بسم الله الرحمن الرحيم

ISLAMIC UNIVERSITY OF TECHNOLOGY

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ORGANISATION OF ISLAMIC COOPERATION

STUDY OF STANDARD GRID SUBSTATION

A thesis submitted to the department of Electrical and Electronic Engineering (EEE), Islamic University of Technology (IUT), in the partial fulfillment of the requirement for degree of B.Sc. in Electrical Engineering.

PREPARED BY:

Moamen A. Abumuaileq	Student No.: 102484
M. Mubeen Memon	Student No.: 102493
Abdelrahman Bakri	Student No.: 102492

SUPERVISED BY:

Prof. Dr. Md. Shahid Ullah

CO-SUPERVISED BY:

Md. Rakibul Hasan Sagor

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)

DHAKA, BANGLADESH

CERTIFICATE OF RESEARCH

The thesis title "STUDY OF STANDARD GRID SUBSTATION" submitted by Moamen A. Abumuaileq (Student No.: 102484), M. Mubeen Memon (Student No.: 102493), and Abdelrahman Bakri (Student No.: 102492) has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of B.Sc. in Electrical and Electronic Engineering (EEE) on December, 2015.

Approved by:

____

Prof. Dr. Md. Shahid Ullah

Head of the Department

____

Md. Rakibul Hasan Sagor

Assistant Professor

Department of Electrical and Electronic Engineering
Islamic University of Technology (IUT), Bangladesh
Organisation of Islamic Cooperation (OIC)

Date of Approval: ________________

DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree.

Authors:

___________________	___________________	___________________
Moamen A. Abu Muaileq	M. Mubeen Memon	Abdelrahman Bakri
Student No.: 102484	Student No.: 102493	Student No.: 102492

Date: ________________

Supervisor:

____

Prof. Dr. Md. Shahid Ullah

Head of the Department

Co-Supervisor:

____

Md. Rakibul Hasan Sagor

Assistant Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

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Excuse us for any errors that might occur in this report despite of our best efforts.

ABSTRACT

In this thesis, we are discussing the definition of a standard grid substation, its purpose, and its significance. We also talk about the many faults and abnormal conditions that may occur in case of a breakdown, protective relaying and what it does in a substation. The compression between the current electrical substation and a smart grid substation, there is also a discussing about the smart grid with graphs and images. We also talk about our IUT substation, and what we studied.

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CHAPTER 1

INTRODUCTION

1.1 Overview:

This thesis introduces us to the function of substations at all levels of the power grid, with an introduction to typical substation components included. Substation safety issues are reviewed, and we get introduced to one-line diagrams used in the power industry.

1.2 Background:

The construction of new substations and the expansion of existing facilities are commonplace projects in electric utilities. However, due to its complexity, very few utility employees are familiar with the complete process that allows these projects to be successfully completed. This chapter will attempt to highlight the major issues associated with these capital-intensive construction projects, and provide a basic understanding of the types of issues that must be addressed during this process. There are four major types of electric substations. The first type is the switchyard at a generating station. These facilities connect the generators to the utility grid and also provide off-site power to the plant. Generator switchyards tend to be large installations that are typically engineered and constructed by the power-plant designers and are subject to planning, finance, and construction efforts different from those of routine substation projects. Because of their special nature, the creation of power-plant switchyards will not be discussed here, but the expansion and modifications of these facilities generally follow the same processes as system stations. Another type of substation, typically known as the customer substation, functions as the main source of electric power supply for one particular business customer. The technical requirements and the business case for this type of facility depend highly on the customer’s requirements, more so than on utility needs; so this type of station will also not be the primary focus of this discussion. The third type of substation involves the transfer of bulk power across the network, and is referred to as a system station. Some of these stations provide only switching facilities (no power transformers) whereas others perform voltage conversion as well. These large stations typically serve as the end points for transmission lines originating from generating switchyards and provide the electrical power for circuits that feed transformer stations. They are integral to the long-term reliability and integrity of the electric system and enable large blocks of energy to be moved from the generators to the load centers. Since these system stations are strategic facilities and usually very expensive to construct and maintain, these substations will be one of the major focuses of this thesis. The fourth type of substation is the distribution station. These are the most common facilities in power electric systems and provide the distribution circuits that directly supply most electric customers. They are typically located close to the load centers, meaning that they are usually located in or near the neighborhoods that they supply, and are the stations most likely to be encountered by the customers.

