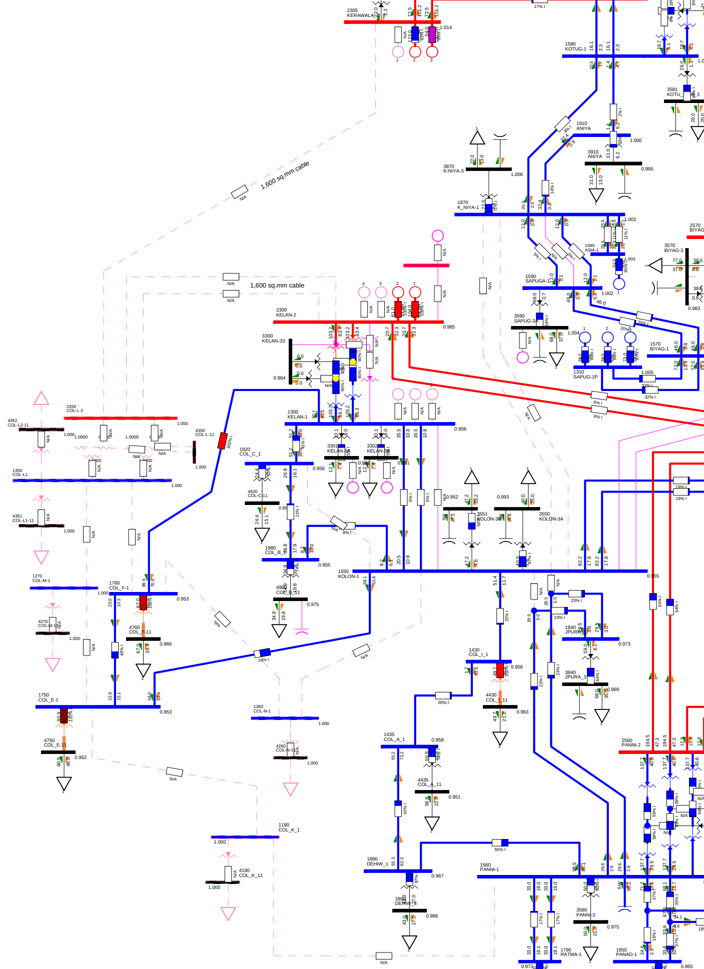


1,600 sq.mm cable
1,200 sq.mm cable
1,000 sq.mm cable
2580 KOTUG-2
3580 KOTUG-3
1580 KOTUG-1
3581 KOTU_3
3305 KERAW
2305 KERAWALA_2
3830 VEYAN
1910 ANIYA
3910 ANIYA
1870 K_NIYA-1
2570 BIYAG-2
BIYAG-3
1590 SAPUGA-1
3590 SAPUG
1310 SAPUG-1
1570 BIYAG-1
2300 KELAN-2
3300 KELAN-33
4352 COL-L2-11
2350 COL-L-2
4350 COL-L-11
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
1350 COL-L1
1920 COL_C_1
4920 COL-C-11
4351 COL-L1-11
1820 ATURU-1
1980 COL_B_1
4980 COL_B_11
1550 KOLON
3551 KOLON-3B
3550 KOLON-3A
1270 COL-M-1
1760 COL_F-1
4270 COL-M-11
4760 COL_F-11
1840 JPURA
3840 JPURA_3
1540 ORUWA-1
3540 ORUWA-3
1430 COL_I_1
4430 COL_I_11
1260 COL-N-1
4260 COL-N-11
1750 COL_E-1
4750 COL_E-11
1435 COL_A_1
4435 COL_A_11
2560 PANNI-2
3565 PANNI-T
1190 COL_K_1
4190 COL_K_11
3420 HORANA_3
1420 HORANA_1
1890 DEHIW_1
3890 DEHIW_3
1560 PANNI-1
3560 PANNI-3
1790 RATMA-1
1850 PANAD-1
1290 KALUT-1
1800 MATU
3790 RATMA-3A
3850 PANAD-3
3290 KALU

