INDUSTRIAL TRAINING REPORT II

TRAINING ORGANIZATION	: CEYLON ELECTRICITY BOARD
PERIOD OF TRAINING	: FROM 05/03/2019 TO 10/05/2019
FIELD OF SPECIALIZATION	: ELECTRICAL AND ELECTRONIC ENGINEERING

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E/14/279

ACKNOWLEDGEMENTS

During my internship at Ceylon Electricity Board (CEB), I had a great opportunity to learn about the power generation, transmission, distribution and retailing framework in Sri Lanka. And also, I had a great opportunity to improve my technical knowledge, interpersonal skills and specially to interact with various people with the scheduled training scheme given by the Ceylon Electricity Board training center.

I want to thank all the staff, I interacted during my training period within the Ceylon Electricity Board(CEB), especially Mrs. Chandini Premarathne, training officer (internal training) at the Training branch of Ceylon Electricity Board and Various Chief engineers, Deputy general managers, engineering assistants, technical officers for their valuable contribution that lead to improve my experience with the power engineering and control, communication aspects related to an electricity company.

And I would also like to thank the staff at the Industrial Training and Career Guidance Unit of the faculty of engineering, University of Peradeniya for nominating me to undergo this training under Ceylon Electricity Board.

Finally I would like to thank my parents and all other non mentioned people who played an important role in making my training period successful.

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LIST OF ABBREVIATIONS

AGM	Additional General Manager
AVR	Automatic Voltage regulator
CEB	Ceylon Electricity Board
CVT	Capacitor voltage transformer
DGM	District General Manager
GND	Ground
GSS	Grid substation
HP	High pressure
IP	Intermediate pressure
IPP	Independent power producers
LP	Low pressure
MIV	Main Inlet Valve
PUCSL	Public Utilities Commission of Sri Lanka
TF	Transformer
UPS	Uninterruptible power supply

Chapter 1
INTRODUCTION

1.1 TRAINING SESSION

During this training session, I was allocated to the Ceylon Electricity Board (CEB) during the period from 05/03/2019 to 10/05/2019. Throughout this period, I was assigned to various divisions under the CEB. The training schedule mainly consisted of places covering generation, transmission and distribution of electricity. The training schedule provided by the training branch CEB included places such as,

- Lakvijaya power plant
- Laxapana power plant complex
- Communication branch
- System control
- Transmission and design unit
- Project and heavy maintenance unit
- Distribution maintenance unit
- Construction unit

The training session mainly consisted of learning various techniques, components and procedures associated within an electricity company.

1.2 INTRODUCTION TO TRAINING ORGANIZATION

Ceylon electricity board (CEB) is a cooperate body established by the parliament of Sri Lanka and is the largest electricity supplier company in Sri Lanka. The CEB mainly consists of the following divisions.

- Generation division
- Transmission division
- Distribution division
- Projects division
- Asset management division
- Finance division
- Corporate strategy division

The vision and mission of CEB are as follows

VISION: Enrich life through power

MISSION: To develop and maintain an efficient coordinated and economic system of electricity supply to the whole of Sri Lanka, while adhering to our core values.

The company aims to provide a continuous supply of electricity at an affordable rate to enhance life and to assist development projects in the rural regions of the county. As of 2017, the CEB had 6.6 million electricity consumers, with 87% of domestic consumer base. Table 1.1 shows the consumer base of the CEB in 2017.

Table 1.1 Consumer base of the CEB as of 2017

Electricity Consumer base	
Domestic	5,813,077
Religious	39,744
General Purpose	726,271
Industrial	62,437
Government	2,212
Hotel	565
Bulk+S.L.	2,768
Total	**6,647,074**

The CEB works continually to enhance electricity accessibility via by increasing the electricity distribution throughout Sri Lanka. As of 2017, the electrification level of Sri Lanka holds at a level of 99.7%. The distribution network coverage of Sri Lanka is shown in figure 1.1.

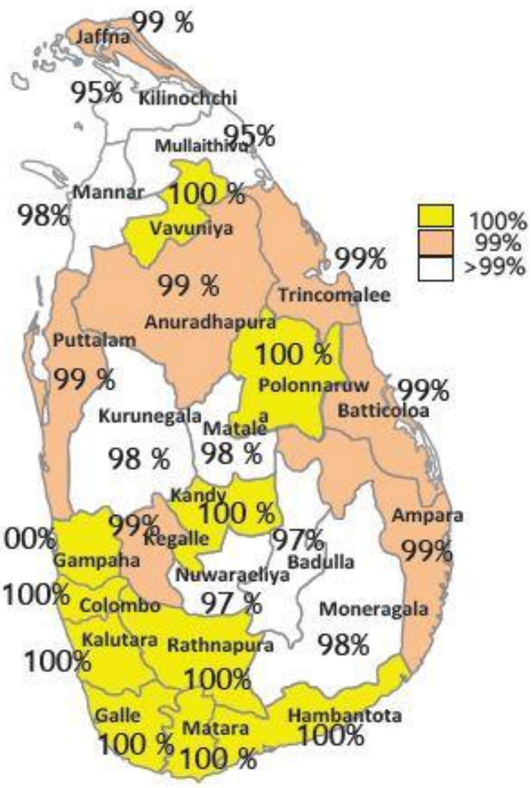

Figure 1.1 Electrification level of the CEB as of 2017

The CEB is controlled under the ministry of power and energy and is regulated by bodies such as PUCSL which governs the economic, technical and the safety of the electricity industry in Sri Lanka.

The Ceylon electricity board comprises of a chairman and a team of board members then followed by a general manager, as shown in figure 1.2 below. To manage easier, CEB has divided its distribution into four geographical regions and controlled by AGM's as follows,

- Generation AGM 1x
- Transmission AGM 1x
- Distribution AGM 4x
- Projects AGM 1x
- Cooperate and strategy AGM 1x

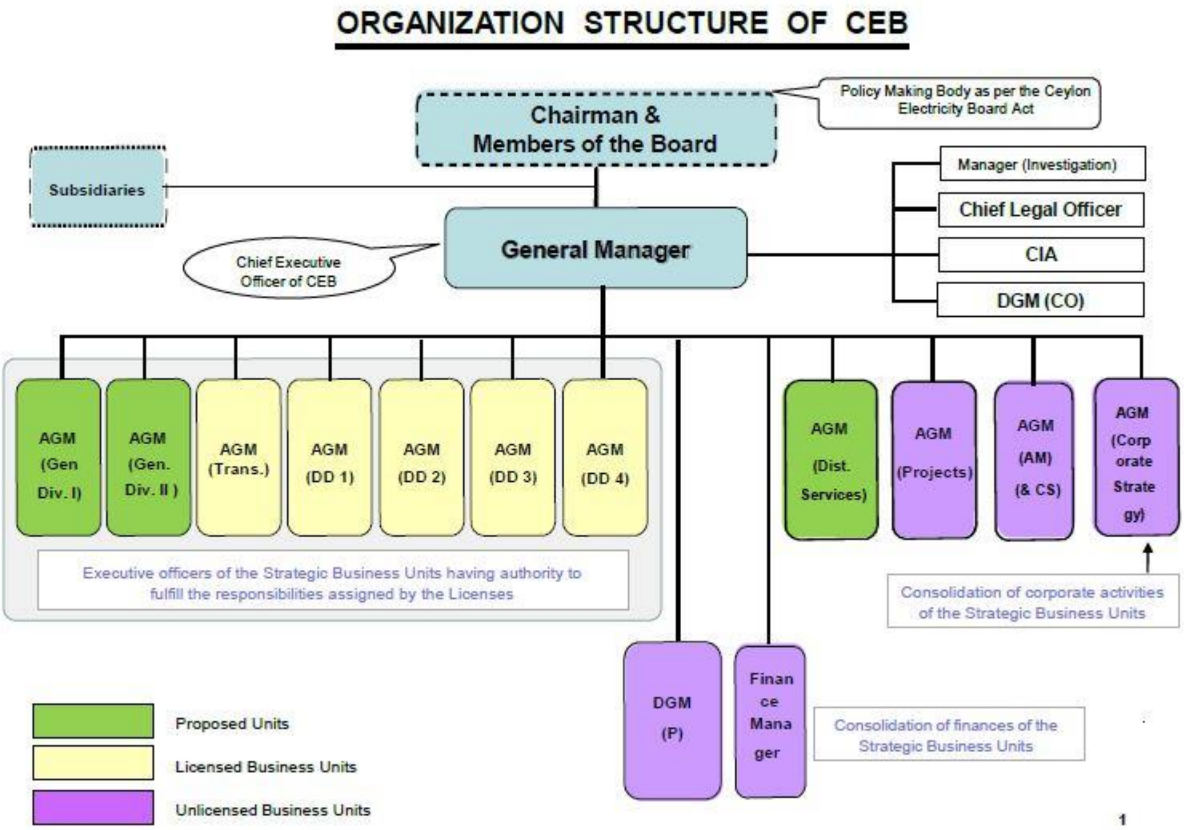

Figure 1.2 Company hierarchy for the CEB

CEB carries out various development and feasibility studies with the help of funding granted via foreign countries, Asian development bank etc. Current and future projects funded by these types of organizations include,

- Generation projects – projects which add more power generation to the local grid
- Feasibility studies
- Rehabilitation – upgrading of existing CEB assets

- Transmission projects
- Clean energy and access improvement projects – (example-fiber optic communication network)

1.3 SUMMARY OF THE WORK ENGAGED IN TRAINING

During my training period in CEB, I was assigned to the following main sections, as shown in table 1.1. During my training period, I carried out tasks such as field visits, studies related to many components and procedures related to the power generation, transmission, distribution provided by the CEB.

