Democratic Socialist Republic of Sri Lanka
Ceylon Electricity Board

Data Collection Survey on Transmission and Distribution Loss Reduction in Democratic Socialist Republic of Sri Lanka

FINAL REPORT

SEPTEMBER 2011

Japan International Cooperation Agency
(JICA)

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

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EXECUTIVE SUMMARY

1. Objective

The main objectives of this Survey are to:

1) collect and organize the latest information and data on transmission and distribution losses in Sri Lanka,

2) confirm the loss reduction program prepared by the CEB and shortlist the CEB's requested projects, which will contribute to transmission and distribution loss reduction, to be applied Japan's Loan Aid among the program, and

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

2. Candidate Projects

As a result of discussions with the CEB, the following projects are selected for the candidate projects for Japan's loan aid. The base costs shown in the table are estimated by the CEB.

Table -1 Candidate Projects for Japan's Loan Aid

no.	Projects	base costs (MLKR)
Transmission Projects		
1	New Habarana – Veyangoda 220 kV transmission Project	8,400.2
2	Reconstruction of Polpitiya – Habarana 132 kV TL	4,037.1
3	Grid Substation Construction and Augmentation Projects	
	A. Augmentation of Colombo-A GS	242.9
	B. Construction of Kalutara 132/33 kV GS	936.6
	C. Augmentation of Madampe GS	375.1
	D. Installation of reactive power compensation devices for 8 GSs	1,162.8
Distribution Projects		
1	Installation of LV Scheme	2,812.0
2	Single Phase to 3 Phase Conversion	1,750.0
3	Installation of Energy Meters	91,060.0
4	Construction of New PSs and 33 kV Distribution Line	975.0
5	Introducing the DAS for Central Province	1,146.0

(Source: CEB)

Outline of the transmission and distribution candidate projects are described in Chapters 3 and 4, respectively.

3. Amount of Loss Reduction by the Candidate Projects

The Survey Team reviewed the project costs and estimated the amount of loss reduction of each project and EIRR as shown in Table-2. The details are described in Chapters 6 and 7.

Table-2 Summary of Candidate Projects

Projects	Projects Costs		Loss Reduction	EIRR
Transmission Projects	MLKR	MJPY eq.*2	MWh/year	
1) New Habarana – Veyangoda 220 kV TL Project (142 km)*1	10,821.4	8,224.3	196,261.0	19.29%
2) Polpitiya – Habarana 132 kV TL Reconstruction Project (164 km)*1	6,968.2	5,295.8	36,792.0	10.92%
3) Substation Construction and Augmentation Project				32.10%
A. Augmentation of Colombo A 132/33 kV GS (+31.5 MVA Tr)	297.6	226.2	51.3	
B. Construction of Kalutara 132/33 kV GS (2x31.5 MVA)	1,227.0	932.5	12,113.8	
C. Augmentation of Madampe 132/33 kV GS (+31.5 MVA Tr)	503.0	382.3	537.2	
D. Installation of Reactive Power Compensation Devices (8 GS)	1,771.3	1,346.2	97,545.1	
Total Transmission Projects	21,588.5	16,407.3	343,300.4	-
Distribution Projects				
4) Distribution Project Package in NWP of Region 1	665.7	519.2	2,813.0	27.07%
5) Distribution Project Package in WPN of Region 2	707.0	537.3	2,732.0	16.70%
6) Distribution Project Package in CP of Region 2	3,254.0	2,473.0	8,029.0	10.46%
7) Distribution Project Package in WPS-2 of Region 3	758.0	576.1	3,101.0	21.04%
8) Distribution Project Package in SP of Region 3	858.0	652.1	3,451.0	10.22%
9) Distribution Project Package in WPS-1 of Region 4	432.0	328.3	920.0	21.50%
Total Distribution Projects	6,674.7	5,086.0	21,046.0	-
Grand Total	28,263.2	21,493.3	364,346.4	-

Note *1: with Japan's Technique, *2: LKR 1 = JPY 0.76

(Prepared by the Survey Team)

As shown in the above table, total project cost is estimated at 28,263.2 MSLR (21,493.3 MJPY equiv.) and total loss reduction amount is estimated at 364,346.4 MWh/year.

4. Environmental and Social Considerations

According to the National Environmental Act of Sri Lanka, an overhead transmission line project of length exceeding 10 km and voltage above 50 kV is being classified as prescribed one which is needed to take an EIA procedure and to prepare IEE/EIA report. Therefore, among the candidate projects, only two transmission line projects, New Habarana-Veyangoda and Polpitiya-Habarana, are the prescribed project and the other substation and distribution line projects are not.

The candidate projects are categorized in view of JICA Guideline as follows:

1) New Habarana-Veyangoda transmission line project is decided to mandate to prepare an IEE document where the potential adverse environmental impacts can be mitigated to an acceptable level by adequate implementation of the mitigation measures. Taking into full account of environmental judgments on the New Habarana - Veyangoda TL project, the project would be **Category B** under JICA environmental requirements as

the impacts would be relatively low level, largely confined in extent of site and would be few irreversible, and if any, effective mitigation measures can be designed and implemented to minimize adverse impacts.

2) It is readily difficult to categorize the Polpitiya-Habarana TL Reconstruction Project because the project is under planning and its scale and construction method are not fixed yet. However, since the past transmission line projects used to judged to prepare the IEE documents from the same reasons of the above item 1), the project will be applied to **Category B** under JICA environmental requirements.

3) All the other candidate projects are applied to **Category C** under JICA environmental requirements as they are being exempting from taking environmental procedure to prepare IEE or EIA document.

5. Economic Evaluation

Table-3 shows the result of EIRR calculation and sensitivity analysis in case of 30% increase in costs. The details of the economic evaluations are described in Chapter 7.

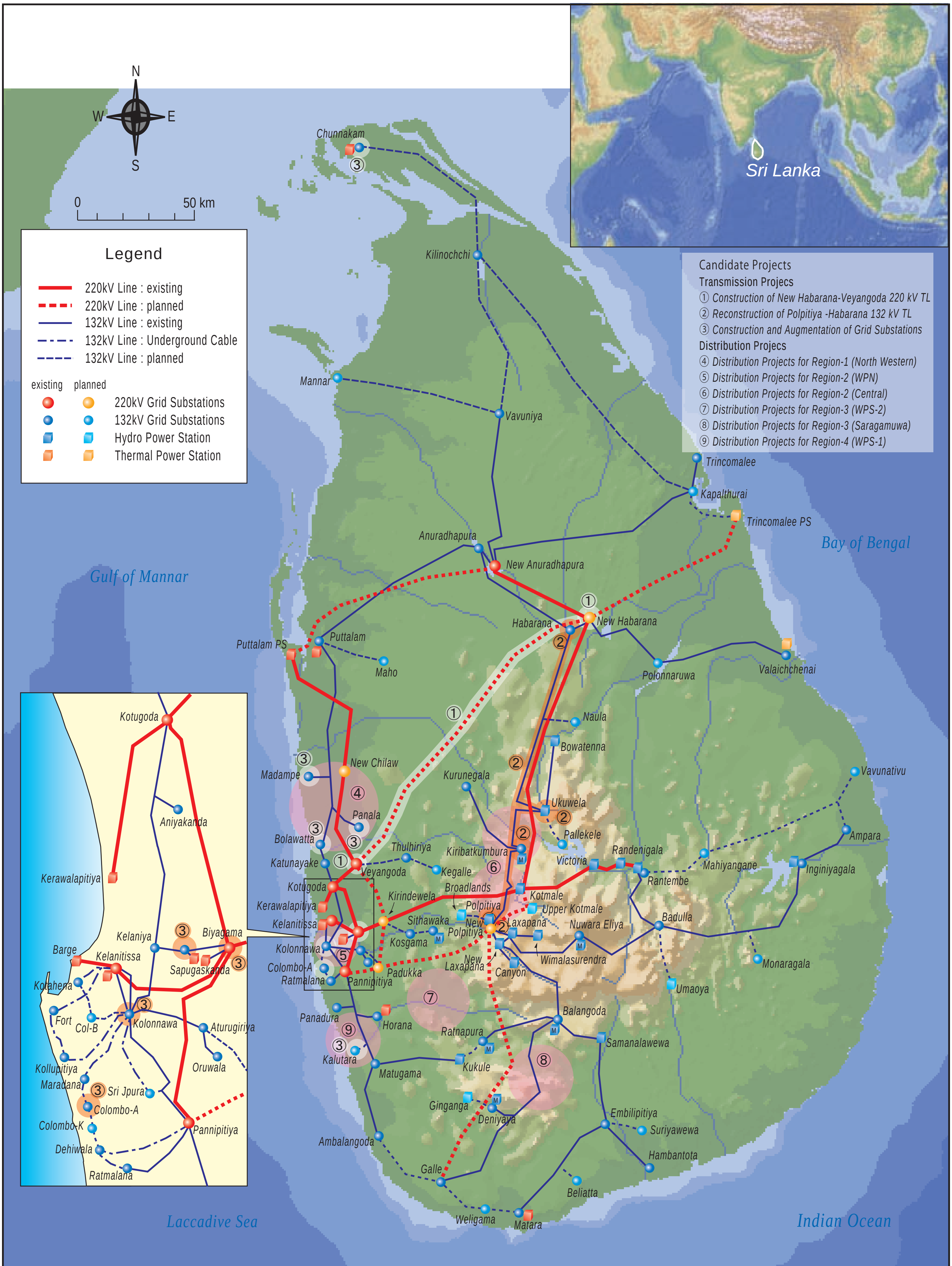
Table-3 EIRR under the Base and Pessimistic Conditions

Projects	EIRR base case	EIRR +30% cost
Candidate 1 New Habarana - Veyangoda TL Project (w/o. Japan's Tech.)	17.41%	14.36%
Candidate 1 New Habarana - Veyangoda TL Project (w. Japan's Tech.)	19.29%	16.14%
Candidate 2 Polpitiya - Habarana TL Reconstruction Project (w/o. Japan's Tech.)	9.90%	6.79%
Candidate 2 Polpitiya - Habarana TL Reconstruction Project (w. Japan's Tech.)	10.92%	8.23%
Candidate 3 Construction and Augmentation of Grid Substations	32.10%	26.09%
Candidate 4 Distribution Project Package in NWP of Region 1	27.07%	21.95%
Candidate 5 Distribution Project Package in WPN of Region 2	16.70%	12.98%
Candidate 6 Distribution Project Package in CP of Region 2	10.46%	7.46%
Candidate 7 Distribution Project Package WPS-2 of Region 3	21.04%	16.74%
Candidate 8 Distribution Project Package SP of Region 3	10.22%	7.24%
Candidate 9 Distribution Project Package WPS-1 of Region 4	21.50%	17.13%

(Prepared by the Survey Team)

Under the most pessimistic case with condition of 30% cost increase, the EIRR values are still enough ranging from 12.98% to 26.09% (excluding Candidates 2, 6 and 8). This means that these projects under study are economically sound. Candidates 2, 6 and 8 show a low EIRR as compared to the discount rate of 10%. This means that Candidates 2, 6 and 8 should be carefully considered in terms of cost savings and hedging against price escalation.

However, since economic benefits applied for the above evaluations are amounts of loss reduction and greenhouse gases reduction only, in case a project adoption, the project shall be re-evaluated considering the project’s particulars.



Project Location Map

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

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TABLES

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Abbreviations

ACSR	:	Aluminum Conductor Steel Reinforced
ADB	:	Asian Development Bank
AEA	:	Atomic Energy Authority
AFD	:	Agence Française de Développement (French Development Agency)
BSC	:	Breaker Switched Capacitors
CCEED	:	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	:	Distribution Control Center
DER	:	Department of External Resources
DL	:	Distribution Line
DT	:	Distribution Transformer
EDB	:	Export Development Bank (of Iran)
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EMP	:	Environmental Management Plan
EU	:	European Union
EXIM	:	Export and Import (Bank of China)
FC	:	Foreign Currency
FOB	:	Free on Board
GEF	:	Global Environment Facility
GIS	:	Gas Insulated Switchgear
GoSL	:	Government of Sri Lanka
GPRS	:	General Packet Radio Service
GS	:	Grid Substation
GT	:	Gas Turbine
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)
LC	:	Local Currency
LBS	:	Load Break Switch
LECO	:	Lanka Electricity Company Ltd.
LDC	:	Load Dispatching Center
LKR	:	Sri Lanka Rupee

LMRC	:	Long Run Marginal Cost
LV	:	Low Voltage (400 V in Sri Lanka)
MPE	:	Ministry of Power and Energy
MV	:	Medium Voltage (33 kV and 11 kV in Sri Lanka)
NEA	:	National Environmental Act
NPV	:	Net Present Value
O&M	:	Operation and Maintenance
ODA	:	Official Development Assistance
PAA	:	Project Approving Agency
PP	:	Project Proponent
PPA	:	Power Purchase Agreement
PS	:	Primary Substation
PUCSL	:	Public Utilities Commission of Sri Lanka
RTU	:	Remote Terminal Unit
SIA	:	Social Impact Assessment
SCADA	:	System Control and Data Acquisition
SFC	:	Standard Conversion Factor
SLSEA	:	Sri Lanka Sustainable Energy Authority
TA	:	Technical Assistance
TDE	:	Transmission Design and Environment
TEC	:	Technical Evaluation Committee
TL	:	Transmission Line
UNFCCC	:	United Nations Framework Convention on Climate Change
UNDP	:	United Nations Development Program
USD	:	United States Dollar
WB	:	World Bank

Exchange Rate

1 US dollar = 83.4 Japanese Yen

1 US dollar = 110 Sri Lankan Rupee

1 Sri Lankan Rupee = 0.76 Japanese Yen

CHAPTER 1 INTRODUCTION

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1.1 Background and Objective

The Japan International Cooperation Agency (JICA) has been continuously supporting the power sector of the Democratic Socialist Republic of Sri Lanka (Sri Lanka) considering its economic and social importance. Especially, since the efficiency of transmission and distribution facilities was considered to lead directly to the stabilization of electric power supply and economic development of Sri Lanka, JICA has been assisting transmission and distribution lines reinforcement projects through Japan's Loan Aid in and at the suburbs of Colombo City, and rural areas since the end of the 1990s.

However, as a result of advanced investments for the development of generating plants to meet the rapidly increasing electricity demand in Sri Lanka, transmission and distribution facilities have not been developed enough showing high rates of systems losses of about 14.59%. Of these, in 2009, distribution loss was at 11.02%, transmission loss was at 2.77% and generation loss was at 0.80%. Moreover, the systems are having problems of network weakness. Although long-term development plans for transmission lines (TLs) and medium voltage (MV) distribution lines have been prepared by the Ceylon Electricity Board (CEB), a development plan for low voltage (LV) lines has not been prepared yet.

Under such circumstances, JICA decided to conduct a data collection survey (the Survey) in order to collect and organize necessary information on transmission and distribution loss reduction and to confirm the requirements for Japan's Loan Aid assistance for the loss reduction program, considering the possibility to apply Japan's loss reduction techniques.

The main objectives of the Survey are as follows:

1) Collect and organize the latest information and data on transmission and distribution losses in Sri Lanka;

2) Confirm the loss reduction program prepared by the CEB and shortlist CEB's requested projects, which will contribute to transmission and distribution loss reduction, 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 requested projects.

1.2 Scope of the Survey

The scope of the Survey is as follows:

1) Confirmation of CEB's policies and countermeasures to be taken for loss reduction;
2) Confirmation of the current situation of transmission and distribution losses in Sri Lanka;
3) Confirmation of assistance to the power sector by other international donors;
4) Preparation of the shortlist of candidate projects for loss reduction to be applied for Japan's Loan Aid;
5) Site visit survey of candidate project sites;
6) Consideration of the environmental and social conditions of the candidate projects based on JICA's environmental guideline;
7) Consideration of the possibility to apply Japanese loss reduction technology to the candidate projects;
8) Preparation of the project summary including conceptual design, approximate cost estimate, environmental and social considerations, simple project evaluation, procurement and implementation plan, operations and maintenance (O&M) plan, etc.;
9) Preparation of several reports shown in Section 1.3; and
10) Explanation and discussion with JICA and Sri Lankan officials.

1.3 Survey Schedule

The entire survey period is about four months, from June 2011 to September 2011. The first field survey in Sri Lanka was conducted from June 26 to July 28, 2011. The second field survey in Sri Lanka was conducted from August 29 to September 4, 2011.

The following reports were submitted during the survey period:

1) Inception Report June 2011
2) Progress Report July 2011
3) Draft Final Report August 2011
4) Final Report September 2011

1.4 Survey Team

The Survey Team is organized in the association of Nippon Koei Co., Ltd. (NK), Tokyo Electric Power Service Co., Ltd. (TEPSCO) and Mitsubishi Research Institute Inc. (MRI).

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 Survey Team

	Name	Position	Firm
1.	Junichi FUKUNAGA	Leader / Power System Planner	NK
2.	Hitoshi EGAWA	Deputy Leader / Transmission Line Expert	NK
3.	Fukiyoshi KOREZAWA	Substation Expert	NK
4.	Kiyotaka KATO	Distribution Line Expert	TEPSCO
5.	Akihiro HAYASHI	Distribution Loss Analyst	TEPSCO
6.	Shigeaki WADA	Environmental and Social Consideration Specialist	TEPSCO
7.	Shota INOUE	Economic Analyst	MRI

(Prepared by the Survey Team)

Note: NK: Nippon Koei Co., Ltd.
TEPSCO: Tokyo Electric Power Service Co., Ltd.
MRI: Mitsubishi Research Institute Inc.

1.5 Concerned Personnel

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

CHAPTER 2 POWER SECTOR

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2.1 General

(1) Ministry of Power and Energy

The Ministry of Power and Energy (MPE) is responsible to formulate and implement policies relating to the generation, transmission, distribution and retailing of electrical energy in Sri Lanka. 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) Direction for 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) Investigation, 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 electricity sector, which has been formulated with a view of enabling Sri Lanka to all and to meet the increasing demand for electricity in the future. The Act cites provisions to regulate 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 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 to be compatible with the latest technology advances and to protect the rights and safeguard the interests of consumers.

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 MPE are:

- Ceylon Electricity Board (CEB)
- Sri Lanka Sustainable Energy Authority (SLSEA)
- Atomic Energy Authority (AEA)
- Lanka Electricity Company (Pvt) Limited. (LECO)
- Lanka Transformer (Pvt) Ltd. (LTL)
- Lanka Coal Company (Pvt) Ltd.
- Polipto Lanka (Pvt) Ltd.

(2) Power Utilities

The CEB and LECO are the only two power utilities in the electric power sector. The CEB was established in terms of the Act of Parliament No.17 of 1969 as a state-owned, vertically integrated utility. It is responsible for power generation, transmission, distribution and about 89.2% of electricity sales in Sri Lanka, serving 4.48 million customers in 2010. The LECO was formed in 1983 as a distribution company under the Sri Lankan Companies Act. It purchases electric power from CEB and distributes 1,123 GWh energy to approximately 678 thousand consumers in 2010 in the western and coastal belt townships between Negombo and Galle.

The power sector of Sri Lanka struggled to meet the growing electricity demand. Most of the economically viable hydropower potentials have already been developed. The past power crises caused by vulnerability to rainfall and limitations of hydropower plants during severe drought fluctuations forced load shedding to limit daily electricity demand and drew attention to the importance of timely implementation of new generating plants to meet the growing demand. Since 1996, the Government of Sri Lanka has allowed Independent Power Producers (IPPs) to build, own, and operate thermal power plants to encourage private sector participation in meeting power supply requirements. The share of electric energy from hydropower plants in the power generation mix declined from 99.7% in 1986 to 52.6% in 2010. Sri Lanka relies heavily on imported fuel for its electric energy requirements.

Total installed power generation capacity in 2010 amounted to 2,818 MW, including the capacity of IPPs of 1,059 MW. Of the capacity feeding the main grid, 49% was hydropower and the balance was thermal, except for 45 MW of new renewable energy such as wind, solar, dendro, and biomass. The peak demand in 2010 was 1,955 MW. Of the total 9,268 GWh electricity sale of CEB in 2010, domestic (households) had the largest share at 33.9%, followed by industrial (31.0%), general and commercial consumers (18.9%), bulk supply by CEB to LECO (13.0%), street lighting (1.2%), and religious (0.5%).

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

Table 2.1-1 Power Sector Performance

	Items	2009	2010	growth rate (%)
1.	Total installed capacity	2,684 MW	2,818 MW	5.0
1.1	Installed capacity: CEB	1,758 MW	1,758 MW	0.0
	Hydro	1,207 MW	1,207 MW	0.0
	Thermal	548 MW	548 MW	0.0
	Wind	3 MW	3 MW	0.0
1.2	Installed capacity: IPP's	926 MW	1,060 MW	14.5
	Hydro	171 MW	175 MW	2.3
	Thermal	742 MW	842 MW	13.5
	Renewable energy	13 MW	43 MW	231
2.	Gross generation	9,882 GWh	10,714 GWh	8.4
2.1	Gross generation: CEB	5,450 GWh	6,386 GWh	17.2
	Hydro	3,356 GWh	4,988 GWh	48.6
	Thermal	2,091 GWh	1,395 GWh	-33.3
	Wind	3 GWh	3 GWh	0.0
2.2	Gross generation: IPPs	4,432 GWh	4,328 GWh	-2.3
	Hydro	525 GWh	646 GWh	23.0
	Thermal	3,884 GWh	3,600 GWh	-7.3
	Renewable energy	23 GWh	82 GWh	257
3.	Electricity sales	9,491 GWh	10,391 GWh	9.5
3.1	Electricity sales: CEB	8,441 GWh	9,268 GWh	9.8
	Domestic and religious	2,927 GWh	3,186 GWh	8.8
	Industrial	2,518 GWh	2,870 GWh	14.0
	General purpose and hotel	1,768 GWh	1,903 GWh	7.6
	Bulk sales to LECO	1,120 GWh	1,201 GWh	7.2
	Street lighting	108 GWh	108 GWh	0.0
3.2	Electricity sales: LECO	1,050 GWh	1,123 GWh	7.0
	Domestic and religious	486 GWh	510 GWh	4.9
	Industrial	208 GWh	229 GWh	10.1
	General purpose and hotel	331 GWh	363 GWh	9.7
	Street lighting	25 GWh	21 GWh	-16.0
4.	Overall system Loss of CEB	14.59 %	13.50 %	-1.1
	TL & DL loss	13.90 %	12.97 %	-0.9
5.	No. of consumers: CEB+LECO ('000)	4,749	4,958	4.4
	Domestic and religious	4,207	4,392	4.4
	Industrial	46	48	4.3
	General purpose and hotel	496	518	4.4

(Source: Central Bank of Sri Lanka Annual Report - 2010 and CEB Statistical Digest 2010)

2.2 Policies for Loss Reduction

The MPE revised the National Energy Policy and Strategies on June 10, 2008 consisting of (i) Energy policy elements, (ii) Implementing strategies and (iii) Specific targets, milestones and institutional responsibilities.

The major policy elements are as follows:

1) Providing basic energy needs
2) Ensuring energy security
3) Promoting energy efficiency and conservation
4) Promoting indigenous resources
5) Adopting an appropriate pricing policy
6) Enhancing energy sector management capacity
7) Consumer protection and ensuring a level playing field
8) Enhancing the quality of energy services
9) Protection from adverse environmental impacts of energy facilities

Focusing on the loss reduction as an implementing strategy for the above item 3) Promoting energy efficiency and conservation, the National Energy Policy and Strategies 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.".

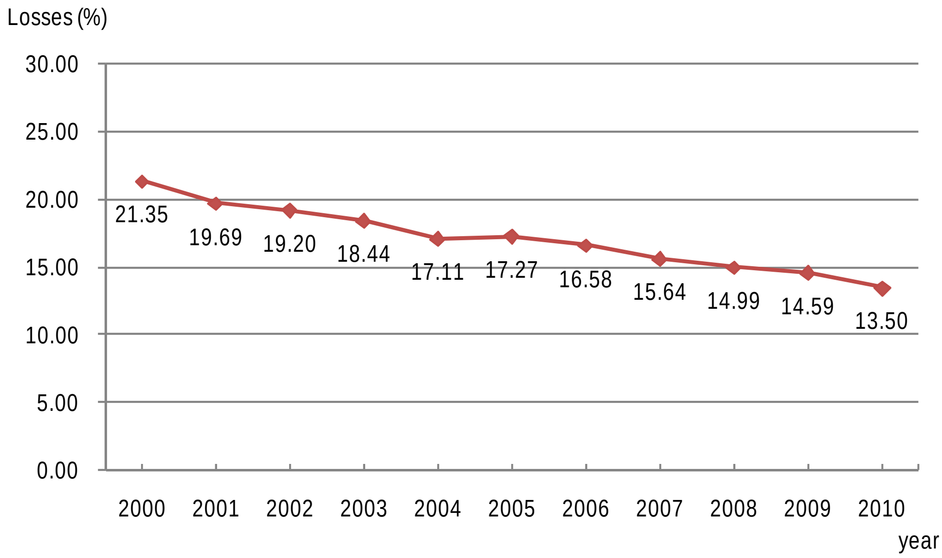
To achieve the above objective, CEB has been continuously exerting quite a lot of effort for transmission and distribution loss reduction, which will be discussed in the following sections.

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.

The system energy loss in 2010 was 13.50%, of which transmission and distribution loss was 12.97% and generation loss was 0.53%. Compared with the transmission and distribution loss of 13.79% in 2009, a 0.82% reduction was achieved in 2010 as a result of CEB's reduction efforts. However, transmission and distribution loss, especially the latter, was still at high level and countermeasures for loss reduction are to be taken continuously.



(Source: CEB 2009 Annual Report and Statistical Digest 2010)

Figure 2.3-1 System Energy Losses

2.3.2 Transmission Network

(1) Current Situation

The present Sri Lanka transmission system consists of a nationwide network of 220 kV and 132 kV transmission lines feeding several 220/33 kV and 132/33 kV grid substations (GS). Table 2.3-1 shows the summary of the existing transmission lines and grid substations:

Table 2.3-1 Existing Transmission Lines and Grid Substations

Length of Existing TLs		
	Transmission Lines	Length(km)
1	220 kV overhead line	484
2	132 kV overhead line	1,711
3	132 kV underground cable	41

Numbers and Capacities of Existing GSs			
	Grid Substations	Number	Capacity(MVA)
1	220/132/33 kV	5	2,100/500
2	220/132 kV	2	405
3	132/33 kV	44	2,874
4	132/11 kV	4	306

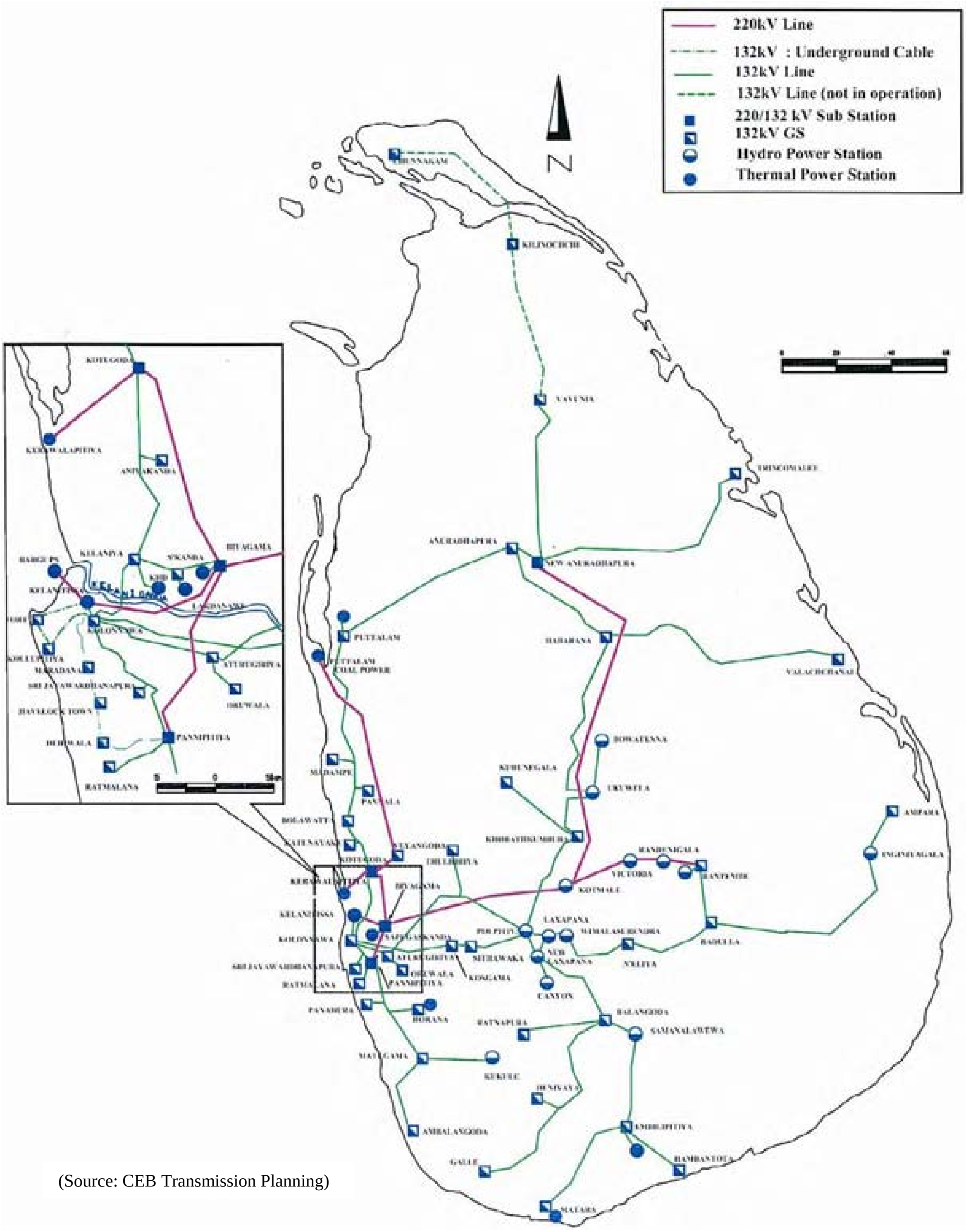
(Source: CEB Statistical Digest 2010)

There are three major 220 kV transmission corridors to transmit bulk power generated from large-scale generating plants to major load centers through 220 kV grid substations, as follows.

1) From hydropower stations in Mahaweli Complex in Central Province to Biyagama GS in Western Province
2) From Kotomale HPP Central Province to New Anuradhapura GS in North Central Province
3) From Norochcholai coal thermal power plant in North Western Province to Kotugoda GS in Western Province

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

Figure 2.3-2 shows the existing transmission network of Sri Lanka.



(Source: CEB Transmission Planning)

Figure 2.3-2 Existing Transmission Network as of 2011

(2) Issues on Transmission Network

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

1) 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 2.3-2. These sections were designed for small conductors such as 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.

Table 2.3-2 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)

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 due to the maximum operation temperature rations the power flow and remains a serious obstacle for system operation. In addition, small conductors produce transmission losses.

2) System Reliability

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

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

3) Shortage of Reactive Power

Since electricity demand in Colombo has been rapidly increasing after 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 is also contributing to transmission loss reduction.

4) Voltage drop

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

To improve such situation, countermeasures such as construction of new grid substation, reconstruction and augmentation of transmission lines, and installation of static capacitors are to be taken.

2.3.3 Distribution Network

(1) General

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

CEB's Statistical Digest 2010 shows that the household electrification ratio is 88.0% in 2010. Although electrification ratio in urban areas is generally high, the ratio in rural areas is very low, especially in Northern Province where there was an ethnic problem. Since the electricity demand density of consumers is very thin in the rural areas, the distribution lines become very long and it causes the large resistive losses on the distribution lines. Also more than 10% of voltage drops are observed in every rural area. Some components of the distribution systems are aged and this is observed to cause some failures due to poor quality of equipment.

The distribution system does not provide sufficient energy metering facility to grasp the coming and sending of electric power energy. It is essential to provide such a function to measure energy losses accurately.

Recently, Colombo City has developed the Distribution Automation System (DAS) and under commissioning in the Colombo City Electricity Distribution Development (CCEDD) Project funded by JICA. It can control the switchgear up to 11 kV PSs from the Distribution Control Center (DCC), but other regions/areas do not have such a DAS as Colombo City. At this moment, North Western Province in Region 1 has the simplified DAS named 'Micro SCADA' which can operate and monitor the switchgear in the network using communication links by GPRS on public mobile telephone network. In other areas, the switchgear in the network is manually operated by an operator with telephone communication but not by DAS.

In the MV Development Plans prepared by each distribution region or any other information from the CEB, any proposal/statement regarding 'Smart Grid System' has not been proposed yet. The CEB targets to proceed with the electrification and rectification of several problems such as overloading and voltage drop. It seems possible to apply the technique of 'Smart Meter' to the remote monitoring of energy meters which is proposed by the CEB in a letter to the MPE.

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

(2) Current Status of CEB's Distribution System

1) Territory of Transmission and Distribution in CEB

The boundary of responsibility between the Transmission Division and Distribution Division is the MV gantries of GS. The Distribution Division is responsible for the facilities from the gantries to the consumers. Further, the proposal issued by the Distribution Division covers MV distribution lines (33 kV and 11 kV), PSs, distribution substations and LV lines but does not include facilities such as capacitor banks or voltage controllers in the GS. When the Distribution Division needs to provide such facilities to solve the problems on the distribution system, the Distribution Division will propose to the Transmission Division to provide necessary equipment.

2) Growth of Electricity Power Demand

The peak demand growth of each region which is reported in the MV Development

Plans, is shown in Table 2.3-3. As shown in the table, total peak demand is increasing by 5% to 9% every year in each region and overall CEB.

Table 2.3-3 Peak Power Demand in Distribution System (unit: MW)

	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	1003	1054	1111	1165
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 Plans)

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.

3) Electrification

The CEB intends to increase the electrification ratio to 100% in accordance with the instructions from the GoSL. However, the electrification ratio in rural areas is lower than that of urban areas, as shown in Table 2.3-4 below.

Table 2.3-4 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	89.2%	24.9
North Central	10,472	1.25	447,000	295,924	66.2%	8.9
Northern	8,847	1.17	224,000	143,611	64.1%	6.1
Colombo City	37	0.74	155,000	154,268	99.5%	6,811
Region 1 Total	27,112	5.00	1,493,000	1,188,702	79.6%	12.6 (excl CC)
Western P N	1,421	2.50	492,878	465,010	94.3%	290
Central	4,600	2.26	659,340	600,000	91.0%	36
East	9,780	1.82	453,531	322,253	71.1%	13
Region 2 Total	15,801	6.58	1,605,749	1,387,263	86.4%	45
West-South 2	1,200	0.80	341,000	334,436	98.1%	187
Sabaragamuwa	8,350	1.45	353,000	346,000	98.0%	26
Uva	5,053	2.39	394,000	386,035	98.0%	13
Region 3 Total	14,603	4.64	1,088,000	1,066,471	98.0%	226
West-South 1	1,230	1.44	419,190	375,980	89.7%	120
Southern	5,497	2.90	669,667	650,446	97.1%	36
Region 4 Total	6,727	4.34	1,088,857	1,026,426	94.3%	51
CEB Total	64,243	20.35	5,092,468	4,217,391	82.8%	32

(Source: CEB MV Development Plans)

In rural areas, the electrification levels of the southern provinces are higher than that of the northern provinces. It is remarkable that the level of Northern Province is 64.1%. Some islands in the province are not connected to the transmission network and an independent generating system such as diesel generator is operated. Consequently these are not synchronized with the main transmission network of CEB.

4) Current Status of Distribution Lines

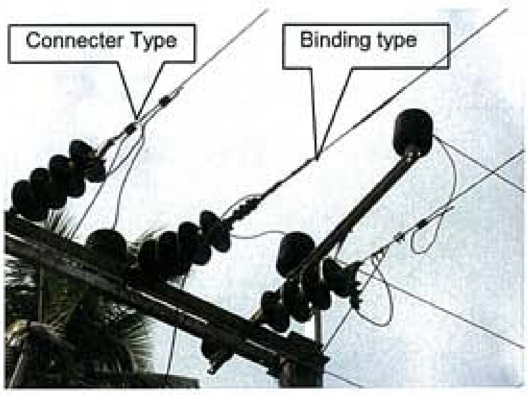
In the CEB's distribution system, two kinds of Aluminum Conductors Steel Reinforced (ACSR) conductors are used. One is ACSR Lynx (37/2.79 mm) used for 33 kV trunk (tower) lines named the backbone (BB) Lines and the other is ACSR Raccoon (7/4.09 mm) used for 33/11 kV branch lines named the pole (distribution) lines. As far as the specifications of conductors used for distribution lines, any problem or inadequacy cannot be seen; however, the long distribution distance may be causing much distribution losses. Table 2.3-5 shows the network components of CEB's distribution system.

Table 2.3-5 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	24,356
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 Plans)

As shown in the above table, the length of distribution line is quite long compared with the total lengths of distribution lines and the quantity of distribution substations. Also, it is obvious that LV lines are very long as calculated from the total lengths of LV lines and quantity of distribution substation. Actually, the lengths to the most distant consumer is 1.8 km and total lengths of LV lines connected to one distribution substation is 8 km on the average and 15 km maximum.