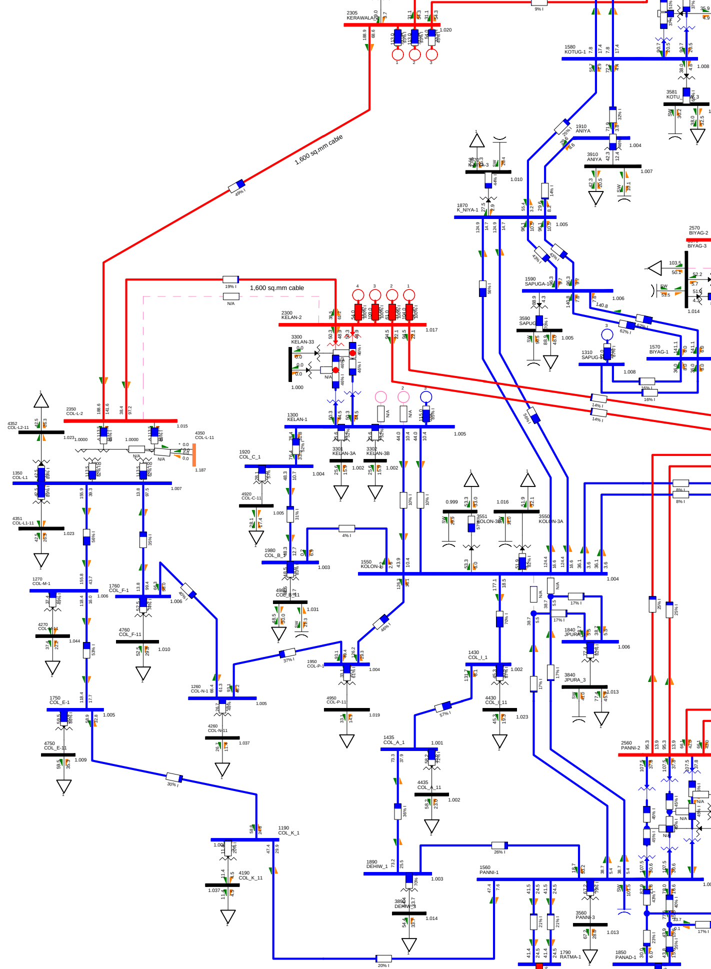

2580 KOTUG-2
3804 KOTUG-3
1580 KOTUG-1
2305 KERAWALA_2
1,600 sq.mm cable
1,200 sq.mm
1910 ANIYA
3910 ANIYA
3870 K-NIYA-3
1870 K_NIYA-1
2570 BIYAG-2
3570 BIYAG-3
1570 BIYAG-1
1590 SAPUGA-1
2300 KELAN-2
3300 KELAN-33
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
2350 COL-L-2
4352 COL-L2-11
4351 COL-L1-11
1760 COL_F-1
4760 COL_F-11
1920 COL_C_1
4920 COL-C-11
1980 COL_B_1
4980 COL_B_11
1550 KOLON-1
3551 KOLON-3B
3550 KOLON-3A
1820 ATURU-1
1540 ORUWA-1
3540 ORUWA-3
2270 COL-M-1
4270 COL-M-11
1750 COL_E-1
4750 COL_E-11
1260 COL-N-1
4260 COL-N-11
1430 COL_I_1
4430 COL_I_11
1435 COL_A_1
4435 COL_A_11
1840 JPURA
3840 JPURA_3
2560 PANNI-2
3565 PANNI-T
2190 COL_K_1
4190 COL_K_11
1890 DEHIW_1
3890 DEHIW_3
1560 PANNI-1
3560 PANNI-3
3420 HORANA_3
1420 HORANA_1
1790 RATMA-1
3790 RATMA-3A
1850 PANAD-1
3850 PANAD-3
1290 KALUT-1