Table 1.2 Training schedule

Worksite/Workplace	Period	
	From	To
Distribution division (Kandy city)	2019/03/05	2019/03/15
Deputy general manager’s office (communication division)	2019/03/18	2019/03/19
Deputy general manager’s office (system control)	2019/03/21	2019/03/22
Transmission design unit (CEB headquarters Colombo)	2019/03/25	2019/03/29
Deputy general manager’s office (Laxapana)	2019/04/01	2019/04/14
Office of power plant manager (Lakvijaya power plant)	2019/04/16	2019/04/26
Chief engineers office (transmission operation and maintenance - Pallakelle)	2019/04/29	2019/05/03
Office of the deputy general manager (Projects and heavy maintenance -Kandy)	2019/05/06	2019/05/10

The training period mostly involved in visiting various locations within the CEB electricity generation, transmission distribution network and studying of these components and their importance in the electricity network from the CEB to the consumer.

CHAPTER 2
GENERATION

2.1 INTRODUCTION

CEB has various methods of power generation schemes to diversify its power needs, ensuring system stability. The total installed capacity of the national power grid is 4043MW as of 2017. The main methods of electricity generation used by the CEB are as follows.

- Major hydro
- Thermal
    - Coal
    - CEB owned thermal
    - IPP
- Renewable energy
    - Mini hydro
    - Wind
    - Solar
    - Biomass

The generation division of the CEB is responsible for operation and maintenance of the thermal, hydro and renewable energy power plants owned by the CEB. There are 17 large hydropower plants owned by the CEB and seven large oil-fired thermal power plants, one coal-fired power plant and one wind power plant. There are also few power plants in the isolated networks in surrounding islands of Jaffna peninsula.

The peak demand for electricity, of around 2600MW, was observed during the training session. As forecasted by the CEB long term generation plan, it is predicted that the average demand growth rate is 5.9% up to 2020. To compensate with the growing electricity demand, there are some generation expansion projects underway such as,

- Uma Oya hydropower plant (2x 60MW)
- Broadlands hydropower project (2 x 17.5 MW)
- Moragolla hydropower plant project
- Development of a combined cycle power plant at Kerawalapitiya (300MW +/- 10%)
- Semi dispatchable wind power project in Manner island (100MW)

Few hydropower expansion projects are also underway to upgrade the existing hydropower plants.

2.2 MAIN TASKS CARRIED OUT WITH THE GENERATION DIVISION

For the generation section, I was assigned to,

- Laxapana Hydropower Complex
- Lakvijaya Coal Power station
- System control

During my period of training in the generation section, I interacted with chief electrical engineers, shift engineers, instrumentational engineers, mechanical engineers, control engineers, engineering assistants, technical officers. The staff instructed us with the procedures, importance of various equipment, testing procedures, decision making related to the operation of generation power plants

2.3 LAXAPANA HYDROPOWER COMPLEX

2.3.1 INTRODUCTION TO LAXAPANA HYDROPOWER COMPLEX

Laxapana complex is situated along Kehelgamu Oya and Maskeli Oya where there are six power plants included in the Laxapana complex. The total current power generation capability of this complex is 353.8MW.

- Old Laxapana power station (9.6MW x 3 + 12.5MW x2)
- New Laxapana power station (57MW x 2)
- Wimalasurendra Power Station (25MW x 2)
- Canyon power station (30MW x 2)
- Samanala (Polpitiya) power station (37.5MW x 2)
- Broadlands power station (Under construction) (35MW)

The reservoirs, ponds and power stations associated with the Laxapana complex is shown in figure 2.1. The two main reservoirs related to this complex are Castlereagh reservoir in Kehelgamu Oya and Maussakelle reservoir in Maskeli Oya respectively.

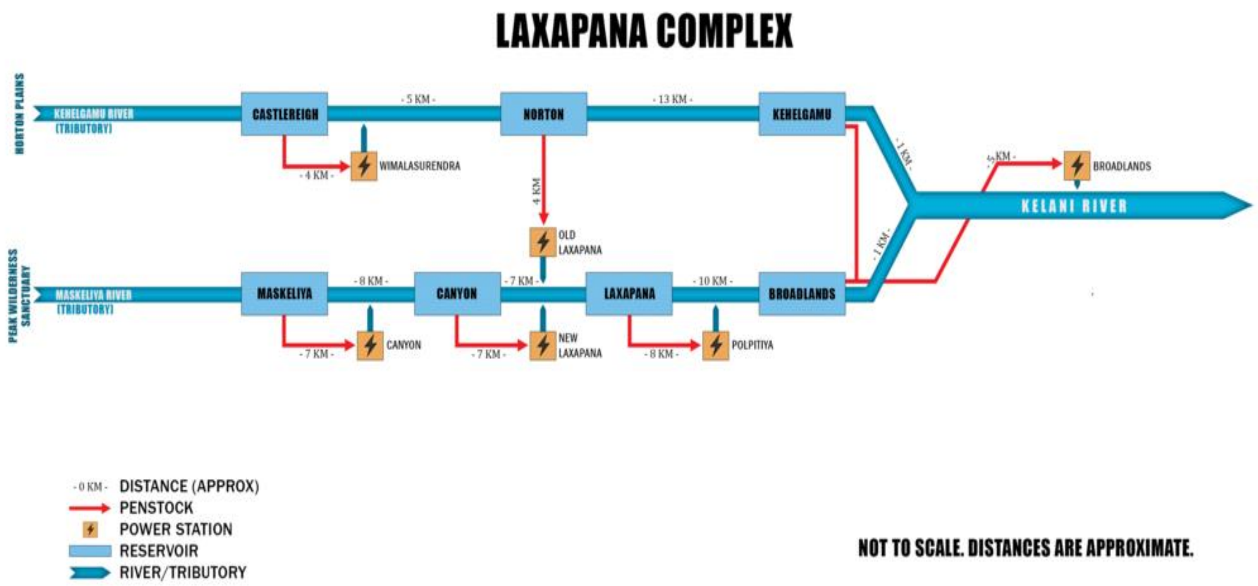

Figure 2.1 Laxapana complex

2.3.2 ARRANGEMENT OF A STORAGE TYPE HYDROPOWER PLANT

A typical hydropower plant consists of a reservoir or a pond which stores water, which is used for electricity generation and irrigation. The power plant generated electricity according to the dispatch instructions received from the system control center. The layout of the storage type power plant consists of the following main components before the powerplant, as shown in figure 2.2.

