Chapter 1

Introduction

1.1. Background

In the present energy crisis, saving power has become a major problem at an international level. Studies have shown that reduction of losses in the power network is much more beneficial than the increase of generating capacities, and energy efficiency represents the cheapest resources of all. Nowadays, it is univocally acknowledged that the reduction of losses - especially in the distribution networks leads to power and energy cheaper than building new capacities of generation and transmission. Energy efficiency is accepted by the specialists as the most available, the least pollutant and cheapest resources of all. In fact, it has been established that 1 installed kW is four times more expensive than 1 saved kW [8].

The International Energy Agency publishes electricity statistics for a range of countries, including data on transmission and distribution losses [5]. Although the methodology behind their estimates is not entirely transparent, they are reported on a consistent basis across the countries. Table 1.1 below summarizes transmission and distribution losses for countries that may be compared to the UK.

Country	1980	1990	1999	2000
Germany	5.3	5.2	5.0	5.1
Italy	10.4	7.5	7.1	7.0
Denmark	9.3	8.8	5.9	7.1
United States	10.5	10.5	7.1	7.1
Switzerland	9.1	7.0	7.5	7.4
France	6.9	9.0	8.0	7.8
Sweden	9.8	7.6	8.4	9.1
Australia	11.6	8.4	9.2	9.1
United Kingdom	9.2	8.9	9.2	9.4

Table 1.1 - Transmission and Distribution Loss % in Selected Countries

Electrical losses are an inevitable consequence of the transfer of energy across electricity distribution networks. The level of reported losses in any given year will be influenced by number of factors, both technical and operational.

Many utilities suffer with high technical and non-technical energy losses. Experience has shown that the optimal total power losses in the distribution network ranges between 6 and 12 percent. Sample studies of a number of utilities showed, however, that the secondary distribution network alone could have losses that exceed 12 percent.

1.2. Distribution System Losses of the Ceylon Electricity Board (C.E.B)

The distribution network of the CEB consists of about 24,000 km of 33kV/11kV lines, 95,000 km of low voltage lines (400/230V) and 19,700 distribution substations which feeds about 4.0 million customers [3].

Even though the total system losses in year 2000 was 21.4% over the last 8 years, the system losses have come down by about one third and the present system losses now stands at 14.98% (end of 2008)[1]. The total of the system losses of the CEB could be separated into generation auxiliary losses, transmission losses and distribution losses. The generation auxiliary losses are about 0.83% and the transmission losses now stands at 2.58%. Hence the overall distribution losses as a percentage of gross generation are about 11.57%.

	Percentage Loss
Generation	0.83
Transmission	2.58
Distribution	11.57
Total System Losses	**14.98**

Table 1.2 – System Losses of the CEB (Year 2008)

The distribution system losses could again be divided into technical and non-technical losses. Technical losses are due to the transformer losses, power losses in the medium voltage network (33kV &11kV) and low voltage line losses. The non-technical losses are due to unmetered supply connections, illicit tapings, tampering of meters, meter errors, unauthorized street illuminations etc.