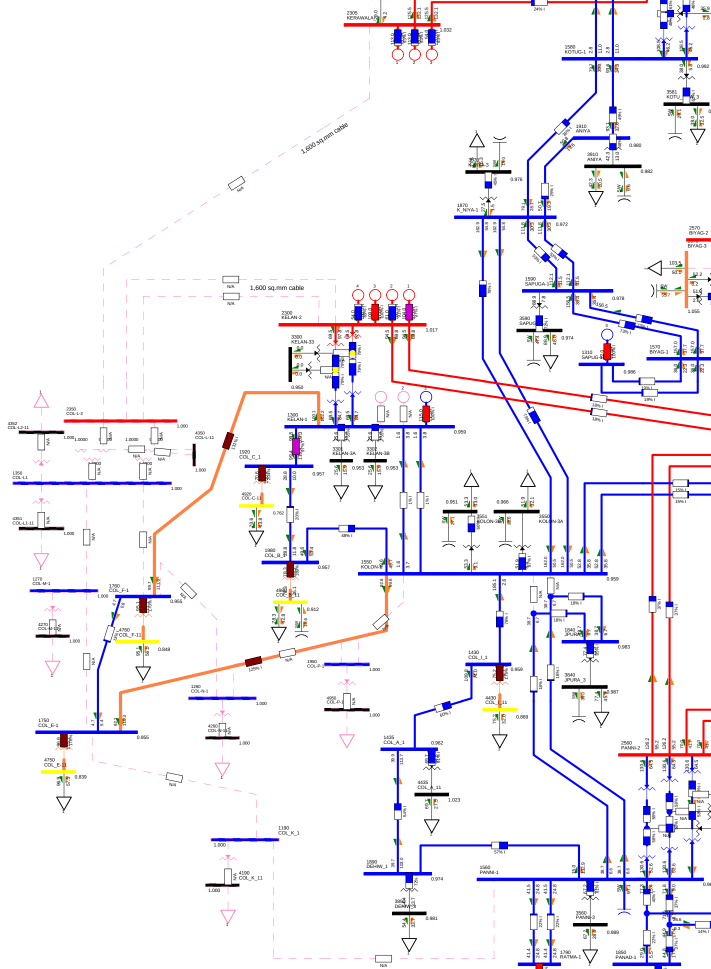
2305 KERAWALA
1,600 sq.mm cable
1,600 sq.mm cable
1580 KOTUG-1
3581 KOTU
1910 ANIYA
3910 ANIYA
3870 K-NIYA-3
1870 K_NIYA-1
1595 ASIA-1
2570 BIYAG
3570 BIYAG-3
1590 SAPUGA-1
3590 SAPUG-3A
1570 BIYAG-1
1310 SAPUG-1P
2300 KELAN-2
3300 KELAN-33
2350 COL-L-2
4352 COL-L2-11
4350 COL-L-11
1350 COL-L1
4351 COL-L1-11
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
1920 COL_C_1
4920 COL-C-11
1980 COL_B_1
4980 COL_B_11
3551 KOLON-3B
3550 KOLON-3A
1550 KOLON-1
1270 COL-M-1
4270 COL-M-11
1760 COL_F-1
4760 COL_F-11
1750 COL_E-1
4750 COL_E-11
1260 COL-N-1
4260 COL-N-11
1430 COL_I_1
4430 COL_I_11
1840 JPURA
3840 JPURA_3
2560 PANNI-2
1435 COL_A_1
4435 COL_A_11
1190 COL_K_1
4190 COL_K_11
1890 DEHIW_1
3890 DEHIW_3
1560 PANNI-1
3560 PANNI-3
1790 RATMA-1
1850 PANAD-1