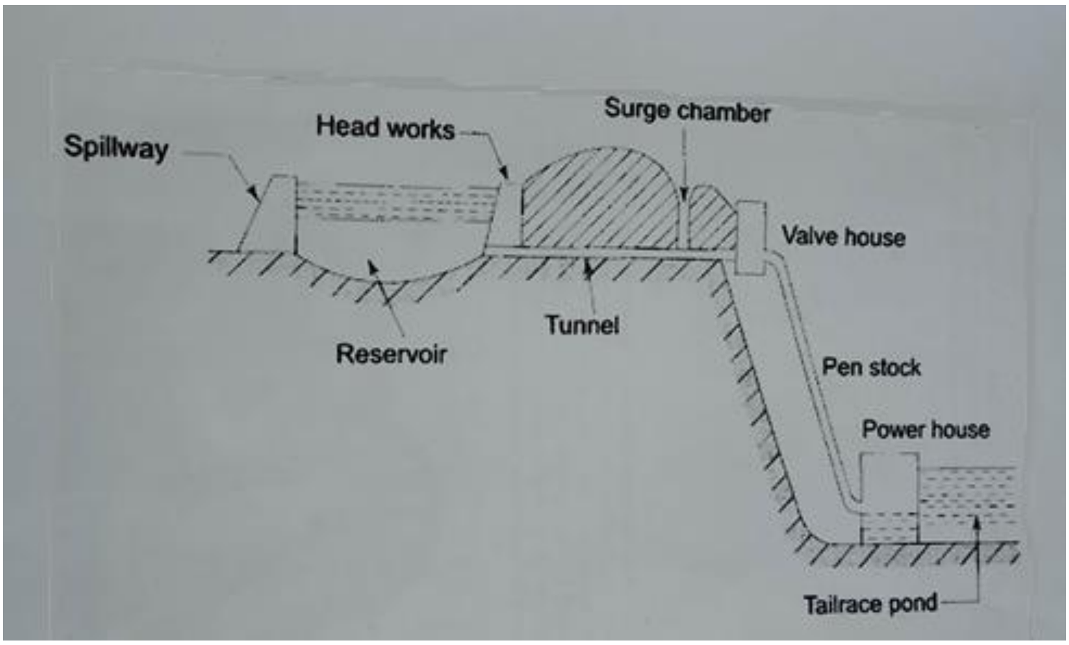

Figure 2.2 Typical arrangement of a storage type power plant

An underground tunnel from the reservoir/pond carries the water via a tunnel to the valve house, which is situated at the top of the penstock line. The tunnel entrance (tunnel intake) of the water body has a filter which filters any large foreign objects from entering the water tunnel via a screen. The valve house consists of guard valve (to control water flow); flow sensors to detect the water flow rate and a vacuum breaker which release trapped air into the tunnel in case of a vacuum occurrence on the penstock line which might caused by a sudden increase of the load or a leak on the penstock. The surge chamber acts as a protection mechanism for the tunnel, which releases the backpressure if there is a back surge (Water hammering effect) in the penstock line. The penstock line vertical height provides the potential energy that is needed for the turbine to rotate, which connected to the generator that produces electricity. A penstock line is shown in figure 2.3.

Figure 2.3 Penstock line of storage type hydropower plant

The penstock then connects to the Main Inlet Valve (MIV), which then connected to the turbine chamber. In new and old Laxapana power stations, the turbine used for this process is the Pelton type turbine which is shown in figure 2.4.

Figure 2.4 Pelton type rotor used in the Laxapana power plant

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Old Laxapana power plant uses horizontal shaft type turbine arrangement, while the new Laxapana power plant uses semi umbrella type turbine arrangement. All other power plants in the Laxapana Complex uses a conventional two bearing type turbine arrangement in their power plants.

2.3.3 POWER GENERATION PROCEDURE OF LAXAPANA HYDROPOWER PLANT

The generators in the Laxapana power plants are 3-phase synchronous machines, with AVR capabilities. The rated output of the machines of the new and old Laxapana power station with detailed specifications is shown in Table 2.1.

Table 2.1 Generator specifications for the Laxapana complex

Power station	Stage	Exciter type	Generated Voltage (kV)
Old Laxapana power station	I II	Brushless Brushed	11 11
New Laxapana power station	N/A	Brushless	12.5
Wimalasurendra power station	N/A	Brushless	11
Canyon power station	N/A	Brushless	12.5
Samanala power station	N/A	Brushed	12.5

The amount of power generated by each of the machines of a power plant is determined by two factors

- Height of the water head (Which is constant)
- The rate of water flow (Which can be adjusted by the MIV)

The active power generated is maintained with the active load of the system (By maintaining the system frequency within a range), while the reactive power is maintained by adjusting the exciter voltage of the synchronous generator.

2.4 LAKVIJAYA COAL POWER PLANT

2.4.1 INTRODUCTION LAKVIJAYA POWER PLANT

Lakvijaya power plant (Also known as Norochcholai power station) is a coal power plant situated in Puttalam, in the Kalpitiya peninsula. Lakvijaya power plant is the largest power generation plant in Sri Lanka with a capacity of 900MW, consisting of 3 phases with 300MW each. The power plant uses bituminous coal as its primary fuel and Auto Diesel as its startup fuel during the startup. Lakvijaya power plant provides the Baseload for the daily generation curve of the electricity which shown in figure 2.5.

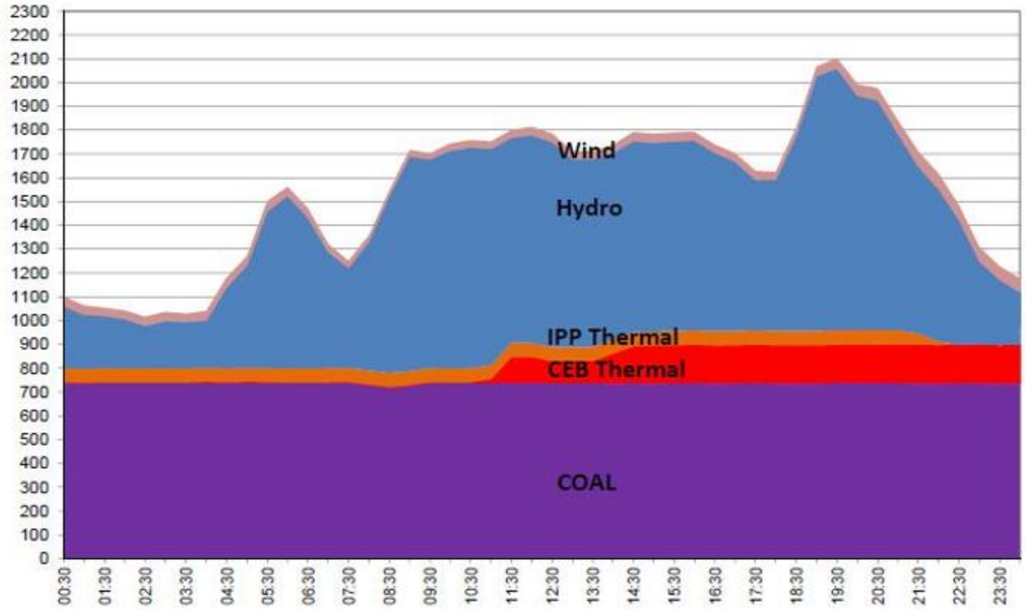

Figure 2.5 Typical Load variation for 24 hours with the energy contribution in Sri Lanka

2.4.2 STEAM GENERATION PROCEDURE OF THE LAKVIJAYA POWER STATION

The bituminous coal is imported from countries such as South Africa, Indonesia, Russia is used as the primary source of fuel used by the Lakvijaya power plant. Auto diesel is also used as a fuel for the startup and shutdown sequence of the power generation. Lakvijaya power plant consists of a delivery pump scheme for the supply of auto diesel and a conveyor system for coal delivery. A stacker/reclaimer is used for this purpose, as shown in figure 2.6.

Figure 2.6 Coal loading into the conveyor belt by using stacker

Initially, the coal obtained from the courtyard is ground into small particles, and then fed into the feeders, these feeders transfer the coal into the mill which turns the coal into a fine powder. Resultant fine powder (pulverized coal) is then fed into the furnace by using primary air fans. A secondary air pump system is also present, which supplies air that is needed for the combustion. Lakvijaya power plant uses up to 110tonnes of coal per hour. The operation process of the boiler is shown in figure 2.7.

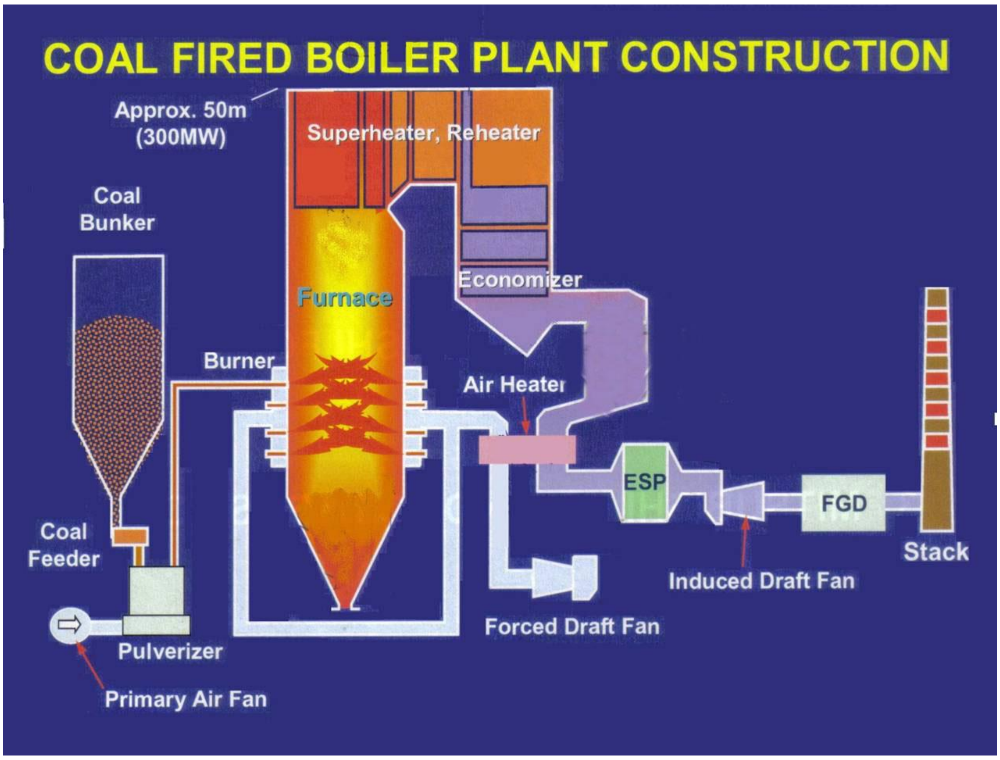

Figure 2.7 The operation process of the boiler

The power plant uses ranking cycle, which reheats the steam coming out of the turbine to maximize the efficiency of the power plant. The simple working of the boiler cycle is shown in figure 2.8.