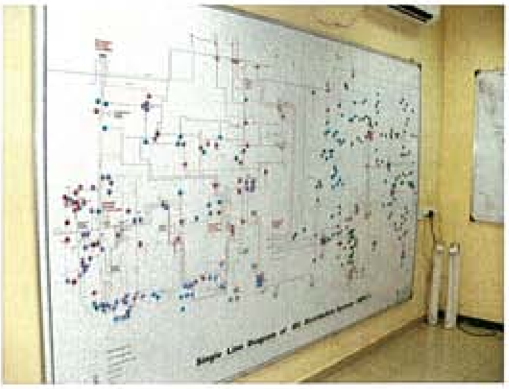
In addition, improper connections of wires were observed during site inspection, which may cause the resistive losses at the connection point. Actually, as shown in the right photograph, the winding connection and connector connection are mixed on poles. This may cause loosing because of the mechanical characteristics of aluminum which can be deformed by continuous stress in long durations.

All distribution lines are underground cables in Colombo City. As their standard, 11 kV cables are used instead of 33 kV cables because of the cost difference. However, the losses on 11 kV distribution lines are not so large while their lengths are very short in Colombo City. Actually, in the CCEDD Project, existing old 33 kV underground cables have been replaced with 132 kV cables.

5) Distribution Automation System

The Distribution Automation System (DAS) is provided in Colombo City by the CCEDD Project. But the other regions/areas have no DAS. Only North Western Province (NWP) in Region 1 applies a simplified DAS named 'Micro SCADA' which can control and indicate the status of the switchgear from the remote control center through mobile telephone network. However, it has no status indication because it uses General Packet Radio Service (GPRS) and it does not communicate the status periodically. When an operator accesses to the remote station, he should confirm firstly the present status of the switchgear and operate them next.

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



Region 2 has started to develop a DAS by themselves using GPRS for communication links. Considering safety and dependability of the system, it is recommended to use dedicated lines on the public telephone network or dedicated communication link such as optical fiber communication. The specification of each system is summarized in Table 2.3-6.

Table 2.3-6 SCADA System Applied in CEB Distribution System

Function	Colombo City (Under commissioning)	Region 1 NWP (Micro SCADA)	Region 2 WPN (Under design)	Region 4 WPS-1 (Manual)
Communication	O/F cable and Public telephone links	GPRS	GPRS	Telephone com.
Operated SWGR	All SWGR/TR	SWGR	SWGR	Not operated
Database	Provided for almost all event, status and electrical quantity	Equipment status and events	Provided for almost all event, status and electrical quantity	Database control manually
Log Report*1	Provided	Provided	Provided	Not provided
Intelligent function*2	Provided	Not available	Provided	Not provided

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

Note 2: In intelligent function, there are several features for example the optimum recovery routine can be instructed to operator.

(Prepared by the Survey Team)

(3) Current Status of Distribution Losses and Countermeasures

1) Non Technical Losses

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

2) Technical losses

Technical loss is composed of MV distribution losses (about 2%) and LV distribution losses (about 10%). MV distribution losses are reported in the MV Development Plans as shown in Table 2.3-7.

However, LV distribution losses are not given in MV Development Plans. The CEB explained that they have no facilities to measure the energy input to LV distribution lines. It is supposed to calculate 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 to each LV distribution line.

Table 2.3-7 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 Plans)

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

1) Overloading in GS/PS

In CEB's distribution system, transformers and MV distribution lines do not have operation margins in their current capacities. For instance, a planned shutdown is carried out in Kuriyapitiya to prevent overloading on equipment. It is very important to reinforce the GS, PS and transformers to give ample margin in operation. The CEB produces the reports on the MV Development Plan every two years. However, such overloading on the facilities happens again every year. The following hidden problems are to be included in the development plan and operation/reinforcement.

i) Growth of power demand is rapidly increasing than expected.
ii) Remarkable delay on the schedule of reinforcement/installation.
iii) Expected margin of facility is too small.
iv) Quality of distribution facility is very poor because of aging, improper design and poor equipment quality

It is recommended to take the soonest action to find the root cause why CEB have encountered and not improved overloading.

2) Voltage drop

On the CEB's distribution system, voltage drop is observed at many locations. The root cause of voltage drop is the distribution of electric power on long distribution lines and overloading. The following three countermeasures can be considered to rectify voltage drop.

i) To provide additional distribution lines and/or size up the conductors
ii) To provide new GS to shorten the distribution lines
iii) To provide voltage compensation facilities such as Step Voltage Regulator (SVR)

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

3) Distribution Automation System (DAS)

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

i) Continuous Monitoring of Switchgear

It is very essential to indicate the present status of the switchgear in the Domestic Control Center (DCC). At the present system, the Call Center receives the claim from consumers and confirms the status of equipment. On the other hand, if the 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 sections
- Support system to instruct fault locations on a map and failed equipment identifications

ii) Remote control of equipment

At the present system, the Call Center receives the information from consumers and the Control Center may instruct operators to visit the site and to change status of the switchgear. It takes a long time for the changeover of 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 the 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 according to pre-determined routine. Also, the DAS can monitor power factors on the system and can control reactive power outputs by switching static capacitors installed in several substations.

However, it is essential to provide the operating mechanism in the switchgears to control them 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 complicated calculation. For example, in the case of overloading on some distribution lines, it is detected automatically and a changeover of the switchgear status is made to evenly distribute the load current on each line.

iv) Database and reporting

In the present system, operators record the status and/or disturbance on log books or input the record to the PC database manually. The DAS has functions of automatic recording to a database and can issue a report of any information automatically or on request. It can eliminate human error in recording and reporting.

v) Intelligent DAS functions

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

4) Provision of energy meters and data transmission

At 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 or it takes much time to read the meter indication on site. To analyze the distribution losses, energy meters are effective tools to measure the losses.

In case of resistive loss on distribution lines, it is possible to calculate the loss by impedance of conductor and 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 because of the large numbers (more than 1,000 sets) of energy meters, and the distance of the place of installation 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.

5) Increase of transformer loss by inadequate transformer capacity

A series of distribution transformer capacity is standardized as 100 kVA, 160 kVA and 250 kVA in CEB's distribution system. If the power demand in a rural area is very small at a distribution substation, however, the minimum rating of 100 kVA transformers shall be used for the substation. In this case, no-load loss (iron loss) is very large because of the too-large transformer rating compared with the power demand. If a transformer with adequate capacity such as 16, 25, 30 and 50 kVA is used for one small-demand substation, it is possible to reduce the no-load loss of the transformer.

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

6) Distribution losses caused by long LV lines

It was confirmed that the lengths of LV line 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 maximum. It seems that the too long LV lines produce large distribution losses. It is therefore an effective measure to provide additional LV distribution substations to reduce the lengths of LV lines and the distribution losses.

7) Theft of electric power

It is easy to steal electric power by hanging a hook on an LV line in the rural areas, because population density is very thin and it is very difficult to find such an activity in a wide area. At this moment, it is difficult to discover the steal of power because electric energy is not monitored exactly on LV lines. Therefore, it is recommended to provide energy meters on every LV line.

8) Resistive loss at connection points on LV lines

It was observed that LV distribution wires are connected by either a connector or through manual winding connection. There are two reasons of connection losses on LV lines. One is the 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 executes the connection work without any proper checking by others. The other reason is the connection by screw connector. Aluminum can be deformed at the screw connection during the long term and improper contact causes heating loss by contact resistance at the connection point. Actually, heating was observed at the connection site through a thermo camera.

It is necessary to use hydraulic compression tools by which proper compression clamp connection can be done easily even without long term experience of an electrician. Also, it is recommended to train the workers adequately to eliminate defective connection.

9) Rehabilitation of aged facilities

It was observed at the site investigation that too old 11/0.4 kV transformers manufactured more than 70 years ago are still working at the 11 kV substation. Considering the technique level of those days, it is possible to reduce transformer loss by applying recent techniques. Thus, rehabilitation/replacement of aged facilities is one of the options to reduce distribution losses.

10) Salt contamination along seaside

Since salt contaminations are observed on overhead lines along the seaside, 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 for distribution lines instead of overhead bare conductors. It is effective to reduce distribution losses to provide new small unmanned GS or PS to which 132 kV or 33 kV cables will be connected from the 132 kV or 33 kV network to minimize lengths of 11 kV overhead lines.

(5) Others

1) Street Lighting

The power required for street lightings, which is one of non technical losses, is fed from LV distribution lines. Any tariff for street lighting is not paid to CEB. To reduce the demand, the CEB proposes energy saving activities to concerned departments in Colombo City.

2) Capacity Building

When the Survey Team visited the CEB Training Center, the Deputy General Manager (DGM) explained that the software 'SynerGEE' (USA) has been used for distribution planning for more than 10 years, extending its license every year and giving each regional office the license. Thus, providing other software for distribution planning is not necessary, because CEB is accustomed to and satisfied with SynerGEE. The DGM of the Training Center requested us to supply hydraulic compression tools for connecting distribution conductors and to train electricians how to use the tools correctly to reduce distribution loss. The Survey Team supposes it is very effective for loss reduction.

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 2011-2020. The Survey Team received the draft plan during the first survey period.

The objectives of the Long-Term Transmission Development Plan 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 Long-Term Transmission Development Plan 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 and the long-term generation expansion plan.

Chapter 5 of the Long-Term Transmission Development Plan 2011-2020 (draft) includes transmission expansion proposals with the following three categories:

1) Transmission expansion proposals identified by system analysis
   The transmission network expansion proposals, which are identified as a result of system analysis done by CEB System 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
   The proposals include transmission system development required for power plant developments.

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

Table 2.4-1 Transmission Expansion Proposals (Uncommitted Projects)

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	CEB
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
7	Construction of Kerawalapitiya 220/33 kV GS	2013	880.8	140.3	ADB
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	ADB
10	Construction of Kalutara 132/33 kV GS with single in/out connection from Panadura - Mathugama 132 kV TL	2013	760.4	172.6	JICA
11	Installation of 2nd 220/132 kV, 105 MVA inter-bus ATR at Rantambe PS	2013	389.4	74.5	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	Construction of Kukule - Ratnapura Zebra, 132 kV, 25 km, 2-cct TL with 2 TL bays at Kukule PS and 2 TL bays at Ratnapura GS	2013	500.8	229.5	N/A
14	Installation of reactive power compensation devices at Kurunegala GS (30 MVar) and Galle GS (20 MVA)	2013	297.4	53.7	N/A
15	Reconstruction of Polpitiya-Kiribathkumbra-Ukuwela-Habarana 132 kV, 164 km 2-cct TL (from Lynx to Zebra)	2014	2,652.8	1,384.3	JICA
16	Construction of Vauniya-New Anuradhapura Zebra, 132 kV, 55 km 2-cct TL	2014	889.6	464.3	N/A
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	JICA
18	Construction of Pannipitiya-Ratmalana Zebra, 132 kV, 7 km, 2-cct TL	2014	113.2	59.1	JICA
19	132 kV TL upgrades to operate at 75 deg C, Bolawatta-New Chilaw and Bolawatta-Pannala	2014	84.5	58.4	N/A
20	Augmentation of Madampe GS	2014	318.7	56.4	JICA
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	N/A
22	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
23	Construction of New Polpitiya GS with Polpitiya - New Polpitiya 2xZebra, 132 kV, 10 km, 2-cct TL	2014	1,436.7	298.3	N/A
24	Construction of Padukka GS with Athurugiriya - Padukka 2xZebra, 132 kV, 12.5 km 2-cct TL	2014	1,577.0	323.3	JICA
25	Construction of New Polpitiya - Padukka - Pannipitiya 2xZebra, 220 kV, 58.5 km, 2-cct TL	2014	1,987.4	779.2	N/A
26	Construction of Athurugiriya - Kolonnawa 2xZebra, 132 kV, 15 km, 2-cct TL	2014	320.1	158.3	JICA
27	Installation of 3rd 220/132/33 kV, 250 MVA inter-bus ATR at Pannipitiya GS	2014	340.9	68.4	N/A
28	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	N/A
29	Augmentation of Aniyakanda GS	2014	234.6	48.3	N/A
30	Installation of reactive power compensation devices at 8 GS	2014	1,084.2	78.6	JICA

31	Construction of Upper Kotomale - New Polpitiya 2xZebra, 220 kV, 25 km, 2-cct TL with 2 TL bays at Upper Kotomale PS	2015	909.9	333.4	N/A
32	132 kV TL upgrades to operate at 75 deg C, Pannipitiya-Sri J'pura, Samanalawewa-Embilipitiya, N-Lax.-Balangoda and N-Lax.-Polpitiya	2015	250.9	173.3	N/A
33	Augmentation of Kelaniya GS	2016	312.0	53.9	N/A
id	Projects	comm.. year	Base Cost (MLKR) FC	LC	Expected Funding
34	Construction of Weligama 132/33 GS with double in/out connection from Galle - Matara 132 kV TL	2016	729.5	130.4	N/A
35	Installation of reactive power compensation devices at Valachchenai GS (20 MVar) and Matara GS (20 MVar)	2016	154.9	11.2	N/A
36	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
37	Augmentation of Chunnakam GS	2016	207.0	29.1	N/A
38	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
39	Upgrade Galle GS to install 220 kV ATR	2017	799.6	151.3	N/A
40	Installation of reactive power compensation devices at Colombo-A GS (20 MVar)	2017	77.4	5.6	N/A
41	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
42	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
43	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
44	Augmentation of Deniyaya 132/33 kV GS to double in/out connection	2018	46.6	8.3	N/A
45	Installation of reactive power compensation devices at Padukka GS (100 MVar)	2018	187.7	12.7	N/A
46	Augmentation of Pannala GS	2019	234.6	48.3	N/A
47	Augmentation of Athurugiriya GS	2019	234.6	48.3	N/A
48	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
49	Augmentation of Dehiwala GS	2020	234.6	48.3	N/A
50	Augmentation of Kilinochchi GS	2020	207.0	29.1	N/A
	Total		43,184.3	13,842.4	

(Source: CEB Transmission Planning)

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

2.4.2 Distribution Line Development Plans

(1) MV Development Plans

The CEB plans several MV distribution projects in the Medium Voltage Distribution Development Plans 2010 – 2019 (the MV Development Plans), which were prepared by each distribution region and issued every two years. However, any development plan for the LV distribution system is not included in the MV Development Plans.

Although the Survey Team received the MV Development Plans prepared by Region-1, Region-2 and Region-4, the MV Development Plan for Region-3 was under preparation and the Survey Team has not received it yet during the first survey period.

The MV Development Plans include construction of the 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

The CEB plans several development projects to evaluate them by computer-based modeling using the planning software 'SynerGEE Ver. 3.52/36', briefly described 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 options to select the optimum techno-economic solution, analysis of simulated network

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

2) MV Development Plans

After forecasting the future system (Future System Analysis) by referring to the planning criteria, the proposal will be produced. Then, economical evaluation on candidates will be carried out and 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	-	171
	Lynx SC Tower	0	113	-	17
	Lynx DC Pole	272	0	-	0
	Lynx SC Pole	239	105	-	28
	Racoon DC Pole	12		-	
	Racoon SC Pole	82		-	
	Racoon		40	-	
	Racoon Pole			-	3
Distribution Gantries (Nos)	DBB Tower Gantry	18	32	-	
	SBB Pole Gantry	6	22	-	
	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		-	
	Elm			-	36
	Weasel → Racoon		10	-	12
	Weasel/Racoon → Lynx		15	-	4

Description	Type	Region 1	Region 2	Region 3	Region 4
New Primaries (Nos)	Manned Primaries	4		-	
	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 (km)		4		-	3
Others	Conversion 33 kV to 11kV			-	2
	Change Line Tapping			-	1

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

Other projects and/or activities, which are planned in each regional office, are summarized in Table 2.4-3.

Table 2.4-3 Additional Projects in Each Region

Region	Additional Project or Activity
1	Colombo City (CC) office tries to propose low energy lights for street lighting and they are doing consultant service to the public sector because these two consumptions are major non technical losses. Also CC office provides 132/11kV GS to upgrade the 33 kV to 132 kV.
2	The Western Province North (WPN) office has a development plan for Distribution Automation System (DAS) using GPRS communication. In addition to DAS, they planned to provide reclosers and LBS on each distribution line section. Also, WPN office planned to provide energy meters to measure incoming/outgoing energy at boundaries of distribution lines. The Central Province office has a development plan for DAS using GPRS communication. In addition to DAS, they planned to provide reclosers and LBS on each distribution line section. The WPN office is looking for the countermeasure against salt contamination to upgrade the system voltage from 11 kV to 33 kV along the seaside.
4	The Western South-1(WPS-1) office has an intention to develop DAS but there is not any actual study started yet. The WPS-1 office is planning to provide energy meters to all distribution substations.

(Prepared by the Survey Team)

(2) Proposal for Distribution Loss Reduction Project (Low Voltage)

In addition to the above mentioned MV Development Plans, CEB has prepared a separate proposal for low voltage distribution system (LV Development Proposal) to reduce the distribution losses of LV distribution lines, gathering the requirements from each region/province office.

The Survey Team received the LV Development Proposal, which was submitted from the MPE to the Department of External Resources (DER).

The LV Development Proposal contains reinforcement plans, including construction of LV lines with distribution substations, LV line interconnections, single phase to three-phase conversions, and installation of energy meters, as shown in the following table.

Table 2.4-4 Distribution Loss Reduction Project (LV)

Projects		Province/Region	Quantity	Costs (MLKR)
1.	New LV Scheme	R2-Eastern Province	120 nos.	480.0
		R2-Central Province	400 nos.	1,600.0
		R2-Western Province North	40 nos.	160.0
		R3-Western Province South II	100 nos.	400.0
		R3-Uva Province	90 nos.	360.0
		R3-Sabaragamuwa Province	125 nos.	500.0
		R4-Southern Province	25 nos.	100.0
		R4-Western Province South I	38 nos.	152.0
2.	1 ph to 3 ph Conversion	R1-Northern Province	1,000 km	500.0
		R1-North Western Province	1,000 km	500.0
		R1-North Central Province	1,000 km	500.0
		R2-Eastern Province	300 km	150.0
		R2-Central Province	1,000 km	500.0
		R2-Western Province North	100 km	50.0
		R3-Western Province South II	700 km	350.0
		R3-Uva Province	700 km	350.0
		R3-Sabaragamuwa Province	700 km	350.0
3.	Substation Energy Meters	Region-4	1 lot	44.0
4.	LV Interconnections	R3-Western Province South II	10 km	14.0
		R3-Sabaragamuwa Province	50 km	70.0
			Total	7,130.0

(Source: Project Proposal for Distribution Loss Reduction Project (LV))

2.5 Other Donors' Assistance

The Government of Sri Lanka borrowed USD 1.857 billion from different foreign donors for power and energy sector development during the period 2005 - 2010. The highest commitment was made by the Government of China, followed by Asian Development Bank (ADB), Iran and JICA during the period. These four donors accounted for about 92% of the total commitment made for the power and energy sector during the period.

Table 2.5-1 shows the committed or on-going projects for CEB's transmission and distribution section.

Table 2.5-1 Assistance for Transmission and Distribution Projects

No	Projects	Project Cost	Fund	Comm. year
1	Kotsugoda GS Expansion Project	LKR 780.0 mil	KfW	2011
2	Colombo City Distribution Development Project	JY 5,959 mil	JICA	2011
3	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		

No	Projects	Project Cost	Fund	Comm. year
	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		
4	Vauniya - Kilinochchi Transmission Project	JY 1,422 mil JY 1,278 mil	JICA	2012
5	Kilinochchi - Chunnakam Transmission Project	US$ 28.7 mil	ADB	2012
6	Sustainable Power Sector II Project	US$ 95.4 mil LKR 29 mil	ADB	2013
7	Procurement of materials for the Power Sector Development Programme in Northern Province	US$ 31.7 mil	EXIM Bank of China	(committed in 2010)
8	Rural Electrification Project -8 (Northern and Eastern Provinces)	Euro 77.1 mil	EDB of Iran	2012
9	Rural Electrification Scheme - in North Central Province - in Trincomalee and Batticoloa Districts - in Badulla and Monaragala Districts under Uva Udanaya project - in Jaffna, Vavuniya, Mannar, Mullathivu and Killinochchi districts under Uthuru Vasanthaya project	 US$ 57.9 mil US$ 60 mil US$ 34 mil US$ 34 mil	EXIM Bank of China	2012

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

In addition to the above assistances, Table 2.5-2 shows the assistances for the generating plants and others.

Table 2.5-2 Assistance for Generating Plants and Others

No	Projects	Project Cost	Fund	Comm. year
1	Rehabilitation of Ukuwela HPP (40 MW)	LKR 1,573 mil	JBIC	Completed
2	Norochcholai (Puttalam) Coal Power Plant Project (900 MW)	US$ 891 mil	EXIM Bank of China	Ph-1 (300 MW) 2011, Ph-2&3 (600 MW) 2014
3	Uma Oya Multipurpose Development Project including Uma Oya HPP (120 MW)	US$ 529 mil	EDB of Iran (85%) GoSL (15%)	2012
4	Upper Kotomale Hydropower Project (150 MW)	JY 4,552 mil JY 33,265 mil JY 1,482 mil	JICA	2011
5	Rehabilitation of Old Laxapana HPP (50 MW)	US$ 32.5 mil	UniCredit Bank of Austria AG	(committed in 2010)
6	Rehabilitation of Wimalasurendra (50 MW) and New Laxapana Power Stations (100 MW)	US$ 55.2 mil	AFD	2013
7	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	Trincimalee 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 LOSS REDUCTION PROJECT

CHAPTER 3 TRANSMISSION LOSS REDUCTION PROJECTS

3.1 General

The Transmission Panning Section of CEB submitted the following shortlist which is needed for the Japan's Loan Aid to the Survey Team as basis of discussion. The shortlist was prepared by means of selecting sub-projects from the long list (Table 2.4-1) described in Sub-section 2.4.1, Chapter 2. The order in the short-list shows CEB's development priority.

Table 3.1-1 Short-list for Japan's Loan Aid

No.	Sub-projects	Base Costs (MLKR)		Comm. Year	Long List No.
		FC	LC		
1	New Habarana – Veyangoda 220 kV transmission project	6,268.9	2,131.3	2017	# 36
2	Reconstruction of Polpitiya – Habarana 132 kV TL	2,652.8	1,384.3	2014	#15
3	Augmentation of Colombo – A GS	203.8	39.1	2014	#8
4	Construction of Kalutara 132/33 kV GS	760.4	172.6	2014	#10
5	Augmentation of Madampe GS	318.7	56.4	2014	#20
6	Installation of reactive power compensation devices for 8 GSs	1,084.2	78.6	2014	#30
7	Construction of Thulhiriya – Veyangoda 132 kV TL	645.6	304.7	2014	#17
8	Construction of Pannipitiya – Ratmalana 132 kV TL	113.2	59.1	2014	#18
9	Construction of Kirindiwela 220/132/33 kV GS	1,518.0	291.5	2014	#22
10	Construction of Padukka 220/132/33 kV GS	1,577.0	323.3	2014	#24
11	Construction of Athurugiriya – Kolonnawa 132 kV TL	320.1	158.3	2014	#26
12	Construction of Kirindiwela – Veyangoda 220 kV TL	774.4	246.2	2018	#42
13	Construction of Padukka – Kirindiwela 220 kV TL	854.8	279.2	2018	#43
	Total	17,091.9	5,524.6		

(Source: CEB Transmission Planning)

The Survey Team evaluated the shortlist of sub-projects based on the following criteria:

1) Urgency of the sub-project (existence of project proposal)
   - 3 points: existing project proposal
   - 2 points: partly existing or under preparation
   - 1 point: not existing
2) Expected loss reduction effects including distribution loss reduction
   - 3 points: TL reconstruction, 132 kV GS construction and reactive power compensation projects
   - 2 points: TL construction and GS augmentation projects
   - 1 point: 220 kV GS construction projects
3) CEB's development priority
   - 3 points: #1 – #5
   - 2 points: #6 – #10
   - 1 point: #10 –

4) Requirements of the distribution development

3 points: 132 kV GS construction and augmentation projects

2 points: 132 kV TL projects

1 point: 220 kV TL and GS construction projects

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

3 points: existing IEE report or GS augmentation projects (an IEE is not necessary)

2 points: GS construction or TL reconstruction projects

1 point: TL construction projects

6) Applicability of Japan's technology

3 points: TL projects

2 points: GS construction projects

1 point: GS augmentation projects

Table 3.1-2 shows the result of the evaluation.

Table 3.1-2 Result of Evaluation

No.	Sub-projects	1)	2)	3)	4)	5)	6)	score
1	New Habarana – Veyangoda 220 kV transmission project	3	2	3	1	3	3	15
2	Reconstruction of Polpitiya – Habarana 132 kV TL	2	3	3	2	2	3	15
3	Augmentation of Colombo-A GS	3	2	3	3	3	1	15
4	Construction of Kalutara 132/33 kV GS	3	3	3	3	2	2	16
5	Augmentation of Madampe GS	3	2	3	3	3	1	15
6	Installation of reactive power compensation devices for 8 GSs	3	3	2	3	2	1	14
7	Construction of Thulhiriya –Veyangoda 132 kV TL	1	2	2	2	1	3	11
8	Construction of Pannipitiya - Ratmalana 132 kV TL	1	2	2	2	1	3	11
9	Construction of Kirindiwela 220/132/33 kV GS	1	1	2	1	2	2	9
10	Construction of Padukka 220/132/33 kV GS	1	1	2	1	2	2	9
11	Construction of Athurugiriya – Kolonnawa 132 kV TL	1	2	1	2	1	3	10
12	Construction of Kirindiwela – Veyangoda 220 kV TL	1	2	1	1	1	3	9
13	Construction of Padukka – Kirindiwela 220 kV TL	1	2	1	1	1	3	9

(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) New Habarana – Veyangoda Transmission Project (#1)
2) Reconstruction of Polpitiya – Habarana Transmission Line (#2)
3) Sub–station construction and augmentation project including the following sub-projects
   i) Augmentation of Colombo-A GS (#3)
   ii) Construction of Kalutara 132/33 kV GS (#4)
   iii) Augmentation of Madampe GS (#5)
   iv) Installation of reactive power compensation devices for 8 GSs (#6)

Regarding the above Item 3), four sub-projects are compiled into one component project in consideration of the scale (project costs) of the sub-projects.

3.2 Candidate Projects

3.2.1 New Habarana – Veyangoda 220kV Transmission Project

(1) Objective

According to the "Long Term Generation Expansion Plan 2009–2022", a large number of bulk power generation units will be added to the CEB's transmission network from 2012 onwards. Thus, transmission networks have to be strengthened to deliver the power from the power stations to the load centers. In 2011, the transmission line of 220 kV surrounding Colombo City is not looped, but a 132 kV transmission line is supplementing the network's reliability.

In the near future, several thermal and hydropower plants will be interconnected to the grids. Power supply through 132 kV transmission lines causes not only insufficiency in capacity of the lines, but also more transmission loss than the power supply through 220 kV lines. Therefore, in view of securing a highly efficient network, there will be a necessity to strengthen the network reliability by connecting New Habarana Switching Substation (SS) and Veyangoda GS, which will be a pivotal GS in the central area of Sri Lanka, and one of the gateway point to Colombo City. Transmission loss in the network will be reduced due to the construction of the New Habarana – Veyangoda 220 kV transmission line. The project is expected to be commissioned in 2016.

(2) Scope of the Project

1) Construction of New Habarana SS

- 2×250 MVA 220/132/33 kV transformers
- 2×220 kV double bus bar transformer bays
- 2×132 kV double bus bar transformer bays
- 8×220 kV double bus bar transmission line bays
- 6×132 kV double bus bar transmission line bays
- 132 kV and 220 kV double bus bar arrangements with bus couplers

Provision for 2×220 kV transmission line bays is required for the enhancement of reliability with an expected 1,000 MW in the future.

Provision should be made to utilize the 33 kV tertiary winding for reactive power compensation or distribution purpose as required in the future.

2) Construction of connection line from Kotmale - New Anuradhapura transmission line

- Double incoming and outgoing (2 cct. 0.5 km, ACSR Zebra)

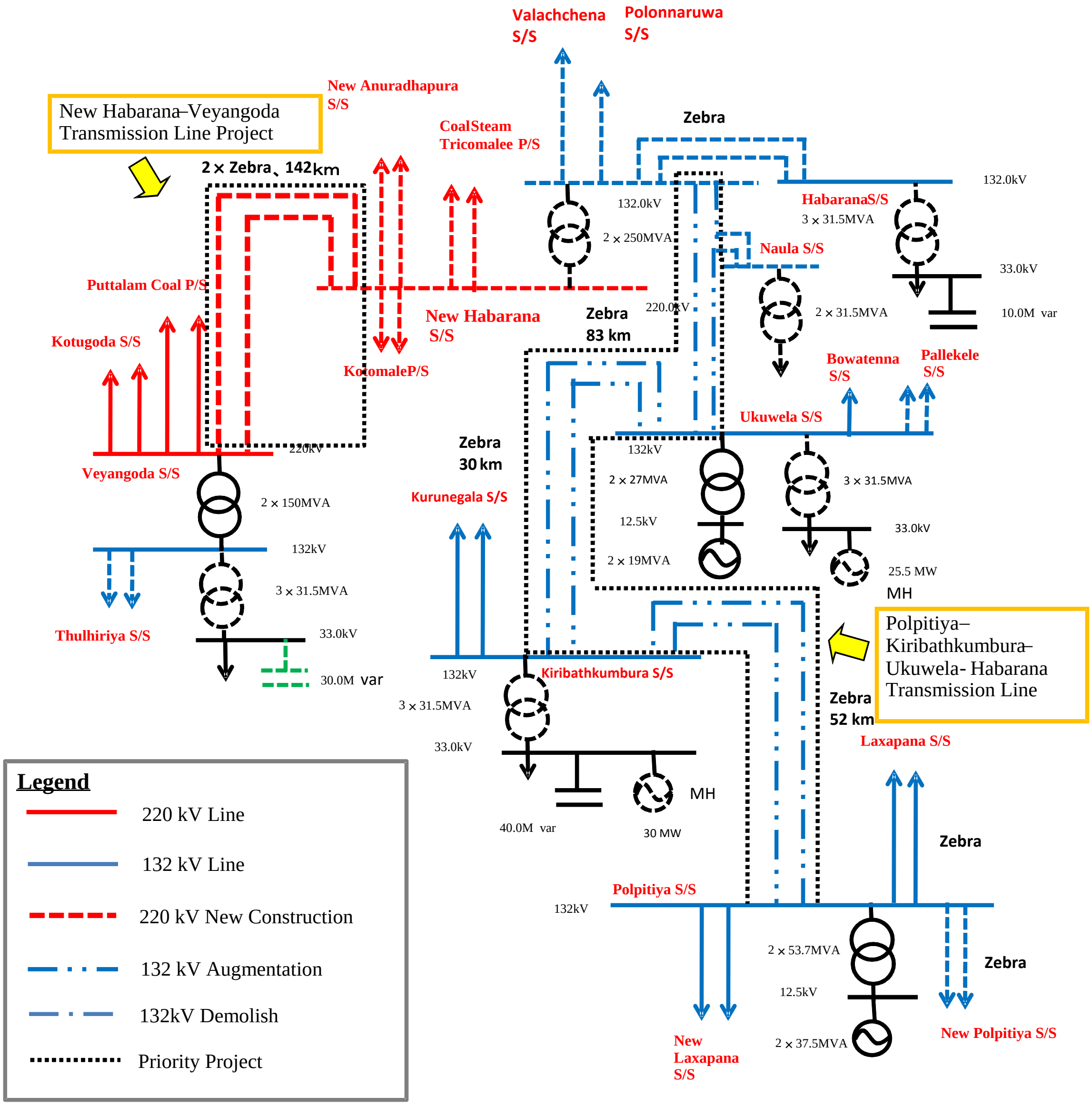
3) Construction of New Habarana - Veyangoda 220 kV transmission line

- 2 cct. 142 km, 2×ACSR Zebra

4) Augmentation of Veyangoda GS

- 2 × 220 kV double bus bar transmission line bays

5) Construction of 1.5 km quadruple 132 kV tower line to carry 132 kV circuits from Ukuwela and Valachenai to New Habarana



(Prepared by the Survey Team)

Figure 3.2-1 Transmission Network related to Transmission Line Development Project

(3) Estimated Base Cost of the Project

The CEB has preliminary estimated the project cost using the standard unit prices quoted for the previous projects as shown in Table 3.2-1. The estimated total project cost (base cost) is 6,268.9 MLKR (FC) and 2,131.4 MLKR (LC).

Table 3.2-1 Project Cost of New Habarana – Veyangoda Transmission Line

Description	Nos.	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of New Habarana SS		FC	LC	FC	LC
Transformer 220/132/33 kV 250 MVA and E. Tr.	2	195.8	12.3	391.5	24.7
220 kV bus coupler/double BB arrangement	1	56.3	3.9	56.3	3.9
220 kV transformer bay double bus bar	2	41.3	3.9	82.6	7.8
220 kV line bay double bus bar	8	52.9	3.8	423.1	30.8
132 kV D/B arrangement with bus coupler	1	43.1	3.4	43.1	3.4
132 kV transformer bay double bus bar	2	27.5	4.5	55.1	9.0
132 kV line bay double bus bar	6	24.1	4.6	144.6	27.7
Common items for 220/132 kV grid	1	209.2	106.3	209.2	106.3
Substation automation	1	45.7	0.5	45.7	0.5
Spare parts (7%)				101.6	15
			Sub-Total	1,552.8	229.1
2) Construction of connection line from Kotmale - New Anuradhapura TL	km				
220 kV transmission line, 2 cct. ACSR "Zebra"	0.5	23.8	10.6	11.5	5.3
3) Construction of New Habarana - Veyangoda 220kV TL	km				
220 kV transmission line, 2 cct. 2×ACSR "Zebra"	142	32.2	13.2	4,567.3	1,872.8
4) Augmentation of Veyangoda GS	nos.				
220 kV line bay double bus bar	2	52.9	3.8	105.8	7.7
5) Construction of 1.5 km quadruple 132 kV tower line	km				
132 kV, 4 cct. tower line	1.5	21.0	11.0	31.5	16.5
			Total 1)～5)	6,268.9	2,131.4
			Grand Total (FC+LC)		8,400.3

(Source: Project Proposal for New Habarana – Veyangoda Transmission Project)

(4) Effect of Transmission Loss Reduction

To estimate the loss reduction amount, it is proposed to compare the cases of 132 kV 4-cct and 220 kV 2-cct transmission lines with the same transmission power in view of the fact that the CEB originally planned to construct 132 kV 4-cct transmission lines and made comparison between 220 kV and 132 kV transmission lines. Since Trincomalee CPP is planned to be developed in three stages and the transmitted powers on the transmission lines are different in each stage, therefore transmission losses calculated for each stage.

Based on the conditions shown in Table 3.2-2, the effect of the transmission loss reduction is calculated as shown in Table 3.2-3

Table 3.2-2 Calculation Conditions

	Stage 1 (2017 -2018)		Stage 2 (2019)		Stage 3 (after 2020)	
Description	132 kV, 2xZebra	220 kV, 2xZebra	132 kV, 2xZebra	220 kV, 2xZebra	132 kV, 2xZebra	220 kV, 2xZebra
Max. transmitted power	500 MW		750 MW		1,000 MW	
Nos. of circuits	4-cct	2-cct	4-cct	2-cct	4-cct	2-cct
Current per conductor (I)	303.8 A	364.5 A	455.6 A	546.8 A	607.5 A	729.0 A
AC resistance (R)	0.0774 Ω/km	0.0775 Ω/km	0.0778 Ω/km	0.0781 Ω/km	0.0783 Ω/km	0.0790 Ω/km
Load factors	55 %					
Route length	142 km					

(Prepared by the Survey Team)

The transmission losses per circuit can be calculated with the following formula:

$$\textit{Transmission loss (kW/cct.)} = 3 \times I^2 R \times \textit{Route length} \times \textit{No. of bundle conductors}$$

Annual energy losses can be calculated by multiplying transmission loss per circuit, 24 hours, 365 days, 0.55 of load factor and numbers of circuits.

Table 3.2-3 Effect of Transmission Line Loss Reduction

		Stage 1		Stage 2		Stage 3	
Description	Unit	132 kV 4-cct	220 kV 2-cct	132 kV 4-cct	220 kV 2-cct	132 kV 4-cct	220 kV 2-cct
Transmission line loss	MW/cct.	6.1	8.8	13.8	19.9	24.6	35.8
Annual energy loss	MWh/yr	117,559	84,797	265,954	191,756	474,091	344,969
Energy loss savings	MWh/yr	32,762		74,198		129,122	
Weighted average for 40 years	MWh/yr					122,931	

(Prepared by the Survey Team)

Table 3.2-3 indicates that the energy loss reduction amounts to 122,931 MWh/yr. In addition, this project is to be contributing to not only transmission loss reduction, but also for the increase of system stability and reliability.