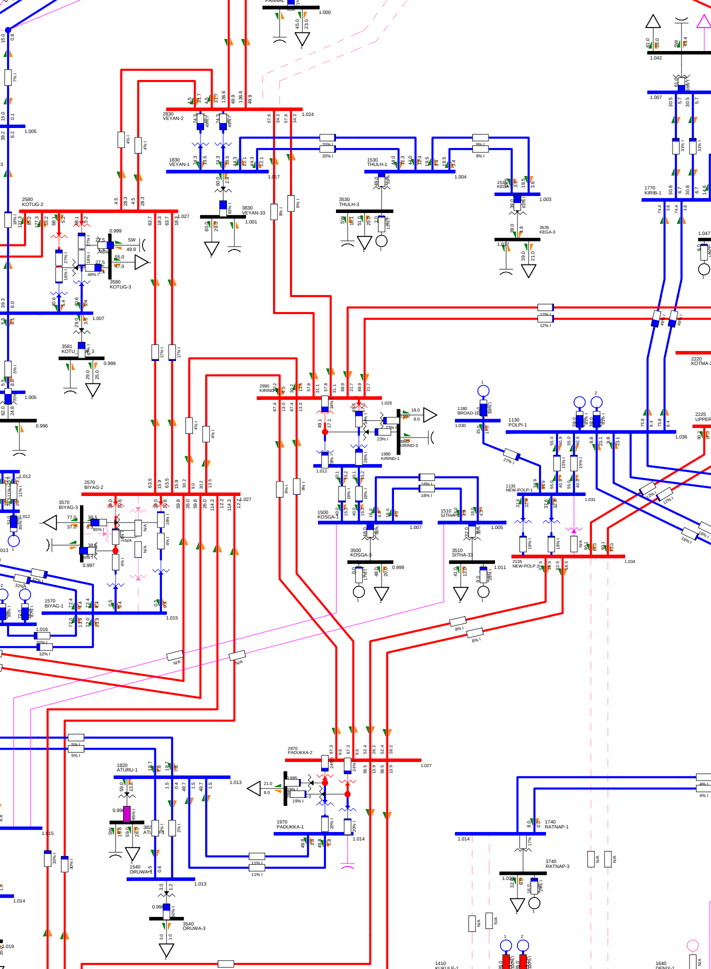


2305 KERAWALA
1580 KOTUG-1
3581 KOTU
1910 ANIYA
3910 ANIYA
3870 K-NIYA-3
1870 K_NIYA-1
1,600 sq.mm cable
1,600 sq.mm cable
2570 BIYAG
3570 BIYAG-3
1595 ASIA-1
1590 SAPUGA-1
3590 SAPUG-3
1570 BIYAG-1
1310 SAPUG-1P
2300 KELAN-2
3300 KELAN-33
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
2350 COL-L-2
4352 COL-L2-11
4350 COL-L-11
1350 COL-L1
4351 COL-L1-11
1920 COL_C_1
4920 COL-C-11
1980 COL_B_1
4980 COL_B_11
3551 KOLON-3B
3550 KOLON-3A
1550 KOLON-1
1270 COL-M-1
4270 COL-M-11
1760 COL_F-1
4760 COL_F-11
1750 COL_E-1
4750 COL_E-11
1260 COL-N-1
4260 COL-N-11
1840 JPURA
3840 JPURA_3
1430 COL_I_1
4430 COL_I_11
1435 COL_A_1
4435 COL_A_11
1190 COL_K_1
4190 COL_K_11
1890 DEHIW_1
3890 DEHIW_3
1560 PANNI-1
3560 PANNI-3
2560 PANNI-2
1790 RATMA-1
1850 PANAD-1