Depending on the type of equipment used, the substations could be

. Outdoor type with air insulated equipment

. Indoor type with air insulated equipment

. Outdoor type with gas insulated equipment

. Indoor type with gas insulated equipment

. Mixed technology substations

. Mobile substations

1.3 Objectives:

Upon completion of this project, we will be able to do the following:

1. Describe the functions performed by various substations.
2. Identify the voltage classes that exist in substations.
3. Identify the following medium- and high-voltage equipment:

- Buses
- Disconnect switches
- Various circuit breakers
- Power transformers
- Instrument transformers
- Capacitors

• Reactors

4. Interpret a one-line substation diagram.

5. Describe the safe work practices used in substations.

1.4 Purpose and Significance:

The **purpose** of a substation is to 'step down' high voltage electricity from the transmission system to lower voltage electricity so it can be easily supplied to homes and businesses through our distribution lines. The substation is often considered to be one of the less exciting parts of an electricity network. However, that does not mean its contribution to driving efficiencies should be overlooked. In today's world of power shortages, increasing demand and the energy efficiency debate, how the electricity network is run right through from the power station to switch on the wall is becoming ever more important. Power companies are now realizing that the substation, while a lot less 'sexy' than carbon coal sequestration projects, for example, can play just a big a part in ensuring the power station meets all modern desires. For years the substation has been overlooked, as old technology and insufficient metering control still seemed to cause problems. But now power companies are starting to pay more attention to potential changes that will drive efficiencies to these once neglected parts of power distribution: isolating faults, updating switchgear, monitoring and controlling substations and using automation, all while maintaining a strong level of security and safety. Less common is the move by some power stations to allow collector substations to gather power from renewable resources like wind turbines, normally stepping up the voltage to connect to the grid. These will often use control circuits and meters, along with power factor correction to ensure this power source is used to its maximum benefit. But there are some more prominent trends in the industry that are making power substations an integral part of power supply and energy efficiency.

CHAPTER 2

SUBSTATION

2.1 Substation Equipment:

In every electrical substation, there are generally various indoor and outdoor switchgear equipment. Each equipment has a certain function requirement. The equipment is either Indoor or outdoor, depending upon the voltage rating and local conditions. Generally indoor equipment's is preferred for voltage up to 33 KV. For voltage 33 KV and above outdoor switchgear is generally preferred. However, in heavily polluted areas indoor equipment may be preferred even for higher voltages. SF6 gas insulated substation (GIS) are preferred in large cities for voltages above 33 KV. The outdoor equipment is installed under the open sky. The indoor switchgear is generally in form of metal enclosed factory assemble units called metal-clad switchgear. Circuit-breaker are the switching and current interrupting devices. Basically a circuit-breaker compromises a set of fixed and movable contacts. The contacts can be separated by means of an operation mechanism. The separation of current carrying contacts procedure an arc, the arc is extinguished by a suitable medium such as dielectric Oil, Air, Vacuum and SF6 gas. The circuit-breaker are necessary at every switching point in substation. Isolators are disconnecting switches which can be used for disconnecting a circuit under no condition. They are generally installed along with the circuit breaker. An isolator can be opened after the circuit breaker. After opening the isolator, the earthling switch can be closed or discharge the trapped electrical charges to the ground, the current transformers and potential transformer are used for transforming the current and voltage to a lower value for the purpose of measurement, protection and control. Lighting arresters used for divert the over-current to earth and protect the substation from thundering or any other faults.

2.2 Elements of substation:

Substations generally have switching, protection and control equipment, and transformers. In a large substation, circuit breakers are used to interrupt any short circuits or overload currents that may occur on the network. Smaller distribution stations may use reclosed circuit breakers or fuses for protection of distribution circuits. Substations themselves do not usually have generators, although a power plant may have a substation nearby. Other devices such as capacitors and voltage regulators may also be located at a substation. Substations may be on the surface in fenced enclosures, underground, or located in special-purpose buildings. High-rise buildings may have several indoor substations. Indoor substations are usually found in urban areas to reduce the noise from the transformers, for reasons of appearance, or to protect switchgear from extreme climate or pollution conditions. Where a substation has a metallic fence, it must be properly grounded to protect people from high voltages that may occur during a fault in the network. Earth faults at a substation can cause a ground potential rise. Currents flowing in the Earth's surface during a fault can cause metal objects to have a significantly different voltage than the ground under a person's feet; this touch potential presents a hazard of electrocution.