3.2.2 Polpitiya - Habarana Transmission Line Reconstruction Project

(1) Objective

Transmission lines of 132 kV from Polpitiya to Habarana via Kiribathkumbura and Ukuwela, which were built more than 40 years ago, are designed with 54°C as the maximum operation temperature for ACSR Lynx conductors. However, there is a necessity to send more power to meet the increasing demand. Actually, these transmission lines have been deteriorating, thus causing difficulties in securing clearance between the ground and the conductors because of the limited operation temperature. These are very important lines in the central area, more specifically in interconnecting the 132 kV grid substations with the north and central area.

This project is to be implemented to improve the stability and reliability of the transmission system and to meet the growing demand by means of reconstructing the transmission lines via the replacement of the old conductors by ACSR Zebra designed with a 75°C maximum operation temperature. Meanwhile, the transmission line is associated with the Ukuwela and Upper Kotmale hydropower plants which is rehabilitated under Japan's Loan Aid because the line runs near Upper Kotmale and is connected directly to Ukuwela as shown in Figure 3.2-1, and transmits the generated power from these plants. The project is expected to be commissioned in 2014.

(2) Scope of the Project

1) Reconstruction of Polpitiya - Kiribathkumbura 132 kV TL (Zebra, 2 cct., 52 km)
2) Reconstruction of Kiribathkumbura - Ukuwela 132 kV TL (Zebra, 2 cct., 30 km)

3) Reconstruction of Ukuwela - Habarana 132 kV TL (Zebra, 2 cct., 82 km)

4) Removal of the existing transmission line (Lynx, 2 cct., 164 km)

(3) Estimated Base Cost of the Project

Table 3.2-4 shows the project cost estimated by the Transmission Planning of the CEB. The estimated total project cost (base cost) is 2,562.8 MLKR (FC) and 1,458.1 MLKR (LC).

Table 3.2-4 Project Cost of Polpitiya - Habarana TL Reconstruction

Description	km	Unit Cost (MLKR)		Total Cost (MLKR)	
		FC	LC	FC	LC
1) 132 kV Polpitiya – Kiribathkumbura TL Zebra 2 cct. 52 km	52	52	16.18	841.12	438.92
2) 132 kV Kiribathkumbura – Ukuwela TL Zebra 2 cct. 30 km	30	16.18	8.44	485.26	253.23
3) Ukuwela –Habarana 132 kV TL Zebra 2 cct. 82 km	82	16.18	8.44	1,326.38	692.15
4) Removal of existing transmission line, Lynx 2 cct. 164 km	164	0.00	0.45	0.00	73.80
Total 1)～4)				2,652.76	1,458.10
Grand Total					4,110.86

(Source: CEB Transmission Planning)

(4) Effect of Transmission Line Loss Reduction

The Survey Team has calculated the losses on these transmission lines, disregarding system loss on both existing and planned lines with the conditions as shown in Table 3.2-5. Table 3.2-6 shows the result.

Table 3.2-5 Calculation Conditions

Description	ACSR Lynx	ACSR Zebra
Nos. of bundle/phase	1	1
Lynx's max. current at 54 °C	190 A	190 A
AC resistance	0.1793 Ω/km	0.0761 Ω/km
Load factors	55%	55%

(Prepared by the Survey Team)

Table 3.2-6 Effects of Transmission Line Loss Reduction

Description	Unit	ACSR Lynx	ACSR Zebra
Transmission line loss	MW/cct.	3.2	1.4
Amount of energy loss	MWh/yr･cct.	28,032	12,264
Energy loss savings	MWh/yr･2cct.	31,536	

(Prepared by the Survey Team)

The result shows that the line loss reduction ratio, which could be brought about by the reconstruction of the transmission line, will approximately be 44%.

3.2.3 Grid Substation Construction and Augmentation Project

The following four substation construction and augmentation sub-projects are compiled into one component project to further enhance the reliability of the network, as well as maximize the benefits from the projects based on the discussion with the CEB.

(A) Augmentation of Colombo A grid substation
(B) Construction of Kalutara 132/33 kV grid substation
(C) Augmentation of Madampe grid substation
(D) Installation of reactive power compensation devices

(A) Augmentation of Colombo A Grid Substation

(1) Objective

At present, Colombo A grid substation which is located in Havelock Town in Colombo City accommodates 2×31.5 MVA transformers. The objective of the project is to install a third additional transformer in the same substation premises to meet the rapidly increasing electricity demand in Colombo City. This project will contribute to improve and stabilize the power supply in Colombo City. The project is expected to be commissioned in 2014.

(2) Scope of the Project

- Installation of 1×31.5 MVA 132/11 kV main transformer
- Installation of one 132 kV single busbar GIS transformer bay
- Installation of one 11 kV GIS transformer bay

(3) Estimated Base Cost of the Project

Table 3.2-7 shows the project cost estimated by the Transmission Planning of CEB. The estimated total project cost (base cost) is 203.8 MLKR (FC) and 39.2 MLKR (LC).

Table 3.2-7 Project Cost for Augmentation of Colombo A GS

Description		Nos.	Unit Cost (MLKR)		Total Cost (MLKR)	
			FC	LC	FC	LC
1)	Transformers 132/11 kV/31.5 MVA & E. Tr	1	83.4	16.9	83.4	16.9
2)	132 kV S/B transformer bay (GIS)	1	51.9	1.2	51.9	1.2
3)	11 kV transformer bay (GIS)	1	15.0	0.3	15.0	0.3
4)	Common items for 132/11 kV grid (GIS)	1	35.2	20.6	35.2	20.6
5)	Substation Remote Control System	1	18.3	0.2	18.3	0.2
				Total 1)～5)	203.8	39.2
				Total (FC+LC)		243.0

(Source: CEB Transmission Planning)

(4) Effect of Loss Reduction

Even after outage of any of the transformers, a grid substation has to continue supplying power in order to meet the electricity demand while maintaining the busbar voltage levels at allowable range. The loading of all the remaining elements should not exceed their specified emergency ratings. Table 3.2-8 shows the demand forecast for Colombo A GS from 2011 to 2020.

Table 3.2-8 Demand Forecast for Colombo A GS

Capacity (MVA)		Forecast Loading (MVA)									
Present	Proposal	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2×31.5	3×31.5	27.7	28.6	29.6	31.3	32.5	35.1	36.9	38.2	40.2	41.7

(Source: CEB Transmission Planning)

As shown in the above demand forecast, during outage of one transformer in N–1 conditions, the other transformer is to be 103% overloaded in 2015. In 2016 and 2017, it will be overloaded up to 111% and 117%, respectively.

If Colombo A GS is to be augmented as proposed in 2014, the load of the other two transformers during outage of one transformer could be reduced up to 51.6% in 2015 and 55.7% in 2016. This will ensure the reliability and quality of power supply in Havelock town area in Colombo City. Considering all of the above facts, it is proposed to install an additional 31.5 MVA transformer at Colombo A GS.

From a loss reduction point of view, Table 3.2-9 shows the comparison of loss reduction ratios calculated by the Survey Team with the following conditions:

- Loading of each transformer: peak loading values of CEB data
- No-load loss of a typical transformer: 40.2 kW at 31.5 MVA base
- Load loss of a typical transformer: 157.0 kW at 31.5 MVA base
- Load factors: 55%
- Utilization factors: 95% for two sets and 75% for three sets

Table 3.2-9 Colombo A GS Transformer Loss Comparison

No.	Description	Condition	Years							Average
			2014	2015	2016	2017	2018	2019	2020	
	CEB Peak Demand Forecast (MVA)		31.3	32.5	35.1	36.9	38.2	40.2	41.7	
1	Two Transformers Loading	31.5MVA x 2 set (63.0 MVA)	49.68%	51.60%	55.70%	58.57%	60.63%	63.81%	66.19%	
		No-load loss (MWh/yr)	669.09	669.09	669.09	669.09	669.09	669.09	669.09	
		Load loss (MWh/yr)	373.42	402.81	469.36	518.98	556.12	615.99	662.80	
		Total Loss (MWh/year)	1,042.51	1,071.89	1,138.45	1,188.06	1,225.21	1,285.08	1,331.89	
2	Three Transformers Loading	31.5MVA x 3 set (94.5 MVA)	33.00%	34.00%	37.00%	39.00%	40.00%	42.50%	44.00%	
		No-load loss (MWh/yr)	792.34	792.34	792.34	792.34	792.34	792.34	792.34	
		Load loss (MWh/yr)	247.12	262.33	310.66	345.16	363.08	409.89	439.33	
		Total Loss (MWh/year)	1,039.47	1,054.67	1,103.01	1,137.50	1,155.43	1,202.23	1,231.67	
	No. 1 - No.2 Loss Capacity	MWh/Year	3.05	17.22	35.44	50.57	69.79	82.85	100.21	51.30
		%	0.29%	1.63%	3.21%	4.45%	6.04%	6.89%	8.14%	4.38%

(Prepared by the Survey Team)

Annual average loss reduction values were calculated at 51.3 MWh.

<u>(B) Construction of Kalutara 132/33 kV Grid Substation</u>

(1) Objective

At present in Kalutara area, there is no 132/33 kV grid substation that is located for power supply. Electric power to the area is being supplied from the nearest grid substations of Matugama and Panadura through long distance 33 kV distribution lines. Apparently, this long distance supply causes much distribution loss. This project is to construct a 132 kV grid substation with 2×31.5 MVA transformers and to connect the new transmission lines to the existing one. This new substation will highly contribute to network reliability as well as distribution loss reduction. The project is expected to be commissioned in 2014.

(2) Scope of the Project

1) Construction of Kalutara 132/33 kV grid substation
   - 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 busbar including bus section

2) Construction of interconnecting line
   - 132 kV single in and out connecting line from Pannipitiya–Matugama 132 kV transmission line (2 cct. 6 km, ACSR Zebra)

(3) Estimated Base Cost of the Project

Table 3.2-10 shows the project cost estimated by the Transmission Planning of CEB. The estimated total project cost (base cost) is 760.4 MLKR (FC) and 172.5 MLKR (LC).

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

Description	Nos.	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Construction of Kalutara 132/33 kV GS		FC	LC	FC	LC
Transformers/132/33 kV/ 31.5 MVA & E.Tr & Aux. Tr.	2	70.5	7.9	141.1	15.7
132 kV S/B transformer bay	2	25.1	4.0	50.2	8.0
132 kV line bay single bus bar	2	23.3	4.2	46.6	8.3
132 kV bus section bay inc. S/B	1	38.8	3.2	38.8	3.2
33 kV transformer bay	2	13.0	0.1	26.0	0.2
33 kV feeder bay	8	12.9	0.1	103.4	0.8
33 kV bus bay inc.BB	1	14.2	0.1	14.2	0.1
Common items for 2×31.5 kV	1	153.8	77.1	153.8	77.1
Substation automation	1	45.7	0.5	45.7	0.5
Spare parts (7 %)				43.4	8.0
			Total	663.3	121.9
2) Construction of interconnecting line	km				
132 kV, Zebra double 2 cct.	6	16.2	8.4	97.1	50.6
			Total 1)～2)	760.4	172.5
			Total (FC+LC)	932.9	

(Source: CEB Transmission Planning)

(4) Effect of Loss Reduction

Table 3.2-11 shows the demand forecast of Panadura and Matugama GSs without introducing Kalutara 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 seen from the load forecast, the loading of Panadura GS is expected to be 90% in 2014, which may increase up to 121% considering an outage of one of the transformers. Furthermore, it will be overloaded by the year 2016.

Table 3.2-11 Demand Forecast for Panadura and Matugama GSs

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)									
	Present	Proposed	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Panadura	2×31.5	1×31.5	76	77	81	85	89	94	99	104	109	115
Matugama	3×31.5	-	79	80	84	89	94	99	103	107	112	117

(Source: CEB Transmission Planning)

To share the growing demand of minimizing the distribution losses and to reduce loading of Panadura and Matugama GS, it is proposed to construct a new grid substation at Kalutara with two sets of 31.5 MVA transformers and eight 33 kV feeders. Table 3.2-12 shows the demand forecast with the proposed new Kalutara GS.

Table 3.2-12 Demand Forecast in Panadura, Matugama and Kalutara GSs

Grid Substations	Capacity (MVA)		Forecast Loading (MVA)								
	Present	Proposal	2011	2012	2013	2014	2015	2016	2017	2018	2019
Panadura	2×31.5	1×31.5	76	77	85	68	71	75	79	83	87
Matugama	3×31.5	-	79	80	89	70	73	77	80	83	87
Kalutara		2×31.5	-	-	-	37	39	41	43	46	48

(Source: CEB Transmission Planning)

Proposed Kalutara GS will also improve the voltage profile of 33 kV distribution system and reduce the distribution losses which thereby enhances the quality of supply in and around Kalutara areas. Kalutara GS is to be connected to the existing Pannipitiya – Matugama 132 kV transmission line.

From a loss reduction point of view, Table 3.2-13 shows the comparison of loss reduction ratios calculated by the Survey Team with the following conditions:

- Loading of each transformer: peak loading values of CEB data
- No-load loss of a typical transformer: 40.2 kW at 31.5 MVA base
- Load loss of a typical transformer: 157.0 kW at 31.5 MVA base
- Load factors: 55%
- Utilization factors: 85% for six sets and 75% for eight sets

Annual average loss reduction values were calculated at 944.8 MWh.

Table 3.2-13 Kalutara GS Transformer Loss Comparison

No.	Description	Condition	Years								Average
			2013	2014	2015	2016	2017	2018	2019	2020	
	CEB Peak Demand Forecast (MVA)		166.0	175.0	183.0	193.0	202.0	212.0	222.0	232.0	
1.	Six Transformer Loading	31.5MVA x 6 set (189 MVA)	87.83%	92.60%	96.83%	102.12%	106.90%	112.00%	117.50%	122.80%	
		No-load loss (MWh/yr)	1,795.98	1,795.98	1,795.98	1,795.98	1,795.98	1,795.98	1,795.98	1,795.98	
		Load loss (MWh/yr)	3,501.09	3,891.70	4,255.37	4,733.03	5,186.48	5,693.16	6,266.04	6,844.07	
		Total Loss (MWh/year)	5,297.07	5,687.68	6,051.35	6,529.01	6,982.46	7,489.14	8,062.02	8,640.05	
2.	Eight Transformers Loading	31.5MVA x 8 set (252 MVA)	65.87%	69.40%	72.60%	76.59%	80.16%	84.13%	88.10%	92.06%	
		No-load loss (MWh/yr)	2,112.91	2,112.91	2,112.91	2,112.91	2,112.91	2,112.91	2,112.91	2,112.91	
		Load loss (MWh/yr)	2,625.86	2,914.58	3,189.55	3,549.77	3,888.41	4,283.10	4,696.87	5,128.59	
		Total Loss (MWh/year)	4,738.77	5,027.49	5,302.46	5,662.68	6,001.32	6,396.01	6,809.78	7,241.51	
	No. 1 - No.2 Loss Capacity	MWh/Year	558.30	660.19	748.88	866.32	981.14	1,093.13	1,252.24	1,398.54	944.84
		%	11.78%	13.13%	14.12%	15.30%	16.35%	17.09%	18.39%	19.31%	15.68%

(Prepared by the Survey Team)

Moreover, the losses on 33 kV distribution lines from Panadura and Matugama, which supply electric power to Kalutara area, are also expected to be reduced in order to shift the lines to new Kalutara GS. Table 3.2-14 shows the calculation results of the expected loss reduction value taking into account the following conditions:

- Loads on the distribution line: 55% of peak demand
- Conductors: ACSR Lynx
- Numbers of distribution lines: 2-cct. from Panadura GS and 2-cct. from Matugama GS

After the extension operation, it attains an annual average loss reduction of 11,169 MWh.

Table 3.2-14 Kalutara GS Distribution Line Loss Comparison

Description	Distance (km)	Years								Ave.
		2013	2014	2015	2016	2017	2018	2019	2020	
Before Extension										
Existing Capacity (MVA)		13.13	13.88	14.63	15.38	16.13	16.13	18.00	18.75	
Capacity of 55% of Load Factor (MVA)		7.00	8.00	8.00	8.00	9.00	9.00	10.00	10.00	
DL Current (A)		122	140	140	140	157	157	175	175	
Panadura GS to Kalutara DL Loss (MW at 2 lines)	18.0	0.29	0.38	0.38	0.38	0.48	0.48	0.59	0.59	2.4
Annual DL Loss (MWh/Year)		2,540	3,329	3,329	3,329	4,205	4,205	5,168	5,168	3,909
Existing Capacity (MVA)		21.88	23.13	24.38	25.63	26.88	26.88	30.00	31.25	
Capacity of 55% of Demand Factor (MVA)		12.00	13.00	13.00	14.00	15.00	15.00	17.00	17.00	
DL Current (A)		210	227	227	245	262	262	297	297	
Matugama GS to Kalutara DL Loss (MW at 2 lines)	30.0	1.42	1.66	1.66	1.94	2.22	2.22	2.85	2.85	5.2
Annual DL Loss (MWh/Year)		12,439	14,542	14,542	16,994	19,447	19,447	24,966	24,966	18,418
Annual Loss Total (MWh/Year)		14,979	17,871	17,871	20,323	23,652	23,652	30,134	30,134	22,327
After Extension										
Extension Capacity (MVA)		13.13	13.88	14.63	15.38	16.13	16.13	18.00	18.75	
Capacity of 55% of Load Factor (MVA)		7.00	8.00	8.00	8.00	9.00	9.00	10.00	10.00	
Modification DL (A)		122	140	140	140	157	157	175	175	
North Side DL of Kalutara GS (MW at 2 lines)	9.0	0.14	0.19	0.19	0.19	0.24	0.24	0.30	0.30	1.2
Annual DL Loss (MWh/Year)		1,226	1,664	1,664	1,664	2,102	2,102	2,628	2,628	1,960
Extension Capacity (MVA)		21.88	23.13	24.38	25.63	26.88	26.88	30.00	31.25	
Capacity of 55% of Load Factor (MVA)		12.00	13.00	13.00	14.00	15.00	15.00	17.00	17.00	
Modification DL (A)		210	227	227	245	262	262	297	297	
South Side DL of Kalutara GS (MW at 2 lines)	15.0	0.71	0.83	0.83	0.97	1.11	1.11	1.42	1.42	2.6
Annual DL Loss (MWh/Year)		6,220	7,271	7,271	8,497	9,724	9,724	12,439	12,439	9,198
Annual Loss Total (MWh/Year)		7,446	8,935	8,935	10,161	11,826	11,826	15,067	15,067	11,158
Loss Reduction Value (MWh/Year)		7,533	8,936	8,936	10,162	11,826	11,826	15,067	15,067	11,169

(Prepared by the Survey Team)

(C) Augmentation of Madampe Grid Substation

(1) Objective

At present, Madampe GS has 2×31.5 MVA transformers. Since the loading in Madampe GS is increasing annually, the loading to Madampe GS will exceed the capacity of the existing transformers in the near future. To solve this and strengthen network reliability of this area, it is proposed that one additional transformer is to be installed in Madampe GS. In addition, it is a necessity to compensate the reactive power of the substation in the future, thus breaker switched capacitors are proposed to be installed at the 33 kV busbar. The project is expected to be commissioned in 2014.

(2) Scope of the Project

1) Augmentation of Madampe 132/33 kV grid substation
- 1×31.5 MVA 132/11 kV transformer
- 1×132 kV single busbar transformer bay
- 1×33 kV transformer bay
- 1×33 kV bus section bay including busbar
- 4×33 kV feeder bays

2) Installation of breaker switched capacitors
- 6×5 MVR breaker switched capacitors at 33 kV bus

(3) Estimated Base Cost of the Project

Table 3.2-15 shows the project cost estimated by the Transmission Planning of CEB. The estimated total project cost (base cost) is 318.8 MLKR (FC) and 56.4 MLKR (LC).

Table 3.2-15 Project Cost for Augmentation of Madampe GS

Description	Nos.	Unit Cost (MLKR)		Total Cost (MLKR)	
1) Augmentation of Madampe 132/33 kV GS		FC	LC	FC	LC
Transformers/132 kV/33 kV/31.5MVA & E.Tr & Aux. Tr.	1	70.5	7.9	70.5	7.9
132 kV S/B transformer bay	1	25.1	4.0	25.1	4.0
33 kV transformer bay	1	13.0	0.1	13.0	0.1
33 kV feeder bay	4	12.9	0.1	51.7	0.4
33 kV bus bay inc.BB	1	14.16	0.12	14.2	0.1
Common items	1	28.02	35.5	28.0	35.5
			Total	202.6	48.0
2) Installation of breaker switched capacitors	nos.				
6×5 MVR breaker switched capacitors at 33 kV bus	6	19.4	1.4	116.2	8.4
			Total 1)～2)	318.8	56.4
			Total (FC+LC)	375.2	

(Source: CEB Transmission Planning)

(4) Effect of loss reduction

Madampe GS mainly supplies electric power to Wennapuya, Chilaw and Kuliyapitiya area through 33 kV feeders. According to the study by CEB, the energy demand in Wennappuwa, Chilaw and Kuliyapitiya area are 122 GWh, 289 GWh and 178 GWh, respectively. Table 3.2-16 shows the demand forecast for Madampe GS in 2011 -2020.

Table 3.2-16 Demand Forecast for Madampe GS

Capacity (MVA)		Forecast Loading (MVA)									
Present	Proposal	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2×31.5	1×31.5	53.9	55.8	59.3	63.3	67.7	72.5	77.2	82.4	87.9	93.9

(Source: CEB Transmission Planning)

The loading ratio of the existing transformer capacity will rise up to 100% by 2014. The loading of the transformers could be reduced down to 67% in 2014 provided that Madampe GS is augmented as proposed in 2014. This will ensure the reliability and quality of the power supply in Wennappuwa, Chilaw and Kuliyapitiya areas. Considering all facts above, it is proposed to install an additional 31.5 MVA transformer to Madampe GS.

From a loss reduction point of view, Table 3.2-17 shows the comparison of loss reduction ratios calculated by the Survey Team with the following conditions:

- Loading of each transformer: peak loading values of CEB data
- No-load loss value of a typical transformer: 40.2 kW at 31.5 MVA base
- Load loss value of a typical transformer: 157.0 kW at 31.5 MVA base
- Load factors: 55%
- Utilization factors: 100% for two sets and 90% for three sets

Table 3.2-17 Madampe GS Transformer Loss Comparison

No.	Description	Condition	Years							Average
			2014	2015	2016	2017	2018	2019	2020	
	CEB Peak Demand Forecast (MVA)		63.3	67.7	72.5	77.2	82.4	87.9	93.9	
1.	Two Transformer Loading	31.5MVA x 2 set (63.0 MVA)	100.50%	107.46%	115.08%	122.50%	131.00%	139.50%	149.00%	
		No-load loss (MWh/yr)	704.30	704.30	704.30	704.30	704.30	704.30	704.30	
		Load loss (MWh/yr)	1,528.02	1,746.99	2,003.53	2,270.22	2,596.21	2,944.05	3,358.68	
		Total Loss (MWh/year)	2,232.32	2,451.29	2,707.84	2,974.53	3,300.51	3,648.35	4,062.99	
2.	Three Transformers Loading	31.5MVA x 3 set (94.5 MVA)	67.00%	71.60%	76.72%	81.69%	87.20%	93.02%	99.37%	
		No-load loss (MWh/yr)	950.81	950.81	950.81	950.81	950.81	950.81	950.81	
		Load loss (MWh/yr)	1,018.68	1,163.36	1,335.69	1,514.35	1,725.52	1,963.54	2,240.78	
		Total Loss (MWh/year)	1,969.49	2,114.17	2,286.50	2,465.16	2,676.33	2,914.35	3,191.59	
	No. 1 - No.2 Loss Capacity	MWh/Year	262.83	337.12	421.34	509.37	624.18	734.00	871.40	537.18
		%	13.35%	15.95%	18.43%	20.66%	23.32%	25.19%	27.30%	20.60%

(Prepared by the Survey Team)

Annual average loss reduction values were calculated at 537.2 MWh.

(D) Installation of Reactive Power Compensation Devices

(1) Objective

Based on demand forecast, it is expected that the reactive power, especially the lagging reactive power, is increasing along with the active power. This causes voltage drop which leads to transmission losses. There are two options to solve this situation which are as follows: 1) supply reactive power from power plants, and 2) install leading reactive power compensation devices in grid substations. This project aims to install compensation devices for leading reactive power in the pivotal GSs which have been selected based on the result of system analysis and demand forecast by CEB. The project is expected to be commissioned in 2014.

(2) Scope of the Project

1) Installation of 10×5 MVar breaker switched capacitors (BSC) at 33 kV busbar in Biyagama GS including BSC bays
2) Installation of 10×5 MVar BSCs at 33 kV busbar in Sapugaskanda GS including BSC bays
3) Installation of 6×5 MVar BSCs at 33 kV busbar in Chunnakam GS including BSC bays
4) Installation of 6×5 MVar BSCs at 33 kV busbar in Pannala GS including BSC bays
5) Installation of 6×5 MVar BSCs at 33 kV busbar in Bolawatta GS including BSC bays
6) Installation of 6×5 MVar BSCs at 33 kV busbar in Veyangoda GS including BSC bays
7) Installation of 6×5 MVar BSCs at 33 kV busbar in Kolonnawa-new GS including BSC bays
8) Installation of 6×5 MVar BSCs at 33 kV busbar in Kolonnawa-old GS including BSC bays

(3) Estimated Base Cost of the Project

Table 3.2-18 shows the project cost estimated by the Transmission Planning of CEB.

Table 3.2-18 Project Cost for Installation of Reactive Power Compensation Devices

Description	No.	Unit Cost (MLKR)		Total Cost (MLKR)	
		FC	LC	FC	LC
1) Installation 10 x 5 MVar BSC in Biyagama GS	10	19.4	1.4	193.6	14.0
2) Installation 10 x 5 MVar BSC in Sapugaskanda GS	10	19.4	1.4	193.6	14.0
3) Installation 6 x 5 MVar BSC in Chunnakam GS	6	19.4	1.4	116.2	8.4
4) Installation 6 x 5 MVar BSC in Pannala GS	6	19.4	1.4	116.2	8.4
5) Installation 6 x 5 MVar BSC in Bolawatta GS	6	19.4	1.4	116.2	8.4
6) Installation 6 x 5 MVar BSC in Veyangoda GS	6	19.4	1.4	116.2	8.4
7) Installation 6 x 5 MVar BSC in Kolonnawa-new GS	6	19.4	1.4	116.2	8.4
8) Installation 6 x 5 MVar BSC in Kolonnawa-old GS	6	19.4	1.4	116.2	8.4
Total 1) ～ 8)				1,084.4	78.4
Total (FC+LC)					1,162.8

(Source: CEB Transmission Planning)

(4) Effect of loss reduction

The Transmission Planning of CEB has carried out the reactive power forecast as shown in Table 3.2-19 based on the demand forecast and power flow analysis.

Table 3.2-19 Reactive Power Forecast

Grid Substations	Forecast Reactive Power(MVar)									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1) Biyagama	37.4	38.5	40.7	35.3	37.4	39.8	42.1	44.5	47.2	50.0
2) Sapugaskanda	35.4	37.0	38.7	40.9	43.2	45.8	48.2	50.9	53.7	56.7
3) Chunnakam		8.9	9.7	10.7	11.8	13.1	14.4	15.8	16.7	17.9
4) Pannala	25.5	24.3	25.9	27.7	29.7	31.8	34.0	36.3	38.8	41.6
5) Bolawatta	22.0	22.8	24.2	25.7	27.4	29.3	31.2	33.2	35.3	37.6
6) Veyangoda	24.0	24.8	26.1	27.7	29.3	31.2	33.0	34.9	37.0	39.2
7) Kolonnawa-New	20.7	21.1	22.0	23.5	24.7	26.1	27.7	29.0	30.5	32.1
8) Kolonnawa-Old	31.6	32.1	28.2	29.5	30.9	32.4	33.8	35.3	37.0	38.7

(Source: CEB Transmission Planning)

In the subject area, electricity demands are mostly for the lighting loads and it causes lagging reactive current which leads to transmission losses. To compensate these losses, the devices to supply leading reactive current are to be installed in the subject grid substations.

From a loss reduction point of view, the Survey Team has calculated the expected improvement values of reactive power in each grid substation with the following conditions as shown in Table 3.2-20:

- Reactive power capacities: peak reactive power values of CEB data
- Reactive capacity step: 1 MVar (1,000 kVar)

Table 3.2-20 Reactive Power Improvement Value

No.	Description	Conditions	Capa. (MVar)	Years							Average
				2014	2015	2016	2017	2018	2019	2020	
1.	Biyagama GS (120 MVA)	CEB Forecast Reactive Power		35.3	37.4	39.8	42.1	44.5	47.2	50.0	
		Capacitor Bank (5MVar x 10 @ 1MVar Step)	50.0	35.0	37.0	39.0	42.0	44.0	47.0	50.0	
		Improvement Capacity (MVar)		0.3	0.4	0.8	0.1	0.5	0.2	0.0	
		Before Improvement Capacity (MW)		114.7	114.0	113.2	112.4	111.4	110.3	109.1	
		After Improvement Capacity (MW)		120.0	120.0	120.0	120.0	120.0	120.0	120.0	
		Improvement rate (%)		4.60%	5.20%	6.00%	6.80%	7.70%	8.80%	10.00%	7.01%
2.	Sapugaskanda GS (121.5 MVA)	CEB Forecast Reactive Power		40.9	43.2	45.8	48.2	50.9	53.7	56.7	
		Capacitor Bank (5MVar x 10 @ 1MVar Step)	50.0	40.0	43.0	45.0	48.0	50.0	50.0	50.0	
		Improvement Capacity (MVar)		0.9	0.2	0.8	0.2	0.9	3.7	6.7	
		Before Improvement Capacity (MW)		114.4	113.6	112.5	111.5	110.3	109.0	107.5	
		After Improvement Capacity (MW)		121.5	121.5	121.5	121.5	121.5	121.4	121.3	
		Improvement rate (%)		6.20%	7.00%	8.00%	8.90%	10.10%	11.40%	12.90%	9.21%
3.	Chunnakam GS (63.0 MVA)	CEB Forecast Reactive Power		10.7	11.8	13.1	14.4	15.8	16.7	17.9	
		Capacitor Bank (5MVar x 6 @ 1MVar Step)	30.0	10.0	11.0	13.0	14.0	15.0	16.0	17.0	
		Improvement Capacity (MVar)		0.7	0.8	0.1	0.4	0.8	0.7	0.9	
		Before Improvement Capacity (MW)		62.1	61.9	61.6	61.3	61.0	60.8	60.4	
		After Improvement Capacity (MW)		63.0	63.0	63.0	63.0	63.0	63.0	63.0	
		Improvement rate (%)		1.50%	1.80%	2.20%	2.70%	3.30%	3.70%	4.30%	2.79%
4.	Pannala GS (94.5 MVA)	CEB Forecast Reactive Power		27.7	29.7	31.8	34.0	36.3	38.8	41.6	
		Capacitor Bank (5MVar x 6 @ 1MVar Step)	30.0	27.0	29.0	30.0	30.0	30.0	30.0	30.0	
		Improvement Capacity (MVar)		0.7	0.7	1.8	4.0	6.3	8.8	11.6	
		Before Improvement Capacity (MW)		90.4	89.7	89.0	88.2	87.3	86.2	84.9	
		After Improvement Capacity (MW)		94.5	94.5	94.5	94.4	94.3	94.1	93.8	
		Improvement rate (%)		4.60%	5.30%	6.20%	7.10%	8.10%	9.20%	10.50%	7.29%
5.	Bolawatta GS (94.5 MVA)	CEB Forecast Reactive Power		25.7	27.4	29.3	31.2	33.2	35.3	37.6	
		Capacitor Bank (5MVar x 6 @ 1MVar Step)	30.0	25.0	27.0	29.0	30.0	30.0	30.0	30.0	
		Improvement Capacity (MVar)		0.7	0.4	0.3	1.2	3.2	5.3	7.6	
		Before Improvement Capacity (MW)		90.9	90.4	89.8	89.2	88.5	87.7	86.7	
		After Improvement Capacity (MW)		94.5	94.5	94.5	94.5	94.5	94.4	94.2	
		Improvement rate (%)		3.90%	4.50%	5.20%	5.90%	6.70%	7.60%	8.60%	6.06%

No.	Description	Conditions	Capa. (MVar)	Years 2014	2015	2016	2017	2018	2019	2020	Average
6.	Veyangoda GS (94.5 MVA)	CEB Forecast Reactive Power		27.7	29.3	31.2	33.0	34.9	37.0	39.2	
		Capacitor Bank (5MVar x 6 @ 1MVar Step)	30.0	27.0	29.0	30.0	30.0	30.0	30.0	30.0	
		Improvement Capacity (MVar)		0.7	0.3	1.2	3.0	4.9	7.0	9.2	
		Before Improvement Capacity (MW)		90.4	89.8	89.2	88.6	87.8	87.0	86.0	
		After Improvement Capacity (MW)		94.5	94.5	94.5	94.5	94.4	94.2	94.1	
		Improvement rate (%)		4.60%	5.20%	5.90%	6.70%	7.50%	8.40%	9.40%	6.81%
7.	Kolonnawa-New GS (63.0 MVA)	CEB Forecast Reactive Power		23.5	24.7	26.1	27.7	29.0	30.5	32.1	
		Capacitor Bank (5MVar x 6 @ 1MVar Step)	30.0	23.0	24.0	26.0	27.0	29.0	30.0	30.0	
		Improvement Capacity (MVar)		0.5	0.7	0.1	0.7	0.0	0.5	2.1	
		Before Improvement Capacity (MW)		58.5	58.0	57.3	56.6	55.9	55.1	54.2	
		After Improvement Capacity (MW)		63.0	63.0	63.0	63.0	63.0	63.0	63.0	
		Improvement rate (%)		7.80%	8.70%	9.90%	11.30%	12.60%	14.30%	16.10%	11.53%
8.	Kolonnawa-Old GS (94.5 MVA)	CEB Forecast Reactive Power		29.5	30.9	32.4	33.8	35.3	37.0	38.7	
		Capacitor Bank (5MVar x 6 @ 1MVar Step)	30.0	29.0	30.0	30.0	30.0	30.0	30.0	30.0	
		Improvement Capacity (MVar)		0.5	0.9	2.4	3.8	5.3	7.0	8.7	
		Before Improvement Capacity (MW)		89.8	89.3	88.8	88.3	87.7	87.0	86.2	
		After Improvement Capacity (MW)		94.5	94.5	94.5	94.4	94.4	94.2	94.1	
		Improvement rate (%)		5.30%	5.80%	6.40%	7.00%	7.60%	8.40%	9.20%	7.10%

(Prepared by the Survey Team)

Based on the above reactive power capacity improvement values, the Survey Team has calculated the expected loss reduction values in each grid substation as shown in Table 3.2-21 with the following conditions:

- Peak losses: 'after improvement' - 'before improvement' from the values in Table 3.2-20
- Load factors (LF): 55%
- SC utilization factors (UF): 40%

Table 3.2-21 Loss Reduction Amounts in each Grid Substations

GSs	units	2014	2015	2016	2017	2018	2019	2020	Average
Biyagama GS									
Peak Loss	MW	5.31	5.98	6.79	7.63	8.56	9.67	10.91	7.83
55% LF & 40% SC UF	MW	1.17	1.31	1.49	1.68	1.88	2.13	2.40	1.72
Annual Loss Reduction	MWh/yr	10,249.20	11,475.60	13,052.40	14,716.80	16,468.80	18,658.80	21,024.00	15,092.23
Sapugaskanda GS									
Peak Loss	MW	7.09	7.94	8.96	9.97	11.17	12.45	13.86	10.21
55% LF & 40% SC UF	MW	1.56	1.75	1.97	2.19	2.46	2.74	3.05	2.25
Annual Loss Reduction	MWh/yr	13,665.60	15,330.00	17,257.20	19,184.40	21,549.60	24,002.40	26,718.00	19,672.46
Chunnakam GS									
Peak Loss	M	0.92	1.10	1.38	1.67	2.00	2.25	2.59	1.70
55% LF & 40% SC UF	MW	0.20	0.24	0.30	0.37	0.44	0.50	0.57	0.37
Annual Loss Reduction	MWh/yr	1,752.00	2,102.40	2,628.00	3,241.20	3,854.40	4,380.00	4,993.20	3,278.74
Pannala GS									
Peak Loss	MW	4.15	4.79	5.49	6.25	7.04	7.92	8.94	6.37
55% LF & 40% SC UF	MW	0.91	1.05	1.21	1.38	1.55	1.74	1.97	1.40
Annual Loss Reduction	MWh/yr	7,971.60	9,198.00	10,599.60	12,088.80	13,578.00	15,242.40	17,257.20	12,276.51
Bolawatta GS									
Peak Loss	MW	3.56	4.06	4.66	5.29	5.97	6.69	7.49	5.39
55% LF & 40% SC UF	MW	0.78	0.89	1.03	1.16	1.31	1.47	1.65	1.18
Annual Loss Reduction	MWh/yr	6,832.80	7,796.40	9,022.80	10,161.60	11,475.60	12,877.20	14,454.00	10,374.34
Veyangoda GS									
Peak Loss	kW	4.15	4.66	5.29	5.90	6.55	7.28	8.06	5.98
55% LF & 40% SC UF	kW	0.91	1.03	1.16	1.30	1.44	1.60	1.77	1.32
Annual Loss Reduction	MWh/yr	7,971.60	9,022.80	10,161.60	11,388.00	12,614.40	14,016.00	15,505.20	11,525.66
Kolonnawa-New GS									
Peak Loss	MW	4.55	5.04	5.66	6.42	7.07	7.88	8.75	6.48
55% LF & 40% SC UF	MW	1.00	1.11	1.25	1.41	1.56	1.73	1.93	1.43
Annual Loss Reduction	MWh/yr	8,760.00	9,723.60	10,950.00	12,351.60	13,665.60	15,154.80	16,906.80	12,501.77
Kolonnawa-Old GS									
Peak Loss	MW	4.72	5.19	5.70	6.17	6.69	7.28	7.89	6.23
55% LF & 40% SC UF	MW	1.04	1.14	1.25	1.36	1.47	1.60	1.74	1.37
Annual Loss Reduction	MWh/yr	9,110.40	9,986.40	10,950.00	11,913.60	12,877.20	14,016.00	15,242.40	12,013.71

(Prepared by the Survey Team)

3.3 Applicability of Japan's Technique

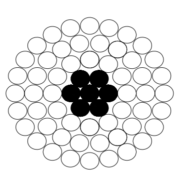
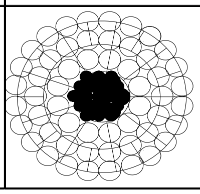
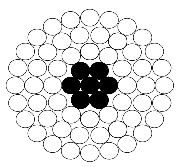
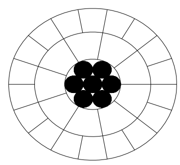
This section introduces applicable Japan's techniques for the candidate transmission projects.