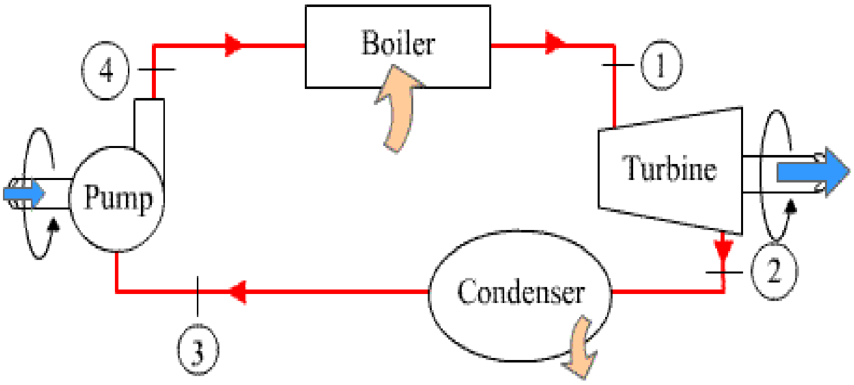

Figure 2.8 Closed-loop steam cycle of the Lakvijaya power plant

The boiler consists of the following main components.

1. Drum – Acts as a reservoir that collects the steam that is sent to the other parts of the boiler.
2. Superheaters – Superheaters are used to further heat the steam from 370^0C steam to 540^0C.

3. Reheaters – These heaters reheat the steam coming out from the high-pressure turbines, which needs to be sent to the intermediate pressure (IP) turbines.
4. Deaerator – This is a Storage tank that holds the water coming from the low-pressure heaters. The oxygen level of the water is reduced in this part, and kept at a rate of 7ppm.
5. Economizer -Heat exchange mechanism that is used to heat the water tubes in the boiler.
6. Air pre-heaters –The primary and secondary air fed into the furnace is heated to make the burning process more efficient.
7. Hot-well – Collects the condensed water while keeping the pressure at a negative value so that a condensate delivery pump is not required for the process.

The bottom ash is collected from the boiler is used as a bi-product to make cement, and the low-quality bottom ash is used to make bricks. The Steam rotates the turbines, which is connected to the generators that generate electricity. The turbine and the generator structures are shown in figure 2.9.

Figure 2.9 The generator and turbine hall in Lakvijaya power plant

There are three types of turbines present in the Lakvijaya power plant. They are as follows

1. High pressure (HP) turbines
2. Intermediate pressure (IP) turbines
3. Low pressure (LP) turbines

These turbines are rotated with the steam produced at different pressures. This is following the ranking heat cycle. The power plant consists of the following main electrical components.

- Generator
- Main transformers (20kV/220kV)

- Auxiliary transformers (20kV/6kV)
- Startup standby transformers (220kV/6kV)
- Stepdown transformers (6kV/400V)
- UPS and battery banks
- 220VDC and 24VDC supply

Lakvijaya power plant has four 220kV main output lines

- New chillaw lines 2x
- Anuradhapura lines 2x

All the systems related to the power generation are monitored by using a SCADA system. There are many systems such as following are maintained by using 4-20mA data transmission lines which are connected to sensors and actuators.

- Condensate water system
- Feedwater system (seawater treatment)
- Cooling system
- Electrical system and protection systems
- 6kV distribution systems
- Emergency power systems (UPS/ Battery banks)

2.4.3 Other power plants connected to the Lakvijaya power plant grid

There are some wind power plants owned by independent power producers that are nearby the Lakvijaya power plant. Single line diagram for these power plants is shown in figure 2.10. These power plants can contribute up to 65MW of power to the local grid.

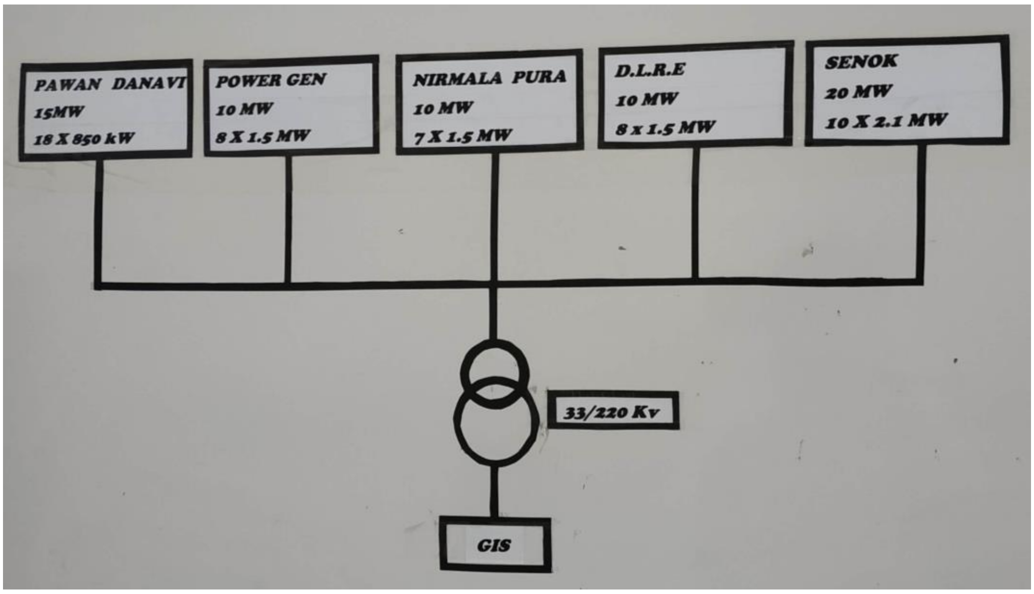

Figure 2.10 IPP wind farms connected to the Lakvijaya power plant

2.5 SYSTEM CONTROL

System control is responsible for monitoring and controlling of all the power plants connected to the CEB grid. Main functions of the system control include,

- Frequency control of the CEB grid
- Voltage control of the CEB grid
- Release of lines and machines for maintenance

Engineers of the system control are responsible for maintaining the CEB grid reliability. So, the standard values for the voltage and frequency ratings are shown in table 2.2. System control can make control decisions on the following power plants

- Hydropower plants
    - Laxapana complex
    - Mahaweli complex
    - Samanala complex
- Thermal power plants
    - Lakvijaya power plant
    - Kelanithissa power plant
    - Sapugaskanda power plant

Table 2.2 System parameter ranges

Parameter	**Normal conditions**		**Emergency conditions**	
	Percentage	Range	Percentage	Range
220kV	±10%	198-242kV	±10%	198-242kV
132kV	±10%	118.8-145.2kV	±10%	118.8-145.2kV
33kV Grid bus	±2%	32.34-33.66kV	-	-
System frequency (50Hz)	±1%	49.5-50.5Hz	±1%	49.5-50.5Hz

Operation policy of the system control depends on various factors such as,

- Safety of persons
- Protection of equipment
- Supply availability
- Demand
- Economics of operation

The system control always works collaboration with other stakeholders such as water and drainage services, irrigation department to make power plant operation decisions, especially for the hydropower plants. It is required by the system control to maintain a spinning reserve at 5% of the gross generation.

2.5.1 FREQUENCY CONTROL

For the frequency control of the CEB grid, active power control is used. By management of the active power demand and active power supply, the frequency is maintained at the required levels. The frequency adjustment of synchronous machines is done with the help of droop curves that is unique to the generator being considered. The drooping curve for the Kothmale and Victoria power plants is shown in figure 2.11.

