 

**ELECTRICITY COMPANY OF GHANA/ENGINEERING DIRECTORATE**

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**A REPORT ON INTERNSHIP DONE AT ECG ENGINEERING DIRECTORATE**

**BY**

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**ABSTRACT**

This report details a two-month internship at the Electricity Company of Ghana, Projects Office. I worked with the Engineering Directorate of the company. I had the opportunity to study from all the three divisions in the Engineering Directorate; the System Planning Division, the Network Design Division and the Research and Development Division

As an intern, I was taken through the core functions of the various divisions. Some of which include; Power Flow Analysis using Cyme, Substation Design, Standards and Specifications, Submittal Review, Design and Construction of overhead lines and underground cables, System Reliability studies.

# TABLE OF CONTENT

[**GENERAL INTRODUCTION** 5](#_Toc98944378)

[**ABOUT THE ELECTRICITY COMPANY OF GHANA** 5](#_Toc98944379)

[ENGINEERING DIRECTORATE 5](#_Toc98944380)

[SYSTEM PLANNING DIVISION 6](#_Toc98944381)

[POWER FLOW FOR SUB-TRANSMISSION AND DISTRIBUTION SYSTEMS 7](#_Toc98944382)

[**Sample of electrical network** 8](#_Toc98944383)

[**SUB-TRANSMISSION & DISTRIBUTION SYSTEM RELIABILITY STUDIES** 9](#_Toc98944384)

[SHORT CIRCUIT ANALYSIS 10](#_Toc98944385)

[POWER QUALITY ANALYSIS 12](#_Toc98944386)

[NETWORK DESIGN DIVISION 13](#_Toc98944387)

[OVERVIEW OF GHANA’S ELECTRICAL NETWORK 14](#_Toc98944388)

[GENERATION OF POWER BY VRA AND IPPs : 14](#_Toc98944389)

[TRANSMISSION OF POWER BY GRIDCo 15](#_Toc98944390)

[DISTRIBUTION OF POWER BY ECG AND NEDCo : 15](#_Toc98944391)

[SUBSTATION DESIGN 15](#_Toc98944392)

[PRIMARY SUBSTATION DESIGN 16](#_Toc98944393)

[INTERCONNECTING CIRCUIT DESIGN 18](#_Toc98944394)

[OVERHEAD LINES 18](#_Toc98944395)

[UNDERGROUND CABLES 19](#_Toc98944396)

[SITE VISIT 20](#_Toc98944397)

[RESEARCH AND DEVELOPMENT DIVISION 21](#_Toc98944398)

[STANDARDS AND SPECIFICATIONS 22](#_Toc98944399)

[SUBMITTAL REVIEW 22](#_Toc98944400)

[SPECIFICATION REVIEW 24](#_Toc98944401)

[CONCLUSION 24](#_Toc98944402)

**INTRODUCTION**

**ABOUT THE ELECTRICITY COMPANY OF GHANA**

Electricity Company of Ghana is a Utility Company operating under the Ministry of Energy (ME). The Company is responsible for the distribution of electricity in the southern part of Ghana namely, Ashanti, Central, Eastern, Greater Accra, Volta and Western Regions. The Company is charged with the under-mentioned responsibilities;

**1**. To transmit, supply and distribute electricity.

**2**. To purchase electricity energy in bulk (from GridCo) or any other supplier for distribution.

**3**. To construct, reconstruct, install, assemble, repair, maintain, operate or remove sub-transmission stations, electrical appliances, fittings and installations.

**4.** To execute national electrification programs on behalf of Government.

**5**. To carry out any other activity incidental or conducive to the attainment of the objectives specified in the instruction above.

# ENGINEERING DIRECTORATE

The Engineering Directorate of the Electricity Company of Ghana is headed by the Director of Engineering with assistance from three General Managers.

The Engineering Directorate is responsible for

1. Planning, designing and constructing the distribution network and updating the company’s construction standards and material specification.
2. Project management practices in the delivery of quality and safe supply of power to customers within economic cost, schedule time and environmentally sound practices.