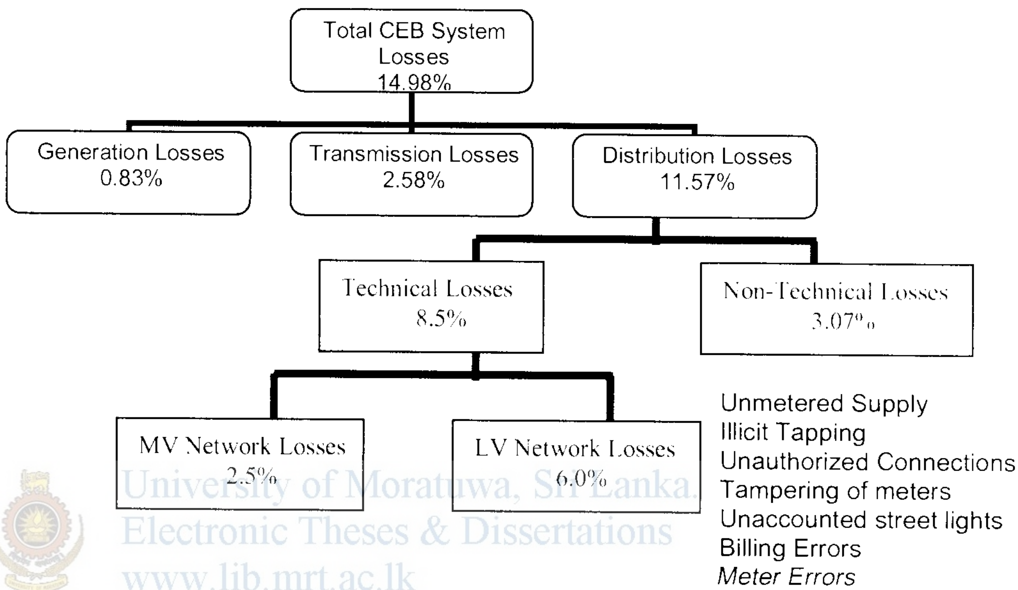

Figure 1.2 -System Losses :(2008)

1.2.1 MV Distribution Network and Losses

The 33kV medium voltage network of CEB is well spread over the island to reach the rural areas and consists about 24,000 km of lines. Since the transmission system is limited to certain load centers only, at certain times the connected 33 kV lines increase the medium voltage line losses [3].

Over the last decade the electrification level of Sri Lanka has increased from 29 % in 1990 to a level of 81 % at the end of year 2008 and the total number of consumers as at end of 2008 is about 4.0 Million.