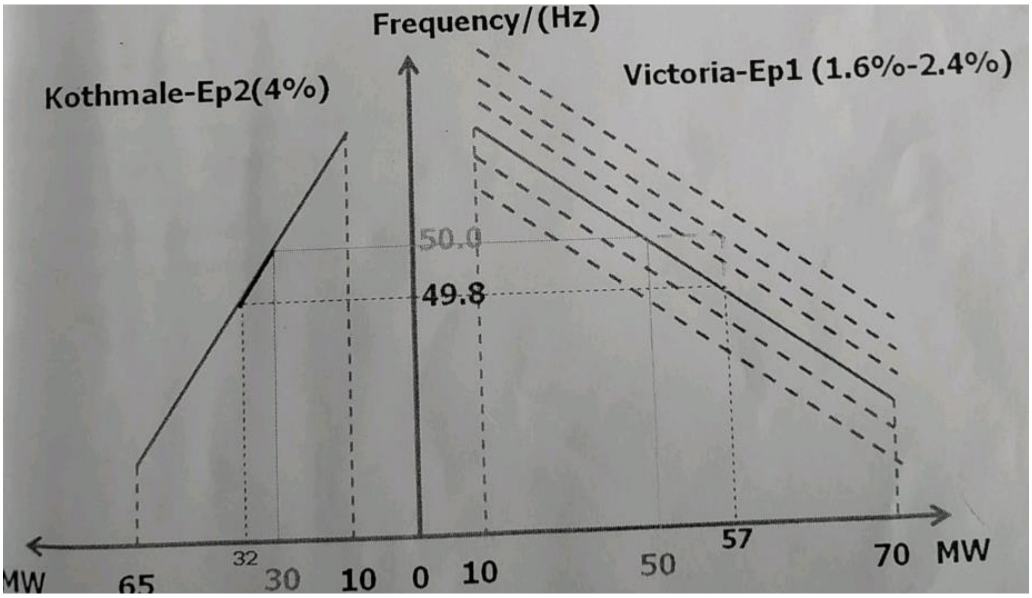

Figure 2.11 Droop settings for the Victoria and Kothmale synchronous machines

2.5.2 VOLTAGE CONTROL

For the control of the system voltage, the reactive power demand and the reactive power supply is controlled. Few sources generate the reactive power required by the CEB grid

- Reactive power is generated by
  - Transmission lines
  - Capacitor banks
  - Var compensators
  - Synchronous machines
- Reactive power is consumed by
  - Machines
  - Reactors

2.6 SUMMERY

Various components related to generation and their functions were learned during this section. Decision-making process and the communication process of the system control pertaining to the generation control is also observed during this section.

CHAPTER 3
TRANSMISSION

3.1 INTRODUCTION

CEB transmission is the management of 132kV and 220kV lines and supplies energy adequate and secure manner to the distribution nodes. Main objectives of the transmission system involve,

- Develop and maintain the transmission system.
- Procure and selling of electricity in bulk.
- Maintain of the transmission line voltages are in acceptable limits. (±10 % of the transmission voltage).

During this training period, I have visited the following branches related to the transmission.

- Transmission design unit
- Transmission operation and maintenance unit

3.2 TRANSMISSION DESIGN UNIT

Transmission design unit is the branch responsible for study, design and plan of the transmission system maintained by the CEB. The studies of this branch include the long-term transmission development plan, which is valid for the years 2015-2024. The funding for these projects is obtained through international lending agencies such as Asian development bank, Japan international cooperation agency etc. The roles of the transmission design unit include

- Initial works that are required for the construction of transmission lines, grid substations (GSS) such as land selection, survey verification, design approval etc.
- Design of suitable transmission lines
- Land acquisition for the transmission network
- Preparation of engineering designs
- Drafting of tender documentation for projects
- Review and approval of design modifications by the contractors
- Collaboration with other interested parties such as irrigation authorities, road development authorities, environmentalists etc.
- Preparation of design reports

Transmission design unit also consisted of civil engineering aspects, for the GSS design and tower design such as the design of control buildings, transmission tower foundations, support structures, grid substations.

3.2.1 Transmission towers

Transmission networks consist of conducting cables such as

- ACSR conductors
- Zebra conductors

It is essential to select the best conducting cable depending on factors such as current carrying capacity required for the project at hand. There are two main tower types by string arrangement present in the CEB transmission network. They are suspension type towers (Line towers) and tension-type (Strain towers) towers. There are few considerations have to be made when building a transmission tower such as,

- Safety to the people and other objects.
- Cost minimization.
- Design issues such as geographical location, weather conditions, wind, temperature, landslides etc.
- Leg extensions for the tower based on the Shape of the terrain.
- Tower angle which is the angle between conductors needed to determine to select the tower type.

Table 3.1 Tower designation according to the sag tension of the cables

TYPES OF TOWERS	
Designation	Tower
TDL	0°- 2°
TD1/TD1S	0°-10° angle
TD3	10° - 30° angle
TD6	30° - 60° angle
TD9/TDT	60° - 90° angle

It is also essential to consider the maximum span between two transmission towers, and the ground clearance, especially for the cases where the terrain may not be even. Usually, the span of transmission lines is kept in the range of 300-350m apart. For that purpose, wind span and weight span are taken into consideration. Typical transmission tower and its components are shown in figure 3.1. Parts such as arcing horns are used in transmission towers for the protection of the insulators during a flashover incident. With the improvement of the technology, an optical fiber ground wire is attached to some transmission lines, that acts as a communication medium between CEB departments and units. This communication channel capable of sending SCADA signals and voice communication between the CEB departments.

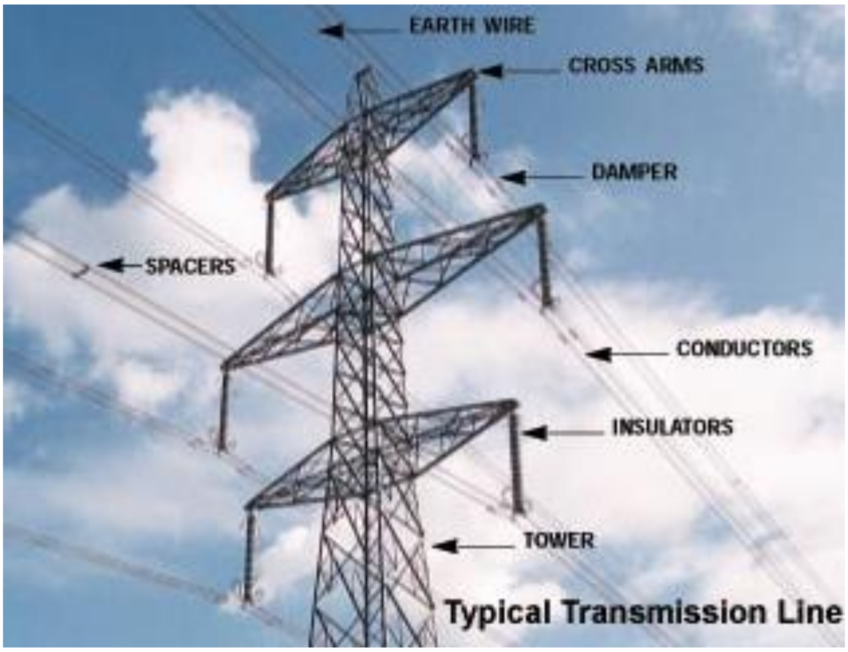

Figure 3.1 Components connected to a transmission tower

For the protection of the transmission towers from unauthorized personals, the tower is also consisting of anti-climbing guards and danger warnings, and color codes signs.

3.3 TRANMISSION OPERATION AND MAINTANCE UNIT

Transmission operation and maintenance unit are responsible for the maintenance and monitoring of grid substations and the towers and all the components attached to the transmission system.

3.3.1 GRID SUBSTATION

Grid substation is the location where the transmission lines of 132kV or 220kV lines are stepped down to 33kV distribution lines. Typically grid substation consists of breakers, isolators, stepdown transformers, a control center. Earthing transformers etc. A typical grid substation is shown in figure 3.2.