3.3.1 Japan's Technique for Transmission Loss Reduction

As Japan's recommendable and applicable technique, it is proposed to apply the technique for conductors which have lower resistivity than normal ACSR conductors. 'LL-ACSR' conductors have the same outer shape as normal ACSR conductors, but its aluminum cross-sectional area is 20%–30% larger to reduce electric resistance. LL-ACSR/AS conductors contribute to transmission loss reduction especially in heavily loaded transmission lines.

Table 3.3-1 shows the specification comparison of ACSR, LL-ACSR/AS, TACSR/AS and LL-TACSR/AS conductors.

Table 3.3-1 Specifications Comparison of Conductors

Description		Unit	ACSR "Zebra"	LL-ACSR/AS 550mm2	TACSR/AS "Zebra"	LL-TACSR/AS 550mm2
Nominal Diameter		—	28.62	28.62	28.62	28.62
Cross Sectional Area	AL	mm2	428.9	550.4	428.9	550.4
	Core		55.59	40.08	55.59	40.08
	Total		484.5	590.5	484.5	590.5
Nominal Weight		kg/km	1,621	1,814	1,555	1,814
Ultimate Tensile Strength		kN	131.9	140.9	130.4	140.9
DC Resistant at 20℃		Ω/km	0.0674	0.0519	0.0857	0.0526
Max. Allowable Temperature		℃	90	90	150	150
Current(A)		68.15℃	—	762	—	757
		75℃	757	875	767	—
		90℃	930	1,077	—	—
		136.1℃	N/A	N/A	—	1,514
		150℃	N/A	N/A	1,423	1,622
Cross Section		—				

(Prepared by the Survey Team)

In order to further augment the transmission capacity with ACSR Zebra, it is recommended to apply LL-ACSR/AS (550 mm^2) or LL-TACSR/AS (550 mm^2) conductors for the new transmission line in terms of the following characteristics compared to ACSR Zebra:

1) Lower transmission loss due to reduction of conductor resistance
2) Same transmission current in 75 °C in lower temperature (68.15 °C)
3) Lower sag in same temperature use

In addition, as LL-TACR/AS conductors can flow current up to a thermal limit of 150 °C, a 2-

circuit transmission line with the conductors can easily satisfy N–1 condition by itself. For example, a 220 kV transmission line with LL-TACS/AS, 550 mm^2, double-bundled conductors can flow approximately 3,244 A (1,236 MVA) in one circuit at the maximum. Taking into account the reliability of the future network in Sri Lanka, in which many bulk coal thermal power plants are planned to be constructed in future, LL-TACSR/AS type of conductors is highly recommended rather than LL-ACSR/AS.

Therefore, the above mentioned Japan's loss reduction technique can be applied for the following candidate projects:

(1) New Habarana – Veyangoda Transmission Project

This project mainly consists of the construction of 220 kV transmission line, New Habarana SS, and augmentation of Veyangoda GS. Conductors for this transmission line is planned to apply a double-bundled ACSR Zebra with a 75 °C maximum operation temperature.

The maximum allowable current of ACSR Zebra at 75 °C is calculated as 649.5 A. Accordingly, 220 kV transmission capacities in MVA are calculated as approximately 247 MVA. Moreover, the total transmission line capacity of 2 × Zebra × 2 cct. is 988 MVA.

To justify an applicability of Japan's technique for the project, the following two scenarios are to be considered:

1) Scenario–1 (Justification without Trincomalee CPP)
Puttalam Coal Power Plant (CPP) will accommodate 3 × 300 MW generating capacity and supply the power through 220 kV transmission lines with 2 × AAAC 630 mm^2 conductors to New Chilaw GS and with AAAC 400 mm^2 conductors to New Anuradhapura GS.

After New Habarana - Veyangoda 220 kV transmission line is constructed, 220 kV transmission network can make a closed loop surrounding Colombo City. Even if an accident happens on the 220 kV transmission lines from New Chilaw to Colombo City, the generated power from Puttalam CPP could be sent to Colombo City through the new transmission line. Furthermore, there is a possibility of the addition of power flow coming from the hydropower stations in central province on the new line.

From these standpoints, New Habarana - Veyangoda 220 kV transmission line should have more capacity than the one in ACSR Zebra based on the present design.

2) Scenario–2 (Justification with Trincomalee CPP)
Trincomalee CPP which is to be constructed in the northeastern costal area is being planned to be implemented as follows:

Table 3.3-2 Development Schedule for Trincomalee CPP

	Commissioning Year	CPP Development
Stage–1	2017	2×250 MW
Stage–2	2019	1×250 MW
Stage–3	2020	1×250 MW
		Total: 1,000 MW

(Prepared by the Survey Team)

Trincomalee CPP will have 1,000 MW generating capacity in Stage–3 in 2020. Along with the development of the CPP, new 220 kV transmission line to New Habarana SS is to be constructed. It is confirmed that the number of circuits of the new transmission line is estimated to have an equivalent capacity as of the four circuits of ACSR Zebra. On the other hand, there is a plan to construct an additional of two circuits of transmission lines in the same route for the final capacity of Trincomalee CPP in Stage–3.

LL-TACSR/AS conductors should be applied for the New Habarana - Veyangoda 220 kV transmission line with the following reasons:

i) Sacrament of N–1 conditions
N–1 condition can be maintained for the power from Trincomalee CPP in one circuit of transmission line in the case of an accident in New Habarana - Veyangoda 220 kV transmission line.

ii) Minimization of construction cost of additional transmission lines
Compared with the construction cost of the additional two circuits of 220 kV transmission line, the construction cost of 220 kV transmission line with LL-TACSR/AS which can be used to supply the whole output of Trincomalee CPP is much cheaper.

iii) Minimization of negative effect on environmental and social aspects
Right of way can be reduced provided that the additional transmission line is not constructed.

iv) Easy maintainability
Maintenance cost can be diminished for one route of the transmission line.

For the application of LL-TACSR/AS conductors, to secure clearance for the sag at 150 °C operation, higher towers are necessary than when applying ACSR Zebra at 75 °C operation. However, it can be proposed to apply LL-TACSR/AS 550 mm^2 for the conductor of New Habarana - Veyangoda 220 kV TL considering the above mentioned strong points. By applying LL-TACSR/AS 550 mm^2, the transmission losses can be reduced as shown in Table 3.3-3 with the same calculation manner applied in Table 3.2-3.

Table 3.3-3 Amount of Loss Reduction of New Habarana - Veyangoda TL with Japan's technique

Description	Units	Stage 1 (500 MW)		Stage 2 (750 MW)		Stage 3 (1,000 MW)	
		2×ACSR Zebra	2×LL-TACSR/AS	2×ACSR Zebra	2×LL-TACSR/AS	2×ACSR Zebra	2×LL-TACSR/AS
Transmission line loss	MW/cct.	8.8	6.8	19.9	15.5	35.8	27.8
Annual energy loss	MWh/yr	84,797	65,525	191,756	149,358	344,969	267,881
Energy loss savings	MWh/yr	19,272		42,398		77,088	
Weighted average for 40 yrs	MWh/yr					73,330	

(Prepared by the Survey Team)

(2) Polpitiya - Habarana Transmission Line Reconstruction Project

This project is to reconstruct 132 kV transmission line from ACSR Lynx to ACSR Zebra. In the case that LL-ACSR/AS or LL-TACSR/AS conductor is applied for the new conductors, more power can be flown into the lines in the same towers and sag as towers for ACSR Zebra. The current carrying capacity of LL-ACSR 550 mm^2 is approximately 744 A at 75 °C against approximately 649 A in ACSR Zebra.

In parallel with this 132 kV transmission line, there is an existing 220 kV transmission line from Kotomale HPP to New Anuradhapura GS. Therefore, N–1 conditions may not be taken into consideration. This means that LL-ACSR/AS is already sufficient for the transmission line.

Therefore, it is proposed to apply LL-ACSR/AS 550 mm^2 for the conductor of Polpitiya - Habarana transmission line. Table 3.3-4 shows the result of the calculation, considering the current condition on ACSR Lynx with 190 A at 54 °C.

Table 3.3-4 Amount of Loss Reduction of Polpitiya-Habarana TL

	Unit	ACSR Lynx	ACSR Zebra	LL-ACSR/AS 550 mm^2
Transmission line losses	MW/cct.	3.2	1.4	1.1
Amount of Energy losses	MWh/yr・2 cct.	(1) 56,064	(2) 24,528	(3) 19,272
Energy Loss Reductions	MWh/yr・2 cct.		(1)-(2) 31,536	(2)-(3) 5,256 (1)-(3) 36,792

(Prepared by the Survey Team)

3.3.2 Japan's Technique for Substation Loss Reduction

Transformers with the latest technology such as 'top-runner transformers' which use amorphous cores can be regarded as Japan's recommendable technique, but at present, the top-runner transformers can be produced up to about 2 MVA scale in general.

As far as application of Japan's technique for transformers are concerned, a special method cannot be identified for the substation facilities. However in general, efficiency of the Japanese-made transformers is high enough for it to be recommended, irrespective of their higher cost compared to others. This is attained not because of a special technique, but due to a high quality management technique such as Total Quality Management (TQM). In this regard, the same performance can be attained in other industrial countries such as Europe and U.S. in terms of production value, provided that detailed specifications are prepared based on custom-made for manufacturers in advance.

The following tables show the Japanese-made transformers' superiority in efficiency as compared with other third world countries:

Table 3.3-5 Transformer Base Data

No.	Manufacture	Voltage (kV)	Capacity (MVA)	No-loss (kW)	Loss (kW)	Total Loss (kW)	Efficiency (%)
1	JAPAN	110	50	40	160	200	99.600
2	3rd Country-1	110	50	21.3	230.4	251.7	99.500
3	3rd Country-2	110	50	47.8	194	241.8	99.520

(Prepared by the Survey Team)

Note: Efficiency values are calculated using total loss data of each transformer.

Table 3.3-6 Transformer Efficiency Comparison

No.	Manufacture	Voltage (kV)	Capacity (MVA)	Efficiency (%)	Dayly Energy Loss (MWh)	Initial Cost (KLKR)	Yearly energy quantities (MWh/Year) & Electricity bill (Kiro Rupee[kSLR])					
							1st Year	5th Year	7th Year	10th Year	15th Year	20th Year
1	JAPAN	110	50	99.600	2.30 MWh	115,320	841	4,205	5,887	8,410	12,614	16,819
					39 KLKR		129,555	186,495	214,965	257,670	328,845	400,020
2	3rdCountry-1			99.500	2.88 MWh	89,834	1,051	5,256	7,358	10,512	15,768	21,024
					49 KLKR		107,719	179,259	215,029	268,684	358,109	447,534
3	3rdCountry-2			99.520	2.76 MWh	95,822	1,009	5,046	7,065	10,092	15,138	20,185
					47 KLKR		112,977	181,597	215,907	267,372	353,147	438,922
	Difference Value for Item No. "2" - No. "1"				0.58 MWh	25,486	210	1,051	1,471	2,102	3,154	4,205
					10 KLKR		-21,836	-7,236	64	11,014	29,264	47,514

(Prepared by the Survey Team)

Note: Loss values of power in each transformer are calculated by using 60 % of peak load and the values of efficiency of each transformer in Table 3.3-6.

The electricity bills are calculated at 1 kWh at 17 LKR.

As seen from the above tables, an initial transformer cost can be balanced in seven years.

CHAPTER 4
DISTRIBUTION LOSS REDUCTION PROJECT

CHAPTER 4 DISTRIBUTION LOSS REDUCTION PROJECTS

4.1 General

The Survey Team received the 'Proposal for Low Voltage Distribution Loss Reduction Project', which was prepared by the CEB Distribution Section and submitted from the MPE to the Department of External Resources (DER). The Survey Team also received the MV Development Plans for Regions -1, -2 and -4 prepared by each distribution region office. Regarding the MV Development Plan for Region-3, the plan was under preparation and the Survey Team has not received it during the first survey period.

In addition to the above plans, when the Survey Team visited the CEB's Local Area Offices, as a result of the discussion with the Deputy General Managers in each office, the Survey Team acknowledged the requirements of the Local Offices.

As a result of the discussion with the CEB based on the above mentioned proposals, plans and requirements, the Survey Team have nominated the following sub-projects considering the contribution to loss reduction:

1) New LV substation (LV scheme)
The density of consumers is very thin in Sri Lanka. Consequently, it makes LV lines longer and causes much distribution losses. It is very effective to provide additional LV substations for the reduction of distribution losses. The details regarding the location and quantity of LV substations shall be carefully studied and chosen. Basically, this activity shall be considered into the Distribution Loss Reduction Project.

2) Single phase to three phase conversion
When single phase circuit is converted to three phase circuit, the maximum distributed power can be 3 times than that of a single phase circuit, and the load current can be reduced to 1/3 times. Accordingly, it is obvious to reduce the resistive loss to 1/6 times considering three wires for the 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) Provision of energy meters
The distribution loss cannot be reduced to provide energy meters at the distribution substation, but it can increase an ability to measure the distribution loss. Energy metering gives the important information to evaluate distribution losses such as non-technical losses. Considering future data transmission, the interface to communication links such as GPRS, will be provided.

4) New 33/11 kV PS and reinforcement of distribution line

Construction of the new 33/11 kV PS and reinforcement of MV distribution lines, which can contribute to distribution loss reduction, are nominated from the several projects proposed in MV Development Plans. The major contribution is resistive loss reduction by reducing the load current through upgrading the voltage and rectification of overloading in order to balance the load current on each MV distribution line. As a supplemental effect, it is possible to improve the reliability of the distribution system to reduce overloading and blackout.

For the execution stage, they will be included in the scope of Transmission Department. The proposed projects and their specific contributions are shown in Table 4.1-1.

Table 4.1-1 Nominated Projects in MV Development Plans

Region	Area	Facility	Contribution to loss reduction
1	North Western	Kalpitiya New PS Koswadiya New PS Daluwa New PS	Distribution loss reduction by voltage upgrade
2	Western Province North	Kepungoda New PS Awarakotuwa New PS	Distribution loss reduction by voltage upgrade
		Re-conductoring of 33 kV lines from Pugoda gantry to Dekatana gantry Re-conductoring of 33 kV lines from Eriyagama gantry to Pichchamalawatta	Reduction of resistance by size up of power wires
4	Western Province South-1	Augmentation of Panadura PS	Rectification for overloading
		Kalutura New PS	Voltage upgrade
		Fullerton gantry to Kalutura PS	Size up of power wire

(Source: CEB MV Development Plans for Region-1, -2 and -4)

5) Distribution Automation System (DAS)

In the MV Development Plan and LV Proposal, any requirement and proposal of Distribution Automation System (DAS) is not described. However, when the Survey Team visited the CEB's local offices, the Survey Team found that they have just started with the development of DAS. Therefore, the Survey Team understood that the CEB has the latent requirement of DAS to control/manage their distribution system. The DAS is a convenient tool to control the load current in a distribution system to select the best operation of distribution system and minimize distribution losses. The DAS has an intelligent function in the system. For example, it is possible to know the current distribution losses, which are calculated from the energy meter data.

In addition, the DAS has several supplemental advantages as mentioned in the inception report such as labor saving, minimizing shut-down area, increasing reliability, automatic logging and reporting, etc.

On the other hand, the Survey Team has the subject to provide communication links between the remote terminals and control center. The CEB can use GPRS network for a very low cost at about 3 USD/month. Thus, communication links can be realized with the combination of the public telephone and GPRS networks.

To maximize the loss reduction effects, the sub-projects were mainly selected to collaborate with the transmission sub-projects mentioned in Chapter 3 which are located in the western, north west, central, and Sabaragamuwa provinces.

4.2 Candidate Projects

4.2.1 New LV Schemes

(1) Small Capacity Distribution Transformer Installation

1) Present situation for distribution transformer in overhead line

The distribution transformers (DT) step down the voltage from MV (33 or 11 kV) to LV (400 V). The DTs in overhead line systems are mounted type, which has either one pole or two poles. Pole-mounted DTs have a series of capacities such as 100 kVA, 160 kVA, 250 kVA and 400 kVA and more, with power fuses, lightning arrester and LV switch boards. LV lines from DT have lengths from several hundred meters to 1.8 km to the most distant consumer.

On the other hand, in Japan, the DTs are only one pole mounted type, have smaller capacity, mainly 10 kVA to 100 kVA, than Sri Lanka's, and the length of LV lines is shorter than that of the CEB.

2) Project scope of small DT installation

Installation of additional DTs (LV scheme) into the existing distribution network, for example it is installed between existing DTs, can reduce the lengths of LV lines from DTs to the last consumer. An example of this is installing it between existing DTs. Consequently, the losses of LV lines can be reduced.

The DTs of the CEB LV scheme have larger capacities than that of DTs used in Japan. Replacing the DT with a smaller capacity may cause much loss reduction.

The Survey Team considers the provision of LV scheme to the North Western Province (NWP) of Region-1, Western Province North (WPN) and Central Province (CP) of

Region-2, Western Province South-2 (WPS-2) and Sabaragamuwa of Region-3 and Western Province South-1 (WPS-1) of Region-4.

3) Loss evaluation

Preconditions for loss calculation of small DT installation are as follows:

i) 100 kVA DT is divided into two by the installation of two 50 kVA DT, 160 kVA DT is divided into three, and 250 kVA DT is divided into five.

ii) Iron losses and copper losses of DT are not considered in the loss calculation.

iii) Collected data will be used for the calculation as input values.

iv) These conditions are decided in consideration of the calculation of the average data and assuming the typical model.

The calculated amount of losses for one year is as follows:

Table 4.2-1 Loss Reduction by Small DT Installation

Before installation	After installation	Reduced losses
25.5 GWh/yr	11.3 GWh/yr	14.2 GWh/yr (-56%)

(Prepared by the Survey Team. For the details, please refer attached Table 4.2-1D.)

(2) DT Replacement

1) Present situation of the existing DTs

The DT has two types of losses, one is the no-load losses (iron loss) and another is the load loss (copper loss).

The objective of this measure is to reduce the technical losses by replacing the existing DTs which have large losses in both the no-load loss and the load loss. The Sri Lankan DT manufacturer has only one type of DT which is not a low loss type. Japanese DT manufacturers have very low loss type DTs that are called “Top Runner Transformers” which are manufactured according to the Japanese regulation on energy efficiency. Comparison of both types of transformers is shown below.

Table 4.2-2 Loss Data of Two Types of DTs

	Sri Lankan DT		Japanese DT (assumed)	
Voltage, Capacity	No Load loss (W)	Full Load loss (W)	No Load loss (W)	Full Load loss (W)
11 kV, 100 kVA	270	2,150	220	1,420
11 kV, 160 kVA	360	2,650	290	1,790
11 kV, 250 kVA	550	3,700	370	2,460
11 kV, 400 kVA	770	4,700	500	3,580
33 kV, 100 kVA	340	1,900	280	1,260
33 kV, 160 kVA	460	2,450	370	1,650
33 kV, 250 kVA	610	3,150	410	2,090
33 kV, 400 kVA	870	4,000	560	3,040

(Prepared by the Survey Team)

2) Loss reduction calculation for DT replacement

Preconditions for loss calculation of DT replacement are as follows:

i) The DTs with the same capacity such as 100 kVA, 160 kVA, 250 kVA, 400 kVA are replaced.

ii) The amount of loss for DT replacement is calculated by the difference of loss of Sri Lankan DT and Japanese DT and summation of load loss and no-load loss.

iii) The indexes necessary for the calculation are considered by the collected and assumed data.

The calculated amount of losses for one year is as follows.

Table 4.2-3 Amount of Loss Reduction in Case of DT Replacement

Before replacement	After replacement	Reduced losses
156.5 GWh/yr	109.0 GWh/yr	47.5 GWh/yr (-30%)

(Prepared by the Survey Team. For the details, please refer attached Table 4.2-3D.)

(3) Loss Reduction to Apply LV Scheme Proposed by the CEB

When new LV schemes are installed in MV system, the following losses are expected to be reduced. The conditions used in the calculation are as follows:

i) Typical LV line in the rural area is used for calculation.

ii) Peak load of DT is 80% and minimum load is 20% of DT rating capacity.

iii) After installation, load current will be half of the previous load current.

iv) After installation, length of LV line is half of the previous line length.

The average loss reduction is 14 MWh/yr per each LV scheme. Thus, the total amount of loss reduction is shown in Table 4.2-4 below.

Table 4.2-4 Amount of Loss Reduction of LV Scheme in Each Region/Province

Region	Area	Required Q'ty	Loss Reduction (MWh/yr)	Total Loss Reduction (MWh/yr)
Region 1	NWP	N/A	N/A	N/A
Region 2	WPN	40	14	560
	Central	400	14	5,600
Region 3	WPS-2	100	14	1,400
	Sabaragamuwa	125	14	1,750
Region 4	WPS-1	38	14	532
	Total		-	9,842

(Prepared by the Survey Team. For the details, please refer attached Table 4.2-4D.)

There are above mentioned three options to improve the distribution losses. Considering the necessary cost and time to realize each option, the 'LV scheme' in Item (3) above as proposed by the CEB is recommended.

(4) Project Cost

The cost was estimated as mentioned in the LV Proposal applying the CEB's standard unit prices. The unit price includes costs of 33 kV/LV transformer, 33 kV or 11 kV MV line, LV line and other material and installation work. The cost of the LV scheme is summarized in Table 4.2-5 below.

Table 4.2-5 Cost of LV Scheme and Installation

Region	Area	Required Q'ty	Unit Cost (MLKR)	Cost (MLKR)
Region 1	NWP	N/A	N/A	N/A
Region 2	WPN	40	4	160
	Central	400	4	1,600
Region 3	WPS-2	100	4	400
	Sabaragamuwa	125	4	500
Region 4	WPS-1	38	4	152
Total			-	2,812

(Prepared by the Survey Team based on the LV Proposal)

4.2.2 Single-Phase to Three-Phase Conversion

(1) Outline (Improvement of LV line phase unbalance)

1) Present Situation for LV Line System

In Sri Lanka, three-phase four-wire system is adopted for LV lines, but many single-phase two-wire systems still remain in the rural areas. The conversions from single-phase to three-phase are being carried out one by one at the present, consequently it may take much time to convert a single-phase line into a three-phase line.

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

It is possible to reduce the losses to 1/6 as mentioned in Clause 4.1 by converting the existing single-phase lines to three-phase lines. The Survey Team assumes that this measure is to be adopted in NWP of Region-1, WPN and CP of Region-2, WPS-2 and Sabaragamuwa of Region-3 and WPS-1of Region-4.

(2) Loss Reduction Calculation

Preconditions for loss calculation of the conversion are as follows:

1) The DTs with each capacity are the subject of this project.
2) The amount of loss for the conversion is calculated by the difference of loss before and after the conversion.
3) Collected data will be used for calculation as input values.
4) These conditions are decided in consideration of calculation of the average data and assuming the typical model.

The calculated amount of reduced losses for one year is as follows.

Table 4.2-6 Amount of Loss Reduction of Three-phase Conversion

Before conversion	After conversion	Reduced losses
10.187 GWh/year	1.684 GWh/year	8.503 GWh/year

(Prepared by the Survey Team. For the details, please refer attached Table 4.2-6D.)

Note: The above values are for modified feeders only.

(3) Project Cost

As the CEB proposed in the LV Proposal, the following cost is estimated with standard unit prices of the CEB. The unit prices include the costs of conductors, insulators, poles and installation work.

Table 4.2-7 Cost of Three Phase Conversion

Region	Area	Required Q'ty	Unit Cost (MLKR)	Cost (MLKR)
Region 1	NWP	1,000 km	0.5	500
Region 2	WPN	100 km	0.5	50
	Central	1,000 km	0.5	500
Region 3	WPS-2	700 km	0.5	350
	Sabaragamuwa	700 km	0.5	350
Region 4	WPS-1	N/A	N/A	N/A
	Total	3,500 km	-	1,750

(Prepared by the Survey Team based on the LV Proposal)

4.2.3 Provision of Energy Meters and Remote Data Transmission

(1) Outline

The existing mechanical energy meter on site and electronic energy meter (current type) are shown in the following photographs for reference.

According to the CEB proposal in LV Proposal, only a provision of energy meters is proposed. Considering future data transmission to the Control Center, the communication interface should be included.

Typical specifications of energy meters, which is used in the CCEDD Project, is shown in Table 4.2-8.

Table 4.2-8 Typical Specifications of Energy Meter (type Alpha A1500)

- wide voltage range power supply
- same meter can be used at all voltage levels
- one meter for 3-wire and 4-wireapplications
- high accuracy and stability
- display according to the VDEW specification
- Efficient certification mode reduction of the test and certification time
- 4-quadrant measurement (+P,-P, +Q, -Q, Q1..Q4)
- 4 energy and 4 demand tariffs, independently controllable
- measurement of active, reactive and apparent demand
- integrated tariff clock (option)
- integrated ripple control receiver(option)
- time back-up with internal super-capacitor or battery
- time synchronization by connection of a DCF77 antenna
- log file for registration of all events with time stamps
- registration of instrumentation values
- settable service list
- improved load profile storage ability
  - 13 months of 15 minute intervals
  - selectable up to 8 channels
  - different storage modes (demand, energy/interval, register data)
  - load profile for pulse inputs
- readout of load profile data according to VDEW specification by use the EN62056-21 protocol
- 4 control inputs
- 6 electronic pulse/control outputs
- 1 mechanical relay output (option)
- auxiliary power supply (option)
- up to 4 pulse inputs (option)
- user friendly reading, setting and programming tool

(Prepared by the Survey Team)

The General Packet Radio Service (GPRS), which the CEB considers to apply to communication links, will be used for data transmission. Energy meters which provide interface to the GPRS are to be selected. If the GPRS cannot be used at some locations, operators have to visit the energy meters periodically to read and collect data.

(2) Contribution to Distribution Loss Reduction

Generally, energy meters cannot reduce the distribution losses directory, but they are very effective tools to measure energy losses on LV lines. It offers the following advantage for the energy management:

1) Possible to grasp the energy on LV line exactly
It is possible to know the current energy on LV lines. Consequently, it is possible to grasp the non-technical and technical losses.

2) Real time reading of energy meter (in future)
Providing communication, it is possible to sent real time reading of energy meter to the control center.

3) Improve of accuracy of energy meter
The accuracy of the latest electronic energy meter is class 1.0. Accurate measurement can be possible for every metering.

4) Memory of past reading
It is possible to memorize the past reading of energy meter for one month.

(3) Project Cost

The costs of energy meters, boxes and installation work are included in the Proposal of LV Distribution Loss Reduction Project; however, the cost of data transmission devices is not included.

Table 4.2-9 Cost of Energy Meter and Installation

Region	Area	Required Q'ty	Unit Cost (KLKR)	Cost (KLKR)
Region 1	NWP	250	62.8	15,700
Region 2	WPN	125	62.8	7,850
	Central	125	62.8	7,850
Region 3	WPS-2	125	62.8	7,850
	Sabaragamuwa	125	62.8	7,850
Region 4	WPS-1	700	62.8	43,960
	Total	1,450	-	91,060

(Prepared by the Survey Team based on the LV Proposal)

Note: Unit cost of energy meter includes programmable meter with communication interface, CT, enclosure and installation cost.

4.2.4 Provision of New PS and Reinforcement of Distribution Line

(1) Outline of Project

Upgrade of system voltage is one of the effective measures to reduce the distribution losses. If the system voltage is upgraded, it is possible to reduce the load currents on the distribution lines, hence resistive losses on the line are to be reduced as a result. And sizing up 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 associated a new 33 kV distribution line.

(2) Loss Evaluation

The Survey Team evaluates the losses with the following simplified method in this report:

a) If the new PS is provided, the reduced 11 kV line length is equal to the length of 33 kV line. The difference of losses is calculated before and after the new PS is in operation. Typical load pattern is applied to load current on 11/33 kV lines.

b) If an 11 kV line is upgraded to 33 kV, the difference of losses is calculated when the load current with a typical load pattern may flow on the 33/11 kV lines.

Table 4.2-10 shows the calculated reduced losses.

Table 4.2-10 Reduced Losses in Each Project

Region	Area	Project	Reduced Losses (MWh/yr)
1	North Western Province	Kalpitiya New PS	192
		Koswadiya New PS	192
2	Western Province North	Keoungoda New PS	153
		Awarakotuwa New PS	61
		Pugoda Gabtry to Dekatana Gantry	796
		Eriyagama gantry to Pichcha-malawatta	919
4	Western Province South-1	Augmentation of Panadura PS	306
		Kalutura New PS	77
		Fullerton gantry to Kalutura PS	5
		Total Loss Reduction	2,701

(Prepared by the Survey Team. For the details, please refer attached Table 4.2-3D.)

(3) Project Cost

The costs of PSs and new distribution lines are estimated based on the standard unit prices of the CEB as shown in Table 4.2-11.

Table 4.2-11 Nominated Projects and Costs

Region	Area	Project	Estimated Cost (MLKR)
1	North Western	Kalpitiya New PS	75
		Koswadiya New PS	75
2	Western Province North	Keoungoda New PS	75
		Awarakotuwa New PS	175
		Pugoda Gabtry to Dekatana Gantry	59
		Eriyagama gantry to Pichcha-Malawatta	180
4	Western Province South-1	Augmentation of Panadura PS	150
		Kalutura New PS	175
		Fullerton gantry to Kalutura PS	11
		Total cost	975

(Prepared by the Survey Team based on the CEB's MV Development Plans)

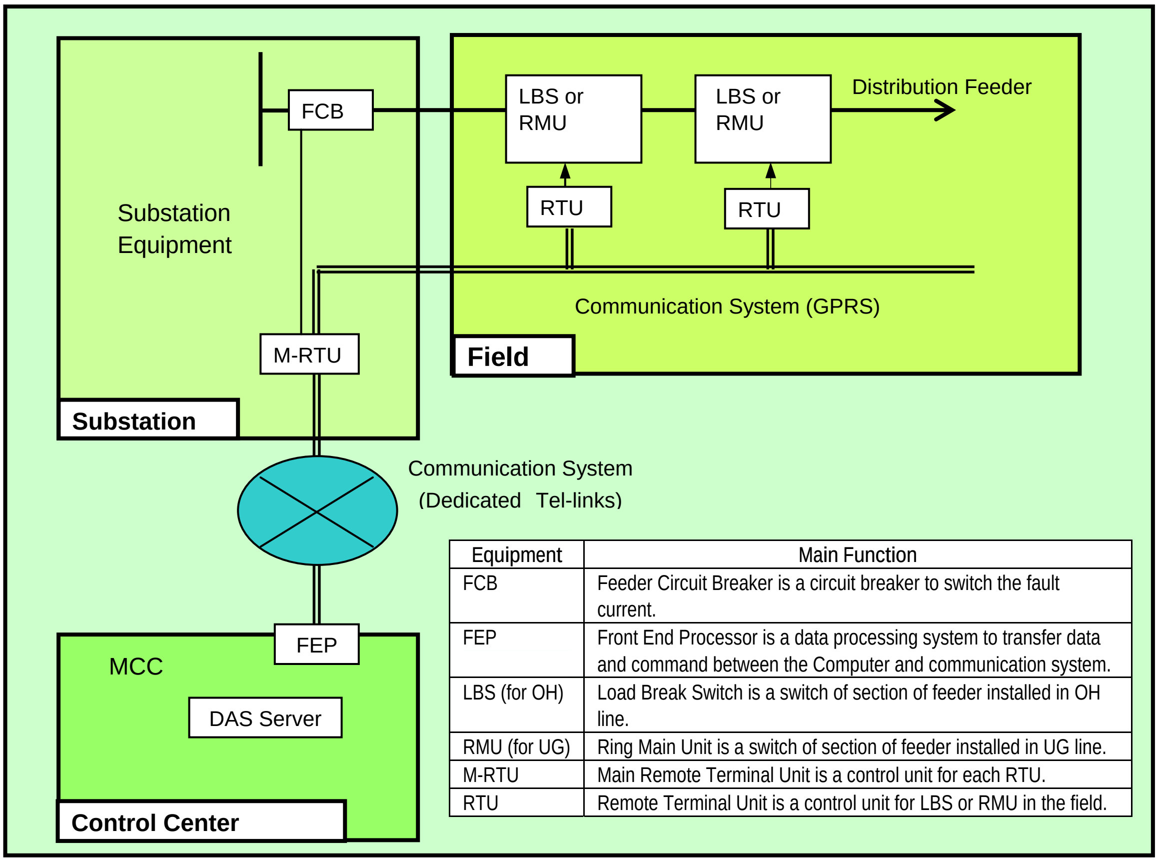
4.2.5 Provision of DAS for Optimum Operation and Loss Reduction

(1) Outline of Project

The DAS is very useful to control and manage the distribution system. It was proposed to provide DAS in the central province of Region-2 in the discussion with the CEB. In view of loss reduction and automation of distribution system, the Survey Team nominated this project, but the subject to be solved is the communication links between the central unit and remote terminal unit (RTU). For this subject, the CEB proposed to use dedicated public telephone communication links for important substation and GPRS for Load Break Switches (LBSs) at the distribution substation. The CEB is developing the GPRS to use communication between the center unit and RTU. They provide firewall and separated Local Area Network (LAN) like virtual LAN in GPRS.

The GPRS is very useful communication link, but its speed and security sometimes become a problem. On the other hand, the acceleration of communication speed and firewall may solve the problems. Central units, RTUs, associated intelligent software and switchgear such as LBSs are to be included in this project.

The necessary components and configuration are shown in Figure 4.2-1.



Equipment	Main Function
FCB	Feeder Circuit Breaker is a circuit breaker to switch the fault current.
FEP	Front End Processor is a data processing system to transfer data and command between the Computer and communication system.
LBS (for OH)	Load Break Switch is a switch of section of feeder installed in OH line.
RMU (for UG)	Ring Main Unit is a switch of section of feeder installed in UG line.
M-RTU	Main Remote Terminal Unit is a control unit for each RTU.
RTU	Remote Terminal Unit is a control unit for LBS or RMU in the field.

(Prepared by the Survey Team)

Figure 4.2-1 Basic Configuration of DAS

In order to draw the maximum ability in DAS, the distribution system is recommended to provide the following features:

1) Multiple divisions and multiple interconnections will be the standard.
2) It will be considered to switch-over LBSs to minimize the shut down at the time of a fault on a line.
3) In order to minimize the shut-down section, distribution lines will be inter-connected as much as possible.
4) Automatic reclosing system will be provided to isolate and minimize the shut-down section.

(2) Loss Evaluation

Detailed loss evaluation of DAS is to be done in quantifiable benefit after detailed information of the distribution system is available. Here, only unquantifiable evaluation of loss reduction will be highlighted.

1) Rapid switching is available to even the load on distribution lines to suppress the losses.
2) The facilities such as capacitor bank can be switched on rapidly when it is necessary to operate and suppress the losses.
3) If voltage drop is caused in the distribution system, the soonest action can be available to compensate the voltage drop.