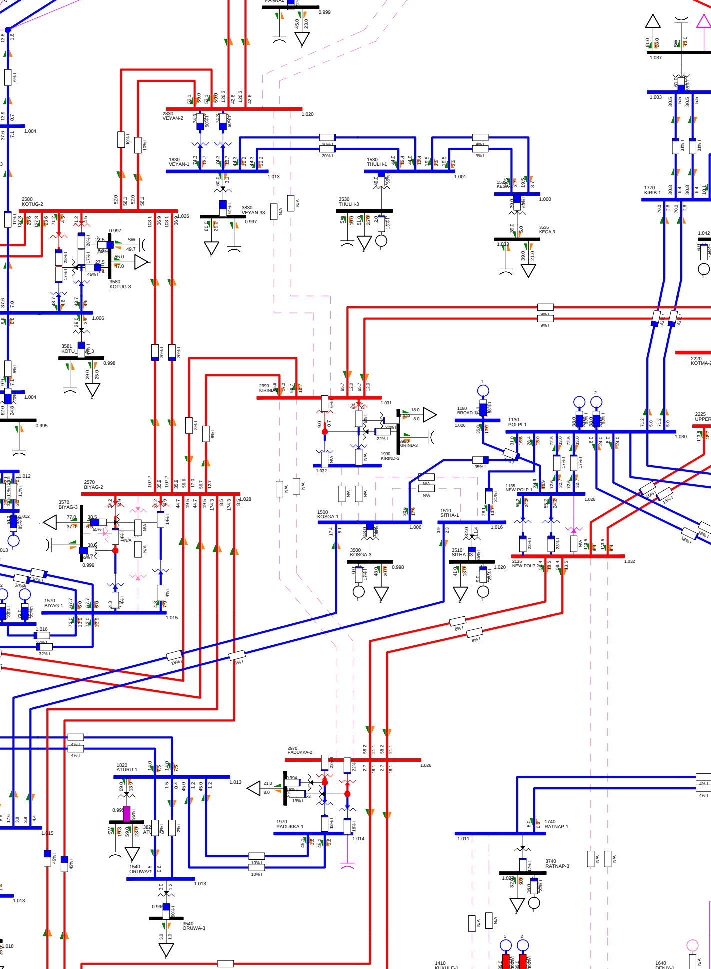


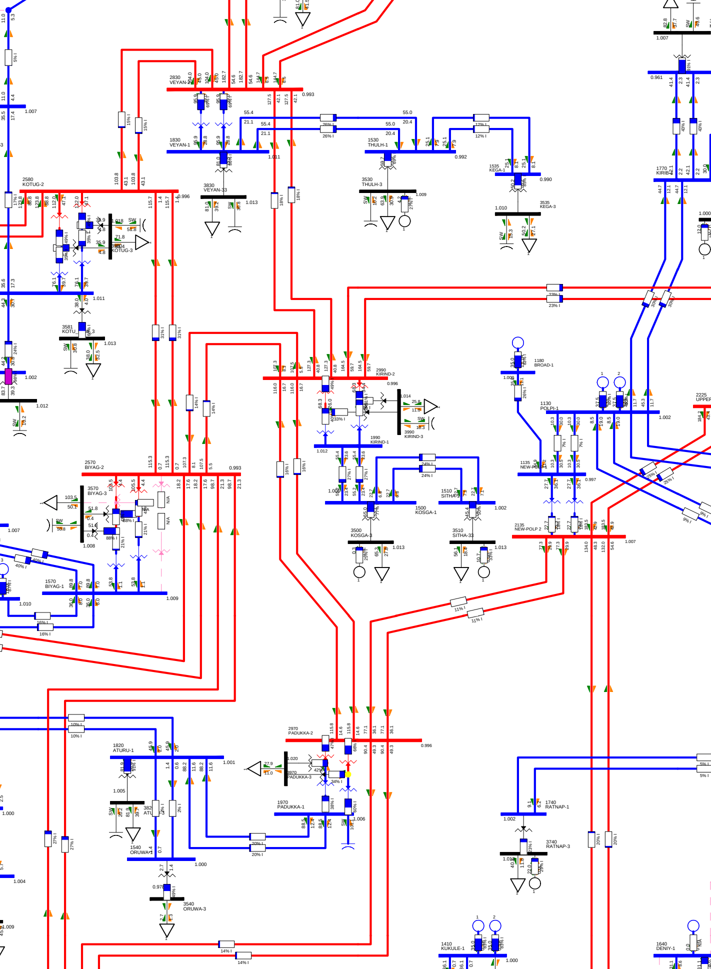
2305 KERAWALA
1,600 sq.mm cable
1,600 sq.mm cable
2300 KELAN-2
3300 KELAN-33
2350 COL-L-2
4352 COL-L2-11
4350 COL-L-11
1350 COL-L1
4351 COL-L1-11
1270 COL-M-1
4270 COL-M-11
1760 COL_F-1
4760 COL_F-11
1750 COL_E-1
4750 COL_E-11
1260 COL-N-1
4260 COL-N-11
1190 COL_K_1
4190 COL_K_11
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
1920 COL_C_1
4920 COL-C-11
1980 COL_B_1
4980 COL_B_11
1950 COL-P-1
4950 COL-P-11
1550 KOLON-2
3551 KOLON-3B
3550 KOLON-3A
1430 COL_I_1
4430 COL_I_11
1435 COL_A_1
4435 COL_A_11
1890 DEHIW_1
3890 DEHIW-3
1560 PANNI-1
3560 PANNI-3
2560 PANNI-2
1790 RATMA-1
1850 PANAD-1
1840 JPURA-1
3840 JPURA_3
1580 KOTUG-1
3581 KOTU
1910 ANIYA
3910 ANIYA
1870 K_NIYA-1
1590 SAPUGA-1
3590 SAPUG
1310 SAPUG
1570 BIYAG-1
2570 BIYAG-2
3570 BIYAG-3