Grid substation uses SCADA system to monitor and control most of the breakers and transformers in the substation. A 4-20mA current signal is used on the SCADA system as the data transmitting channel. Grid substation is capable of feeding multiple feeder lines (33kV) either underground or via areal towers. A simplified switchyard arrangement is shown in figure 3.3

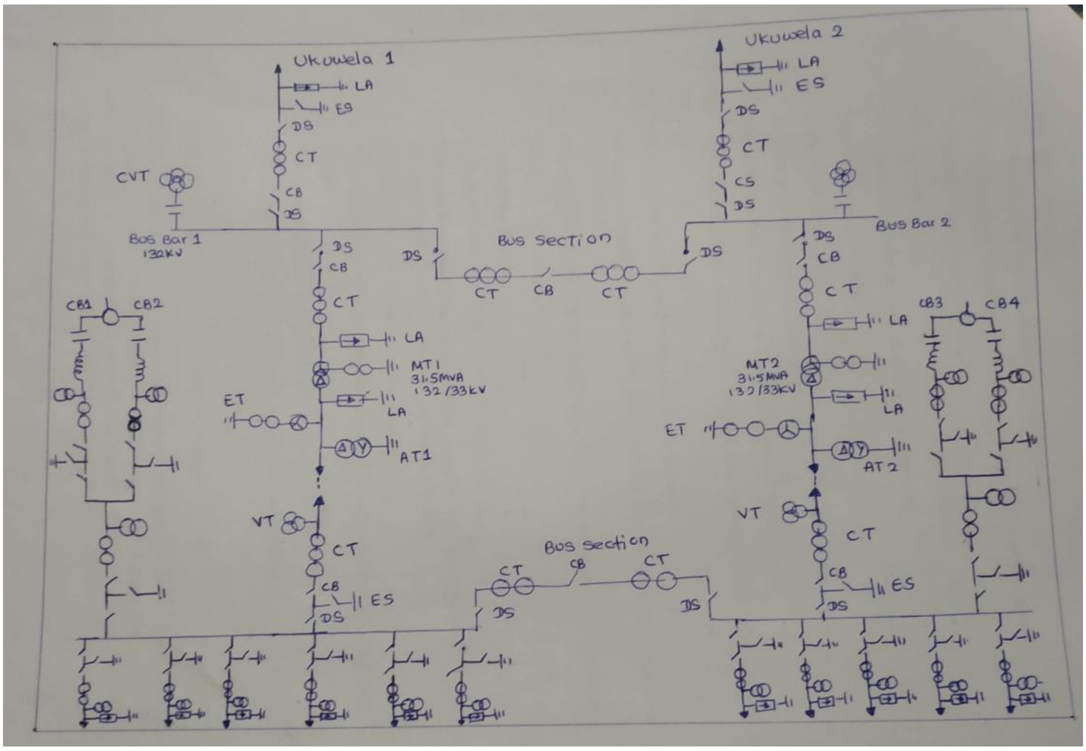

Figure 3.2 Line diagram of Pallakele grid substation

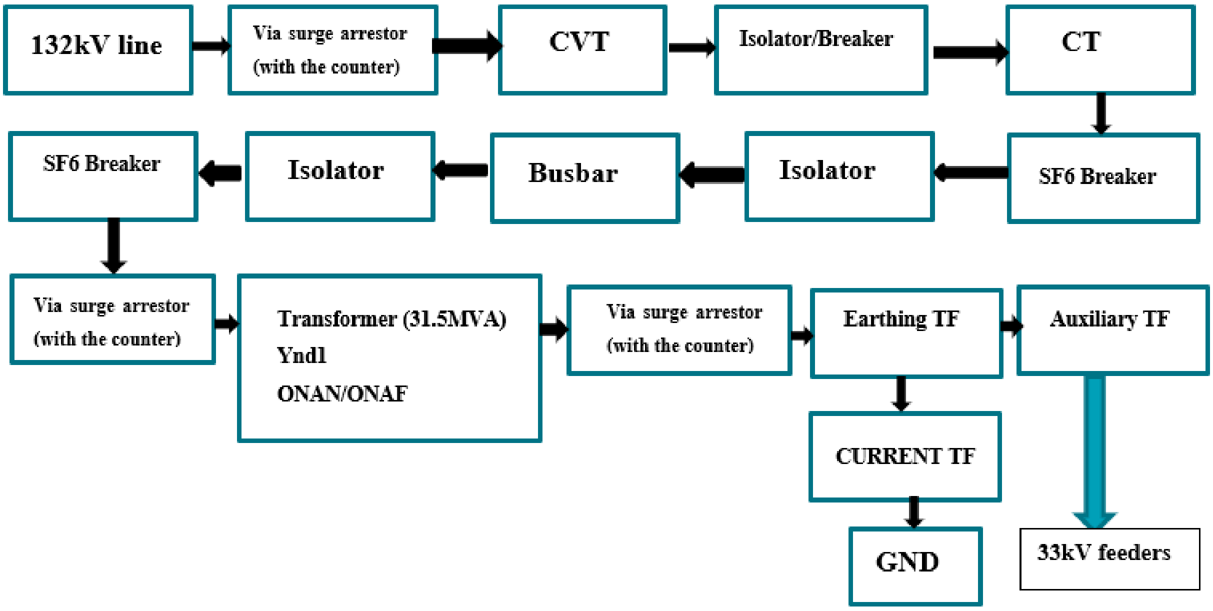

Figure 3.3 Typical switchyard arrangement

Typical switchyard arrangement consists of the following main components for the instrumentation and protection purposes.

- Surge arrestors – This provides insulation up to predetermined voltage and can discharge overloads that may cause by transients in the conducting lines

- Capacitive voltage transformers – Instrumental transformers that can withstand higher voltages than a typical voltage transformer
- Isolators – They are used for isolation of a specific section of the grid. This also gives visual confirmation that the line is disconnected for the protection of the people that are working on that section.
- Current transformers – These are instrumental transformers that measures phase current by stepping down the voltage to a much safer level.
- Circuit breakers – These comprise of SF_6 gas which quenches the arching that causes by line disconnection; there are also oil-based circuit breakers present in some switchyard arrangements.
- Earthing transformers – Earthing transformer is used in power systems to create a virtual neutral point for the lines when there is no neutral point available, especially in delta connected wiring. The earthing transformer can handle load unbalances, harmonics.

Some switchyards also consist of capacitor banks that primarily used to mitigate harmonics present in the system. Figure 3.3 shows a switchyard arrangement with capacitor banks to filter 3rd, 5th and 7th harmonic components present in the 33kV lines

Figure 3.4 Switchyard arrangement with the 33kV Filter capacitor banks

3.4 SUMMERY

Various components associated with a grid substation, protection features, different control techniques related to the industry standards were observed during this section. The importance of learning harmonics and their effects with the theory which were learned by myself were clearly understood within this section.

CHAPTER 4
DISTRIBUTION

4.1 INTRODUCTION

The distribution network is the part of the CEB that delivers electricity to the end-users. The distribution network consists of 33kV,11kV lines and 400V lines. Distribution division consists of main branches such as

- Projects and heavy maintainer
- Planning and development
- Commercial and cooperate branches

4.2 DISTRIBUTION DIVISIONS

The distribution division of the CEB is divided into four main regions

- Distribution division (DD) 1
- Distribution division (DD) 2
- Distribution division (DD) 3
- Distribution division (DD) 4

Around 88% of the total electricity distribution is handled by these distribution divisions. Apart from these divisions, the other 12% is dealt with LECO, a subsidiary of CEB. Under this training period, I was assigned to DD2 which includes Western North, Central province and Eastern province as shown in figure 4.1 The main reasons for the distribution divisions is to provide efficient management of resources and improve the reliability of the CEB infrastructure.

Each of these distribution divisions is led by a deputy general manager and subdivided into areas which are handled by areal electrical engineers. Main functions of the distribution section of the CEB includes

- Maintenance of 33kV lines
- Maintenance of primary substations
- Maintenance of low voltage (400v) area; distribution lines and transformers
- Maintenance of Underground lines and their transformers
- Handling of customer care (Billing, Channeling of complaints, New connections)