As supplemental benefits for DAS, the following unquantifiable benefits may be obtained:

1) Shorten the blackout time
2) Saving manpower
3) Automatic event and disturbance log and report
4) Safety for operator by remote operation

(3) System Software and Design

The CEB decided to use a unique software to implement DAS in all provinces. Accordingly, the development of application software and the design of hardware will be carried out by the CEB, and other equipment facilities will be supplied as loose. Considering difficulties to design the application software and to realize the necessary functions in view of hardware and software for DAS, the Survey Team does not deny the intention of the CEB, however the Survey Team recommends supplying DAS as a total system supplied in Colombo City. It is recommended to proceed with the development considering quality control of the product in both the software and hardware. Especially the risk of a latent defect, EMC/EMI, the safety of system and the security of GPRS communication shall be carefully studied.

(4) Project Cost

The proposed system is combined with the overhead distribution line and underground cable system which is an identical DAS of CCEDD Project. The expected cost of DAS is shown in Table 4.2-12.

Table 4.2-12 Expected Cost of DAS for Central Province

No.	Description of items	Quantity	Unit Cost (MLKR)	Total Cost (MLKR)
1	Auto-reclose unit with remote operable facility	65 pcs.	1.8	117
2	Local breaker switches/sectionalizers with remote operable	125 pcs.	1.6	200
3	Sectioanlizers with remote monitoring facility(sets)	250 pcs.	0.5	125
4	Fault Indicators with remote monitoring facility(sets)	400 pcs.	0.1	40
5	Energy meters with remote monitoring facility	125 pcs.	0.08	10
6	Installation of SF6 ring main unit with remote operable facility	20 sets	1.8	36
7	Installation of 33kV UG or overhead insulated cable between Pogolla PSS to Bogambara PSS	10 km	20	200
8	Installation of 33 kV UG or overhead insulated cable between Bogambara PSS to Gatambe PSS	10 km	20	200
9	Installation of new Wattaranthenna PSS	2x5 MVA PSS	175	175
10	33 kV transmission line to nearest junction point	1.5 km	14	21
11	Capacity building for engineer in Region-2	1	22	22
			Total Cost	1,146

(Prepared by the Survey Team)

Note: Item Nos. 7, 8, 9 and10 is necessary for DAS to change over the lines.

4.3 Applicability of Japan’s Technique

As well known in Japan, Japanese manufacturers have developed a new low-loss type transformer called “Top Runner Transformer” which offers very low load loss and no-load loss in its operation. The transformers have been manufactured according to the severe requirement by the laws and regulations. However, there is no such requirement in Sri Lankan laws and regulations. It is obvious that Japanese transformers have smaller no-load and load losses than that of transformer manufactured in Sri Lanka. If these techniques are to be introduced to Sri Lanka, it is possible to reduce much loss in the distribution system as the Survey Team studied.

On the other hand, the Survey Team has felt difficulty to use the Top Runner Transformer in Sri Lanka, because it is manufactured according to the different standard and difference in primary voltage. If Japanese manufacturers can produce the transformer with the specification of a Top Runner Transformer in Japan with an economical price according to the standard used in Sri Lanka, it is possible to reduce the distribution losses remarkably.

Japanese DAS is a sophisticated computer-aided control system, which Japanese electric power companies introduced more than 30 years ago. It is possible to introduce this Japanese technique to the planned DAS to be developed by the CEB. However, the CEB aims to develop the application software by themselves, so the Survey Team considers that introducing the complete Japanese DAS to the CEB is difficult. Japanese manufacturers may take some part of the development of application software if they agree. In addition, successful bidder of the DAS under the CCEDD project was a European manufacturer, which proposed more competitive quotation than that of Japanese manufacturers.

In addition, hardware such as LBS and re-closers of Japanese manufacturers are not competitive compared to the products of European and Australian manufacturers.

Table 4.2-1D Loss Reduction by Small DT Installation

	Power factor	Demand rate	Rated voltage (V)	Resistance rate (Ω/m)	Loss factor	Candidate area rate*
parameter	0.800	0.650	0.400	0.271	0.484	0.57

* Candidate area rate = Total power demand of Candidate area(1,173MW) / Total power demand over all area(2068MW)

(1) 33 kV line

1) 100 kVA

	DT capacity (kVA)	Outgoing peak current (A)	Power losses (kW)/DT Length of LV line (m) 225	Power losses (kW)/DT Length of LV line (m) 115	Number of DT/feeder of SS assumed)	Power loss (kW)/feeder of SS
Before	100	117	0.42		46	19
After	50	59		0.11	95	10

*100 is divided into two with 50

*Length of LV line is longest one in voltage appropriate range

2) 160 kVA

	DT capacity (kVA)	Outgoing peak current (A)	Power losses (kW)/DT Length of LV line (m) 140	Power losses (kW)/DT Length of LV line (m) 50	Number of DT/feeder of SS assumed)	Power loss (kW)/feeder of SS
Before	160	188	0.67		19	13
After	50	59		0.07	62	4

*160 is divided into three with 50

3) 250 kVA

	DT capacity (kVA)	Outgoing peak current (A)	Power losses (kW)/DT Length of LV line (m) 85	Power losses (kW)/DT Length of LV line (m) 30	Number of DT/feeder of SS assumed)	Power loss (kW)/feeder of SS
Before	250	293	0.50		9	4
After	50	59		0.04	43	2

*250 is divided into five with 50

4) Subtotal

	Total power loss (kW)/feeder of SS	Total number of feeder of SS (assumed)	Total power loss (kW)	Total energy loss (GWh/year)
Before	36	155	5,647	23.9
After	16	155	2,529	10.7

(2) 11 kV line

1) 100 kVA

	DT capacity(kVA)	Outgoing peak current(A)	Power losses(kW)/DT Length of LV line(m) 225	Power losses(kW)/DT Length of LV line(m) 115	Number of DT/feeder of SS(assumed)	Power loss(kW)/feeder of SS
Before	100	117	0.42		13	5
After	50	59		0.11	27	3

2) 160 kVA

	DT capacity(kVA)	Outgoing peak current(A)	Power losses(kW)/DT Length of LV line(m) 140	Power losses(kW)/DT Length of LV line(m) 50	Number of DT/feeder of SS(assumed)	Power loss(kW)/feeder of SS
Before	160	188	0.67		6	4
After	50	59		0.07	17	1

3) 250 kVA

	DT capacity(kVA)	Outgoing peak current(A)	Power losses(kW)/DT Length of LV line(m) 85	Power losses(kW)/DT Length of LV line(m) 30	Number of DT/feeder of SS(assumed)	Power loss(kW)/feeder of SS
Before	250	293	0.50		2	1
After	50	59		0.04	12	1

4) Subtotal

	Total power loss (kW)/feeder of SS	Total number of feeder of SS (assumed)	Total power loss (kW)	Total energy loss (GWh/year)
Before	10	476	4,973	21.1
After	5	476	2,182	9.3

(3) Total

	Sum of total loss overall area (GWh/year)	Sum of total loss of candidate area (GWh/year)*	Loss reduction (GWh/year)
Before	45.0	25.5	14.2
After	20.0	11.3	

*Sum of total power loss of candidate area(GWh/year) = Sum of total power loss over all area * Candidate area rate

Table 4.2-3D Amount of Loss Reduction in Case of DT Replacement

	Loss factor	Candidate area rate*
parameter	0.484	0.57

* Candidate area rate = Total power demand of Candidate area(1,173MW)/ Total power demand over all area (2,068 MW)

(1) 33 kV line

1) Existing DT (Sri Lankan)

Capacity (kVA)	No Load loss/DT (W)	Full Load loss/DT (W)	No Load loss/DT (kWh)	Full Load loss/DT (kWh)	Number of DT/feeder (assumed)	No Load loss/feeder (MWh)	Full Load loss/feeder (MWh)	Loss/feeder (MWh)	Total number of feeder of SS (assumed)	Total loss (GWh/year)
100	340	1,900	2,978	8,056	42	125	338	463	155	71.8
160	460	2,450	4,030	10,388	19	77	197	274		42.5
250	610	3,150	5,344	13,356	9	48	120	168		26.1
400	870	4,000	7,621	16,960	1	8	17	25		3.8
									Subtotal	144.2

2) Top Runner DT (Japanese)

Capacity (kVA)	No Load loss/DT (W)	Full Load loss/DT (W)	No Load loss/DT (kWh)	Full Load loss/DT (kWh)	Number of DT/feeder (assumed)	No Load loss/feeder (MWh)	Full Load loss/feeder (MWh)	Loss/feeder (MWh)	Total number of feeder of SS (assumed)	Total loss (GWh/year)
100	280	1,260	2,453	5,342	42	103	224	327	155	50.7
160	370	1,650	3,241	6,996	19	62	133	195		30.1
250	410	2,090	3,592	8,861	9	32	80	112		17.4
400	560	3,040	4,906	12,889	1	5	13	18		2.8
									Subtotal	101.0

(2) 11 kV line

1) Existing DT (Sri Lankan)

Capacity (kVA)	No Load loss/DT (W)	Full Load loss/DT (W)	No Load loss/DT (kWh)	Full Load loss/DT (kWh)	Number of DT/feeder (assumed)	No Load loss/feeder (MWh)	Full Load loss/feeder (MWh)	Loss/feeder (MWh)	Total number of feeder of SS (assumed)	Total loss (GWh/year)
100	270	2150	2,365	9,116	13	31	119	149	476	71.0
160	360	2650	3,154	11,236	6	19	67	86		41.1
250	550	3700	4,818	15,688	2	10	31	41		19.5
400	770	4700	6,745	19,928	0	0	0	0		0.0
									Subtotal	131.7

2) Top Runner DT (Japanese)

Capacity (kVA)	No Load loss/DT (W)	Full Load loss/DT (W)	No Load loss/DT (kWh)	Full Load loss/DT (kWh)	Number of DT/feeder (assumed)	No Load loss/feeder (MWh)	Full Load loss/feeder (MWh)	Loss/feeder (MWh)	Total number of feeder of SS (assumed)	Total loss (GWh/year)
100	220	1,420	1,927	6,021	13	25	78	103	476	49.2
160	290	1,790	2,540	7,589	6	15	46	61		28.9
250	370	2,460	3,241	10,430	2	6	21	27		13.0
400	500	3,580	4,380	15,179	0	0	0	0		0.0
									Subtotal	91.1

(3) Total

DT	Sum of total power loss over all area (GWh/year)	Sum of total power loss of candidate area (GWh/year)*	Loss reduction (GWh/year)
Existing DT (Sri Lankan)	275.8	156.5	47.5
Top Runner DT	192.2	109.0	

*Sum of total power loss of candidate area(GWh/year) = Sum of total power loss over all area * Candidate area rate

Table 4.2-4D Loss Reduction of LV Scheme

Transf. Capacity (kVA)	Lengths of LV line (km)	Max. Load (%)	Duration Max load (h)	Min. Load (%)	Duration Min load (h)	Nos of LV Feeders	Rated Voltage (V)
160	2.0	80%	4	20%	20	5	400

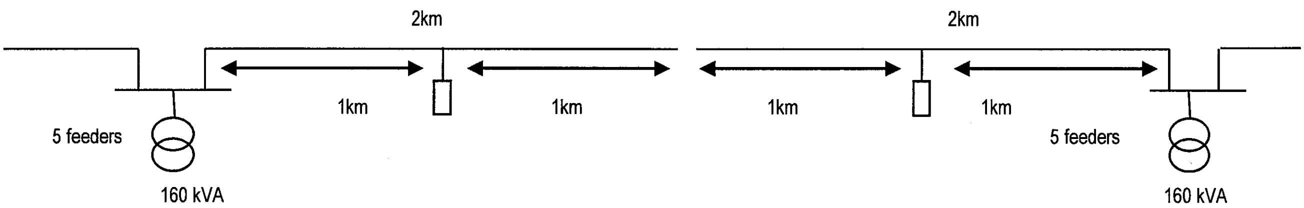
Load perttern ai considered as follows.
-80% for 1h in the morning (7:00 to 8:00)
-80% for 3 hour in the evening (6:00 to 9:00)
-20% for other time

① Min. Load current per feeder before installation (A)	② Max. Load current per feeder before installation (A)	③ Min. Load current per feeder after installation (A)	④ Max. Load current per feeder after installation (A)	Lengths of LV line after installation (km)	Resistance of power wire (ohm)	⑤ Loss before installation during min load (Wh/day)	⑥ Loss before installation during max load (Wh/day)	⑦ Loss after installation during min load (Wh/day)	⑧ Loss after installation during max load (Wh/day)	Loss reduction per day (Wh)	Loss reduction per year (MWh)
9.24	36.95	4.62	18.48	1.8	0.45	11,763.89	37,644.45	2,603.67	8,331.75	38,472.91	14.04

①Load current is calculated during min load(20%) brfore installation.
②Load current is calculated during max. load(80%) before installation.
③Load current is calculated during min load(20%) after installation.
④Load current is calculated during max. load(80%) after installation.

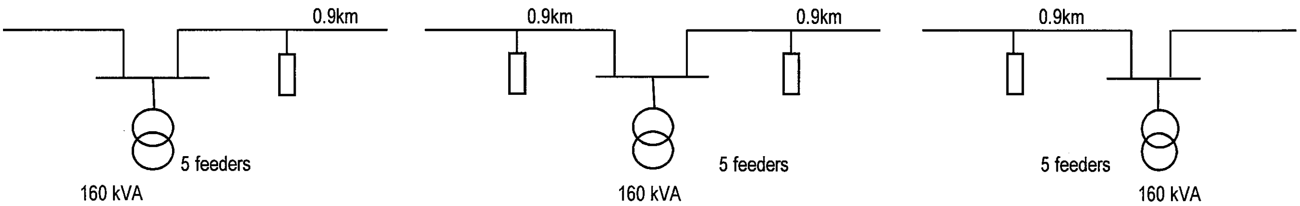
⑤Loss on LV line during min. load current per day before installation for 20 hours
⑥Loss on LV line during max. load current per day before installation for 4 hours
⑦Loss on LV line during min. load current per day after installation for 20 hours
⑧Loss on LV line during max. load current per day after installation for 4 hours

Before Installation



Note: Loss on distribution line is calculated when concentrated load on the center of LV line.

After Installation



Note: Loss on distribution line is calculated when concentrated load on the center of LV line.

Table 4.2-6D Loss Reduction of 3 Phase Conversion

Transf. Capacity (kVA)	Lengths of LV line	Max. Load (%)	Duration Max load (h)	Min. Load (%)	Duration Min load (h)	Nos of LV Feeder (N)	Resistance before conversion (Ω/kn)	Resistance after conversion (Ω/km)
100	1	80%	4	20%	20	6	0.452	0.452

Load pertterns are considered as follows.
-80% for 1h in the morning (7:00 to 8:00)
-80% for 3 hour in the evening (6:00 to 9:00)
-20% for other time

Load currents are calculated in each duration before and after conversion.

Losses of each duration are calculated in each duration before and after conversion.

Min. Load current per feeder before conversion (A)	Max. Load current per feeder before conversion (A)	Min. Load current per feeder after conversion (A)	Max. Load current per feeder after conversion (A)	Loss before conversion during min load (WH/day)	Loss before conversion during max load (WH/day)	Loss after conversion during min load (WH/day)	Loss after conversion during max load (WH/day)	Loss reduction per day (WH)	Loss reduction per year (MWH)
14.49	57.97	4.81	19.25	1,898.76	6,076.03	313.91	1,004.50	6,656.38	2.43

Loss Reduction

Region/Province	Lengths (km)	Loss reduction per km (MWh/yr.)	Loss reduction per year (MWh/yr.)
R1-NWP	1000	2.43	2,429.58
R2-CP	1000	2.43	2,429.58
R2-WPN	100	2.43	242.96
R3-WPSII	700	2.43	1,700.71
R3-Sabara	700	2.43	1,700.71
		Total	8,503.53

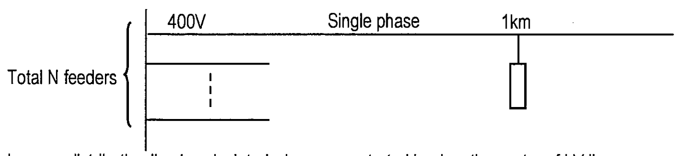
Before Conversion

Region/Province	Lengths (km)	Loss reduction per km (MWh/yr.)	Loss reduction per year (MWh/yr.)
R1-NWP	1000	2.91	2,910.80
R2-CP	1000	2.91	2,910.80
R2-WPN	100	2.91	291.08
R3-WPSII	700	2.91	2,037.56
R3-Sabara	700	2.91	2,037.56
		Total	10,187.80

After Conversion

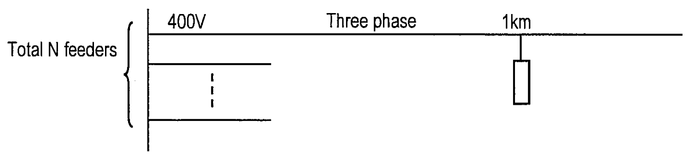
Region/Province	Lengths (km)	Loss reduction per km (MWh/yr.)	Loss reduction per year (MWh/yr.)
R1-NWP	1000	0.48	481.22
R2-CP	1000	0.48	481.22
R2-WPN	100	0.48	48.12
R3-WPSII	700	0.48	336.85
R3-Sabara	700	0.48	336.85
		Total	1,684.27

Before Conversion



Note: Loss on distribution line is calculated when concentrated load on the center of LV line.

After Conversion



Note: Loss on distribution line is calculated when concentrated load on the center of LV line.

Table 4.2-10D Loss Reduction of New PSs

Project No.	Transf. Capacity (MVA)	Max. Load (%)	Duration Max load (h)	Min. Load (%)	Duration Min load (h)	Nos of 11kV Feeder (N)	Nos of grade-up feeder	Rated voltage before installation	Rated voltage after installation	11kV feeder lengths (km) L11	33kV feeder lengths (km) L33	Resistance of 11kV Feeder wire-Raccoon	Resistance of 33kV Feeder wire-Lynx
R1/PS/NW/06	5	80%	4	0.2	20	2	1	11000	33000	5	5	0.3632	0.2733
R1/PS/NW/07	5	80%	4	0.2	20	2	1	11000	33000	5	5	0.3632	0.2733
R2/PS/WPN/03	5	80%	4	0.2	20	2	1	11000	33000	4	4	0.3632	0.2733
R2/PS/WPN/04	10	80%	4	0.2	20	4	1	11000	33000	1	1	0.3632	0.2733
R2/CV/WPN/01	10	80%	4	0.2	20	4	1	11000	33000	13	13	0.3632	0.2733
R2/CV/WPN/02	10	80%	4	0.2	20	4	1	11000	33000	15	15	0.3632	0.2733
R4/PS/WPS-1/1	10	80%	4	0.2	20	4	1	11000	33000	5	5	0.3632	0.2733
R4/PS/WPS-1/2	5	80%	4	0.2	20	2	1	11000	33000	2	2	0.3632	0.2733
R4/CV/WPS-2/1	0.9	80%	4	0.2	20	1	1	11000	33000	2	2	0.3632	0.2733

Load perttern is considered as follows.
-80% for 1h in the morning (7:00 to 8:00)
-80% for 3 hour in the evening (6:00 to 9:00)
-20% for other time

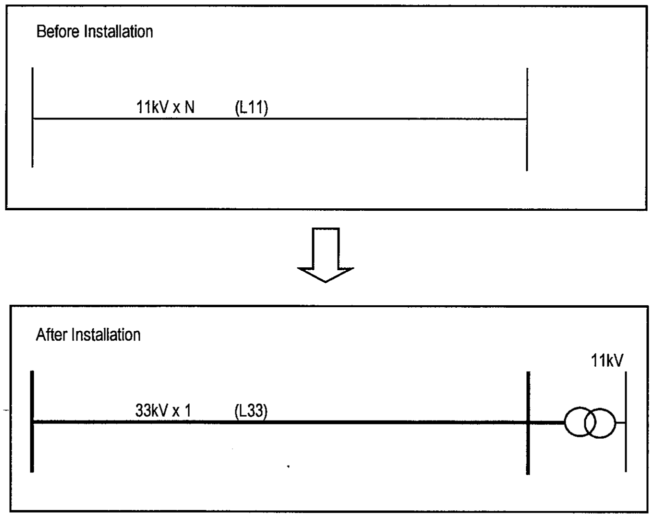
After installation of 33kV line/PSs, load current will be shifted to new 33kV line from existing 11kV lines.

Project No.	Min. load current on 11kV feeder (A)	Max. load current on 11kV feeder (A)	Min. load current on 33kV feeder (A)	Max. load current on 33kV feeder (A)	Loss on 11kV feeder during min. load (WH)	Loss on 11kV feeder during max. load (WH)	Loss on 33kV feeder during min. load (WH)	Loss on 33kV feeder during max. load (WH)	Loss Reduction per day (WH)	Loss Reduction per year (MWH)	Region Total
R1/PS/NW/06	26.24	104.98	17.50	69.98	150,091.45	480,292.64	25,097.89	80,313.25	524,972.95	191.62	
R1/PS/NW/07	26.24	104.98	17.50	69.98	150,091.45	480,292.64	25,097.89	80,313.25	524,972.95	191.62	383.230
R2/PS/WPN/03	26.24	104.98	17.50	69.98	120,073.16	384,234.11	20,078.31	64,250.60	419,978.36	153.29	
R2/PS/WPN/04	26.24	104.98	34.99	139.97	60,036.58	192,117.06	20,078.31	64,250.60	167,824.72	61.26	
R2/CV/WPN/01	26.24	104.98	34.99	139.97	780,475.54	2,497,521.73	261,018.07	835,257.82	2,181,721.38	796.33	
R2/CV/WPN/02	26.24	104.98	34.99	139.97	900,548.70	2,881,755.84	301,174.69	963,759.02	2,517,370.83	918.84	1929.717
R4/PS/WPS-1/1	26.24	104.98	34.99	139.97	300,182.90	960,585.28	100,391.56	321,253.01	839,123.61	306.28	
R4/PS/WPS-1/2	26.24	104.98	17.50	69.98	60,036.58	192,117.06	10,039.16	32,125.30	209,989.18	76.65	
R4/CV/WPS-2/1	9.45	37.79	3.15	12.60	3,890.37	12,449.19	325.27	1,040.86	14,973.43	5.47	388.391
									Total	2701.339	

Load currents are calculated before and after installation of 33kV line/PSs according to load pattern.

Losses of 33kV and 11kV lines are calculated in each duration.

Difference of losses before and after the installation of 33kV



CHAPTER 5
ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

CHAPTER 5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

5.1 General

JICA's guideline encourages proponents of Japan's Loan Aid projects to implement appropriate measures for environmental and social considerations which demand for adequate study and assessment in order to prevent, minimize or mitigate the project's adverse impacts on the environment or society during the project's planning stage.

Under the above JICA's principal requests, the Survey Team has carried out "Environmental Review" to confirm whether adequate environmental and social considerations are being made for the candidate projects in accordance with JICA's guidelines, while taking into account Sri Lanka's environmental laws which describes the environmental assessment procedure.

The Survey Team also visited the candidate project sites in order to collect information on the particular conditions of the project planned regions.

5.2 Related Laws and Regulations

5.2.1 National Environmental Act of Sri Lanka

(1) Environmental Impact Assessment System

In the new constitution of Sri Lanka (enacted in 1978), environmental conservation was enacted in Article 18, which states that "It is the duty of every person in Sri Lanka to protect nature and conserve its riches", and also in Article 27, which states that "The state shall protect, preserve and improve the environment for the benefit of the community".

Based on these constitution articles, the National Environmental Act (NEA) was enacted in 1980 to serve as the main legislation for environmental protection. The Central Environmental Authority (CEA) was established in August 1981 under the provisions of NEA No. 47 of 1980, which was later amended in 1988 (Act No. 56) and in 2000 (Act No. 53). The objectives of establishing the CEA were as follows: to make provision for the protection, management and enhancement of the environment; to regulate, maintain and control the quality of the environment; and to prevent, abate, and control pollution.

In 1983, the Cabinet of Ministers considered including the NEA for "Environmental

Assessment Provisions", which became mandatory for environmental impact assessment (EIA) for development projects with significant environmental impact. Detailed procedures of the EIA were subsequently specified in 1988.

Thereafter in 1990, the Ministry of Environment was established for the formulation of environmental policies.

(2) Institutional Arrangement for EIA

The evaluation of environmental impacts was delegated to various government bodies depending on the nature of the project. Part IV C of the NEA mandated that all "prescribed" development projects are required to be subjected for EIA.

Only large-scale development projects that are likely to have significant impacts on the environment are listed as the prescribed projects. Only prescribed projects located in "environmental sensitive areas" are required to undergo EIA irrespective of their magnitude. The prescribed projects are listed in gazette nos. 772/22 of 24 June 1993, 859/14 of 23 February 1995, 1104/22 of 5 November 1999, and 1108/1 of 29 November 1999.

Concerning transmission lines, gazette no. 772/22 of 24 June 1993 stipulates Part I (10) as shown below.

> "Installation of overhead transmission lines of length exceeding 10 kilometers and voltage above 50 kilovolts is being classified as Prescribed"

The construction of individual facilities such as switching stations, grid substations and primary substations were not listed as a prescribed project, which is needed to undertake EIA.

Moreover, projects planned in or near the following protected areas as designated by law, are required to undertake EIA despite of its description as prescribed projects:

1) 100 m from the boundaries of or within any area declared under the National Heritage Wilderness Act No. 3 of 1988
2) 100 m from the boundaries of or within any area declared under the Forest Ordinance (Chapter 451) of 1981
3) Coastal zone as defined in the Coast Conservation Act No. 57 of 1981
4) Any erodible area declared under the Soil Conservation Act (Chapter 450)
5) Any flood area declared under the Flood Protection Ordinance (Chapter 449)
6) Any flood protection area declared under the Sri Lanka Land Reclamation and Development Corporation Act No. 15 of 1968 as amended by Act No. 52 of 1982

7) 60 m from the bank of a public stream as defined in the Crown Lands Ordinance (Chapter 454) and having width of more than 25 m at any point of its course
8) Any reservations beyond full supply level of a reservoir
9) Any archaeological reserve, ancient or protected monument as defined or declared under the Antiquities Ordinance (Chapter 188)
10) Any area declared under the Botanic Gardens Ordinance (Chapter 446)
11) Within 100 m from the boundaries of or within any area declared as a sanctuary under the Fauna and Flora Protection Ordinance (Chapter469)
12) 100 m from the high flood level contour of or within a public lake as defined in the Crown Lands Ordinance (Chapter 454) including those declared under section 71 of the said ordinance
13) Within a distance of one mile of the boundary of a national reserve as declared under the Fauna and Flora Protection Ordinance

Note: 1) to 10) by Gazette No. 772/22 of 24 June 1993, Part III
11) and 12) by Gazette No. 859/14 of 16 February 1995
13) by the Fauna and Flora Protection Ordinance

The NEA stipulates that the approval for all prescribed projects must be granted by a project approving agency (PAA). As of 2011, 23 government agencies have been designated as PAAs by gazette nos. 859/14 of 23 February 1995, and 1373/6 of 29 December 2004.

(3) Steps of the EIA Process

The EIA process is implemented through designated PAA specified under section 23Y of the NEA. Once a project is initiated by a private or state agency, the following are several stages for the implementation of EIA (see Figure 5.2-1):

1) Submission of preliminary Information

The project proponent is required to provide the CEA with “preliminary information” on the proposed project in order for the EIA process to be initiated. Preliminary information is to be summarized by using the “basic information questionnaire (BIQ) sheet” prepared by the CEA.

The PAA shall acknowledge in writing the receipt of such preliminary information within six days based on Article 6-(i) of gazette no. 772/22 of 24 June 1993.

2) Scoping and compiling the terms of reference (TOR)

The CEA will decide a suitable PAA based on the submitted preliminary information, and then, the appointed PAA will carry out scoping in order to determine the environmental impacts in a preliminary fashion.

The PAA solicits the participation of those affected, queries the project proponent for clarifications, and decides whether an EIA or initial environmental examination (IEE) would be done based on two levels of the EIA process as indentified in the NEA. If the environmental impacts of the project are not very significant then the project proponent may be asked to do an IEE, which is a relatively short and simple study; however, if the potential impacts appear to be more significant, the project proponent may be asked to do an EIA which is a more detailed and comprehensive study of environmental impacts.

Accordingly, the PAA shall convey in writing to the project proponent the TOR within 14 days in case of IEE or 30 days in case of EIA from the date of acknowledging the receipt of preliminary information, based on Article 6-(iii) of gazette no. 772/22 of 24 June 1993.

The issuance of the TOR for IEE requests for the simplest possible process as compared to that of EIA, and it should be compiled based on the "guidance" issued by CEA, as shown below.

Preparation of TOR for IEE

IEEs are intended to be brief documents, generally not longer than ten pages, which aims at helping decision makers to ensure that projects are implemented with appropriate mitigation measures to avoid significant impacts.

PAAs may wish to establish page limits, checklists or other guides for project proponents to meet IEE requirement effectively and efficiently.

In general, IEEs should contain the following sections:

-- Summary (one page)
-- Proposed Action's Purpose, Needs and Legal Requirements
    - Legal actions required by the government to approve action
-- Proposed Action
    - Brief description of the proposed action, including any mitigation measures designated to reduce environmental impacts

The IEEs may need to contain description of reasonable alternatives

-- Affected Environment
-- Environmental Consequences of the Proposed Action
-- Mitigation and Monitoring Plan
-- Appendixes
    - List of IEE prepares, reference, backup data and analysis

(Source: Guidance of CEA)

3) EIA/IEE report preparation and publication

The EIA/IEE report should be prepared in any of the national languages by the project proponent, and then submitted to the PAA for evaluation. If there is a request from the public, these reports are translated to any of the other two national languages.

Based on Article 11-(i) of gazette no. 772/22 of 24 June 1993, the PAA is required to announce that the particular EIA is available for inspection by the public in national newspapers using all three languages.

4) Public participation and public hearings (if necessary)

The PAA and CEA will review the EIA report. Queries can be directed at the project proponent through the PAA. Based on Article 11-(i) of order gazette no. 772/22 of 24 June 1993, the public is allowed to submit queries and observations on the EIA document within 30 days.

Based on Article 12 of gazette no. 772/22 of 24 June 1993, if the EIA required project is controversial as described below, the PAA and CEA can decide to hold public hearings.

Based on Article 12 of gazette no. 772/22 of 24 June 1993, if there are any public comments on the EIA report, these will be sent to the project proponent for response and it must respond to their queries within six days.

Criteria on controversial cases

- Where a proposed prescribed project is highly controversial, whether more expressions of public views are essential to make a decision
- Whether the proposed prescribed project might cause unusual national or regional impacts
- Whether it might threaten nationally important and environmentally sensitive areas
- Whether a formal request for a public hearing has been requested by an interested party

(Source: Guidance of CEA)

5) Approval

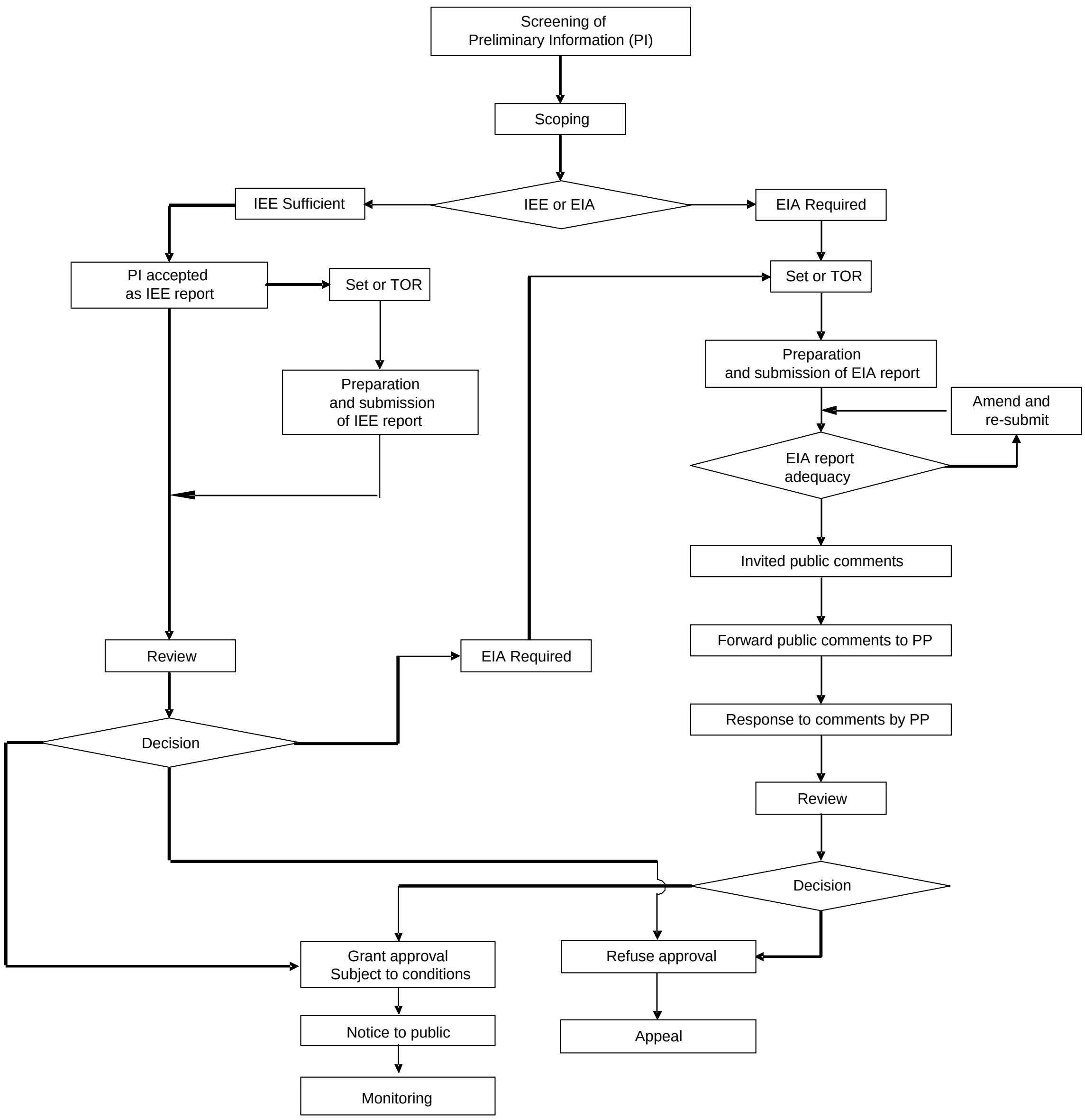
Subsequent to the public participation period, the PAA will appoint a “technical evaluation committee (TEC)” to evaluate the EIA/IEE report and make its recommendations.

Based on the recommendations of the TEC, the PAA will make its decision on whether to grant approval for a project within 21 days in case of IEE, or 30 days in case of EIA, as stated within Articles 9 and 13 of gazette no. 772/22 of 24 June 1993.

Table 5.2-1 Timing of Each Step in the EIA Process

Step	Timing		Law Background
	EIA	IEE	
Acknowledgement of the preliminary information	6 days	6 days	Regulations Article 6-(i) of gazette no. 772/22,18 June 1993
Producing of the TOR	30 days	14 days	Regulations Article 6-(iii) of gazette no. 772/22, 18 June 1993
Public commenting	30 days	-**	Regulations Article 11-(i) of gazette no. 772/22, 18 June 1993
Sending of comments to the project proponents	6 days	-**	Regulations Article 12 of gazette no. 772/22, 18 June 1993
Approval (after receiving the comments of the PP)	30 days	21 days*	Regulations Article 13 of gazette no. 772/22,18 June 1993 *Regulations Article 8 of gazette no. 1159/22, 21 November 2000

(Prepared by the Survey Team) Note: -** article on disclosure of IEE was repealed on November 2000



(Source: CEA)

Figure 5.2-1 EIA Process

(4) Comparison of JICA's guidelines with Sri Lankan policies

The major differences related to "Environmental and Social Conditions" which JICA requires the borrowing country to conform to JICA's guidelines, include compilation of EIA documents, public participation, and monitoring mechanisms, which do not exist in Sri Lankan policies as shown in Table 5.2-2.

Table 5.2-2 Comparison between JICA's Guidelines and Sri Lankan Policies

Items	National Environmental Act (NEA) of Sri Lanka	JICA's Guidelines
Priority alternatives and mitigation measures	(Alternatives) "Description of alternatives to the activity together with the reasons why such alternatives were rejected" are required by guidance* (Mitigation measures) Mitigation measures are required to be included in the IEE/EIA document by guidance*	Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan.
Compiling of EIA report	The NEA (amended in 2000) requires compiling EIA document based on "Part IV C" of its article	EIA reports must be produced for projects in which there is reasonable expectation for particularly large-scale adverse impacts on the environment.
Disclosure of information and participation of affected people	The NEA (amended in 2000) requires public participation based on "Part IV C" of its article	For projects with potentially large environmental impact, sufficient consultations with local stakeholders such as local residents must be conducted via disclosure of information at an early stage at which time alternatives for project plans may be examined.
Carrying out of monitoring program	Monitoring plan is required to be included in the IEE/EIA document by guidance* and required to be cleared "parameters to be monitored", "institutional responsibility and procedures for reporting".	After the project begins, the project proponents, etc. monitor whether any unforeseeable situation occurs, and whether the performance and effectiveness of mitigation measures are consistent with the assessment's prediction.