2305 KERAWALA
1580 KOTUG-1
3581 KOTU
1910 ANIYA
3910 ANIYA
1870 K_NIYA-1
1,600 sq.mm cable
2570 BIYAG-2
BIYAG-3
1590 SAPUGA-1
3590 SAPUG
1310 SAPUG
1570 BIYAG-1
1,600 sq.mm cable
2300 KELAN-2
3300 KELAN-33
1300 KELAN-1
3301 KELAN-3A
3302 KELAN-3B
2350 COL-L-2
4352 COL-L2-11
4350 COL-L-11
1350 COL-L1
4351 COL-L1-11
1920 COL_C_1
4920 COL-C-11
1980 COL_B_1
4980 COL_B_11
3551 KOLON-3B
3550 KOLON-3A
1550 KOLON
1270 COL-M-1
4270 COL-M-11
1760 COL_F-1
4760 COL_F-11
1950 COL-P-1
4950 COL-P-11
1260 COL-N-1
4260 COL-N-11
1750 COL_E-1
4750 COL_E-11
1190 COL_K_1
4190 COL_K_11
1840 JPURA
3840 JPURA_3
1430 COL_I_1
4430 COL_I_11
1435 COL_A_1
4435 COL_A_11
2560 PANNI-2
1890 DEHIW_1
3890 DEHIW-3
1560 PANNI-1
3560 PANNI-3
1790 RATMA-1
1850 PANAD-1