The Directorate is made up of three Divisions namely :

1. System Planning Division
2. Network Design Division
3. Research and Development Division

Based on my schedule during the internship, I had the opportunity to work with all the three divisions.

# SYSTEM PLANNING DIVISION

During my three weeks stay at the System Planning Division, as an intern, I learnt that the System Planning Division is concerned with network development planning studies aimed at satisfying present and future network requirements. I was taken through some of the functions of the division. The functions include the following but not limited to;

1. Power Flow for Sub-transmission and Distribution Systems
2. Sub-transmission & Distribution System Reliability Studies
3. Short Circuit Analysis
4. Short, medium and long term system planning.
5. Preparation of proposals aimed at electricity infrastructure improvements and changes for investments

# POWER FLOW FOR SUB-TRANSMISSION AND DISTRIBUTION SYSTEMS

Load/Power flow study is the numerical analysis of the flow of electric power in a system.

Is a mechanism, which aims to evaluate a power system’s capability to adequately supply the connected load while staying within power voltages and currents ranges. The information that is critical from a proper load flow is the voltages and power factor at all your buses, and currents or power flow on all your feeders.

As an intern, I was also introduce to a software called CYME. This application helps in carrying out the various studies associated with the electrical networks.

*Steps taken to conduct Power Flow Studies using CYME;*

1. The power system network is modelled to mimic the actual power system.
2. Assign power consumption at load of buses of a known electric power system configuration.
3. Assign power production at each generator (i.e. how much active power to be generated).
4. Determine power flows and losses in each feeder and transformer of the interconnecting network.
5. Determine the voltage magnitude and phase angle at each bus.

*Example of an electrical network is shown below;*



**Sample of electrical network**

From the network, using the CYME software

* We can obtain the voltage magnitudes and angles at each bus in the steady state.
* The losses in a particular line can also be computed.
* The overload and underload conditions can be determined.
* Decide the best operation of existing system
* Short circuit analysis and also plan for future expansion of the network

**SUB-TRANSMISSION & DISTRIBUTION SYSTEM RELIABILITY STUDIES**

The System Planning Division undertakes various studies to discover areas in the network that need improvement. One of the studies that helps the division perform their functions is Reliability Studies. Reliability of a power system is the ability of the power system components to supply electricity to all points of consumption in the quantity and with the quality demanded by the customer/consumer. The division performs reliability assessment for sub-transmission networks in ECG’s operational areas.

Reliability Studies are done to :

1. Allow the efficient and reliable use of the power system.
2. Allow for an assessment of the adequacy of the system to serve customer load.
3. Help detect areas that are deficient and need system upgrades.
4. Provide a measure of the expected performance of the system.

Reliability studies entails Bus Operational Voltage Analysis using Power Flow Studies, Transfer Capability Analysis and Primary Substation Transformers. Capability Analysis is used to determine the total transmission capacity of the network.

Reliability of a power system is often measured by power supply outage indices. These outage indices are based on the duration of each power supply interruption and the frequency of interruption. Some common indexes which are used to describe the power system include :

1. System Average Interruption Frequency Index (SAIFI) : This refers to the average number of sustained interruptions per consumer during the year.
2. System Average Interruption Duration Index (SAIDI) : This refers to the average duration of interruptions per consumers during the year.
3. Customer Average Interruption Duration Index (CAIDI) : This is a ratio of the total duration of interruptions to the total number of interruptions during the year.
4. Average Service Availability Index (ASAI) : This is a ratio of the total number of customer hours that electricity was supplied to the total number of customer hours demanded.

## SHORT CIRCUIT ANALYSIS

The power system is such that at any instance, there can be a short-circuit fault on any of the transmission lines. Short circuits create a path of very low resistance for the current, causing the current to increase substantially and creating excessive heat in the short circuit path. Short circuit current if not detected early enough and is left to circulate in the system, can cause many equipment to get damaged. To prevent this, relays and circuit breakers are added to the power system to detect abnormally high current and cut the flow of power when a short-circuit fault is detected in the power system.