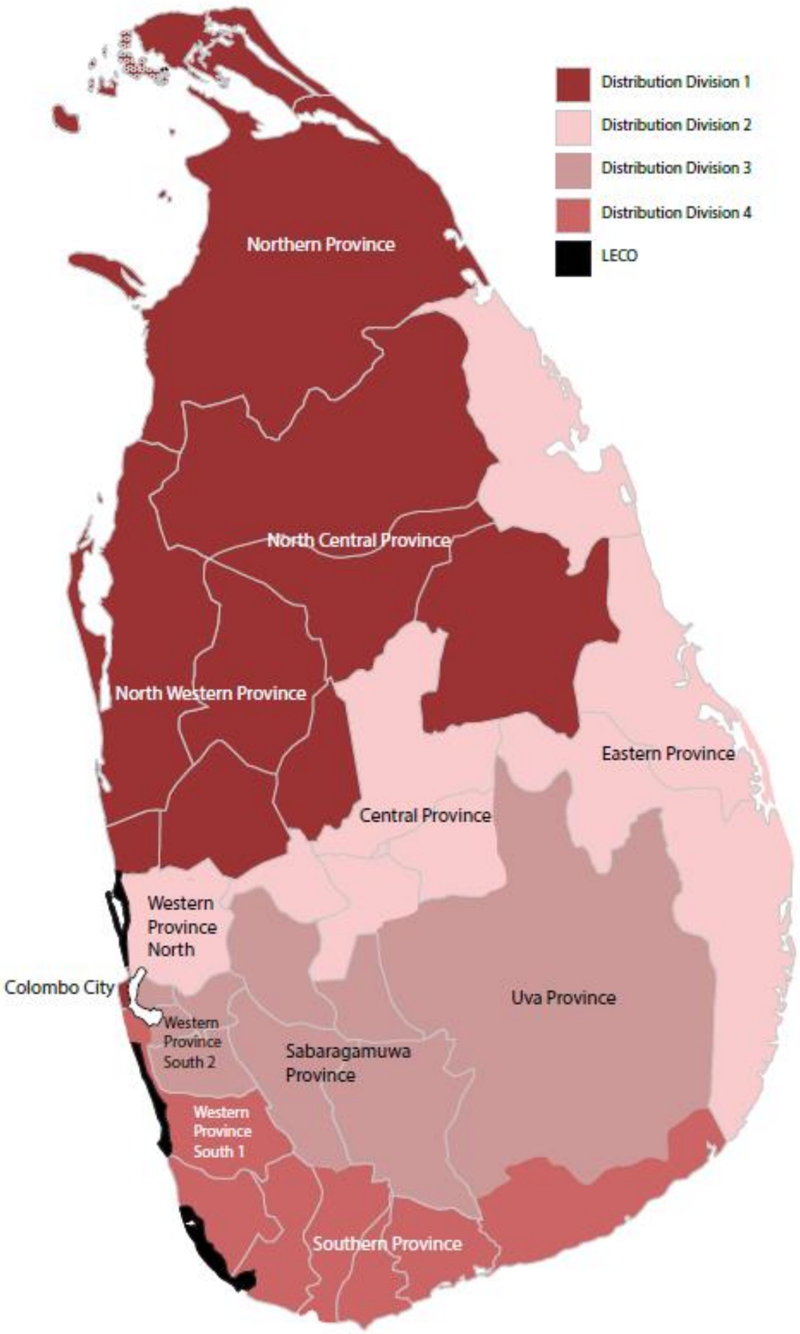

Figure 4.1 CEB distribution divisions in Sri Lanka

4.2 AREA ENGINEERS OFFICE

Area engineer’s office is responsible for maintaining of distribution lines, distribution transformers and Gantries and other asset management in the area allocated to the area engineers office.

4.2.1 TRANSFORMERS USED IN DISTRIBUTION

CEB consists of distribution transformers with the following ratings. 1000kVA,800kVA,630kVA,500kVA,400kVA,250kVA,200kVA,160kVA,100kVA. And the mounting methods of these transformers can be,

- Pole mounted transformers
  - Single pole-mounted transformers
  - Double pole-mounted transformers
- Plinth mounted transformers
- Indoor mounted transformers

Each of these transformers consists of components such as on-load tap changers, bushes, surge arrestors, Buchholz relays, cooling systems, protection circuits, thermometers etc. It is required by the CEB staff to periodically check the transformers for issues such as,

- Oil level and leaks
- Noise checks
- Tap positions
- Readings
  - Current
  - Voltage
  - Frequency
  - Temperature

For the transformers available in primary substations it is required to perform monthly checks and maintenance for the factors such as mechanical tightening, electrical connection cleaning, breather system checking, oil testing, arching horn gap checking, fire protection tests, auxiliary relay tests and checks for possible corroding.

Depending on the region where the transformer is installed, it is required to maintain a proper cooling system. There are four main cooling systems available.

1. Oil Natural Air Natural (ONAN) – there is no fan or mechanism to manually cool the transformer.
2. Oil Natural Air Forced (ONAF) – These transformers consist of a fan installed that activated if, the transformer temperature is rising.
3. Oil Forced Air natural – Typically used to avoid the oil being frozen.
4. Oil Forced Air Forced – There are two mechanisms present to change the temperature of the oil and the transformer.

4.2.2 FEEDER LINES

Feeder lines are the lines that supply 33kV to the distribution transformers or the primary substations. Typically, feeder lines are implemented in a ring connected path so that the maintenance and restoration of the power in case of a breakdown would be much more comfortable. A feeder network in the Kandy region is shown in figure 4.2.

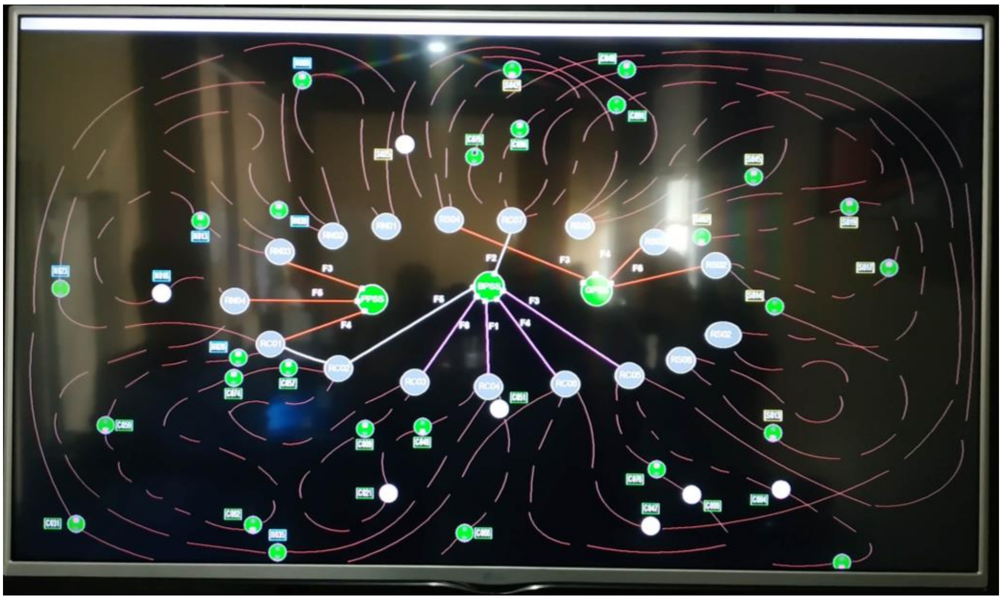

Figure 4.2 Ring network of feeder lines in the Kandy region

4.3 PROJECTS AND HEAVY MAINTENANCE

This section is responsible for the construction and maintenance of,

- 33kV tower lines
- Primary substations
- Gantries
- Other equipment associated with 33kV lines.

4.3.2 REASONS FOR USING 11KV IN UNDERGROUND LINES

One of the main reasons for the selection of 11kV over 33kV voltage for using underground cables is that the cost of insulation increases dramatically with the increase of the voltage. For some coastal areas, the salt deposition on the conductor insulators can cause the insulators to become conductive, which may result in maloperation of the insulators with higher voltages. Even for the aerial cables in some urban areas, due to the lack of proper clearance between the buildings and the conductor lines, 11kV is preferred over 33kV overhead lines. Laying out of underground cables in Peradeniya area is shown in figure 4.3

Figure 4.3 Underground cable laying in Peradeniya university

4.3.2 PRIMARY SUBSTATION

Primary substation in CEB acts as the interconnection between 33kV lines and the 11kV lines.11kV lines used mostly in residential areas with underground cables. The primary substation consists of transformers that step down the 33kV voltage into 11kV voltage and sent to the feeder lines. In a primary substation, there are many protection schemes present to maintain the security of the components and to maintain the standards necessary. For the case of transformers, there are mechanical protection and electrical protection present.

- Mechanical protection
    - Buchholz relays- Due to internal faults such as winding failures or oil losses, gas is accumulated inside the transformer. Buchholz relay detects this gas accumulation to provide protection
    - Pressure relays – This relay monitor sudden rate of change of pressure inside the tap changer oil enclosure
    - Oil level monitoring devices
    - Winding thermometer – This detects the maximum temperature of the winding
- Electrical protection
    - Differential protection – This scheme compares the current between primary and the secondary windings of the transformer with the help of current transformers and if an unbalance is found, it sends a signal to the transformer circuit breaker
    - Overcurrent and earth fault protection – This protection scheme able to detect 3 phase faults and phase to phase faults.

4.3.3 GANTRY

Gantry is an overhead tower structure that is used to connect multiple 33kV lines to nearby substations and other feeder lines. Typically, a gantry structure consists of breakers, isolators, auto reclose switches, instrumental transformers. Gantry can reroute 33kV lines and disconnect them in case of maintenance. Routine maintenance of a gantry structure is shown in figure 4.4

Figure 4.4 Routine maintenance of a gantry structure in Iriyagama

4.4 SUMMERY

Within the distribution section of this training, various components, protective features, used in the electrical industry and how CEB maintained its consumer relations were studied. Several worksites and projects such as laying out of new connections, replacement of overhead cables was visited during this period.

Chapter 5
SAFETY

5.1 INTRODUCTION

During the training period, in all of the worksites and power plants belong to the CEB, safety was considered as a priority for the wellbeing of the workforce and the customers. The following cases were observed within my period of training

- It is considered mandatory to proceed with a safety procedure when working with the transmission and distribution lines. This involves confirming that the lines are disconnected by the SF_6 breakers or the oil breakers, and then disconnection of the line physically and grounding it by using the isolators. The technical staff always wear safety helmets and safety belts while working on the field. This is shown in figure 5.1, where it can be seen that the isolators are grounded.