(Prepared by the Survey Team)

Note: * Guidance for implementing the environmental impact assessment process by CEA

5.2.2 Related Laws concerning Natural and Social Matters

The construction of one candidate project, consisting of 146 km of 220 kV transmission line, out of several candidate projects falls under the prescribed projects which require to carry out the EIA procedure under the NEA. In addition to this act, the following legislations may also be concerned about the candidate project in view of its natural and social condition matters.

Table 5.2-3 Related Laws concerning Natural and Social Matters in Sri Lanka

Laws	Objectives	Key Areas	Key Agencies
Fauna and Flora Protection Act 1993	To provide utmost protection to fauna and flora	Protected areas	Department of Wild Life, and Department of Forest
Forest Ordinance Act	Management of forests	Forest reserves	Department of Forest
Felling of Trees Act	Controlling the removal of trees	Regulates the removal of trees	Department of Forest
Coconut Development Act	To provide rules for compensation on coconut trees	Coconut plantations	Coconut Cultivation Board
Land Acquisition Act	To provide the rules on acquisition of land for public purpose	Areas to be paid for any damage including acquisition	
Public Utilities Commission of Sri Lanka Act	Create an environment for all inhabitants of Sri Lanka	All utilities in Sri Lanka	The Public Utilities Commission of Sri Lanka
Sri Lank National Involuntary Resettlement Policy	To avoid, minimize and mitigate negative impacts of involuntary resettlement	Affected people and areas	The Ministry of Land Development

(Prepared by the Survey Team)

5.3 Environmental and Social Considerations for Candidate Projects

The Survey Team made a site survey of two candidate transmission line (TL) projects, namely the “New Habarana–Veyangoda TL”, and the “Reconstruction of Polpitiya–Habarana TL”, in order to examine the present environmental situation of nature and society, and to forecast and evaluate environmental impacts caused by the proposed project.

Meanwhile, the Survey Team reviewed the IEE report on the New Habarana–Veyangoda TL project which has been prepared by the CEB to confirm whether it has been compiled with due environmental consideration for the principles underlying JICA’s project appraisal as stated in JICA’s guidelines.

5.3.1 Identifying Candidate Projects to Comply with JICA’s Guidelines

Out of many projects, two candidate projects, the “New Habarana–Veyangoda TL” and the “Reconstruction of Polpitiya–Habarana TL”, have been categorized as “prescribed” which means that the said projects are required to obtain environmental clearance from the CEA or PAA which are authorized under the NEA for TLs over 50 kV and above 10 km in length.

However, the Polpitiya–Habarana TL reconstruction project has still been at the planning stage, and the CEB has not yet prepared an IEE document including detailed reconstruction method for this project.

For the reconstruction of existing lintels, the CEB has planned to construct new towers with 35 m width of right-of-way along the existing line with 30 m width of right-of-way. According to CEA' s director, who is responsible for legal issues, such reconstruction is required to undertake EIA procedure of the NEA, and the PAA will ask project proponents to make an IEE document. The CEB is now planning an optimal method of construction which is oriented on minimizing the resettlement of residents living under the TL.

Thus, the study on environmental and social conditions related to TL has been the focus of the New Habarana–Veyangoda TL project.

5.3.2 EIA Procedure concerning the Project

The procedure stipulated in the Act on the approval of projects requires the submission of two types of reports, namely IEE report and EIA report.

The New Habarana–Veyangoda TL project was judged by the Ministry of Power and Energy (MPE), the PAA, that the potential adverse impacts on the environment can be mitigated to an acceptable level by adequate implementation of mitigation measures. It was then decided by the MPE that an IEE document would be sufficient instead of a full EIA document.

Based on this decision, the IEE document for the project has been already prepared in accordance with the TOR provided by the CEA, and it has submitted to the relevant PAA by the CEB. According to the CEB, the IEE document was submitted on 6 July 2011.

According to the Act, the PAA shall grant or refuse approval for implementation of the proposed project within a period of 21 days. In this regard, the approval of the project will be issued around the end of July 2011.

5.3.3 Evaluation of IEE Report in View of JICA's Guidelines

(1) Impact on Natural Protected Areas

There are no important natural areas, such as strict natural reserves, national parks, nature reserves, jungle corridors, and intermediated zones, in the route alignment of the proposed transmission line which have been designated by the Fauna and Flora Protection Act.

(2) Impact on Protected Areas Designated by International Treaty

There are no important archaeological, historical, cultural, and biological sites, such as World Heritage sites and Ramsar Convention wetlands, along the route alignment.

(3) Effect on Flora and Fauna

Since there are no declared environmentally sensitive ecological areas located within the project-affected area, it is not expected that many plants and animals which are rare, endangered, endemic or threatened will be affected. There will be no significant effects on about 35 elephants, which have been roaming near the forest plantation with "teak" trees as their prime habitat.

According to the IEE document, it assumes that significant impact on elephants is foreseen during the construction period but it will be much reduced after construction. Thus, it does not recommend effective mitigation measures to avoid significant impacts, but only requests to carry out monitoring of elephant behavior during after the construction stage. The part of the IEE report related to the above is shown below.

During the construction period of transmission line, there will be significant impact on elephants, as they will be disturbed and they might move into habitable areas thus creating human–elephant conflict. However, after the construction phase, it is expected that this impact will be much reduced.

(Monitoring program)

- Number of human elephant conflicts occurring in the locality

(IEE Report page 88 and 109)

Effective mitigation measures for affected rare species are briefly described in the IEE report.

Table 5.3-1 Rare Species Found in the Project Site (Flora and Fauna)

	Specie	Family	English Name	Origin	Conservation Status
Flora					
1	*Diosphyros ebenum*	Ebenaceae	-	Native	EN (endangered)
2	*Mitragyna parvifolia*	Rubiaceae	-	Native	VU (vulnerable)
Fauna					
1	*Moschiola meminna*	-	Sri Lankan mouse-deer	-	EN(endangered)
2	*Semnopithecus vetulus*	-	Purple-faced leaf monkey	-	VU (vulnerable)
3	*Ratufa macroura*	-	Giant squirrel	-	VU (vulnerable)
4	*Otocryptis wiegmannl*	Elephantidae	Sri Lankan kangaroo lizard	-	NT (nearly threatened)
5	*Elephas maxinus*	-	Elephant	-	EN (endangered)

(Source: IEE Report for the New Habarana–Veyangoda Transmission Line Project)

(4) Impact on Land Use

The land use along the line corridor does not occupy the sensitive areas where there are known habitats of rare, threatened, and vulnerable species or resident areas of vulnerable social groups, as shown in Table 5.3-2.

Table 5.3-2 Land Use along the Line Corridor

Land Use	Extent (ha)	% of Total Area	Impacts
Paddy	808.5	56.5%	Land use will not be changed drastically although towers will be built at 350 m intervals
Coconut plantation	164.2	11.5%	Completely removed, thus the land use will be changed in a corridor of 35 m
Home garden	250.0	17.5%	A strip of 35 m corridor will be removed (uprooting over 3 m)
Chena cultivation	52.7	3.7%	Not affected, toll of trees are under 3 m
Forest	24.4	1.7%	A strip of 35 m corridor will be removed, land use will be changed.
Teak plantation	18.4	1.3%	Completely removed, thus the land use will be changed in a corridor of 35 m
Scrubs, etc.	111.7	7.8%	Not significantly changed
Total	1,429.9	100%	

(Source: IEE Report for the New Habarana–Veyangoda Transmission Line Project)

Permanent and temporary loss of paddy and forest areas will occur due to the location of towers in these areas, and loss of crop due to the location right-of-way and access roads. However, there will be no land acquisition for erection of towers.

(5) Resettlement and Rehabilitation

There are 46 houses with 179 residents (90 males and 89 females as of 2011) which are directly[1] or indirectly[2] under or within the TL. About 14% of the line runs over or is adjacent of housing areas.

However, for the construction of the TL, no land acquisition is required; hence the project does not involve resettlement and rehabilitation.

(6) Enforcement of Monitoring

The CEB has an existing and well-established Transmission Design and Environment Section headed by the Deputy General Manager, and an Environment Unit headed by the Environment Officer with full capacity in safeguards planning and implementation.

During the construction and operation phase of this project, monitoring of environmental aspects shall be done by the Transmission Design and Environment Section.

(7) Public Consultation and Information Disclosure

Information about the project was disclosed to the public prior to the EIA procedure. No public consultations were carried out on the specific schemes of construction since these

[1] Some trees over 3 m-height will be removed or cut in their home garden and trees of under 3 m-height will be pruned away by regulation on the Right of Way.

[2] Transmission line will be passed through some part of home gardens but not causes physical damages on the home garden.

have not yet been identified yet.

However, to disclose the outline of the project and understand the process, a small meeting consisting of the affected people and local officials was held. The demands of the participants to CEB about the proposed project have been reflected on the IEE report, and the grievances of the affected people are being solved by CEB.

(8) Recommendations and Conclusions

The Survey Team has almost concurred with the IEE report on the New Habarana–Veyangoda TL project, which has elaborated that negative impacts to the environment and social issues are relatively minor and would be suitably managed by the mitigation measures proposed (see Attachment-4 'Environmental Checklist').

However, the Survey Team has some apprehension about not addressing the adverse impact and effective mitigation measures on the roaming elephants, which have been designated as endangered species by the International Union for the Conservation of Nature and Natural (IUCN). Without the above mentioned item regarding elephants, the Survey Team has appreciated that the IEE report has correctly and rigorously identified, assessed, and fully taken into account the relevant environmental and social impacts of the project.

The Survey Team recommends that the CEB should integrate local ecological knowledge of the roaming elephants near the project site into project planning in order to avoid significant threats of social groups living along the TL.

5.3.4 Categorization of Candidate Projects in view of JICA's Guideline

(1) New Habarana–Veyangoda TL Project

According to the NEA, the EIA process has identified two levels of IEE and EIA (Part IV C 23BB (1)), and the Guidance for Implementing the Environmental Impact Assessment Process promulgated by the CEA based on the NEA in 2006 stipulates criteria of EIA/IEE, as shown below.

> The PAA should determine whether an IEE or EIA is required for a proposed project based on assessment of the likely significance of the impacts of the proposed project on the environment and （*also describes*） that EIAs, rather than IEEs, should be required for prescribed projects under the regulations that are likely to have significant impacts on the environment.
>
> (Article 2.3 Criteria for IEE or EIA-Determination of Significant Impacts)

Based on Article 2.3 "Criteria for IEE or EIA" shown above, the PAA decided that the candidate project for the New Habarana–Veyangoda TL is a project which requires to prepare an IEE document since the potential adverse environmental impacts can be mitigated to an acceptable level by adequate implementation of mitigation measures.

Taking into full account the environmental judgments of the CEA and PAA on this project, the New Habarana–Veyangoda TL project would be under Category B of JICA's environmental requirements since the impacts would be relatively at a low level, largely confined in the extent of the site and a few would be irreversible, and if any, effective mitigation measures can be designed and implemented to minimize adverse impacts.

(2) Reconstruction of Polpitiya–Habarana TL Project

Almost all of its planned TLs are being designed to be constructed along the existing line, which occupies mountainous areas that are designated neither as natural reserves nor residential areas.

If the CEA and PAA take into account such existing natural and social conditions when the CEB, as project proponent, is asked to take necessary environmental procedure based on the NEA for implementation of this project, the CEB would be likely be asked to prepare an IEE document which will be applied under Category B of JICA's environmental requirements.

(3) Other Candidate Projects

All other candidate projects are applied under Category C of JICA's environmental requirements. These projects are exempted from taking environmental procedure such as to prepare an IEE or EIA document for the CEA and PAA, since these projects do not apply under the Gazette Extra Ordinary No. 722/22 of 24 June 1993, and 1104/22 of 5 November 1999, which elaborate on IEE/EIA required projects.

CHAPTER 6
PROJECT IMPLEMENTATION PLAN

CHAPTER 6 PROJECT IMPLEMENTATION PLAN

6.1 General

All candidate projects do not require any special construction methodologies and tools. However, although these are common projects in Sri Lanka, there are some considerations needed for implementing a selected project in order to highly attain its benefits. Considerations to be taken for project implementation are summarized in this chapter.

6.2 Implementation Agency

6.2.1 Transmission Projects

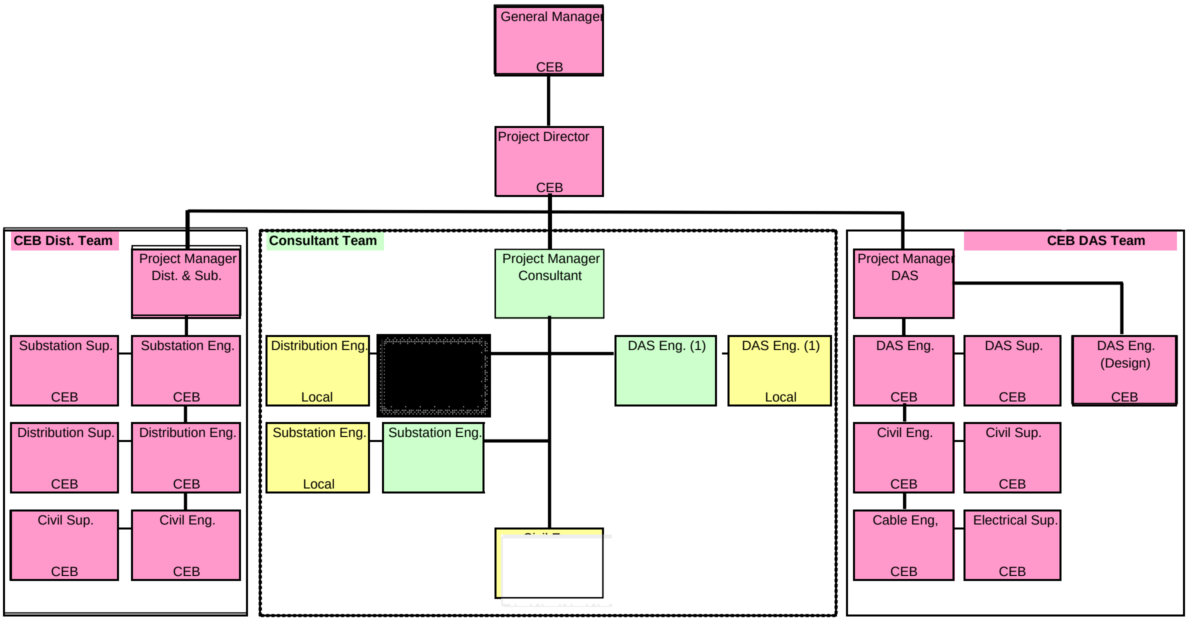
To implement a transmission line project, the CEB generally forms a project implementation unit (PIU) and entrusts them to manage and supervise the project. The PIU basically consists of some personnel to be selected from project-related departments such as the Transmission Projects Department. For these selected projects, without exception, it is imperative to form a PIU.

Related to the Trincomalee Coal Power Project (CPP), the PIU for the Habarana–Veyangoda TL project has been formed in the present design stage and the project office has been established. Once the project launches after some funds have been allocated for it, the present PIU will continuously work on project management. Once the TL is completed, management of the line will be handed over to the Transmission Department.

6.2.2 Distribution Projects

(1) Project Organization

The organizational structure of distribution projects is shown in Figure 6.2-1. The distribution project is divided into two groups; one is the distribution and substation group, and the other is the distribution automation system (DAS) group. A consultant team, a distribution and substation team, and a DAS team will be organized under the Project Director of the CEB. Project managers will be assigned in each group.

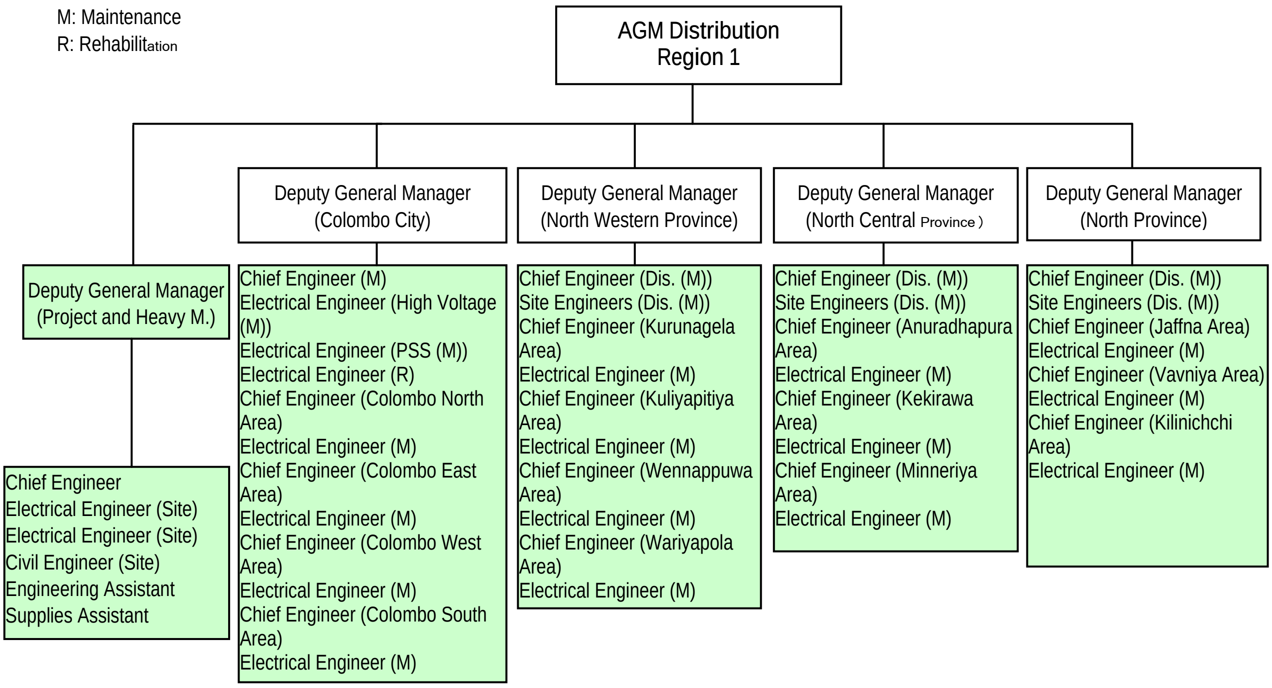


(Source: CEB Distribution Division)

Figure 6.2-1　Organizational Structure of the Project Management

(2)　Maintenance Organization

The maintenance structure of CEB Region-1 is shown in Figure 6-2-2 as a sample. Under AGM Distribution, the deputy general manager (DGM) for project and heavy maintenance is assigned. Meanwhile, under the DGM of each region, a chief engineer and an electrical engineer for maintenance are assigned.



(Source: CEB Distribution Division)

Figure 6-2-2　Maintenance Structure of CEB

6.3 Implementation Plan

6.3.1 Transmission Projects

Although some selected projects are planned to be constructed by 2016, most are planned to be constructed by 2014. In order to attain the most benefits as possible, it is apparently vital to launch the project as early as possible. In addition, through the project implementation period, it is important to implement appropriate project management such as quality control, schedule management and safety management under the CEB and a consultant.

To implement the potential projects, the following process has to be undertaken:

1) Basic and detailed design
2) Preparation of tender documents
3) Tendering
4) Contract with contractors
5) Procurement and installation of equipment and materials
6) Commissioning tests and take over

In general, the CEB can cope with project management up to tendering. However, in the construction stage, the CEB should manage site supervision in cooperation with a consultant.

Each project implementation plan is shown in the following paragraphs:

(1) New Habarana–Veyangoda TL Project

1) Present situation

The Survey Team carried out the site survey mainly to confirm the existing Veyangoda Grid Substation (GS), new Habarana Switching Substation (SS) and TL route. In the line route survey, obstacles and crossing points of the line route such as railways, rivers, trunk roads and natural reserve areas were confirmed to exist along the line route.

Veyangoda GS

Bus Extension Space in Veyangoda GS

For the Veyangoda GS, which is to extend its TL bays, it was confirmed that no special consideration is necessary for the space needed for the extension of the existing busbar for the New Habarana–Veyangoda TL.

The line route has been determined to avoid as much obstacles and major crossing points as possible. Since there are a lot of angle towers located to avoid them, almost 60% of the line route crosses above paddy fields. There is a plantation of mahogany and teak trees following the line route near the new Habarana SS site; however, it has not been confirmed that it will have negative effects on environmental and social aspects.

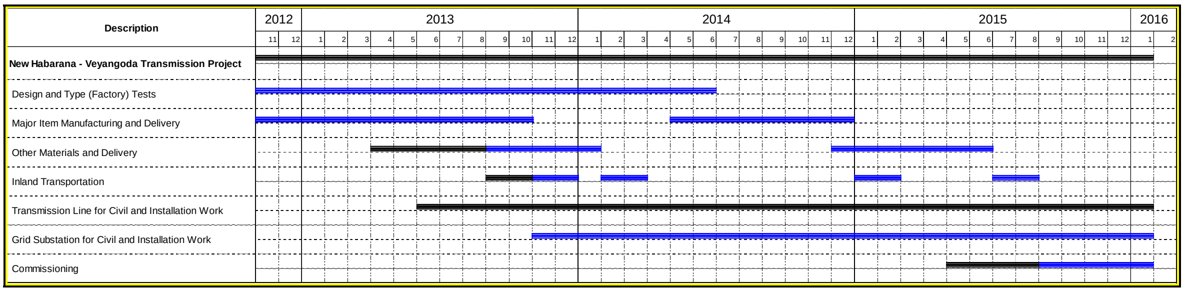
On the other hand, it was reported that a number of angle towers accounts for almost 45% of the total number of towers. In review of the TL route, it is necessary to study the possibility to minimize as much of angle towers as possible to minimize construction cost.

The proposed site for the new Habarana SS has an area of 200 m by 300 m, and it has been acquired according to the CEB. After completion of the new SS, the TL from this SS is to be mutually interlinked to the existing Habarana GS.

2) Project schedule

Table 6.3-1 shows the planned implementation schedule for the project.

Table 6.3-1 Implementation Schedule for New Habarana–Veyangoda TL



(Prepared by the Survey Team)

According to the CEB's project proposal, the project is expected to be completed by the beginning of 2016 so that the completion of the 220 kV TL can be provided for the development of the Trincomalee CPP. In order for the project to be completed by its due date, project implementation has to be launched around the end of 2012. However, according to the interview with the CEB, the Trincomalee CPP is expected to be commissioned at the beginning of 2017 considering several reasons. Under such circumstances, the New Habarana–Veyangoda TL may be completed by around the middle of 2016.

3) Consideration for procurement and construction

Equipment procurement stage

It was suggested that the place of origin where the equipment and materials will be procured will be selected among relevant places with due consideration. For procurement related to both the transmission and switching station of the project, the following considerations have to be taken:

i) For procurement of substation equipment, the country of origin shall be selected with careful attention.
ii) The selection of equipment and materials have to be carried out with due consideration on the quality of the products first.
iii) Since an inexpensive product tends to deviate from global standards and to be of lower quality, major equipment such as high voltage switchgear, GISs, main transformers, instrument transformers, protection relays, etc. will be procured from qualified and reputed manufacture in the world.
iv) Procurement of the LL-TACSR/AS conductor from Japan is crucial in managing the schedule for manufacturing and transportation.

Construction stage

Special construction method and tools are not necessary. However, the following considerations have to be taken:

i) Careful attention has to be made for neighboring residents during construction.
ii) Environmental/social trouble has to be avoided during construction.
iii) During conductor stringing works, it is necessary to monitor the tension of the conductor because is a possibility to damage equipment and harm workers.
iv) Since energized points such as busbars are to be located near the extension area of Veyangoda SS, maximum attention has to be paid to in order for workers to avoid electrocution.
v) It is necessary to investigate the existing equipment for sequential control, interlock control, and protection coordination.
vi) The power shutdown schedule shall be carefully prepared and forewarned for workers' safety.

(2) Polpitiya–Habarana TL Reconstruction Project

1) Present situation

The Survey Team carried out the site survey for the exiting TL route from Habarana to

Polpitiya. This TL route runs mostly over forest areas.

Since the TLs were designed with 54°C maximum operation temperature, which limit the current capacity and clearance to the ground, it was sometimes observed that the height of the towers are generally low, and clearance between the tower and ground seems insufficient.

At present, a tangible construction method based on power outage plans has not been prepared for this reconstruction project. If new higher transmission towers are erected next to the existing towers, necessary survey on negative environmental impacts seems to be inevitable for implementation.

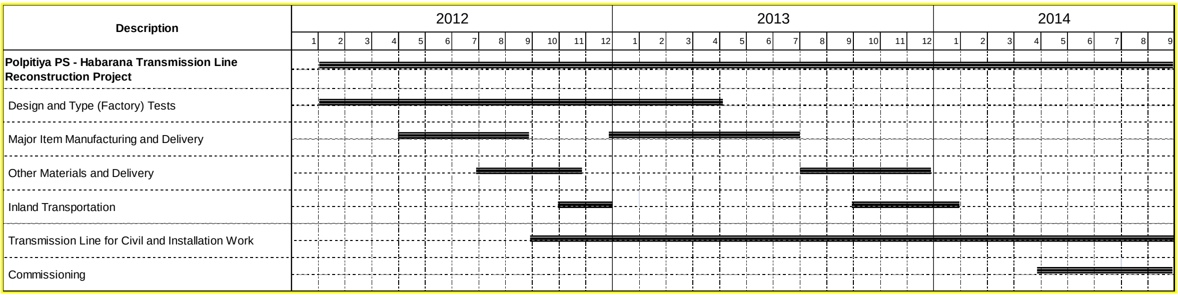

Low Sag Condition (from Polpitiya)


Low Sag Condition (from Kiribathkumbra)

2) Project Schedule

Table 6.3-2 shows the planned implementation schedule for the project.

Table 6.3-2 Implementation Schedule for Polpitiya–Habarana TL Reconstruction



(Prepared by the Survey Team)

As shown in the table, the CEB plans to complete the project by the end of 2014. If construction is to be completed by 2014, construction has to commence as early as 2012. As new towers are to be constructed next to the existing tower, surveys on environmental and social matters have not been conducted yet. Before proceeding to project implementation, IEE for the project is necessary.

3) Consideration for procurement and construction

<u>Equipment procurement stage</u>

i) The selection of equipment and materials have to be carried out with due consideration on the quality of the products first.

ii) Procurement of the LL-ACSR/AS conductor from Japan is crucial in managing the schedule for manufacturing and transportation.

iii) Major equipment such as high voltage switchgear, main transformers, instrument transformers, protection relays, etc. will be procured from qualified and reputed manufacture in the world.

Construction stage

i) It is crucial to make a shutdown schedule and forewarn workers for them to be able to work safely.

ii) It is important to supervise along the line route during stringing works in order to prevent workers and the public from accidents.

iii) It is necessary to monitor the tension of stringing in order to prevent flaw and dent to towers.

iv) Appropriate measures should be taken for the stringing of conductors by tensioning in order to avoid accidents that loose conductors may cause during nonworking days.

v) Since energized points such as busbars are to be located near the extension area of each substation, maximum attention has to be paid to in order for workers to avoid electrocution.

(3) Substation Construction and Augmentation Project

(A) Augmentation of Colombo A GS

1) Present situation

Through the site survey for Colombo A GS project, the following information has been confirmed:

- Since the installation area for the third power transformer is limited in space, it could be suggested that the newest space saving transformer should be installed.


Transformer Installation Area

- The laying routes of the 132 kV and 11 kV power cables were confirmed. It is necessary to make the installation plan carefully so that it may not interfere with the existing power cable.

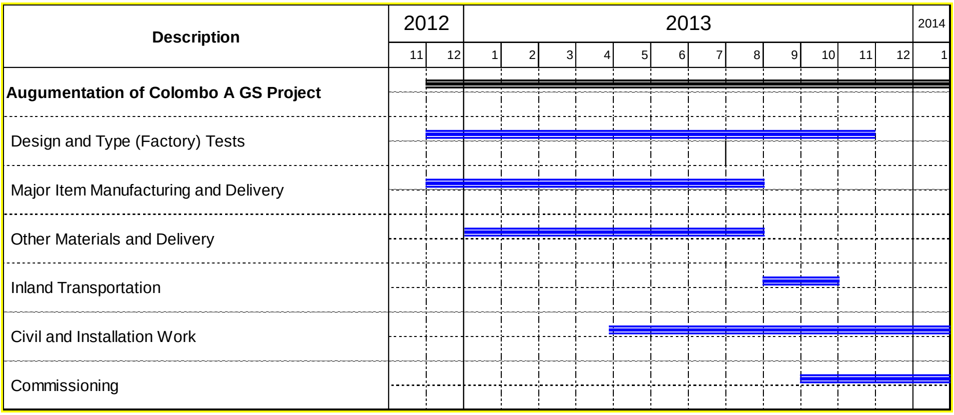

132 kV GIS Extension Point

- Since Colombo A GS is composed of a 132 kV power receiving system of pi-branch circuit, it is necessary to investigate the situation of coordination of protective relays, etc. for the next step.

2) Project Schedule

The planned implementation schedule for the project is shown in Table 6.3-3.

Table 6.3-3 Implementation Schedule for Augmentation of Colombo A GS



(Prepared by the Survey Team)

Since the project is expected to be completed by the beginning of 2014, it is necessary to launch the project around the end of 2012 at the latest.

3) Consideration for procurement and construction

<u>Equipment procurement stage</u>

i) Since there is limited space for the installation of an additional transformer, a 31.5 MVA transformer will be procured considering its size with the same performance and functions of existing transformers.

ii) The 132 kV GIS and 11 kV switchgear, which were planned to be procured under the project, will be the product of the same manufacturer or of compatible manufacturers.

<u>Construction stage</u>

i) Since installation space is very limited, the installation plan has to be established ahead of construction.

ii) Since energized points of the existing transformers are located very near the working area for civil and erection works, it is important to monitor appropriate clearance to avoid workers from electrocution.

iii) It is important to pay attention to the connection and adjustment of the existing equipment. Based on the route map of the existing 132 kV and 11 kV power cables, it is necessary to make the installation plan carefully so that it will not interfere with the existing power cables.

iv) It is necessary to investigate the existing equipment for sequential control, interlock control, and protection coordination. Since Colombo A GS is composed of a 132 kV power receiving system of pi-branch circuits, it is mandatory to investigate the situation of protective relays coordination.

<u>(B) Construction of Kalutara 132/33 kV GS</u>

1) Present situation

Through the site survey for the branch point at the Panadura–Matugama TL and planned Kalutara construction site, the following information has been confirmed:

- Although it is necessary to investigate the structural strength of the existing tower for the branch point, it seems effective to use this tension tower for branching considering the location and type of tower. However, it seems that the clearance between conductor and bank is very narrow that some countermeasure would be necessary.
- Since the planned line route will run through damp areas and across a small river, the route is to be carefully surveyed.
- Since the construction site of Kalutara GS is planned along Route B224, it is necessary to investigate its transportation condition.

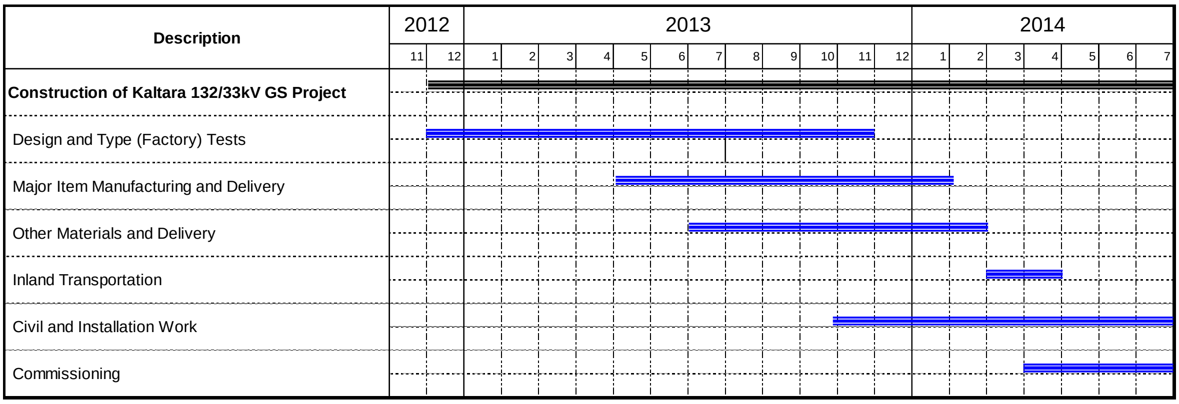
Branch Tower Connection Point

Temporary GS Site

2) Project Schedule

The planned implementation schedule for the project is shown in Table 6.3-4.

Table 6.3-4 Implementation Schedule for Construction of Kalutara 132/33 kV GS



(Prepared by the Survey Team)

The project was planned to be completed by the beginning of 2014. In order to complete it by 2014, it is necessary to launch the project around the end of 2012 at the latest.

3) Consideration for procurement and construction

Equipment procurement stage

i) Major equipment such as main transformers, HV and MV switchgear, instrument transformers, protection relays, etc. shall be procured from qualified and reputed manufacture in the world.

Construction stage

i) The 132 kV TL route should be determined with consideration of the types of branched tower and route circumstances in order to avoid heavily populated and traffic congested areas.
ii) So far, no substation exists in Kalutara area, therefore, maximum attention should be paid to with regards to public nuisance during construction.
iii) It is necessary to monitor the conductor stringing works with due consideration in order to prevent accidents.

(C) Augmentation of Madampe GS Project

1) Present situation

Through the site survey for Madampe GS, the following information has been confirmed:

- Although the installation space for a 132 kV switchyard extension area has already been secured, it is necessary to shift the net-fence at about 2.0 m from the existing location in order to maintain clearance the earth.
- Since the extension area for the 33 kV cubicles is limited in space, it is necessary to widen the space of the building.
- The laying routes of the 33 kV power and control cables were confirmed. It will be necessary to prepare the plan carefully so that the new cables will not interfere with the existing power cables.

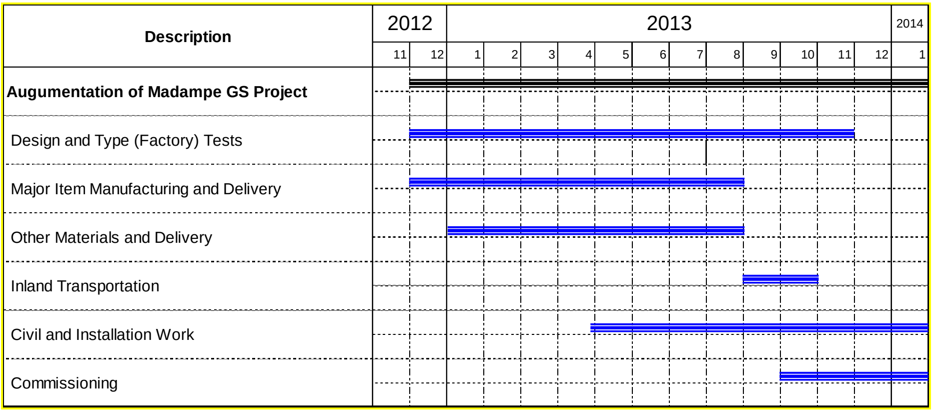

132 kV Switchyard Extension Area


33 kV Cubicle Extension Area

2) Project schedule

The planned implementation schedule for the project is shown in Table 6.3-5.

Table 6.3-5 Implementation Schedule for Augmentation of Madampe GS



(Prepared by the Survey Team)

Since the project is expected to be completed by the beginning of 2014, it is necessary to launch the project around the end of 2012 at the latest.

3) Consideration for procurement and construction

<u>Equipment procurement stage</u>

i) The 33 kV switchgear, which were planned to be procured under the project, will be the product of the same manufacturer or of compatible manufacturers.

ii) Major equipment such as main transformers, HV and MV switchgear, instrument transformers, protection relays, etc. will be procured from qualified and reputed manufacture in the world.

<u>Construction stage</u>

i) Since energized points such as busbars are located near the construction area of Madampe GS, maximum attention has to be paid to in order for workers to avoid electrocution.

ii) Although the installation space for the 132 kV switchyard extension area has already been secured, it is necessary to shift the net-fence at about 2.0 m from the existing location in order to maintain clearance for the grounding distance for electric security. Since the space for the installation of additional 33 kV cubicles in the control building is limited, extension of the building is necessary.

iii) It is necessary to pay attention to the connections and adjustments with the existing equipment. Once the existing 33 kV power cable laying routes are confirmed, it is mandatory to prepare the installation plan carefully so that such cables may not interfere with the existing power cable.