Short Circuit Analysis determines the maximum available three-phase and single phase-to-ground fault currents at various location in an electric power system.

Short Circuit Analysis is important because it helps in :

1. Dimensioning of switchgears.
2. Assessment of the capability of power system components to safely handle maximum prospective fault currents.
3. Determining optimum power system protection relaying schemes.
4. Determining power system protection relay settings.

Short Circuit faults can be grouped into two namely, Balanced or Symmetrical Faults and Unbalanced or Unsymmetrical faults.

Balanced faults are faults which occur in all three phases. They are three-phase faults or three-phase-to-ground faults. For these faults the power system can be treated by using a single phase representation.

Unbalanced faults are faults that do not occur in all three phases. These faults give rise to unequal line currents with unequal displacement. The power system cannot be solved by using a single phase representation. These faults include faults that occur between only two phases (line-to-line faults), between two phases and ground (two line-to-ground faults) and between a phase and ground (line-to-ground faults)

I was taken through several examples of both types of faults and taught how to calculate the fault currents for both balanced and unbalanced faults. It was observed that the highest level of fault current occurred when there was a balanced fault.

## POWER QUALITY ANALYSIS

Many bulk customers such as factories and some institutions that ECG supplies with electric power need constant supply of power of good quality. There is therefore a need to analyse the power system to make sure the power supplied to these customers is of good quality.

Power quality is the concept of maintaining a near sinusoidal waveform of power distribution bus voltages and currents at rated magnitude and frequency.

Power quality can be quantified by measuring the different characteristics of the voltage and current on the supply such as Dips, Swells, Transients, Unbalanced Phases, Harmonics, Flicker, Power Factor.

The methodology for Power Quality Analysis is as follows :

1. Set the Power Quality Analyzer to monitor the relevant parameters (voltage, current, Active Power, Reactive Power, Apparent Power, Power Factor, Harmonics, Flickers)
2. Program the Analyzer to monitor and save the selected parameters for pre-defined time intervals eg. 15 minutes, 30 minutes, 1 hour etc.
3. The data is exported and analyzed to identify out of limit events.
4. Recommendations are proposed to tackle the identified the Power quality deviations.
5. Financial Justification of the cost of proposed interventions against the benefits is assessed.

After studying the theory behind Power Quality Analysis, there was a site visit to ECG’s Secondary Distribution Substation where a Power Quality Analyzer was used to measure the various voltages, currents, Active Power, Reactive Power, Apparent Power, Power Factor, Harmonics of the three phases namely, the red, yellow and blue phases.

# NETWORK DESIGN DIVISION

The next division I worked with was the Network Design Division. I worked with them for three weeks.. I learnt about the job functions of this division which include :

1. Substation Design which entails :

* Preparation of Geographic Layout drawing and Single Line Diagram (SLD) to show the relative position of the substations/circuits on a geographical map and how they are connected.
* Defining the required scope of works for constructing any part of the network, including metering requirements
* Extraction of the Bill of Quantities (BOQs) for any proposed project. From the generated Bill of Quantities, Cost Estimates for the project are prepared.

1. Overhead line and underground cable network design
2. Reviewing contractors’ and suppliers’ design submittals i.e. Equipment Layout Drawings, Single Line Diagrams, Lightning Protection Designs, Earth-grid Designs Plan and Profile designs of lines, LV design submittals .
3. Liaising with stakeholders to determine Right of Way of lines and for appropriate location of proposed substations.
4. Handing over of approved projects for their procurement and implementation.

## OVERVIEW OF GHANA’S ELECTRICAL NETWORK

The job functions of the Network Design Division centers on knowing the electrical network in the country. Ghana’s electrical network can be thought of as constituting substations and inter-connecting circuits or lines. Knowing a general overview of the country’s electrical network helps the design engineer to effectively design these substations and interconnecting circuits.

Ghana’s electrical network has three main parts : Generation, Transmission and Distribution.