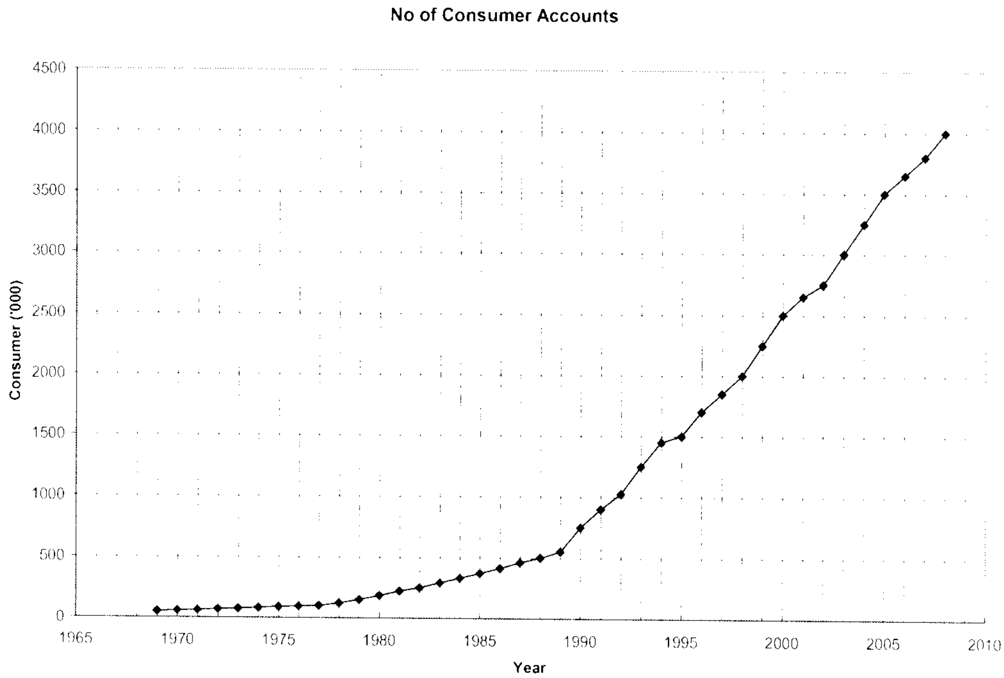

Figure 1.2.1 Number of Consumers Vs Years

About 75 % to 80 % of population of Sri Lanka lives in rural areas and the 33 kV network has been extended to greater distances to reach the rural population, thus increasing the 33 kV line losses in the system. There had been a rapid expansion in electrification in rural areas to meet the government objective of at least reaching a level of 75 % electrification by year 2006. As a result long lengths of 33 kV MV lines have been constructed without new grid substations, interconnections and express lines being built.

Under these circumstances, the MV distribution loss level still remains at 2.5 % and heavy investments are needed to reduce this level.

1.2.2 LV Distribution Network and Losses

LV Technical losses are mainly due to long length of LV lines from the distribution substations feeding the domestic and other retail consumers. In the past LV lines from a distribution substation were extended to a distance of about 2.4 km. and in certain instances even beyond. All LV extensions have been single phase construction and as a result 50% or more LV lines in the CEB distribution system are single phase lines contributing to high losses.

Island wide study was carried out in the year 2004 to collect data on all distribution substations and connected LV lines. The observations made from these studies are as follows [3].

1. 60% of the LV schemes in Sri Lanka are having low voltage below 10% of the stipulated voltage of 230 V.
2. About 55% of the LV schemes have unbalanced 3 phase feeders.
3. The average voltage drop at the end of a LV distribution line is about 15%.

Taking into consideration, the status of LV distribution network as stated above and also based on certain studies carried out on rural electrification schemes, a reasonable estimate for average LV losses in the CEB system is 6.0% of gross generation.

In order to improve the supply voltage and to arrest the LV distribution losses, a decision has been taken to limit the LV 3 phase feeder distance to 1.8 km and to construct only 3 phase lines. The voltage drop and the level of energy losses vary with the distance of the 3 phase line from the distribution transformer and depend on the consumer density. The graph below shows the variations at 1.4 km, 1.8km and 2.4 km for rural schemes for different consumer densities.

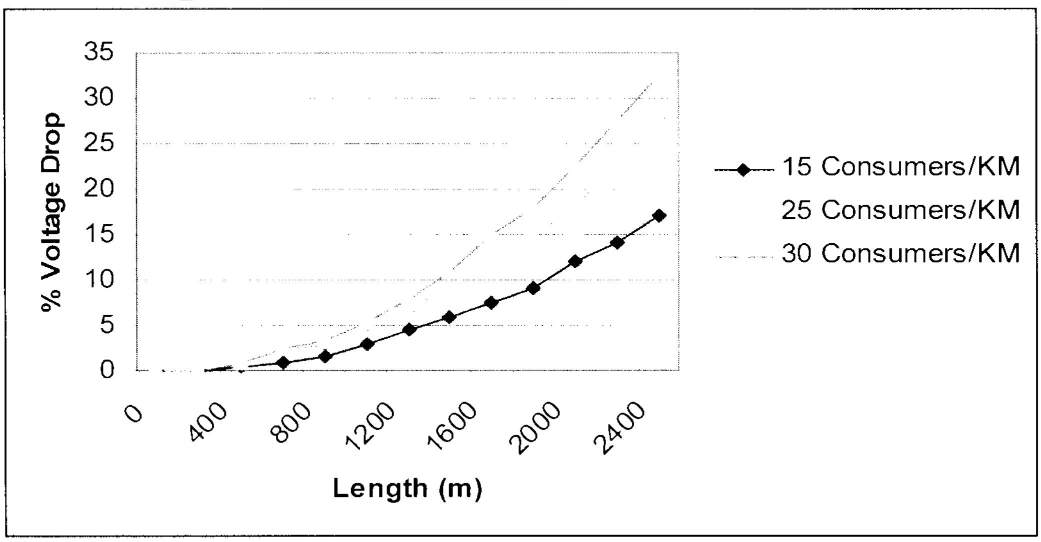

Figure 1.2.2 – Percentage Voltage Drop vs. Line Length

The feeder distance, after detailed studies were limited to 1.8 km in rural areas as th consumer density is low in RE schemes. However, the LV line distance in urban areas has to be below 1.0 km to maintain required voltage regulation and also to bring down LV losses. It was agreed that this length would be limited to 1.8 km initially and once that has been achieved, consider lowering this norm further to1.4 km. and beyond.