(D) Installation of Reactive Power Compensation Devices

1) Present situation

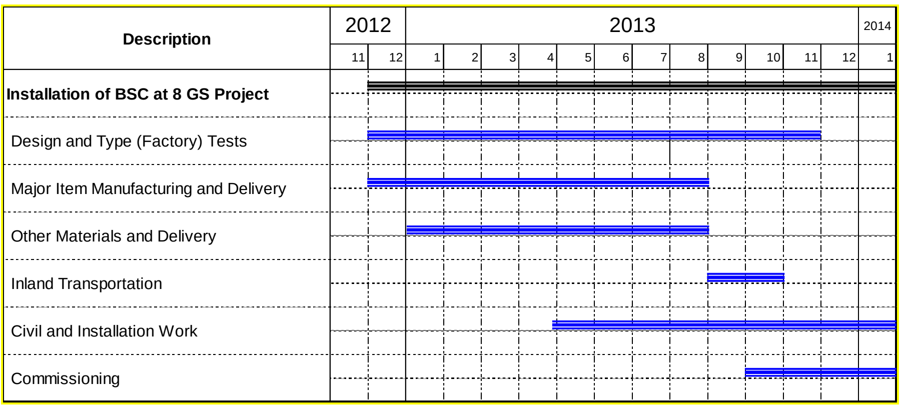
Through the site survey for the Biyagama, Sapgaskanda, Kolonnawa (new and old), Bolawatta and Pannala GSs, the following information has been confirmed:

- The 33 kV capacitor banks which connect to each GS have a different system. The systems differ depending on the existing connection and extension of feeders by each GS. Therefore, the specifications for switching should be confirmed for the next step.
- The laying routes of the 132 kV and 33 kV power and control cables were confirmed. It is necessary to prepare the plans carefully so that such cables may not interfere with the existing power and control cables.
- Since there are no layout plan drawings of each existing substation, it will be necessary to conduct measurement and drafting for the next step.

2) Project schedule

The planned implementation schedule for the project is shown in Table 6.3-6.

Table 6.3-6 Implementation Schedule for Installation of BSC at Eight GSs



(Prepared by the Survey Team)

Since the project is expected to be completed by the beginning of 2014, it is necessary to launch the project around the end of 2012 at the latest.

3) Consideration for procurement and construction

<u>Equipment procurement stage</u>

i) The 33 kV switchgear, which were planned to be procured under the project, will be the product of the same manufacturer product or of compatible manufacturers.

ii) Major equipment such as medium voltage switchgear, static capacitor banks, instrument transformers, protection relays, etc. will be procured from qualified and reputed manufacture in the world.

<u>Construction stage</u>

i) It is important to pay attention to the connection and adjustment with the existing equipment. Based on the route map of the existing 132 kV and 33 kV power cables, it is necessary to prepare the installation plan carefully so that such cables may not interfere with the existing power cables.

ii) The power shutdown schedule shall be carefully prepared and forewarned for worker's safety.

6.3.2 Distribution Projects

(1) Implementation Schedule

1) Low voltage (LV) scheme project

The implementation period for the LV scheme at a total of 703 locations was planned for 24 months, as shown in Table 6.3-7.

Table 6.3-7 Implementation Schedule for LV Scheme

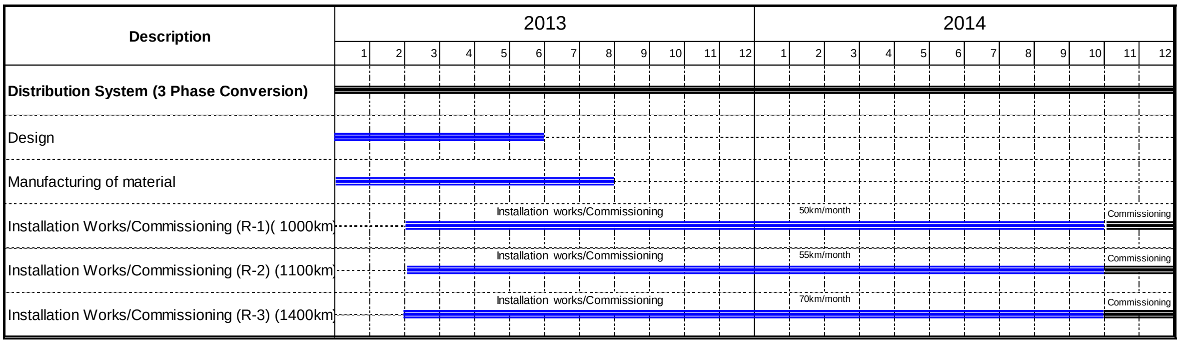
Description	2013												2014											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Distribution System (LV Scheme)																								
Design																								
Manufacturing of equipment																								
Installation Works/Commissioning (R-2) (440 locations)											22 locations/ month												Commissioning	
Installation Works/Commissioning (R-3) (225 locations)											11 locations/ month				Commissioning								Commissioning	
Installation Works/Commissioning (R-4) (38 locations)											3 locations/ month				Commissioning									

(Prepared by the Survey Team)

2) Single phase to three phase conversion project

The implementation period for LV single phase to three phase conversion of a total of 3,500 km of was planned for 24 months, as shown in Table 6.3-8.

Table 6.3-8 Implementation Schedule for Three Phase Conversion

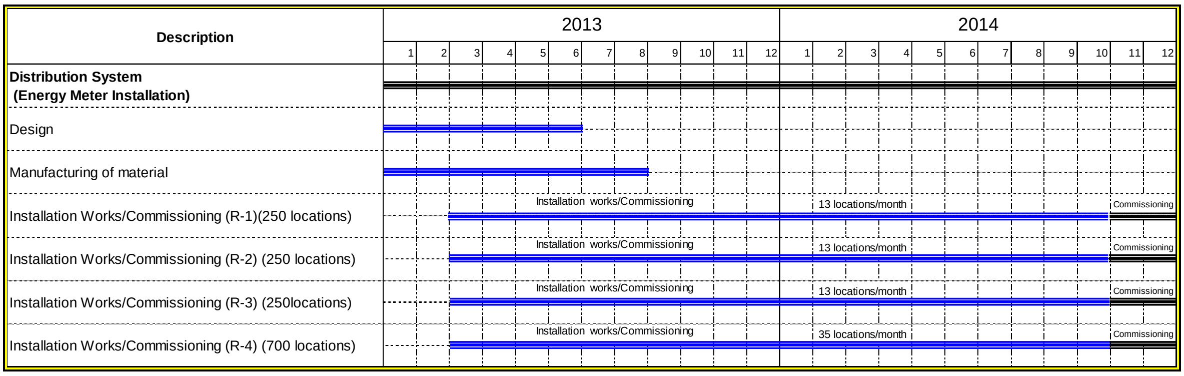


(Prepared by the Survey Team)

3) Energy meter installation project

The implementation period for energy meter installation of a total of 1,450 units was planned for 24 months, as shown in Table 6.3-9.

Table 6.3-9 Implementation Schedule for Energy Meter Installation

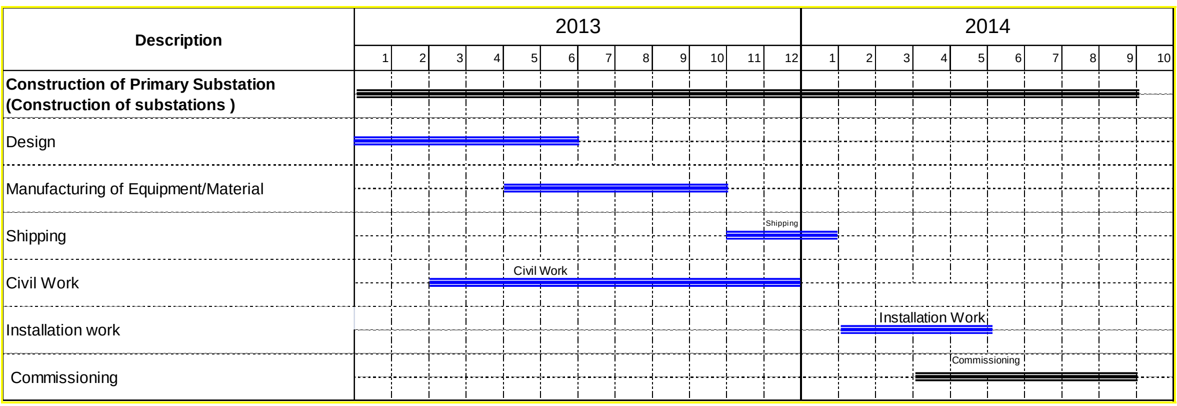


(Prepared by the Survey Team)

4) Construction of primary substations (PSs) and 33 kV distribution lines

The implementation period for the construction of a total of six primary substations was planned for 21 months, as shown in Table 6.3-10.

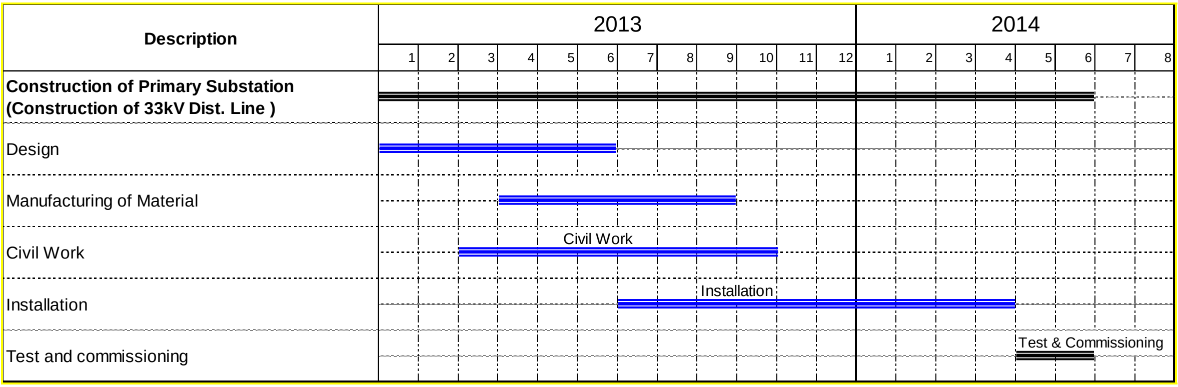
Table 6.3-10 Implementation Schedule for the Construction of Primary Substations



(Prepared by the Survey Team)

In addition, the implementation period for the re-conductoring of a total of 28 km of 33 kV distribution lines was planned for 17 months, as shown in Table 6.3-11.

Table 6.3-11 Implementation Schedule for the Construction of 33 kV Distribution Lines

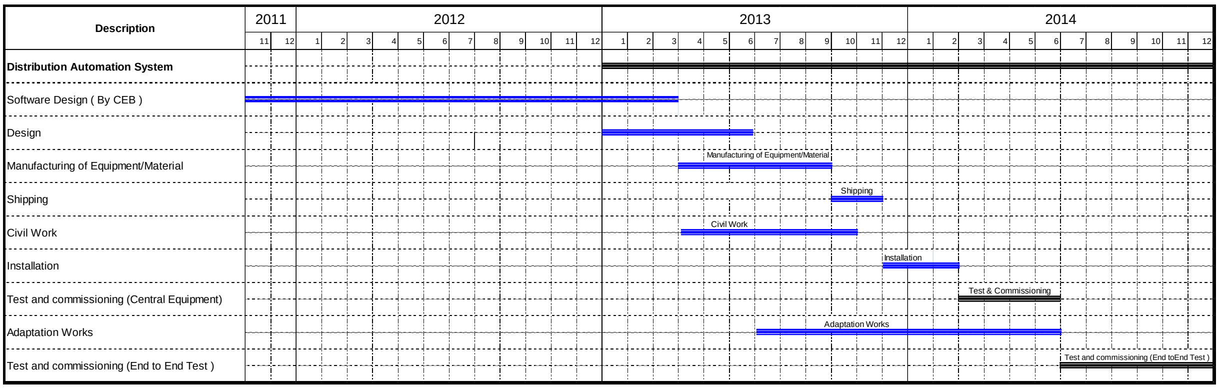


(Prepared by the Survey Team)

5) Distribution automation system (DAS)

The implementation period for introducing DAS, including software development by the CEB, was planned for 38 months, as shown in Table 6.3-12.

Table 6.3-12 Implementation Schedule for DAS



(Prepared by the Survey Team)

(2) Supply Source of Equipment

The supply sources of each equipment or material are as shown in Table 6.3-13 with consideration with the following situations:

1) Most of the major equipment is to be supplied from Europe, USA and Australia.

2) It was assumed that distribution transformers are to be purchased in Sri Lanka due to the standardized the CEB specifications for distribution transformers.

3) It was assumed that 33/11 kV substation equipment is to be supplied from Europe, China and Southeast Asia since prices are more economical.

Table 6.3-13 Supplier of Distribution Equipment

System	Equipment	Countries	Manufacturers
LV scheme	Distribution Transformer (DT)	Sri Lanka	LT Limited
	Insulators, etc.	USA	-
Three Phase Conversion	Insulators, etc.	USA	-
Energy Meter	Watt Hour Meter	Europe Singapore	Secure EDMI
New PS	33/11 kV Transformer	Europe/Asia	-
	33/11 kV Switchgear	Europe	ABB, Siemens and others.
DAS	Software	To be provided by the CEB	
	Recloser	Australia, China	Schneider Elec. Zhejiang Yuguang
	LBS	France Australia	Novexia Export Schneider Elec
	Fault Indicator	Norway Australia	Nortroll – Schneider Elec.
	Watt Hour Meter	Europe Singapore	Secure EDMI
	Ring Main Unit	UK India	Lucy Electric Siemens India

(Prepared by the Survey Team)

(3) Important Matters to be considered at the Construction Site

1) The equipment shall be installed according to the standardized drawings. Then it is necessary to leave its information at each location for traceability.
2) In the project, some equipment will be supplied as back up. Then the scope of supply shall be decided not to make any discrepancy.
3) Interface conditions will be coordinated between each package under the project when the contract is divided into several contracts.
4) Sufficient training will be given to workers so as not to cause quality and safety problems at the construction site.
5) A safety supervisor shall be assigned at the construction site to manage its safety. Especially, confirmation of de-energizing of electrical power and temporary earth works will be checked.

6.4 Revised Project Costs

6.4.1 Transmission Projects

The Survey Team has estimated the costs for the candidate projects by applying revised unit rates, which were prepared by the Survey Team based on past records of projects carried out in Sri Lanka and actual unit costs. The revised unit rates are attached at the end of this chapter.

(1) New Habarana–Veyangoda TL Project

Table 6.4-1 shows the revised base costs of the New Habarana–Veyangoda TL Project.

Table 6.4-1 Reviewed Project Costs of New Habarana–Veyangoda TL

New Habarana–Veyangoda TL Project	CEB's Estimate (MLKR)		Survey Team's Estimate (MLKR)	
	FC	LC	FC	LC
1) Construction of new Habarana SS	1,552.8	229.1	2,195.1	289.3
2) Construction of connection line from Kotmale–new Anuradhapura TL	11.5	5.3	24.2	5.6
3) Construction of new Habarana–Veyangoda 220 kV TL	4,567.3	1,872.8	5,744.9	821.7
4) Augmentation of Veyangoda GS	105.8	7.7	100.7	20.8
5) Construction of 1.5 km quadruple 132 kV tower line to carry 132 kV circuits from Ukuwela and Valachenai to New Habarana	31.5	16.5	47.2	8.3
Total of 1) ～ 5)	6,268.9	2,131.4	8,112.1	1,145.7
Total (FC+LC) in MLKR		8,400.3		9,257.8
Total in MJPY equiv.		6,384.2		7,035.9

(Prepared by the Survey Team)

In addition, Table 6.4-2 shows the comparison of construction costs between the TLs of 2× ACSR Zebra and 2×LL-TACSR 550 mm^2 in two circuits, as estimated by the Survey Team.

Table 6.4-2 Comparison of Construction Costs

2 x ACSR Zebra		2 x LL-TACSR/AS 550 mm^2	
MLKR	MJPY eq.	MLKR	MJPY eq.
6,566.6	4,990.6	8,130.1	6,178.9
	Amount of Increase	1,563.5	1,188.3
	Ratio of Increase		24%

(Prepared by the Survey Team)

Table 6.4-3 shows the assumed loss reduction amounts and costs with and without Japan's technology.

Table 6.4-3 Loss Reduction Amounts and Costs

CEB's Proposed Project (2 x ACSR Zebra, 2-cct)			Japan's Technique applied Project (2 x LL-TACSR/AS 550 mm^2 2-cct)		
Loss Reduction (MWh/year)	Reviewed Cost by the Survey Team		Loss Reduction (MWh/year)	Estimate by the Survey Team	
	MLKR	MJPY eq.		MLKR	MJPY eq.
122,931	9,257.8	7,035.9	196,261 (122,931 + 73,330)	10,821.4	8,224.3
		Amount of Increase	73,330	1,563.6	1,188.4
		Ratio of Increase	59.7%		16.9%

(Prepared by the Survey Team)

Although there is a cost increase of 16.9 % as a result of applying LL-TACSR/AS instead of ACSR Zebra, annual loss reduction of 59.7 % can be attained. It was found out that the application of LL-TACSR/AS through Japan's technique achieves high cost performance.

(2) Polpitiya–Habarana TL Reconstruction Project

Table 6.4-4 shows the revised base costs of the Polpitiya–Habarana TL Reconstruction Project.

Table 6.4-4 Reviewed Project Costs of Polpitiya–Habarana TL Reconstruction

Reconstruction of Polpitiya–Habarana TL Project 1)–4)	CEB's Estimate (MLKR)		Survey Team's Estimate (MLKR)	
	FC	LC	FC	LC
1) Reconstruction of Polpitiya – Kiribathkumbura TL	841.12	438.92	1,214.58	581.96
2) Reconstruction of Kiribathkumbura – Ukuwela TL	485.26	253.23	698.45	334.61
3) Reconstruction of Ukuwela –Habarana TL	1,326.38	692.15	1,918.40	919.27
4) Removal of existing TL	0.00	73.80	0.00	73.80
5) Conversion of existing Habarana SS	-	-	89.47	20.16
Total 1) ～5)	2,652.76	1,458.10	3,920.90	1,929.80
Total (FC+LC) in MLKR	4,110.86		5,850.70	
Total in MJPY equiv.	3,124.25		4,446.53	

(Prepared by the Survey Team, 1 LKR = 0.76 JPY)

The project cost estimated by the CEB does not include the costs of conversion of the existing TL to Habarana SS. As a result of adding the cost, the project cost reviewed by the Survey Team becomes 1.42 times of the CEB's project cost.

Table 6.4-5 shows the assumed construction costs for the 132 kV TL with ACSR Zebra and LL-ACSR 550 mm^2 in two circuits, with cost data of Japanese products.

Table 6.4-5 Loss Reduction Amounts and Costs

CEB's Proposed Project (ACSR Zebra, 2-cct)			Japan's Technique applied Project (LL-ACSR/AS 550 mm^2, 2-cct)		
Loss Reduction (MWh/year)	Reviewed Cost by the Survey Team		Loss Reduction (MWh/year)	Estimate by the Survey Team	
	MLKR	MJPY eq.		MLKR	MJPY eq.
31,536	5,850.7	4,446.5	36,792 (31,536 + 5,256)	6,968.2	5,295.8
Amount of Increase			5,256	1,117.5	849
Ratio of Increase			16.7%	19.1%	

(Prepared by the Survey Team, 1 LKR = 0.76 JPY)

(3) Substation Construction and Augmentation Project

Table 6.4-6 shows the revised base costs of the substation construction and augmentation projects.

Table 6.4-6 Reviewed Project Costs of Substation Construction and Augmentation

Projects	CEB's Estimate (MLKR)		Survey Team's Estimate (MLKR)	
	FC	LC	FC	LC
(A) Augmentation of Colombo A GS				
1) Transformers 132/11 kV/31.5 MVA and E. Tr	83.4	16.9	108.7	0.8
2) 132 kV S/B transformer bay (GIS)	51.9	1.2	56.9	0.4
3) 11 kV transformer bay (GIS)	15.0	0.3	5.9	0.2
4) Common items for 132/11 kV grid (GIS)	35.2	20.6	47.6	0.5
5) Substation remote control system	18.3	0.2	9.7	0.1
6)Civil works, installation and other services	-	-	34.3	32.5
Total 1) ～6)	203.8	39.2	263.1	34.5
Total (FC+LC) in MLKR		243.0		297.6
Total in MJPY equiv.		184.7		226.2
(B) Construction of Kalutara 132/33 kV GS				
1) Construction of Kalutara 132/33kV GS	663.3	121.9	774.2	247.8
2) Construction of interconnecting line	97.1	50.6	138.1	66.9
Total 1) ～2)	760.4	172.5	912.3	314.7
Total (FC+LC) in MLKR		932.9		1,227.0
Total in MJPY equiv.		709.0		932.5
(C) Augmentation of Madampe 132/33 kV GS				
1) Augmentation of Madampe 132/33kV GS	202.6	48.0	318.8	40.3
2) Installation of breaker switched capacitors	116.2	8.4	138.2	5.7
Total 1) ～2)	318.8	56.4	457.0	46.0
Total (FC+LC) in MLKR		375.2		503.0
Total in MJPY equiv.		285.2		382.3
(D) Installation of Reactive Power Compensation Devices				
Reactive power compensation devices for 8 GSs	1,084.4	78.4	1,643.6	127.7
Total (FC+LC) in MLKR		1,162.8		1,771.3
Total in MJPY equiv.		883.7		1,346.2

(Prepared by the Survey Team, 1 LKR = 0.76 JPY)

6.4.2 Distribution Projects

(1) LV Schemes, Three Phase Conversions and Energy Meters

Table 6.4-7 shows the estimated project base costs of the LV schemes, three phase conversions and energy meters.

Table 6.4-7 Estimated Project Costs of LV Schemes, Three Phase Conversions and Energy Meters

Description	Region	Q'ty.	Unit Cost (MLKR)		Total Cost (MLKR)	
			FC	LC	FC	LC
LV scheme	Region 2	440	0.46	3.54	202.4	1,557.6
	Region 3	225	0.46	3.54	103.5	796.5
	Region 4	38	0.46	3.54	17.5	134.5
3 Phase Conversion	Region 1	1,000	-	0.50	-	500.0
	Region 2	1,100	-	0.50	-	550.0
	Region 3	1,400	-	0.50	-	700.0
Energy Meter	Region 1	250	0.0157	0.0471	3.925	11.775
	Region 2	250	0.0157	0.0471	3.925	11.775
	Region 3	250	0.0157	0.0471	3.925	11.775
	Region 4	700	0.0157	0.0471	10.99	32.97
				Total	22.765	4630.3
					Total in MJPY equiv.	3,536.3

(Prepared by the Survey Team, 1 LKR = 0.76 JPY)

(2) New Primary Substations

Table 6.4-8 shows the estimated project base costs of the new PSs and 33 kV distribution lines.

Table 6.4-8 Estimated Project Costs of New PSs and Distribution Lines

Description	Region	Quantity	Unit Cost (MLKR)		Total Cost (MLKR)	
			FC	LC	FC	LC
Kalpitiya New PS	Region 1	1 lot	64	11	64	11
Koswadiya New PS		1 lot	64	11	64	11
Keoungoda New PS	Region 2	1 lot	64	11	64	11
Awarakotuwa New PS		1 lot	154	21	154	21
Pugoda To Dekatana Gantry		13 km	2.72	1.81	35	24
Eriyagama to Pichcha Gantry		15 km	7.2	4.8	108	72
Augumentation of Pantana PS	Region 4	1 lot	135	15	135	15
Kalutura New PS		1 lot	154	21	154	21
Fullerton to Kalutura PS		2 km	3.3	2.2	6.6	4.4
Total in MLKR					785	190
Total in MJPY equiv.					741	

(Prepared by the Survey Team, 1 LKR = 0.76 JPY)

(3) DAS

Table 6.4-9 shows the estimated project base costs of DAS for the Central Province.

Table 6.4-9 Estimated Cost of DAS for the Central Province

Description	Quantity	Unit Cost (MLKR)		Total Cost (MLKR)	
		FC	LC	FC	LC
Auto-Reclose unit with remote operable facility	65 units.	1.8	-	117	-
Local breaker switches/sectionalizers with remote operable	125 units	1.6	-	200	-
Sectionalizers with remote monitoring facility	250 sets	0.5	-	125	-
Fault Indicators with remote monitoring facility	400 sets	0.1	-	40	-
Energy meters with remote monitoring facility	125 units	0.08	-	10	-
Installation of SF6 ring main unit with remote operable facility	20 sets	1.8	-	36	-
Installation of 33 kV UG or overhead insulated cable between Pogolla PSS to Bogambara PSS	10 km	20	-	200	-
Installation of 33 kV UG or overhead insulated cable between Bogambara PSS to Gatambe PSS	10 km	18	2	180	20
Installation of new Wattaranthenna PSS (2x5 MVA)	1 lot	154	21	154	21
33 kV TL to the nearest junction point	1.5 km	8.4	5.6	13	8
Capacity building for engineers in Region 2	1 lot	22	-	22	-
Total in MLKR				1,097	49
Total in MJPY equiv.				871	

(Prepared by the Survey Team, 1 LKR = 0.76 JPY)

Attachment for Chapter 6: Revised Unit Rates

US $ =yen	83.4
LKR =yen	0.76
EUR € =yen	120.35

Item	Unit Price (Consultant)	
	Foreign	Local
	yen(*1000)	LKR(*1000)
New Habarana SS - Veyangoda GS Transmission Project		
New Habarana Switch Yard for 220kV and 132kV		
220kV Feeder Line Bays (8 Nos.)	14,409	196.4
220kV Bus Coupler Bay (1 No.)	9,207	137.4
220kV Transformer Bay (2 Nos.)	10,964	156.3
Neutral Current Transformer bays (2 Nos.)	1,513	23.7
Transformers	361,200	1,609.0
220kV Double Busbar & Gantries	27,299	2,117.3
132kV Transformer Bay (2 Nos.)	4,694	180.9
132kV Feeder Line Bays (6 Nos.)	5,388	187.3
132kV Bus Coupler Bay (1 No.)	3,662	166.8
132kV Double Busbar & Gantries	16,379	1,270.4
Common Item for 220kV and 132kV Grid	229,427	2,819.6
Substation Automation System	129,602	1,995.2
Civil Works, Installation and Other Services for Substation	217,608	272,315.3
220kV Feeder Line Bays (2 Nos.)	10,964	156.3
220kV Double Busbar & Gantries	3,640	282.3
Common Item for 220kV Grid	19,337	322.2
Modification of Substation Automation System	7,377	100.5
Civil Works, Installation and Other Services for Substation	9,986	19,596.4
Connection line from Kotmale - New Anuradhapura transmission line		
Transmission Materials (Conductor+10%)	15,413	0.0
Civil Works, Installation and Transportation	2,945	5,571.7
Construction of New Habarana - Veyangoda 220kV Transmission Line		
Transmission Materials (Zebra, Conductor+10%)	3,949,554	0.0
Civil Works, Installation and Transportation	416,579	821,670.9
Construction of New Habarana - Veyangoda 220kV Transmission Line with Japan's Technique		
Transmission Materials(LL-TACSR/AS, conductor+10%)	5,137,852	0.0
Civil Works, Installation and Transportation	416,579	821,670.9
Construction of 1.5 km quadruple 132 kV tower line to carry 132 kV circuits from Ukuwela and Valachenai to NEW Habanara		
Transmission Materials(Conductor+10%)	31,919	0.0
Civil Works, Installation and Transportation	3,977	8,303.9
Polpitiya HP - Habarana GS Transmission Project		
OLD Habarana Switch Yard for 132kV		
132kV Feeder Line Bays (2 Nos.)	4,694	187.3
132kV Bus Coupler Bay (1 No.)	3,662	166.8
132kV Single Busbar & Gantries	5,303	50.9
Common Item for 220kV and 132kV Grid	18,598	322.9
Modification of Substation Automation System	7,377	100.5
Civil Works, Installation and Other Services for Substation	8,869	18,975.8
132kV Transmission Line(Polpitiya-Kribathkumbra) (Zebra, Conductor+10%)	923,083	581,964.1
132kV Transmission Line(Polpitiya-Kribathkumbra) (LL-ACSR/AS, Conductor+10%)	1,192,362	581,964.1
132kV Transmission Line(Kribathkumbra-Ukuwela) (Zebra, Conductor+10%)	530,822	334,605.8
132kV Transmission Line(Kribathkumbra-Ukuwela) (LL-ACSR/AS, Conductor+10%)	686,175	334,605.8
132kV Transmission Line(Ukuwela-Habarana) (Zebra, Conductor+10%)	1,457,985	919,270.8
132kV Transmission Line(Ukuwela-Habarana) (LL-ACSR/AS, Conductor+10%)	1,882,617	919,270.8
Removal of Existing Transmission Line	0	73,800.0
Colombo - A GS Extension Project		
132kV GIS Transformer Bay (1 No.)	43,240	395.4
Transformers	82,600	824.5
11kV Switchgear Transformer Bay (1 No.)	4,490	237.2
Common Item for 132kV and 11kV Grid	36,164	472.8
Modification of Substation Automation System	7,377	100.5
Civil Works, Installation and Other Services for Substation	26,081	32,486.2

item	Unit Price (Consultant)	
	Foreign	Local
	yen(*1000)	LKR(*1000)
Kalutara GS New Construction Project		
132kV Feeder Line Bays (2 Nos.)	5,388	187.3
132kV Bus Coupler Bay (1 No.)	3,662	166.8
132kV Transformer Bay (2 Nos.)	3,930	169.3
132kV Single Busbar & Gantries	5,303	50.9
Transformers	83,800	834.5
33kV Switchgear	17,060	711.7
Common Item for 132kV and 33kV Grid	115,829	7,457.6
Substation Automation System	45,361	698.3
Civil Works, Installation and Other Services for Substation	73,861	233,238.0
132kV Single in & out connection from Pannipitiya - Mathugama 132kV Transmission line	104,942	66,921.2
Madampe GS Extension Project		
Madampe GS for 132kV and 33kV		
132kV Transformer Bay (1 No.)	3,757	167.7
132kV Single Busbar & Gantries	2,652	20.4
Transformers	82,600	824.5
33kV Switchgear	17,060	711.7
Static Capacitor Bank	17,500	948.9
Common Item for 132kV and 33kV Grid	66,091	1,642.4
Modification of Substation Automation System	9,072	139.7
Civil Works, Installation and Other Services for Substation	19,656	35,759.2
Reactive Power New Construction Project		
Biyagama GS		
33kV Feeder Bay (2 Nos.)	2,527	163.2
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	25,443	1,510.6
Civil Works, Installation and Other Services for Substation	7,432	11,428.0
33kV Switchgear	6,734	237.2
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	25,923	1,529.1
Civil Works, Installation and Other Services for Substation	6,624	10,429.7
Chunnakam GS		
33kV Switchgear	6,734	237.2
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	21,318	1,004.8
Civil Works, Installation and Other Services for Substation	6,653	6,935.4
Pannala GS		
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	12,082	833.5
Civil Works, Installation and Other Services for Substation	5,854	6,526.8
Bolawatta GS		
33kV Feeder Bay (1 No.)	2,527	163.2
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	21,101	996.0
Civil Works, Installation and Other Services for Substation	7,753	8,230.9
Veyangoda GS		
33kV Switchgear	6,734	237.2
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	21,318	1,004.8
Civil Works, Installation and Other Services for Substation	6,653	6,935.4
New Kolonnawa GS		
33kV Switchgear	6,734	237.2
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	21,318	1,004.8
Civil Works, Installation and Other Services for Substation	6,653	6,935.4
Old Kolonnawa GS		
Static Capacitor Bank	17,500	948.9
Common Item for 33kV Grid	12,082	833.5
Civil Works, Installation and Other Services for Substation	5,854	6,526.8

CHAPTER 7
ECONOMIC EVALUATION

CHAPTER 7 ECONOMIC EVALUATION

7.1 Methodology of Economic Evaluation

(1) Outline

In general, a project will be evaluated with the engineering and economic aspects taken into consideration. The engineering aspects are studied based on the technical feasibility of the project from the viewpoints of construction, and operations and maintenance (O&M). On the other hand, economic analysis focuses on the economic costs and benefits under study in terms of the national economy. In other words, economic analysis evaluates the degree of economic impacts of a project under study that it would bring about in the national economy.

Project inputs such as construction and O&M costs, including fuel cost in case of a project under study for electricity loss reduction, are evaluated in terms of the national economy. These project inputs are called “economic costs”.

Decreased long-term investment costs due to reduction in the electricity loss such as reduced capacity or energy costs are also evaluated in terms of the national economy. These reduced investment costs are called “economic benefits”. In this case, the benefits should be at least as great as those obtainable from other marginal investment opportunities.

Economic costs and benefits are estimated throughout the project life. The first year of the project life is when the first construction disbursement is made, and the last year is when the facilities constructed under the project are to be scrapped.

For the economic evaluation of this study, the following steps will be taken:

1) Measurement of economic costs and benefits and comparison between candidate projects.
2) Sensitivity tests to the conclusion of the base case of such comparison.

Economic costs and benefits throughout the project life are compared in terms of present values. If the total present value of economic costs equals that of economic benefits (B/C=1), the discount rate used to calculate the present value is called the economic internal rate of return (EIRR).

(2) Identification of Economic Benefits of Electricity Loss Reduction Project

The economic benefit of a countermeasure under study can be estimated as the gap between the electricity loss “with the project” and that “without the project”. In this case, the electricity loss evaluated as energy value is as mentioned below. The electricity loss counted as economic benefit should be considered as the total of these values.

(3) Selection of Project Combinations

For the estimation of optimal electricity loss with the projects, the best selection should be made considering the existing situation of both the transmission and distribution systems in Sri Lanka.

The following alternatives were studied in Chapter 6:

Candidate 1 New Habarana–Veyangoda 220 kV TL (without Japan’s technique)
Candidate 1 New Habarana–Veyangoda 220 kV TL (with Japan’s technique)
Candidate 2 Polpitiya–Habarana TL Reconstruction (without Japan’s technique)
Candidate 2 Polpitiya–Habarana TL Reconstruction (with Japan’s technique)
Candidate 3 Construction and Augmentation of Grid Substations
Candidate 4 Distribution Project Package in NWP of Region 1
Candidate 5 Distribution Project Package in WPN of Region 2
Candidate 6 Distribution Project Package in CP of Region 2
Candidate 7 Distribution Project Package in WPS-2 of Region 3
Candidate 8 Distribution Project Package in SP of Region 3
Candidate 9 Distribution Project Package in WPS-1 of Region 4

Both costs and benefits (reduction values of electricity loss) of the countermeasure will depend on these project combinations. These costs and benefits were estimated in terms of the long-run marginal cost (LRMC) in the countermeasure.

(4) Evaluation of Economic Benefits

In order to evaluate the benefits, an energy value described as “GWh-value” was calculated. The GWh-value represents fuel and variable O&M costs of the power plant, and is called “energy benefit”.

Fuel and variable O&M costs depend on the condition of the thermal power plant’s facilities. In the case of Ceylon Electricity Board (CEB), a unit value of cost per GWh is estimated based on standard fuel cost per GWh generated by Kelanitissa Thermal Power Plant (Combined Cycle gas turbine), which is used both for base load and switching load. The benefit is calculated using this unit value multiplied by the designed with- and without-electricity losses.

In general, the direct loss reduction effect of energy meters and distribution automation systems (DAS) are unclear, because these are techniques for monitoring the electricity losses and incidents. But by visualizing the distribution losses and incidents, these techniques become indirectly effective. For example, exact and real-time data will be helpful for accurate decision-making and generation control.

(5) Identification of Economic Cost

The economic cost was identified as the opportunity cost of the project.

(6) Evaluation of Economic Cost

1) Foreign currency (FC) portion

The FC portion of the construction costs was estimated in either cost, insurance, and freight (CIF) price or free on board (FOB) price. These international prices are assumed to reflect economic cost directly.

2) Local currency (LC) portion

Since it was presumed that local markets in developing countries are distorted by price and border controls and other regulations, prices in the domestic markets do not reflect economic scarcity of products and services. This means that the prices cannot be used to evaluate economic costs of local procurement and have to be adjusted into economic prices.

In this case, standard conversion factors (SCF) are used to convert the costs in domestic markets into economic costs. Also, a SCF is estimated by using export and import statistics. However, the SCF is applied only to tradable goods. The economic costs of non-tradable goods and services have to be separately calculated.

(7) Evaluation Criteria

The EIRR is calculated and used as an index of economical feasibility. The EIRR is defined by the following formula:

$$\sum_{t=1}^{t=T} \frac{C_{ep}}{(1+R)^t} = \sum_{t=1}^{t=T} \frac{B_{cc}}{(1+R)^t}$$

where:

T = last year of the project life

C_{ep} = annual economic cost flow of the project under study in year t

B_{cc} = annual benefit flow derived from an alternative candidate in year t

R = EIRR

7.2 Result of Economic Evaluation

7.2.1 Economic Cost

Firstly, the net construction cost of each candidate project was estimated based on the price mentioned in previous chapters. Using these net construction costs, the economic costs of the candidate projects were estimated. In this case, the costs include the following three items: (1) material cost, (2) labor cost, and (3) administration cost with a rate of 10%. For estimating the economic cost of the candidates, the following conditions were considered based on the discussion with the CEB:

1) The shared rates of materials and labor costs to each item cost are applied as 75% and 25% for overhead lines.
2) Of the materials, 25% are to be procured locally. Therefore, 25% of material costs are allocated in the LC portion.
3) The labor costs are allocated in the LC portion.
4) Personal income tax with a rate of 5% is applied for labor costs.
5) Corporation income tax and other levies by the government with a rate of 4% are applied for the total costs.