### GENERATION OF POWER BY VRA AND IPPs :

Power production in Ghana is from two main sources ; State Owned Power Plants and Independent Power Producers (IPPs). Generation of electricity in Ghana is from hydro, thermal or solar plants. State-owned power plants include the Bui Dam, Akosombo Hydroelectric Plant, Kpong Hydroelectric Power Plant, Tema Thermal Plant, Kpone Thermal Power Plant etc. Independent Power Producers include Cenit Energy Limited, Karpowership, Genser Power Ghana Limited, BXC Solar Plant etc. These power producers produce electricity at voltages such as 11.5kV,13.8kV and 14.4kV and step it up to 161kV or 69kV using power transformers. The voltage is stepped up to 161kV or 69kV to reduce I2R losses during transmission to GRIDCo. 69kV is only used in the Volta Region.

### TRANSMISSION OF POWER BY GRIDCo

Transmission of power in Ghana is only done by GRIDCo. After GRIDCo receives 161kV or 69kV from the power producers, it steps it down to 33kV at an interface between GRIDCo and ECG called a Bulk Supply Point. ECG then picks up the 33kV for distribution.

### DISTRIBUTION OF POWER BY ECG AND NEDCo :

There are two main power distribution companies in Ghana namely, ECG and NEDCo. ECG distributes power to the southern part of Ghana whiles NEDCo distributes power to the northern part.

After receiving 33kV from GRIDCo, ECG sends the power to its Primary Substations and steps the voltage down to 11kV. (However for distribution to rural areas, the voltage is transmitted at 33kV instead of 11kV to reduce losses.) The 11kV is transmitted to Secondary Substations where the voltage is finally stepped down to 433V using distribution transformers. 433V is finally distributed to customers. Some factories or companies which require higher voltages to operate are supplied directly with 33kV or 11kV.

### SUBSTATION DESIGN

A substation is a point in the electrical network where voltages are transformed (stepped up or down) and/or transmitted to other substations.

Some functions of a substation are :

Directing the flow of electrical energy in the power system.

Ensuring supply security through protective equipment and communication between power systems

Providing alternative routes

Raising voltage levels for transmission

Lowering voltage to safe levels

Providing switching operations

Interconnecting power systems

Based on the voltage levels found at substations, there are four types of substations in ECG’s network. They are :

Bulk Supply Points : This is the interface between GRIDCo and ECG where GRIDCo steps down 161kV or 69kV to 33kV and delivers 33kV to ECG.

Primary Stations : At these substations, 33kV is stepped down to 11kV. Either of these voltages can be directly fed to bulk customers.

Switching Stations : These are substations where 33kV is transmitted to different Primary Stations. No transformers are found in this type of substations, hence there is no voltage transformation.

Secondary Distribution Stations : At these substations, 11kV is stepped down to 433V for use by customers.

### PRIMARY SUBSTATION DESIGN

Some equipment that can be found at a Primary Substation include:

Power Transformers : They are used for voltage transformation.

Auxiliary or Service Station Transformers : They are power transformers used to to step down high voltage to a low voltage for use in the substation.

Busbars : These are used for collecting electric power from incoming feeders and distributing them to the outgoing feeders.

Circuit Breakers : They are electrical switches that protect the electrical circuit by interrupting current flow after protective relays detect a fault caused by an overload or a short circuit.

Isolators : They are switches that isolate parts of the electric circuit to allow for safe maintenance work to be done in the network.

Neutral Grounding Resistor or Earthing Transformer : This is used to protect the equipment in a power system from fault current.

Instrument transformers (Current Transformers and Voltage Transformers.) : These are used to step down high voltage or high current to operate relays.

Earthing systems (Earth grid or equipment earthing) : This is an underground earth grid system done before the construction of the substation. It is done to protect people from electrical shocks due to step and touch voltages

Protection Relays : They are electrical relays that detect faults and initiate the operation of circuit breakers. They can also be used for metering.

Energy meters : They are measuring devices used to measure voltages, currents, power and other related parameters in the network.

Lightning Systems : These include lightning masts to protect the equipment at the substation from lightning surges.

Substation Automation Systems : This refers to a collection of hardware and software components that are used to monitor and control the electrical system both locally and remotely.