2.3 Type of Substations:

1) Transmission substation
2) Distribution substation
3) Collector substation

2.3.1 Transmission substation:

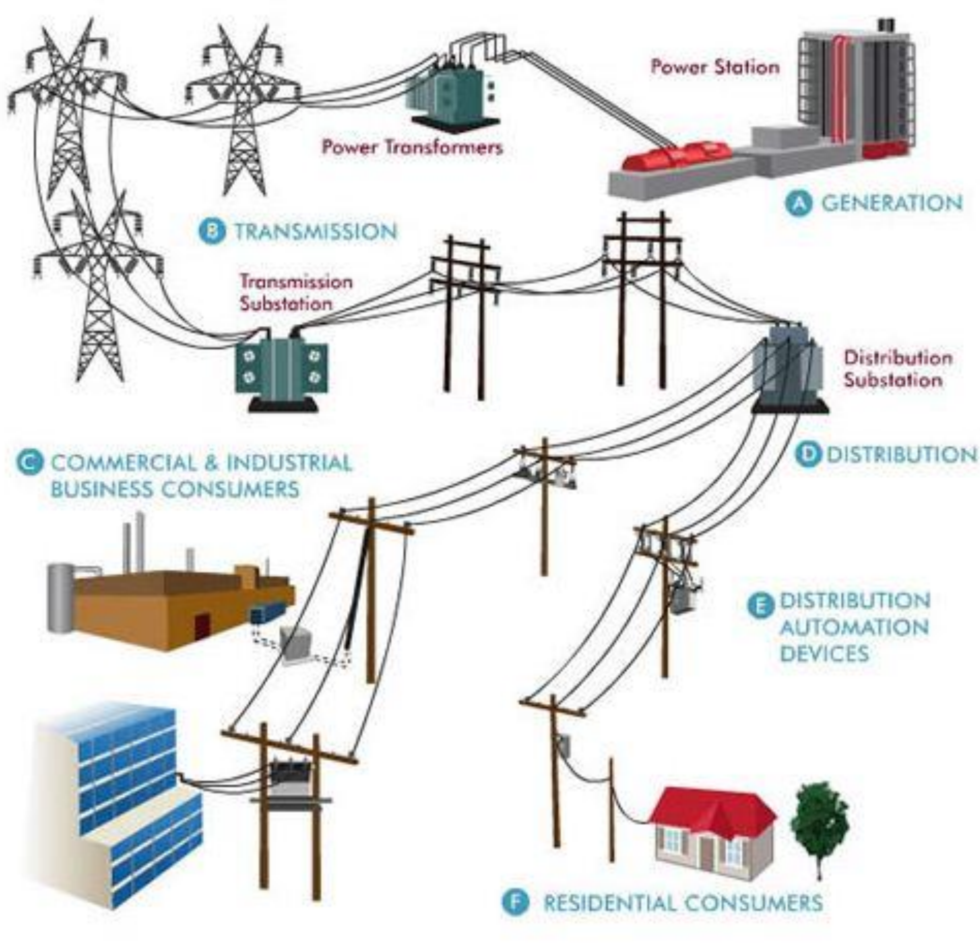
A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages, voltage control/power factor correction devices such as capacitors, reactors or static VAR compensators and equipment such as phase shifting transformers to control power flow between two adjacent power systems. Transmission substations can range from simple to complex. A small "switching station" may be little more than a bus plus some circuit breakers. The largest transmission substations can cover a large area (several acres/hectares) with multiple voltage levels, many circuit breakers and a large amount of protection and control equipment (voltage and current transformers, relays and SCADA systems). Modern substations may be implemented using international standards.

2.3.2 Distribution substation:

A distribution substation transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution. The input for a distribution substation is typically at least two transmission or sub transmission lines. Input voltage may be, for example, 115 kV, or whatever is common in the area. The output is a number of feeders. Distribution voltages are typically medium voltage, between 2.4 kV and 33 kV depending on the size of the area served and the practices of the local utility. The feeders run along streets overhead (or underground, in some cases) and power the distribution transformers at or near the customer premises. In addition to transforming voltage, distribution substations also isolate faults in either the transmission or distribution systems. Distribution substations are typically the points of voltage regulation, although on long distribution circuits (of several miles/kilometers), voltage regulation equipment may also be installed along the line. The downtown areas of large cities feature complicated distribution substations, with high-voltage switching, and switching and backup systems on the low-voltage side. More typical distribution substations have a switch, one transformer, and minimal facilities on the low-voltage side.