1.3 Technical Losses in the Distribution Network

The reason for the technical loss is due to following one or more [6]:

- I^2R losses or heat loss
- High peak load current
- Un-optimized location of transformers
- Lengthy single-phase lines
- Phase imbalance
- Sparking at loose joints
- Low power factor at off peak hours
- Overloading of LT lines
- High harmonics
- Low quality of insulators and conductors
- Low quality earthing at consumer premises

The technical losses of the distribution network are 8.5% of the gross generation. The technical losses are divided into two categories as follows;

1. MV Technical Losses
2. LV Technical Losses

MV technical losses are 2.5% and LV technical losses are 6.0% of the gross generation in the year 2008.

1.4 Technical Loss Reduction Measure

The long term objective of the loss reduction programme is to reduce distribution system losses to half their present level. Our load is continuing to grow at a rate of about 7 percent per annum. It has traditionally doubled over 15 years. Therefore, holding losses at their present level in kWh terms over this period will achieve this objective.

Distribution system loss reduction requires a wide range of measures spanning a large number of mostly small projects. An overall programme is required to integrate the effort and deploy available capital as effectively as possible. Specific and measurable targets are required to ensure progress. We have short term and long term programmes. These details targets in specific areas, such as operational sectionalizing, additional investment in major developments to optimize loss savings, etc. Additional capital requirements and loss savings are estimated, to re-deploy some capital from generation to network development

The optimal losses level of a distribution network would depend on many factors including:

* Long run marginal cost of capacity and energy
* Discount rate
* Capital cost of equipment
* Existing loading
* Load growth rate
* Cost of power and energy losses

These factors affect the optimal specification and design of the components used in distribution systems. The optimal losses level of a distribution network will be the accumulated optimal losses levels of these components. There are number of principal measures that can be taken to reduce the losses in a distribution system. These include;

* MV network reinforcements
* Installing capacitors on primary lines to correct the power factor to 95% or better
* Replacing the high impedance power transformers
* Managing the distribution transformer load
* Reduce the primary conductor loading
* Reduce the secondary conductor loading

In general, the principles of optimal component size and loading are based on evaluation of the operational costs over a number of years, the capital cost of equipment, and any benefit associated with the different options. Analysis using software models allows the effectiveness of various solutions to be evaluated.

1.4.1 MV Network Loss Reduction Measure

The medium voltage network of any power system needs further strengthening and expansion to cater the increasing electricity demand as well as to overcome the weaknesses of the existing MV system. These strengthening and expansions are generally known as network reinforcements.

The MV network reinforcements are needed in timely manner depending on the demand growth of the power system. The proposals for network reinforcements are broadly classified as short term proposals and long term proposals. The short term proposals are those which need to be implemented within the first two years of the planning horizon, where as the long term proposals are those which are to be implemented during the rest of the planning period.

Capacitors are widely used in distribution system for voltage regulation and power factor improvement [13]. Capacitor banks are usually placed near load to provide reactive power locally. The reduced amount of reactive power flowing on distribution lines between the capacitor and the source allows lower current and improve power factor. Thus line losses are smaller and voltage becomes higher at the load.

1.4.2 LV Loss Reduction Measure

In order to overcome the above problems, it was decided to add new distribution transformers to the system and to convert the loaded single phase feeders to three phases. Provision of new distribution transformers will reduce the transformer loading, LV feeder distance and feeder loading while the conversion of single phase lines to 3 phases will improve the line end voltage and the unbalance situation of LV feeders, which cause low voltage.