Primary Substations can further be classified according to constructional features. There are two types; indoor substation and outdoor substation.

Outdoor Primary Substation: At this type of substation, the 33kV switchgear equipment is installed outside but the 11kV switchgear is installed indoors. The switchgear equipment for both 33kV and 11kV include relays, isolators, circuit breakers, fuses and other equipment.

Indoor Primary Substation: At this substation, both the 33kV and 11kV switchgear equipment are installed indoors.

An indoor substation is relatively more expensive than an outdoor substation but requires a smaller size of land as compared to the outdoor substation.

### INTERCONNECTING CIRCUIT DESIGN

The interconnecting circuits are circuits or lines that connect different parts of the network. They connect substations to other substations and to customers. The lines are either :

Subtransmission lines (33kV lines used to connect different primary substations and switching stations.)

Primary Distribution Lines : These are 11kV lines that carry power from primary substations to secondary distribution stations.

LV Lines : These are lines that carry 433V from the secondary distribution stations to customers.

All these circuits can either be designed as either Overhead Lines or Underground Cables.

# OVERHEAD LINES

Overhead lines are conductors mounted on support structures. They are visible and easy to notice. One advantage of the Overhead Lines is that faults on the line are generally easy to find and fix. However, some disadvantages are that it poses some danger to people nearby and the conductors are exposed to faults caused by lightning and wildlife.

An overhead line is basically made up of :

Current Carrying Conductors (Aluminum Bare conductors and Covered conductors). The sizes of these conductors range from 50mm2, 120mm2 150mm2, 265mm2 and 400m2..

Support structures and accessories used to support the conductors. The support structures are mainly Wood Pole, Steel Tubular and Concrete Towers.

# UNDERGROUND CABLES

These are cables that are buried underground and are not visible. The cables are made up of conductors for carrying current and other layers like the conductor shield, insulation shield, armour, outer jacket etc. which provide mechanical protection and protect people from shock hazards caused by accidental contact with the cable.

Some advantages of using underground cables are that they are more reliable since they are not exposed to lightning, wildlife or vegetation.Underground cables are most preferred for areas of significant or prestigious infrastructural development

The disadvantages of using underground cables are that they are more expensive and it takes a relatively longer time to fix faults that may occur in the cable as compared to overhead conductors.

The Underground Cable Circuit is made up of:

The Cables of various sizes

Cable Laying Accessories (Cable tiles, warning tape, insulation tape etc.)

Cable Trench

The following steps must be followed by the design engineer in designing an interconnecting circuit.

Selection of route for the circuits.

Preparation of detailed route designs with associated geographic surveyed route map.

Definition of the full scope of works.

Extraction of Bill of Quantities and determination of Cost Estimate for the proposed circuit.

## SITE VISIT

In my last week of working with the Network Design Division, there were site visits to the Mobole Bulk supply point at Mobole and the Juapong substation.

I observed that for the substation, the transformers were mounted outside but had cables connecting them to the panels inside the control building. There was a firewall separating the two transformers at the OLAM substation. The purpose of the firewall is to protect either transformer from being affected by the explosion of the other transformer.

For the outdoor substations, there was a bay arrangement for each of the transformers (two at each station). The bay arrangement included a 33kV busbar with a bus coupler, incoming feeders, circuit breakers, isolators, Current Transformers and Voltage Transformers. There were indoor panels with busbars for the 11kV feeders.

At the indoor substation, both the 33kV and 11kV busbars and control equipment were inside the control building.

I observed that there were auxiliary transformers at all the substations for servicing the substation. There were also battery rooms with dc batteries and an eye wash stand.

# RESEARCH AND DEVELOPMENT DIVISION

The third division of the Engineering Directorate I worked with was Research and Development Division., I was taken through the organizational structure of ECG and the mandates of the Division which include :

1. Research into new equipment or materials that could improve the reliability and efficiency of ECG’s network.
2. Research into electrical disturbances or faults that do occur in the network and recommends solutions that could mitigate the faults.
3. Perform technical review of ECG’s specifications and equipment ECG intends to procure for network expansion and maintenance purposes. This process is termed as technical submittal review.
4. Research into improvements of ECG’s current designs.