2.3.3 Collector substation:

In distributed generation projects such as a wind farm, a collector substation may be required. It resembles a distribution substation although power flow is in the opposite direction, from many wind turbines up into the transmission grid. Usually for economy of construction the collector system operates around 35 kV, and the collector substation steps up voltage to a transmission voltage for the grid. The collector substation can also provide power factor correction if it is needed, metering and control of the wind farm. In some special cases a collector substation can also contain an HVDC static inverter plant. Collector substations also exist where multiple thermal or hydroelectric power plants of comparable output power are in proximity. Examples for such substations are Brauweiler in Germany and Hradec in the Czech Republic, where power is collected from nearby lignite-fired power plants. If no transformers are required for increase of voltage to transmission level, the substation is a switching station.



2.4 Switchgear:

A switchgear or electrical switchgear is a generic term which includes all the switching devices associated with mainly power system protection. It also includes all devices associated with control, metering and regulating of electrical power system. Assembly of such devices in a logical manner forms a switchgear.

2.4.1 Types of Switchgear:

1. Simple open-air isolator switchgear.
2. Gas insulated switchgear (GIS).
3. Oil insulated switchgear.
4. Vacuum insulated switchgear.

2.4.2 Functions of Switchgear:

One of the basic functions of switchgear is protection, which is interruption of short-circuit and overload fault currents while maintaining service to unaffected circuits. Switchgear also provides isolation of circuits from power supplies. Switchgear is also used to enhance system availability by allowing more than one source to feed a load.

2.4.3 Safety of Switchgear:

To help ensure safe operation sequences of switchgear, trapped key interlocking provides predefined scenarios of operation. For example, if only one of two sources of supply are permitted to be connected at a given time, the interlock scheme may require that the first switch must be opened to release a key that will allow closing the second switch. Complex schemes are possible. Indoor switchgear can also be type tested for internal arc containment (e.g., IEC 62271-200). This test is important for user safety as modern switchgear is capable of switching large currents. Switchgear is often inspected using thermal imaging to assess the state of the system and predict failures before they occur. Other methods include partial discharge (PD) testing, using either fixed or portable testers, and acoustic emission testing using surface-mounted transducers (for oil equipment) or ultrasonic detectors used in outdoor switchyards. Temperature sensors fitted to cables to the switchgear can permanently monitor temperature build-up. SF6 equipment is invariably fitted with alarms and interlocks to warn of loss of pressure, and to prevent operation if the pressure falls too low. The increasing awareness of dangers associated with high fault levels has resulted in network operators specifying closed-door operations for earth switches and racking breakers. Many European power companies have banned operators from switch rooms while operating. Remote racking systems are available which allow an operator to rack switchgear from a remote location without the need to wear a protective arc flash hazard suit.

2.5 Fault and abnormal conditions: (In case of breakdown occurs)

- A fault in an electrical equipment is defined as a defect in its electrical circuit due to which the current is diverted from the intended path.
- Faults are generally caused by breaking of conductors or failure, accidents, excessive internal and external stresses, etc.
- During the fault, the current and voltage undergo continuous change and the phenomena observed are called ‘transient phenomena’.
- As a fault occurs in a power system, the current increases to several times the normal current because of the low fault impedance.
- The circuit breaker operates during the transient state.
- There are generally various indoor and outdoor switchgear.
- In an electric power system, switchgear is the combination of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment.
- Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream. In order to avoid damage every part of the power system is provided with a protective relaying system and an associated switching device.
- The protective relays are automatic devices which can sense the fault and send instruction to the associated circuit breaker to open, the circuit breaker opens and clear the fault.

2.6 Protective Relaying:

A protective relay is a device designed to trip a circuit breaker when a fault is detected. The first protective relays were electromagnetic devices, relying on coils operating on moving parts to provide detection of abnormal operating conditions such as over-current, over-voltage, reverse power flow, over- and under- frequency. Microprocessor-based digital protection relays now emulate the original devices, as well as providing types of protection and supervision impractical with electromechanical relays. In many cases a single microprocessor relay provides functions that would take two or more electromechanical devices. By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays. However, due to their very long life span, tens of thousands of these "silent sentinels" are still protecting transmission lines and electrical apparatus all over the world. An important transmission line or generator unit will have cubicles dedicated to protection, with many individual electromechanical devices, or one or two microprocessor relays. The theory and application of these protective devices is an important part of the education of an electrical engineer who specializes in power systems. The need to act quickly to protect circuits and equipment as well as the general public often requires protective relays to respond and trip a breaker within a few thousandths of a second. In these cases it is critical that the protective relays are properly maintained and regularly tested.