Figure 5.1 Safety procedures when working with a gantry

- The CEB provides its staff with the informative posters instructing them how to safely proceed with specific tasks and in figure 5.2, it shows the correct posture to lift a heavy object.
- The safety standards urge the employees of CEB to perform a checklist to ensure the safety of the people and the components of CEB as shown in figure 5.3

And when performing repairs on the transformers, the lines are disconnected by using load break tool that disconnects the drop-down lift on (DDLO) links, to ensure that the transformer is completely isolated from any outside energized lines.

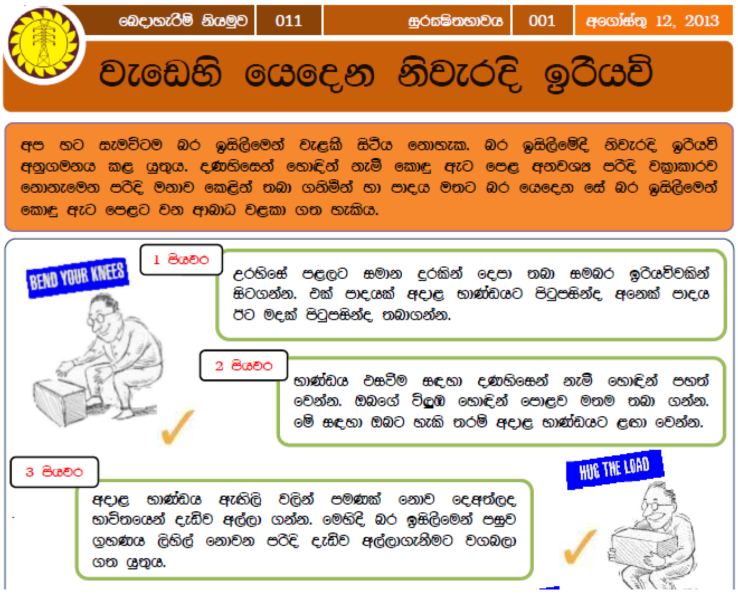

Figure 5.2 Safety instruction posters available within CEB

බෙදාහැරීම් උපපොළ පරීක්ෂා කිරීම

සවි කිරීමෙන් පසුව බල ගැන්වීමට (**Energize**) පෙර සිදු කරන පිරික්සුම්

#	දර්ශකය	ඔව්	නැත
01	උදාසීන අග්‍රය වෙනම සහ අකුණු නවතු නිසියාකාරව තරාපැවි ආවරණයට සම්බන්ධ කර වෙනම භූගත කර ඇත.		
02	භූගත සම්බන්ධක තහඩු හා කම්බි සඳහා තඹ ලෝහය පමණක් භාවිතා කර ඇත		
03	භූගත සම්බන්ධතාවයේ අඛණ්ඩතාවය පරීක්ෂා කරන ලදි.		
04	භූගත ප්‍රතිරෝධය		
	උදාසීන අග්‍රය * *(< 25 Ω)* *අගය :*		
	අකුණු නවතු හා තරාපැවි ආවරණය. * *(<10 Ω)* *අගය :*		
05	ටැප් සිරු මාරුව නාමික හෝ පෙර තීරණය කළ ස්ථානයට යොදා ඇත.* Tap Position :		
06	සියලු සන්නායක කම්බි වල අල්ලු සවි කර නිවැරදිව අග්‍රවලට සම්බන්ධ කර ඇත.		
07	නියම කර ඇති ප්‍රමාණයේ සන්නායක (Tail Wire) භාවිතා කර ඇත.* ප්‍රමාණය :		
08	කලා පිළිවෙළ සම්මත තහඩුවට අනුව නිවැරදිව සම්බන්ධ කර ඇත.		
09	H- සම්බන්ධක භාවිතා කර අධිසැර කම්බියට නිවැරදිව සවිකර (Crimp) ඇත.		
10	නිවැරදි ප්‍රමාණයේ අධිසැර හා අඩුසැර විලායක (HRC Fuse) භාවිතා කර ඇත.		
11	විලායක (HRC Fuse) විසන්ධි කර ඇත.		
12	අඩුසැර අග්‍ර හා විලායක (HRC Fuse) අතර PVC වයර නිවැරදිව සවිකර ඇත.		
13	කණුව දිගේ පහළට යන කම්බි මල නොකන වානේ පටි වලින් කණුවට සවිකර ඇත		
14	විදුලි මීටරය නිවැරදිව සවිකර ඇත.		
15	විදුලි මීටරය හා තරාපැවිය අතර නිවැරදි සම්බන්ධතාවය සිදුකර ඇත.		
16	මල නොබැඳින වානේ ඇණ සවිකිරීමේදී සමතල (Flat) සහ දුනු (Spring) වොෂර නිවැරදිව භාවිතා කර ඇත.		

* අගය සටහන් කරන්න.

Figure 5.3 Grid substation checklist for the safety

For the safety of the equipment that is not in use, CEB has given guidelines on how to store them properly. For example, the proper way of storing concrete poles is provided as a guideline as shown in figure 5.4

Figure 5.4 Informational posters about the safety of the concrete poles

The most important factor when constructing tower or pole lines is to ensure the safety of the general public to do that; it is essential to keep a proper clearance between the conductor wires and the ground. For 33kV lines, this clearance is maintained at least,

- For roads – 6.4m
- For other places -6.1m
- For uninhabited lands-4.9m

This also applies to the railway tracks, but for that case, a grounded mesh net is used to ensure more protection as shown in figure 5.5

දුම්රිය මාර්ග සඳහා ආරක්ෂිත පරතරය

අ	33kV විවෘත විදුලි රැහැන්	7.0 මී.
ආ	ම. වො. බිම් ගැන්නුම් දැල	6.7 මී.

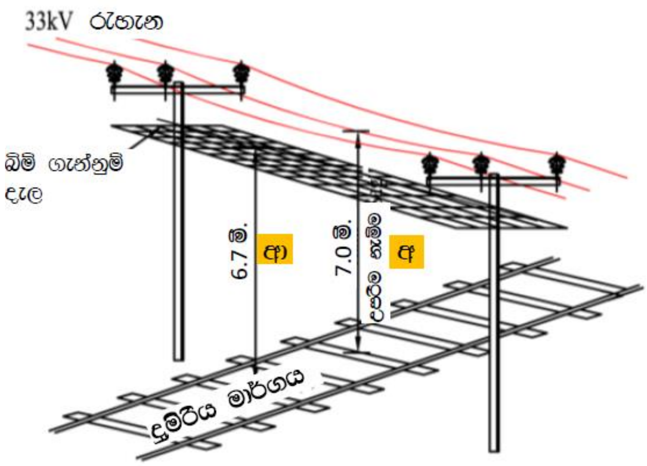

Figure 5.5 Safety standard for railway tracks

And it is important to remove any tree branches, dead trees that might fall into the conducting lines. So, the CEB has vegetation clearers who cuts off any tree branches and trees that may pose a risk to the conducting lines. They also clear off dead animals, kites and other things that may be attached to the conducting lines. Table 5.1 shows the clearance ratings for the vegetation around conducting lines.

Table 5.1 Vegetation Clearance ratings

Line type	Safety distance
11kV pole lines	4.5m
33kV Tower lines	9.0m
33kV pole lines	6.0m
400V lines	1.5m

CONCLUSION

It is essential as an undergraduate engineer to expose oneself to the industry to gain hands-on experience about the application of the aspects learned throughout the undergraduate course. The industrial training course TR400 provides means to archive this objective with the internship opportunities at various industrial sites related to the engineering discipline of the student.

Ceylon Electricity Board (CEB) has carried out a well-structured training programme with the help of the training branch of the CEB. The training programme covered all the significant aspects related to the power industry.

- Electricity generation
- Transmission
- Distribution

For ten weeks from 05th of November 2019 to 10th of May 2019, I have visited multiple in indoor and outdoor training facilities owned by CEB. The things I have archived during my training period can be summarized as follows.

- Gaining knowledge of the functions of various CEB departments
- Understand the working fundamentals of hydropower plant
- Understand the working fundamentals of thermal power plant
- Understanding components and their functions in a transmission network
- Elements and their tasks in the Distribution network
- How system control functions for the optimum operation of power plants
- Understanding the responsibilities of the engineers in the CEB departments

I have obtained detailed knowledge and hands-on experience of how a power producer and transmission system operator work in the power industry. And I have also gained an understanding of the various industry standards and why an engineer needs to acquire theoretical knowledge that is applicable in the industry. So finally, I can conclude that CEB is one of the best places in Sri Lanka to undergo training related to the electrical engineering field.