During my period of working with the Research and Development Division, I gained experience on how to perform some of their job functions. I was taken through :

1. A series of teaching on Standards and Specifications of various equipment in Ghana’s electrical network.
2. A hands-on assignment on technical submittal reviews.
3. The importance of research work and how to conduct research into faults that occur in the network.
4. How to design cables and perform thermal analyses on cables using CYMCAP, a cable ampacity software.

## STANDARDS AND SPECIFICATIONS

Specifications are specific designs or requirements developed based on international and national standards that pertain to a specific equipment/material. Standards are a general sets of rules that help companies and organizations set up their specifications. In setting up the company’s specifications, ECG uses the standards set up by these organizations:

1. International Electrotechnical Commission (IEC)
2. International Standards Organization (ISO)
3. British Standards
4. National Standards
5. American Standards

## SUBMITTAL REVIEW

Submittal review is the process of making sure equipment being purchased by ECG meets ECG’s specifications..

ECG purchases equipment from suppliers. These suppliers submit a technical document for review by the Research and Development Division. This review is done to make sure any equipment or material purchased meets the required specifications. The document from the supplier should contain the Technical Data Schedule, TDS (or Guaranteed Technical Particulars, GTP), Type Test Report (TTR) for major items, routine test report, drawings and a brochure (required from new suppliers).

Technical Data Schedule (TDS)/ Guaranteed Technical Particulars (GTP):

A Technical Data Schedule is a document that contains the specifications of the equipment or material the supplier intends to supply to ECG. When reviewing a submitted TDS, the following salient points should be taken into consideration:

* The TDS should contain the specifications of the equipment being supplied.
* The design of the equipment should meet ECG’s specifications.

Drawing:

For some equipment, drawings are required from the supplier. The parameters stated in the drawing of the equipment should correspond to the parameters or values in the TDS of ECG and the drawing should be same as ECG’s drawing.

Type Test Report:

A type test is a destructive test conducted on equipment to verify their performance in worst-case scenarios. In ECG, Type Test Report (TTR) is one of the means of checking the quality of the equipment being supplied to them. In view of that, ECG sets up criteria which it uses to select competent and recognized international laboratories whose TTR are acceptable by them. In total, ECG currently has 27 recommended laboratories for manufacturers all over the world to test their products from.

In reviewing TDS and TTR, the name of the company on the TDS and the TTR should be the same. In reviewing TTR, parameters such as, voltage level of the equipment, date of issue of the report, material makeup of the equipment, KVA rating in terms of transformers are very key during the review process.

Since technology evolves, ECG requires that TTR submitted on any equipment should not be more than five years old.

After verifying the above details, the report is scanned and sent to the laboratory whose name is on it to be verified. The response from the lab determines the next process to follow.

After submittal review, a Factory Acceptance Test (FAT) is done by third parties in collaboration with ECG’s nominated staff. Generally, FATs are routine tests (non-destructive tests or quality assurance tests) conducted to check the quality of products produced. After the FAT is done, a report is submitted by the supplier to ECG for a review by the Research and Development Division. When the submitted report is found acceptable, dispatch clearance is given by the Procurement Division for the equipment or materials to be shipped to ECG.

Consequently, when the items arrive, destination inspections are done to confirm or otherwise the FAT report submitted. For equipment procured for pilot projects, Research and Development engineers monitor to ensure the equipment is working properly and report on the progress of the pilot to management.

## SPECIFICATION REVIEW

Specification review is updating or revising the specifications of the company to meet improved designs, new IEC standards, or any changes that may have occurred during field visits.

# CONCLUSION

At the end of my stay with the Engineering Directorate, I had learnt about the job functions of the three divisions, ie. Research and Development, Network Design and System Planning. I was also taken through very detailed teachings and practicals on how these job functions are carried out. The skills I have learnt have given me a better understanding and appreciation of my field of study.