2.6.1 Operation principles:

Electromechanical protective relays operate by either magnetic attraction, or magnetic induction. Unlike switching type electromechanical relays with fixed and usually ill-defined operating voltage thresholds and operating times, protective relays have well-established, selectable and adjustable time/current (or other operating parameter) operating characteristics. Protection relays may use arrays of induction disks, shaded-pole magnets, operating and restraint coils, solenoid-type operators, telephone-relay contacts, and phase-shifting networks. Protective relays can also be classified by the type of measurement they make. A protective relay may respond to the magnitude of a quantity such as voltage or current. Induction types of relay can respond to the product of two quantities in two field coils, which could for example represent the power in a circuit. Although an electromechanical relay calculating the ratio of two quantities is not practical, the same effect can be obtained by a balance between two operating coils, which can be arranged to effectively give the same result. Several operating coils can be used to provide "bias" to the relay, allowing the sensitivity of response in one circuit to be controlled by another. Various combinations of "operate torque" and "restraint torque" can be produced in the relay. By use of a permanent magnet in the magnetic circuit, a relay can be made to respond to current in one direction differently from in another. Such polarized relays are used on direct-current circuits to detect, for example, reverse current into a generator. These relays can be made bi-stable, maintaining a contact closed with no coil current and requiring reverse current to reset. For AC circuits, the principle is extended with a polarizing winding connected to a reference voltage source. Light weight contacts make for sensitive relays that operate quickly, but small contacts can't carry or break heavy currents. Often the measuring relay will trigger auxiliary telephone-type armature relays. In a large installation of electromechanical relays, it would be difficult to determine which device originated the signal that tripped the circuit. This information is useful to operating personnel to determine the likely cause of the fault and to prevent its re-occurrence. Relays may be fitted with a "target" or "flag" unit, which is released when the relay operates, to display a distinctive colored signal when the relay has tripped.

2.7 Substation fire protection:

2.7.1 Substation Hazards:

The physical objects or conditions that create latent (undeveloped) demands for fire protection are called hazards. A probability that a fire will actually occur during a specified time interval, one of the key steps in the design of new substations and the assessment of existing substations is to identify conditions that are fire hazards. Once the fire hazards of a planned or existing substation are identified, then fire protection measures can be incorporated to eliminate or lessen the fire hazard. There are a wide range of types and causes of the fires that can occur in substation. The types of fires depend on the equipment and systems used in the stations. Fires involving dc valves, outdoor or indoor oil-insulated equipment, oil-insulated cable, hydrogen-cooled synchronous condensers, or PCB-insulated equipment are usually well documented, and these types of equipment are easily recognized as a fire hazard. There are a number of other substation-specific types of fires that are not as well documented. IEEE 979, “Guide for Substation Fire Protection;” Factory Mutual ‘Data Sheets’; NFPA 851, “Recommended Practice for Fire Protection for Electric Generating Plants and Current Converter Stations”; and CIGRE TF 14.01.04, “Report on Fire Aspects of HVDC Valves and Valve Halls” provide guidance on other types of fire hazards and fire protection Also, the Edison Electric Institute’s ‘Suggested Guidelines for Completing a Fire Hazards Analysis for Electric Utility Facilities (Existing or in Design)’ 1981, provides reference guidelines for the fire-hazard analysis process. Energized electrical cables with combustible insulation and jacketing can be a major hazard because they are a combination of fuel supply and ignition source. A cable failure can result in sufficient heat to ignite the cable insulation, which could continue to burn and produce high heat and large quantities of toxic smoke. Oil-insulated cables are an even greater hazard, since the oil increases the fuel load and spill potential. The hazard created by mineral-oil-insulated equipment such as transformers, reactors, and circuit breakers is that the oil is a significant fuel supply that can be ignited by an electrical failure within the equipment. Infiltration of water, failure of core insulation, exterior fault currents, and tap-changer failures are some of the causes of internal arcing within the mineral insulating oil that can result in fire. This arcing can produce breakdown gases such as acetylene and hydrogen. Depending on the type of failure and its severity, the gases can build up sufficient pressure to cause the external shell of the transformer tank or ceramic bushings to fail or rupture. Once the tank or bushing fails, there is a strong likelihood that a fire or explosion will occur. A possible explosion could cause blast damage. The resulting oil-spill fire could spread to form a large pool of fire, depending on the volume of oil, spill containment, slope of the surrounding area, and the type of the surrounding ground cover (i.e., gravel or soil). Thermal radiation and convective heating from the oil spill fire can also damage surrounding structures and structures above the fire area. Substations are exposed to the common industrial fire hazards such as the use and storage of flammable compressed gases, hot work, storage and handling of flammable liquid, refuse storage, presence of heating equipment, and storage of dangerous goods. The local fire codes or