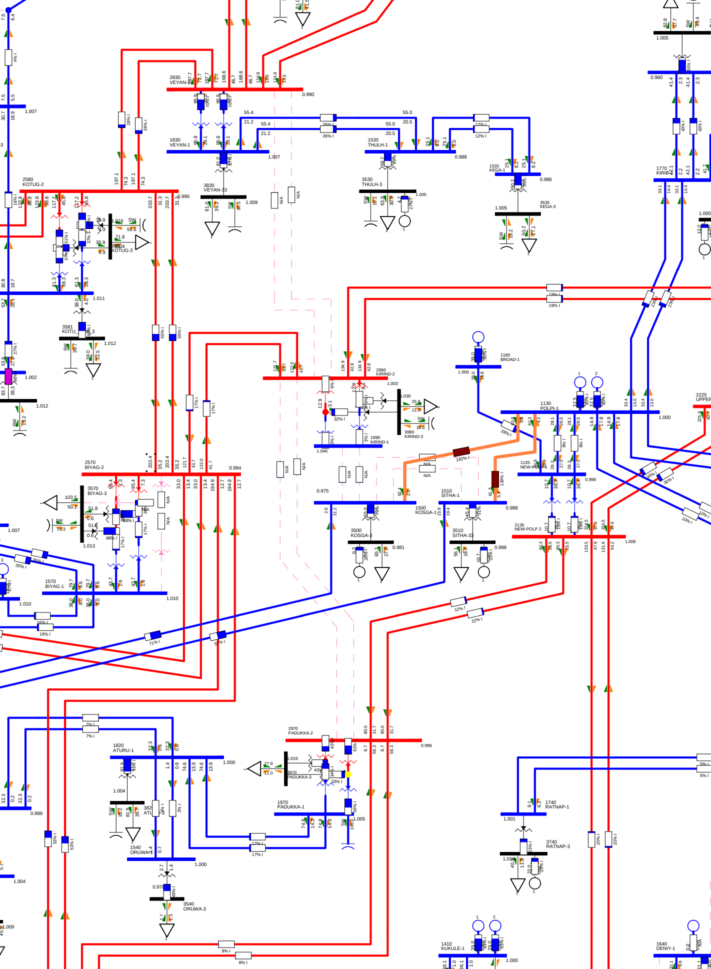


PANNAL
2830 VEYAN-2
1830 VEYAN-1
3830 VEYAN-33
1530 THULH-1
3530 THULH-3
3535 KEGA-3
1770 KIRIB-1
2580 KOTUG-2
3580 KOTUG-3
2990 KIRIND-2
1990 KIRIND-1
3990 KIRIND-3
1180 BROAD-1
1130 POLPI-1
2220 KOTMA-2
2225 UPPER
1135 NEW-POLP-1
2135 NEW-POLP 2
2570 BIYAG-2
3570 BIYAG-3
1570 BIYAG-1
1500 KOSGA-1
3500 KOSGA-3
1510 SITHA-1
3510 SITHA-33
2970 PADUKKA-2
1970 PADUKKA-1
1820 ATURU-1
1540 ORUWA-1
3540 ORUWA-3
1740 RATNAP-1
3740 RATNAP-3
1410 KUKULE-1
1640 DENIY-1


PANNAL
0.999
1.037
1.003
2830 VEYAN-2
1.020
1830 VEYAN-1
1.013
1530 THULH-1
1.001
1535 KEGA-1
1.000
3830 VEYAN-33
0.997
3530 THULH-3
3535 KEGA-3
1.033
1770 KIRIB-1
1.042
2580 KOTUG-2
1.026
3580 KOTUG-3
0.997
1.004
1.006
3581 KOTU
0.998
0.995
2990 KIRIND-2
1.031
1990 KIRIND-1
3990 KIRIND-3
1.032
1180 BROAD-1
1.026
1130 POLPI-1
1.030
2220 KOTMA-2
2225 UPPER
1.012
2570 BIYAG-2
1.028
3570 BIYAG-3
0.999
1570 BIYAG-1
1.015
1.016
1500 KOSGA-1
1.006
3500 KOSGA-3
0.998
1510 SITHA-1
1.016
3510 SITHA-33
1.020
1135 NEW-POLP-1
1.026
2135 NEW-POLP 2
1.032
2970 PADUKKA-2
1.026
1970 PADUKKA-1
1.014
1820 ATURU-1
1.013
1540 ORUWA-1
1.013
3540 ORUWA-3
1740 RATNAP-1
1.011
3740 RATNAP-3
1.023
1.018
1410 KUKULE-1
1640 DENIY-1



2830 VEYAN-2
1830 VEYAN-1
3830 VEYAN-33
1530 THULH-1
3530 THULH-3
1535 KEGA-1
3535 KEGA-3
1770 KIRIB
2580 KOTUG-2
3580 KOTUG-3
3581 KOTU
2990 KIRIND-2
1990 KIRIND-1
3990 KIRIND-3
1180 BROAD-1
1130 POLPI-1
1135 NEW-PO
2135 NEW-POLP 2
2225 UPPER
2570 BIYAG-2
3570 BIYAG-3
1570 BIYAG-1
1500 KOSGA-1
3500 KOSGA-3
1510 SITHA
3510 SITHA-33
2970 PADUKKA-2
3970 PADUKKA-3
1970 PADUKKA-1
1820 ATURU-1
1540 ORUWA-1
3540 ORUWA-3
1740 RATNAP-1
3740 RATNAP-3
1410 KUKULE-1
1640 DENIY-1


2830 VEYAN-2
1830 VEYAN-1
3830 VEYAN-33
1530 THULH-1
3530 THULH-3
1535 KEGA-1
3535 KEGA-3
2580 KOTUG-2
KOTUG-3
3581 KOTU_
2990 KIRIND-2
1990 KIRIND-1
3990 KIRIND-3
1180 BROAD-1
1130 POLPI-1
2225 UPPER
2135 NEW-POLP 2
1510 SITHA-1
3510 SITHA-33
1500 KOSGA-1
3500 KOSGA-3
2570 BIYAG-2
3570 BIYAG-3
1570 BIYAG-1
1820 ATURU-1
1540 ORUWA-1
3540 ORUWA-3
2970 PADUKKA-2
3970 PADUKKA-3
1970 PADUKKA-1
1740 RATNAP-1
3740 RATNAP-3
1410 KUKULE-1
1640 DENIY-1