It is necessary to distribute load evenly across the three phases in order to have a better system performance. As a part of this work, decision must be made about how single and two phase laterals are connected. For example a single phase lateral could be connected to either phase A, B, or C of the main feeder. Making decisions as to how the laterals should be connected is referred to as lateral phase balancing design. Lateral phase balancing will also referred to as just "phase balancing (PB)." PB determines phasing modifications that will produce a more efficient system (i.e.

system with less loss). In addition to efficiency, PB affects the performance, peak load and the cost of the power delivery system.

It is common to find electric utilities that did not record the phasing information of the laterals in the system. This is a major deficiency because such information on the way laterals are connected is vital for any systematic study and analysis of power flows and voltages on power system components.

However, this problem can be tackled. Utilities usually record voltage, current, power factor or real/reactive power measurements taken at some important three phase locations. Furthermore, information associated with loads connected to the laterals is likely to be available. Thus one can use these load and measurement data to determine the unknown phases.

In an electrical distribution system that operates radially, every segment of the system gets its power from only one substation with a unique path from it to the associated substation. This path involves feeders, switches, transformers, etc. Almost always the distribution system has more than one substation and a substation in the system has more than one feeder. This multi-substation, multi-feeder design means that for a segment in the system there might be more than one option regarding from what substation or feeder to obtain power.

Switching operations are used to transfer load from one feeder to another while keeping the system radial. In doing so, system losses are reduced and load balancing can be achieved. Reconfiguration is the process of altering the topological structures of distribution feeders by changing the open/close status of the sectionalizing and tie switches.

During emergency situations such as fault conditions and equipment failures, transferring load and or reconfiguring the system is then performed to isolate the problem area while retaining service to as many customers as possible. This type of action is known as restoration, but is based upon reconfiguration. The reconfiguration tool will affect the reliability, peak load and cost of power delivery system.

1.5 Non-Technical Losses and Reduction Measure

Non-technical losses, sometimes referred to as commercial losses, are those associated with:

- Faulty meters
- Uneven revenue collection
- Tree touching
- Pilferage and theft
- Inadequate metering and billing

Such losses manifest themselves in a mismatch between generated and sold energy that cannot be accounted for by the technical loss component. Reduction of non-technical losses will contribute directly to the revenue receivable. The present total distribution losses are at 11.57% and of which 8.5% is attributed to technical losses. Hence the non-technical losses of the CEB system are estimated at 3.07%.

As non-technical losses are substantial amount of distribution losses, measures have already been taken to bring down non-technical losses to an acceptable level.

Meters are being installed at distribution substations. This will facilitate to carry out an energy audit every month to assess the energy delivered and energy billed. If large discrepancies of energy delivered to energy billed are shown, the electricity scheme should be investigated to find any possible losses or theft [12].

1.6 Motivation

Network losses are a major issue for power utilities, particularly on distribution networks. The scale of losses on distribution system is documented in CEB statistics. 11.57 percent of the power input at time of system peak is dissipated as distribution system loss [4]. These are significant quantities of energy in national term. The cost of such losses is very high. Measures to be taken to reduce these loss rate to about half of this level in relative term over the next 10 years or so.

The outcome of this project will identify and formulate CEB - Western Province South I medium voltage distribution network`s, reinforcement proposals for the years 2010, 2011, 2012 and 2013 in order to operate at minimal level of losses to provide electricity in sufficient quantity and acceptable quality based on change of load pattern of the large committed loads and general load growth.

In addition, the production of additional energy has a significant environmental impact. It is estimated that, a reduction in losses of 1 percent might contribute to 4 percent of reduction in Carbon dioxide emission.

Furthermore, the transportation of additional energy would huge investment in necessary infrastructure development.