For estimation of the actual necessary construction cost, price escalation rates of 3.06% for the FC portion and 5.90% for the LC portion were applied, and physical contingency with a rate of 10% was applied.

The results of estimation of economic costs are shown in Table 7.2-1. In this case, price escalation should be excluded in the economic analysis.

Table 7.2-1 Estimation of Economic Cost of Each Project

Construction Works	Economic Cost (MLKR)		
	FC portion	LC portion	Total
Candidate 1 New Habarana–Veyangoda TL (without Japan's technique)	8,923.3	1,210.7	10,134.0
Candidate 1 New Habarana–Veyangoda TL (with Japan's technique)	10,643.2	1,210.7	11,853.8
Candidate 2 Polpitiya–Habarana TL Reconstruction (without Japan's technique)	4,313.0	2,039.2	6,352.2
Candidate 2 Polpitiya–Habarana TL Reconstruction (with Japan's technique)	5,542.3	2,039.2	7,581.5
Candidate 3 Construction and Augmentation of Grid Substations	3,603.6	552.5	4,156.1
Candidate 4 Distribution Project Package in NWP of Region 1	533.2	191.2	724.4
Candidate 5 Distribution Project Package in WPN of Region 2	583.3	186.8	770.0
Candidate 6 Distribution Project Package in CP of Region 2	2,684.6	859.6	3,544.2
Candidate 7 Distribution Project Package WPS-2 of Region 3	625.4	200.2	825.6
Candidate 8 Distribution Project Package SP of Region 3	707.9	226.7	934.5
Candidate 9 Distribution Project Package WPS-1 of Region 4	356.4	114.1	470.5

(Prepared by the Survey Team)

Attachment 5-1 shows the details of economic cost estimation.

7.2.2 Economic Benefit

In the case of without-projects, the CEB should pay additional energy cost for fuel to cover electricity losses so that customers may be supplied necessary electricity without any trouble. If the projects are executed, these additional costs will be saved. These saved costs are economic benefits in case of similar projects with loss reduction.

A unit marginal energy cost is estimated by the record of fuel consumption and gross electricity generation of power plants. In the case of Sri Lanka, Combined Cycle gas turbines in the Kelanitissa Thermal Power Plant are used universally for base load and switching load. If the projects are executed, operation rate of these facilities can be decreased. The unit marginal energy cost was estimated at 17.87 LKR million/GWh based on the discussion with the Generation Planning Division of the CEB.

Moreover, the Kelanitissa Thermal Power Plant is close to the central area of Colombo City. Reducing its operations rate can lead to the reduction of CO_2, SO_x and NO_x emission. It means that the projects can save external costs which the residents in Colombo City bear, and the projects will produce economic as well as environmental and social benefits. The unit marginal discharge cost of gas was estimated at 1.12 LKR million/GWh (CO_2), 0.86 LKR million/GWh (SO_x) and 0.02 LKR million/GWh (NO_x) based on the "Clean development mechanism simplified project design document for small-scale project activities (SSC-CDM-PDD) Version 02" issued by the United Nations Framework Convention on Climate Change (UNFCCC).

The benefits of energy meters and DAS were measured by indirect loss reduction. It was said that about 5–15% of the total loss can be reduced in similar cases (in Indonesia and Philippine donated by Ministry of Economy, Trade and Industry of Japan). In this study, loss reduction ratio by DAS (Candidate in CP of Region 2) was estimated at 15% and by energy meters was estimated at 5% (Candidates exclude CP) of the total losses.

The amounts of these loss reductions were estimated from the energy loss reduction volumes (GWh) of each project, as shown in Chapters 4 and 5, by multiplying the said unit marginal energy cost (17.87 LKR million/GWh).

In general, these types of projects are designed at least 30 years until effecting of the works, and the effects increase with demand growth corresponding to at least ten years, so that the loss reduction volumes will be increased up to ten years when the projects have started. After reaching the maximum electricity loss reduction, it is assumed that the same amount of loss reduction is sustained up to the end of the project life which ends 30 years after the completion of each project.

In the case of transmission projects, such are mostly composed of TLs which have no movable parts. It means that they have less O&M costs than any other candidate. For this reason, O&M cost of TL is set to 1.0% which is 1.5% less. The results of estimation of maximum electricity loss reduction are shown in Table 7.2-2.

Table 7.2-2 Estimation of Maximum Electricity Loss Reduction

Project items	Annual amount of loss reduction (MLKR)	Attained year
Candidate 1 New Habarana–Veyangoda TL (without Japan's technique)	3,346.0	2025
Candidate 1 New Habarana–Veyangoda TL (with Japan's technique)	4,717.6	2025
Candidate 2 Polpitiya–Habarana TL Reconstruction (without Japan's technique)	984.1	2023
Candidate 2 Polpitiya–Habarana TL Reconstruction (with Japan's technique)	1,148.1	2023
Candidate 3 Construction and Augmentation of Grid Substations	1,809.0	2019
Candidate 4 Distribution Project Package in NWP of Region 1	301.1	2018
Candidate 5 Distribution Project Package in WPN of Region 2	179.7	2018
Candidate 6 Distribution Project Package in CP of Region 2	478.7	2018
Candidate 7 Distribution Project Package WPS-2 of Region 3	230.5	2018
Candidate 8 Distribution Project Package SP of Region 3	134.8	2018
Candidate 9 Distribution Project Package WPS-1 of Region 4	146.8	2018

(Prepared by the Survey Team)

7.2.3 Economic Evaluation

The economic evaluation of the candidate projects was made by using cash flows of the said economic costs and benefits. The results are summarized in Table 7.2-3. In this case, the B/C ratio is the comparison between benefit and cost in their net present value, and B-C is the net cash balance between benefit and cost also in their net present value. For calculation of net present value, a discount rate of 10% was equally applied to similar projects.

Table 7.2-3 Result of Economic Evaluation

Project items	EIRR	B/C ratio	B-C (MLKR)
Candidate 1 New Habarana–Veyangoda TL (without Japan's technique)	17.41%	2.00	9,284.9
Candidate 1 New Habarana–Veyangoda TL (with Japan's technique)	19.29%	2.38	15,010.7
Candidate 2 Polpitiya–Habarana TL Reconstruction (without Japan's technique)	9.90%	0.99	-44.1
Candidate 2 Polpitiya–Habarana TL Reconstruction (with Japan's technique)	10.92%	1.09	619.3
Candidate 3 Construction and Augmentation of Grid Substations	32.10%	3.71	10,287.1
Candidate 4 Distribution Project Package in NWP of Region 1	27.07%	2.94	1512.8
Candidate 5 Distribution Project Package in WPN of Region 2	16.70%	1.65	538.1
Candidate 6 Distribution Project Package in CP of Region 2	10.46%	1.04	137.3
Candidate 7 Distribution Project Package WPS-2 of Region 3	21.04%	2.15	938.1
Candidate 8 Distribution Project Package SP of Region 3	10.22%	1.02	18.7
Candidate 9 Distribution Project Package WPS-1 of Region 4	21.50%	2.20	610.5

(Prepared by the Survey Team)

The result of Candidates 1 and 2 are separated into "with Japan's technique" and "without Japan's technique". It shows that even the construction costs of the projects using Japan's technique are expensive, such are reasonable enough in terms of Sri Lanka's national economic aspects.

Attachment 5-2 shows the details of economic evaluation.

7.3 Sensitivity Analysis

There are constant fluctuations in the prices of construction materials used for these kinds of projects as a reflection of the condition of the economy. Considering this situation, a sensitivity analysis was made under a pessimistic case with condition of plus 30% cost. Table 7.3-1 shows the results of sensitivity analysis for economic features.

Table 7.3-1 Sensitivity of EIRR

Project	EIRR base case	EIRR +30% cost
Candidate 1 New Habarana–Veyangoda TL (without Japan's technique)	17.41%	14.36%
Candidate 1 New Habarana–Veyangoda TL (with Japan's technique)	19.29%	16.14%
Candidate 2 Polpitiya–Habarana TL Reconstruction (without Japan's technique)	9.90%	6.79%
Candidate 2 Polpitiya–Habarana TL Reconstruction (with Japan's technique)	10.92%	8.23%
Candidate 3 Construction and Augmentation of Grid Substations	32.10%	26.09%
Candidate 4 Distribution Project Package in NWP of Region 1	27.07%	21.95%
Candidate 5 Distribution Project Package in WPN of Region 2	16.70%	12.98%
Candidate 6 Distribution Project Package in CP of Region 2	10.46%	7.46%
Candidate 7 Distribution Project Package WPS-2 of Region 3	21.04%	16.74%
Candidate 8 Distribution Project Package SP of Region 3	10.22%	7.24%
Candidate 9 Distribution Project Package WPS-1 of Region 4	21.50%	17.13%

(Prepared by the Survey Team)

As shown in the table, the EIRR values under both benefit and cost in the base case resulted from 9.90% to 32.10% as already studied which is reasonable compared with similar projects. In the case of Candidate 2 (without Japan's Technique), result is lower than the discount rate of 10%, but for using efficient Japan's technique it becomes reasonable result as similar projects.

Under the most pessimistic case with condition of 30% cost increase, the EIRR values are still enough ranging from 12.98% to 26.09% (excluding Candidates 2, 6 and 8). This means that these projects under study are economically sound. However, Candidates 2, 6 and 8 show a low EIRR as compared to the discount rate of 10%. This means that Candidates 2, 6 and 8 should be carefully considered in terms of cost savings and hedging against price escalation.

CHAPTER 8
CASE STUDY FOR LOSS REDUCTION

CHAPTER 8 CASE STUDY ON LOSS REDUCTION

8.1 General

Chapter 8 demonstrates the appropriate project combination, as a case study, to be organized in view of enhancing project benefits for loss reduction out of the candidate projects, including the transmission line (TL), grid substation (GS) and distribution subprojects, which were explained in Chapters 3, 4 and 6.

In order to organize the optimum project components by combining each candidate transmission and distribution project, the following items were considered:

1) Region/area to benefit from the transmission and distribution project
2) Enhancement of loss reduction effects
3) Cost-benefit performance of the project
4) Appropriate project scale
5) Project implementation timing

Especially, regionalization of candidate projects can be expected to enhance more loss reduction and cost minimization benefits.

8.2 Proposed Project Combination and Ranking

Table 8.2-1 shows candidate transmission and distribution projects with project locations selected in Chapters 3 and 4.

Table 8.2-1 Candidate Transmission and Distribution Projects

No.	Ref. No.	Projects	Project Site	
			Region	Area
Transmission/Substation Subprojects				
1	TS1	New Habarana–Veyangoda TL Project	Interregional	
2	TS2	Reconstruction of Polpitiya–Habarana TL Project	Region 2	Central
3	TS3	Augmentation of Colombo A GS	Region 1	Colombo City
4	TS4	Construction of Kalutara 132/33 kV GS	Region 4	WPS-1
5	TS5	Augmentation of Madampe GS	Region 1	NWP
6	TS6.1	Installation of BSC in Biyagama GS	Region 2	WPN
7	TS6.2	Installation of BSC in Sapugaskanda GS	Region 2	WPN
8	TS6.3	Installation of BSC in Chunnakam GS	Region 1	NP
9	TS6.4	Installation of BSC in Pannala GS	Region 1	NWP
10	TS6.5	Installation of BSC in Bolawatta GS	Region 1	NWP
11	TS6.6	Installation of BSC in Veyangoda GS	Region 2	WPN
12	TS6.7	Installation of BSC in New Kolonnawa GS	Region 3	WPS-2
13	TS6.8	Installation of BSC in Old Kolonnawa GS	Region 1	Colombo City

No.	Ref. No.	Projects	Project Site	
			Region	Area
Distribution Subprojects				
1	DS1	New Low Voltage Scheme	Region 2	WPN
				Central
			Region 3	WPS-2
				Saragamuwa
			Region 4	WPS-1
2	DS2	Single Phase to Three Phase Conversion	Region 1	NWP
			Region 2	WPN
				Central
			Region 3	WPS-2
				Saragamuwa
3	DS3	Provision of Energy Meters	Region 1	NWP
			Region 2	WPN
				Central
			Region 3	WPS-2
				Saragamuwa
			Region 4	WPS-1
4	DS4	Provision of New Primary Substations (PSS) and Reinforcement of Distribution Lines	Region 1	NWP
			Region 2	WPN
			Region 4	WPS-1
5	DS5	Provision of Distribution Automation System (DAS)	Region 2	Central

(Prepared by the Survey Team)

(1) Combined Project Components

Table 8.2-2 shows the proposed project components that were combined in consideration of the regions/areas of the project sites.

Table 8.2-2 Evaluation of Loss Reduction Values for Combined Projects

Project Location		Transmission Line/Substation Sub-projects						Distribution Sub-projects						Evaluation of Combined projects by Area (Transmission/Substation+Distribution)			
Region	Area	Project Ref. No.	Loss Reduction (MWh/year)	Project Cost (MLKR)	Loss Reduction by Area (MWh/year) ①	Project Cost by Area (MLKR) ②	Investment Benefit ③=①/②	Project Ref. No.	Loss Reduction (MWh/year)	Project Cost (MLKR)	Loss Reduction by Area (MWh/year) ④	Project Cost by Area (MLKR) ⑤	Investment Benefit ⑥=④/⑤	Loss Reduction (MWh/year) ⑦=①+④	Project Cost (MLKR) ⑧=②+⑤	Total Investment Benefit ⑨=⑦/⑧	Ranking
1	Colombo City	TS3	51.3	297.6	12,065.0	472.4	25.54	-	-	-	-	-	-	12,065.0	472.4	25.54	2
		TS6.8	12,013.7	174.8				-	-	-	-	-	-				
	NP	TS6.3	3,278.7	197.7	3,278.7	197.7	16.58	-	-	-	-	-	-	3,278.7	197.7	16.58	4
	NWP	TS5	537.2	503.0	23,188.0	873.1	26.6	DS2	2,429.0	500.0	2,813.0	665.7	4.2	26,001.0	1,538.8	16.90	3
		TS6.4	12,276.5	174.8				DS3	0.0	15.7							
		TS6.5	10,374.3	195.3				DS4	384.0	150.0							
2	WPN	TS6.1	15,092.2	312.0	46,290.4	831.0	55.7	DS1	560.0	160.0	2,732.0	707.0	3.9	49,022.4	1,538.0	31.87	1
		TS6.2	19,672.5	321.3				DS2	243.0	50.0							
		TS6.6	11,525.7	197.7				DS3	0.0	8.0							
		-	-	-	-	-	-	DS4	1,929.0	489.0							
	Central	TS2	31,536.0	5,850.7	31,536.0	5,850.7	5.39	DS1	5,600.0	1,600.0	8,029.0	3,254.0	2.5	39,565.0	9,104.7	4.35	8
		-	-	-	-	-	-	DS2	2,429.0	500.0							
		-	-	-	-	-	-	DS3	0.0	8.0							
		-	-	-	-	-	-	DS5	0.0	1,146.0							
3	WPS-2	TS6.7	12,501.8	197.7	12,501.8	197.7	63.2	DS1	1,400.0	400	3,101.0	758.0	4.1	15,602.8	955.7	16.33	5
		-	-	-	-	-	-	DS2	1,701.0	350							
		-	-	-	-	-	-	DS3	0.0	8							
	Saragamuwa	-	-	-	-	-	-	DS1	1,750.0	500	3,451.0	858.0	4.0	3,451.0	858.0	4.00	9
		-	-	-	-	-	-	DS2	1,701.0	350							
		-	-	-	-	-	-	DS3	0.0	8							
4	WPS-1	TS4	12,113.8	1,227.0	12,113.8	1,227.0	9.9	DS1	532.0	152.0	920.0	432.0	2.1	13,033.8	1,659.0	7.86	7
		-	-	-	-	-	-	DS3	0.0	44.0							
		-	-	-	-	-	-	DS4	388.0	236.0							
Interregional Project		TS1	122,931.0	9,257.8	122,931.0	9,257.8	13.28	-	-	-	-	-	-	122,931.0	9,257.8	13.28	6

(Prepared by the Survey Team)

The project benefit was derived from the ratio of loss reduction values (MWh/year) per project cost (million LKR) by area for both the proposed transmission and distribution subprojects, and their priorities were evaluated. Please note that the project costs that were revised in Chapter 6 were applied to the study.

From the results of the study, it was clarified that the implementation of the projects in WPN of Region 2 was judged to be the most beneficial in terms of loss reduction. It is then followed by the projects in Colombo City in Region 1, North Western Province (NWP) in Region 1 and Northern Province (NP) in Region 1 as shown in Table 8.2-3.

Table 8.2-3 Ranking of Combined Projects

Ranking	Project Site		Combination of Sub-project Ref. No							Loss Reduction (MWh/year)	Project Cost (MLKR)	Investment Benefit	Project Cost (MJPY)	Cumulated Project Cost (MJPY)
	Region	Coverage Area								(1)	(2)	(1) / (2)	1Rs =0.76Y	
1	2	WPN	TS6.1	TS6.2	TS6.6	DS1	DS2	DS3	DS4	49,022.4	1,538.0	31.9	1,168.9	1,168.9
2	1	Colombo City	TS3	TS6.8						12,065.0	472.4	25.5	359.0	1,527.9
3	1	NWP	TS5	TS6.4	TS6.5	DS2	DS3	DS4		26,001.0	1,538.8	16.9	1,169.5	2,697.4
4	1	NP	TS.6.3							3,278.7	197.7	16.6	150.3	2,847.7
5	3	WPS-2	TS6.7	DS1	DS2	DS3				15,602.8	955.7	16.3	726.3	3,574.0
6	Interregional Project		TS1							122,931.0	9,257.8	13.3	7,035.9	10,609.9
7	4	WPS-1	TS4	DS1	DS3	DS4				13,033.8	1,659.0	7.9	1,260.8	11,870.7
8	2	Central	TS2	DS1	DS2	DS3	DS5			39,565.0	9,104.7	4.3	6,919.6	18,790.3
9	3	Saragamuwa	DS1	DS2	DS3					3,451.0	858.0	4.0	652.1	19,442.4

(Prepared by the Survey Team)

The total proposed cost of the combined projects (ranking from one to nine) amounts to LKR 25,582.1 million (JPY 19,442.4 million[1]).

(2) Projects with Japan's Technique

In case that Japan's technique is to be applied especially for TS1 and TS2 as mentioned in Chapter 6, the loss reduction effects for the combined projects were calculated, as shown in Table 8.2-4.

[1] Applied exchange rate: LKR 1 = JPY 0.76

Table 8.2-4 Evaluation of Loss Reduction Values for Combined Projects with Japan's Technique

Project Location		Transmission Line/Substation Sub-projects						Distribution Sub-projects						Evaluation of Combined projects by Area (Transmission/Substation+Distribution)			
Region	Area	Project Ref. No.	Loss Reduction (MWh/year)	Project Cost (MLKR)	Loss Reduction by Area (MWh/year) ①	Project Cost by Area (MLKR) ②	Investment Benefit ③=①/②	Project Ref. No.	Loss Reduction (MWh/year)	Project Cost (MLKR)	Loss Reduction by Area (MWh/year) ④	Project Cost by Area (MLKR) ⑤	Investment Benefit ⑥=④/⑤	Loss Reduction (MWh/year) ⑦=①+④	Project Cost (MLKR) ⑧=②+⑤	Total Investment Benefit ⑨=⑦/⑧	Ranking
1	Colombo City	TS3	51.3	297.6	12,065.0	472.4	25.54	-	-	-	-	-	-	12,065.0	472.4	25.54	2
		TS6.8	12,013.7	174.8				-	-	-	-	-	-				
	NP	TS6.3	3,278.7	197.7	3,278.7	197.7	16.58	-	-	-	-	-	-	3,278.7	197.7	16.58	5
	NWP	TS5	537.2	503.0	23,188.0	873.1	26.6	DS2	2,429.0	500.0	2,813.0	665.7	4.2	26,001.0	1,538.8	16.90	4
		TS6.4	12,276.5	174.8				DS3	0.0	15.7							
		TS6.5	10,374.3	195.3				DS4	384.0	150.0							
2	WPN	TS6.1	15,092.2	312.0	46,290.4	831.0	55.7	DS1	560.0	160.0	2,732.0	707.0	3.9	49,022.4	1,538.0	31.87	1
		TS6.2	19,672.5	321.3				DS2	243.0	50.0							
		TS6.6	11,525.7	197.7				DS3	0.0	8.0							
		-	-	-	-	-	-	DS4	1,929.0	489.0							
	Central	TS2	36,792.0	6,968.2	36,792.0	6,968.2	5.28	DS1	5,600.0	1,600.0	8,029.0	3,254.0	2.5	44,821.0	10,222.2	4.38	8
		-	-	-	-	-	-	DS2	2,429.0	500.0							
		-	-	-	-	-	-	DS3	0.0	8.0							
		-	-	-	-	-	-	DS5	0.0	1,146.0							
3	WPS-2	TS6.7	12,501.8	197.7	12,501.8	197.7	63.2	DS1	1,400.0	400	3,101.0	758.0	4.1	15,602.8	955.7	16.33	6
		-	-	-	-	-	-	DS2	1,701.0	350							
		-	-	-	-	-	-	DS3	0.0	8							
	Saragamuwa	-	-	-	-	-	-	DS1	1,750.0	500	3,451.0	858.0	4.0	3,451.0	858.0	4.00	9
		-	-	-	-	-	-	DS2	1,701.0	350							
		-	-	-	-	-	-	DS3	0.0	8							
4	WPS-1	TS4	12,113.8	1,227.0	12,113.8	1,227.0	9.9	DS1	532.0	152.0	920.0	432.0	2.1	13,033.8	1,659.0	7.86	7
		-	-	-	-	-	-	DS3	0.0	44.0							
		-	-	-	-	-	-	DS4	388.0	236.0							
Interregional Project		TS1	196,261.0	10,821.4	196,261.0	10,821.4	18.14	-	-	-	-	-	-	196,261.0	10,821.4	18.14	3

(Prepared by the Survey Team)

Table 8.2-5 shows the ranking of combined projects using Japan's technique, based on their corresponding benefits values. It is clarified in the ranking that installation of breaker switched capacitors as shown in TS6.1~TS6.8 are highly effective subproject. However, it is actually difficult to apply Japanese products because of price competitiveness.

Table 8.2-5 Ranking of Combined Projects using Japan's Technique

Ranking	Project Site		Combination of Sub-project Ref. No							Loss Reduction (MWh/year) (1)	Project Cost (MLKR) (2)	Investment Benefit (1) / (2)	Project Cost (MJPY) 1Rs =0.76Y	Cumulated Project Cost (MJPY)
	Region	Coverage Area												
1	2	WPN	TS6.1	TS6.2	TS6.6	DS1	DS2	DS3	DS4	49,022.4	1,538.0	31.9	1,168.9	1,168.9
2	1	Colombo City	TS3	TS6.8						12,065.0	472.4	25.5	359.0	1,527.9
3	Interregional Project		TS1							196,261.0	10,821.4	18.1	8,224.3	9,752.2
4	1	NWP	TS5	TS6.4	TS6.5	DS2	DS3	DS4		26,001.0	1,538.8	16.9	1,169.5	10,921.7
5	1	NP	TS.6.3							3,278.7	197.7	16.6	150.3	11,072.0
6	3	WPS-2	TS6.7	DS1	DS2	DS3				15,602.8	955.7	16.3	726.3	11,798.3
7	4	WPS-1	TS4	DS1	DS3	DS4				13,033.8	1,659.0	7.9	1,260.8	13,059.1
8	2	Central	TS2	DS1	DS2	DS3	DS5			44,821.0	10,222.2	4.4	7,768.9	20,828.0
9	3	Saragamuwa	DS1	DS2	DS3					3,451.0	858.0	4.0	652.1	21,480.1

(Prepared by the Survey Team)

The total proposed cost of the combined projects (ranking from one to nine) amounts to LKR 28,263.2 million (JPY 21,480.1 million).

CHAPTER 9
CONCLUSION AND RECOMMENDATION

CHAPTER 9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

(1) Amount of Loss Reduction by the Candidate Projects

Table 9.1-1 summarizes the candidate projects that were selected by the CEB, their project costs, amount of loss reduction and EIRR as estimated by the Survey Team.

Table 9.1-1 Summary of Candidate Projects

Projects	Projects Costs		Loss Reduction	EIRR
Transmission Projects	MLKR	MJPY eq.*2	MWh/year	
1) New Habarana – Veyangoda 220 kV TL Project (142 km)*1	10,821.4	8,224.3	196,261.0	19.29%
2) Polpitiya – Habarana 132 kV TL Reconstruction Project (164 km)*1	6,968.2	5,295.8	36,792.0	10.92%
3) Substation Construction and Augmentation Project				32.10%
A. Augmentation of Colombo A 132/33 kV GS (+31.5 MVA Tr)	297.6	226.2	51.3	
B. Construction of Kalutara 132/33 kV GS (2x31.5 MVA)	1,227.0	932.5	12,113.8	
C. Augmentation of Madampe 132/33 kV GS (+31.5 MVA Tr)	503.0	382.3	537.2	
D. Installation of Reactive Power Compensation Devices (8 GS)	1,771.3	1,346.2	97,545.1	
Total Transmission Projects	21,588.5	16,407.3	343,300.4	-
Distribution Projects				
4) Distribution Project Package in NWP of Region 1	665.7	519.2	2,813.0	27.07%
5) Distribution Project Package in WPN of Region 2	707.0	537.3	2,732.0	16.70%
6) Distribution Project Package in CP of Region 2	3,254.0	2,473.0	8,029.0	10.46%
7) Distribution Project Package in WPS-2 of Region 3	758.0	576.1	3,101.0	21.04%
8) Distribution Project Package in SP of Region 3	858.0	652.1	3,451.0	10.22%
9) Distribution Project Package in WPS-1 of Region 4	432.0	328.3	920.0	21.50%
Total Distribution Projects	6,674.7	5,086.0	21,046.0	-
Grand Total	28,263.2	21,493.3	364,346.4	-

Note *1: with Japan’s Technique, *2: LKR 1 = JPY 0.76

(Prepared by the Survey Team)

As shown in the table above, the total project cost was estimated at LKR 28,263.2 million (JPY 21,493.3 million equivalent), and the total loss reduction amount was estimated at 364,346.4 MWh/year.

(2) Environmental and Social Considerations

According to the National Environmental Act (NEA) of Sri Lanka, an overhead transmission line project with length exceeding 10 km and voltage above 50 kV is classified as prescribed to mandatorily undertake environmental impact assessment (EIA) procedure and prepare an initial environmental examination (IEE) or EIA report. Therefore, among the candidate projects described in Chapters 3 and 4, only two TL projects, namely the New Habarana–Veyangoda TL and the Polpitiya–Habarana TL Reconstruction, are the only prescribed EIA projects.

The candidate projects are categorized in view of JICA's guidelines, as follows:

1) The New Habarana–Veyangoda TL project is mandated to prepare an IEE document where the potential adverse environmental impacts can be lessened to an acceptable level by adequate implementation of mitigation measures. Taking into full account the environmental judgments on the New Habarana–Veyangoda TL project, the project would be under **Category B** of JICA's environmental requirements. This is because the impacts would be relatively at the low level and largely confined within the extent of the site. Only a few impacts would be irreversible. For the latter, if any, effective mitigation measures can be designed and implemented to minimize adverse impacts.

2) It is really difficult to categorize the Polpitiya–Habarana TL Reconstruction project since it is still being planned, and its scale and construction method have not been fixed yet. However, since past TL projects were previously judged to prepare IEE documents for the same reasons as above item 1), the project will also be applied as **Category B** under JICA's environmental requirements.

3) All other candidate projects are applied as **Category C** under JICA's environmental requirements since these are exempted from environmental procedures to prepare IEE or EIA document.

(3) Economic Evaluation

The results of EIRR calculation and sensitivity analysis in the case under the condition of plus 30% cost are as presented in Table 9.1-2.

Table 9.1-2 Sensitivity of EIRR under the Base and Pessimistic Conditions

	EIRR base case	EIRR +30% cost
Candidate 1. New Habarana–Veyangoda TL (without Japan's technique)	17.41%	14.36%
Candidate 1. New Habarana–Veyangoda TL (with Japan's technique)	19.29%	16.14%
Candidate 2. Polpitiya–Habarana TL Reconstruction (without Japan's technique)	9.90%	6.79%
Candidate 2. Polpitiya–Habarana TL Reconstruction (with Japan's technique)	10.92%	8.23%
Candidate 3 Construction and Augmentation of Grid Substations	32.10%	26.09%
Candidate 4 Distribution Project Package in NWP of Region 1	27.07%	21.95%
Candidate 5 Distribution Project Package in WPN of Region 2	16.70%	12.98%
Candidate 6 Distribution Project Package in CP of Region 2	10.46%	7.46%
Candidate 7 Distribution Project Package WPS-2 of Region 3	21.04%	16.74%
Candidate 8 Distribution Project Package SP of Region 3	10.22%	7.24%
Candidate 9 Distribution Project Package WPS-1 of Region 4	21.50%	17.13%

(Prepared by the Survey Team)

Under the most pessimistic case with condition of 30% cost increase, the EIRR values are still enough ranging from 12.98% to 26.09% (excluding Candidates 2, 6 and 8). This means that these projects under study are economically sound. Candidates 2, 6 and 8 show a low EIRR as compared to the discount rate of 10%. This means that Candidates 2, 6 and 8 should be carefully considered in terms of cost savings and hedging against price escalation.

However, since economic benefits applied for the above evaluations are amounts of loss reduction and greenhouse gases reduction only, in case a project adoption, the project shall be re-evaluated considering the project's particulars.

(4) Applicability of Japanese Technique

Japanese-made low-loss type conductors such as LL-ACSR/AS and LL-TACSR/AS can be applied to both new construction and reconstruction of important TLs. Low-loss type conductors have the same outer shape as normal ACSR conductors, but their aluminum cross-section area is higher by 20–30% in reducing electrical resistance. These conductors contribute to transmission loss reduction especially on heavily loaded TLs.

Table 9.1-3 shows the costs and amount of loss reduction in case that low-loss type conductors are applied to the new Habarana–Veyangoda and Polpitiya-Habarana TL projects.

Table 9.1-3 Loss Reduction Amount and Costs with Japan's Technique

	New Habarana–Veyangoda TL (2-cct)		Polpitiya-Habarana TL Reconstruction (2-cct)	
Conductors	2xACSR Zebra	2xLL-TACSR/AS 550	ACSR Zebra	LL-ACSR/AS 550
Loss Reduction (MWh/Year)	122,931	196,261	31,536	36,792
Project Cost (MLKR)	9,257.8	10,821.4	5,850.7	6,968.2
Project Cost (MJPY eq.)	7,035.9	8,244.3	4,446.5	5,295.8

Note: LKR 1 = JPY 0.76

(Prepared by the Survey Team)

Although the costs of both projects increases by applying low-loss type conductors, the amounts of loss reduction of 59.7% and 16.7%, respectively, can be attained in MWh/year. Therefore, the application of Japanese low-loss type conductors achieves high cost performance.

For the distribution system, as mentioned in Section 3.3, Japanese manufacturers produce low-loss type transformers well known as 'Top Runner Transformer'. It was considered that introducing such transformers to CEB's distribution system can very much reduce distribution losses. However, it is very difficult because Lanka Transformers Limited, which is an associated company of the CEB, supplies almost 100% of distribution transformers and it is protected in accordance with the national industry protection policy. In addition, since specifications of the Top Runner Transformer are different from CEB's, it may be costly and time-consuming to modify the specifications. Therefore, it is very difficult to apply Japan's technique in the field of the distribution network.

9.2 Recommendations

9.2.1 Recommendation for Transmission Development

(1) Improvement of System Stability and Reliability

As mentioned in Chapter 8, two candidate TL projects, namely the New Habarana–Veyangoda TL, and the Polpitiya-Habarana TL Reconstruction, show lower cost-benefit performances for loss reduction compared with the other candidates because of high project costs. However, the CEB gives high development priority to the two projects and expected to be commissioned in 2016 and 2014, respectively. It is obvious from the results of the power system analysis done by the CEB's Transmission Planning that the projects contribute not only to transmission loss reduction but also improve the system's stability and reliability. In addition, the projects have an applicability of Japan's loss reduction techniques applying the low-loss type conductors.

Therefore, it is recommended to implement the projects at an early stage.

(2) Reconstruction of TLs with Old Design Concept

There are many sections of the 132 kV TL, which were designed using the old design concept in the existing transmission network. They were designed with thin conductors of 54 °C maximum operation temperature, even though the CEB now applies a larger size conductor (ACSR Zebra) as the standard conductor size for new TLs with 75 °C maximum operation temperature. Some of the sections of the 132 kV TL are important since such carry the bulk power flow. However, the limitation of their current carrying capacity due to the maximum operation temperature rations the power flow and remains a severe obstacle for system operation. In addition, thin conductors produce transmission losses.

Although the Reconstruction of Polpitiya–Habarana TL project, which is one of the candidates, is planned to solve the above mentioned issues, it is recommended to reconstruct as needed, the other sections with the old design concept.

(3) Countermeasures for Voltage Drop

The CEB defines the permitted voltage deviation at the 132 kV busbars as ±10% in the system planning criteria. However, voltage drops exceeding permissible range are sometimes recorded at substations located in the rural areas and at the end of the transmission network such as Galle, Valachchenai and Ampara grid substations. This is due to the long distance and thin conductor TLs. This situation also adds to the increment of transmission losses.

In order to improve such situation, it is recommended to take necessary countermeasures such as construction of new grid substations, reconstruction and augmentation of TLs, and installation of static capacitors.

9.2.2 Recommendation for Distribution Development

(1) Provision of Energy Meters to Grasp Non-technical Losses

In order to reduce nontechnical losses, it is very important to grasp the lost energy and analyze the causes of losses. However, energy meters were not provided at most of the LV substations especially in rural areas. Consequently, it is not possible to know how much energy is lost. Although it was proposed in this report to provide energy meters in some of regions/provinces, it is recommended to provide and increase the energy meters at almost all LV substations, even if these are not provided at the same time.

(2) Provision of DAS

Although the DAS is provided in Colombo City through the CCEDD Project, other regions/areas have no DAS, except a simplified DAS named ‘Micro SCADA’ in the North Western Province (NWP) office of Region 1. The DAS is one of effective facilities to control the conditions of the distribution system and to minimize the distribution losses. In addition to the advantage of loss reduction, the DAS can offer several advantages in saving manpower for logging the event/fault records and reporting, decrease the duration and area of blackouts, and also safety for workers. Therefore, it is recommended to introduce the DAS on a nationwide scale.

The CEB intends to develop the DAS software by themselves using a ready-made software. Although the CEB can realize an economical DAS system, several risks are considered to remain in the design and interface to remote controlled equipment, quality control, and EMC/EMI. It is recommended that the CEB carry out suitable risk assessment and management in the design to make the risks visible and eliminate them.

(3) Provision of Distribution Transformers with Proper Capacity and Shorten the LV Line

Especially in rural areas, larger capacity transformers against the demands are used instead of smaller ones, because the CEB has not standardized the smaller capacity transformers. This results to higher distribution losses because of the non-load loss of transformers. In addition, very long LV distribution lines with average lengths of 5 to 8 km in rural areas, are major causes of distribution losses.

In order to improve the above situations, it is recommended to apply smaller capacity transformers such as 16, 25, 30 and 50 kVA, and to shorten the LV distribution line length as much as possible by providing additional LV schemes. In addition, since distribution transformers applied in the present system have larger losses than low-loss type transformers, introducing low-loss type transformers for distribution substations is expected to decrease the losses.

(4) Proper Connection of Distribution Lines

During site investigation, improper connections on several LV lines by unskilled workers were sometimes observed. These may have caused the resistive losses on the lines. In order to avoid this, it is recommended to enforce the functions and curricula of CEB's training center and to introduce hydraulic compression tools, by which proper compression clamp connection can be done even without long-term experience, to all distribution regions.

(5) Replacement of Aged Equipment

As observed during the site investigation, many aged equipment have been used over their estimated service life in the present distribution network. This may cause reduction of system reliability, several faults, and increment of distribution losses. It is recommended to investigate and replace such aged equipment.

(6) Street Lights

The Survey Team gained the following information on street lights from the CEB.

1) The street lights are installed and maintained by urban/provincial authorities.
2) Newly installed street lights are provided with energy metes when energizing by the CEB. The electricity bill is calculated according to the meter reading and sent to the relevant urban/provincial authorities for payments.
3) Energy meters are not provided with the street lights installed in past times. For those lights, an assessed bill is prepared area-wise and the amount is accumulated as debt region-wise.

The CEB does not receive any payment for the street lights from the authorities at the moment and this issue has created several disputes among the CEB, the government authorities and the Public Utilities Commission of Sri Lanka (PUCSL). Therefore, the CEB considers the supplied energy to street lights as a part of non-technical losses.

In order to reduce non-technical losses, it is recommended that to rectify the payments for street lights from urban/provincial authorities and exclude it from non-technical losses.