NFPA codes can provide assistance in recognizing common fire hazards.

2.7.2 Switchyard Hazards:

Some of the specific components encountered in substation switchyards that are fire hazards are:

- Oil-insulated transformers and breakers
- Oil-insulated potheads
- Hydrogen-cooled synchronous condensers
- Gasoline storage or dispensing facilities
- Vegetation
- Combustible service building
- Storage of pesticides or dangerous goods
- Storage warehouses
- Standby diesel-generator buildings
- The failure of some of the critical components such as transformers and breakers can directly result in losses of revenue or assets.
- Other switchyard components could create a fire exposure hazard to critical operational components (i.e., combustible service buildings located close to bus support structures or transmission lines).

2.7.3 Control and Relay-Building Hazards:

A control or relay building can include the following potential hazards:

- Exposed combustible construction, Combustible finishes.
- Emergency generators, shops, offices, and other noncritical facilities in the control buildings.
- Batteries and charger systems.
- Switchyard cable openings that have not been fire-stopped.
- Adjacent oil-insulated transformers and breakers.

- High-voltage equipment.
- Dry transformers.
- Workshops.
- A fire in any of these components could damage or destroy critical control or protection equipment.
- Damages could result in a long outage to customers as well as significant revenue losses.

2.7.4 Indoor Station Hazards:

Fires in indoor stations are caused by some of the same substation-related hazards as switchyards and control rooms. The impacts of any fires involving oil-insulated equipment, oil-insulated cable, and HVDC. (high-voltage dc) valves in an indoor station can result in major fires, with accompanying large asset losses and service disruptions. The basic problems with major fires in indoor stations is that the building will contain the blast pressure, heat, and smoke, and which can result in:

- Blast damage to the building structure (structural failure)
- Thermal damage to the building structure (structural failure)
- Smoke damage to other equipment (corrosion damage)

2.7.5 Fire protection measures:

The measures to mitigate or lessen fire hazards are normally called “fire protection measures”.

The National Fire Protection Association NFPA (U.S. organization charged with creating and maintaining minimum standards and requirements for fire prevention and suppression activities, training, and equipment, as well as other life-safety codes and standards) standards and local building fire codes set the standards for application and design of fire protection.

The types of measures can be broken down as follows:

Life safety

Passive fire protection

Active fire protection

Manual fire protection

2.7.6 Life safety:

Life safety measures generally include the fire protection measures required under the building, fire, or life safety codes. The main objective of these codes is to ensure that:

The occupants are able to leave the station without being subject to hazardous or untenable conditions (thermal exposure, carbon monoxide, carbon dioxide, soot, and other gases). Firefighters are safely able to Effect a rescue and prevent the spread of fire. Building collapse does not endanger people (including firefighters) who are likely to be in or near the building. To meet these objectives, fire safety systems provide the following performance elements:

Detect a fire at its earliest stage.

- Signal the building occupants and/or the fire department of a fire.
- Provide adequate illumination to an exit (emergency lights).
- Provide illuminated exit signs.
- Provide fire-separated exits within reasonable travel distances from all areas of a building. These exits shall terminate at the exterior of the building.
- Provide fire separations between building floors and high-hazard rooms to prevent the spread of fire.
- Provide passive protection to structural components to prevent their failure due to fire exposure.

2.7.7 Passive fire protection:

Passive measures are static measures that are designed to control the spread of fire and withstand the effects of fire. These measures are the most frequently used methods of protecting life and property in buildings from a fire. This protection confines a fire to a limited area or ensures that the structure remains sound for a designated period of fire exposure. Its popularity is based on the reliability of this type of protection, since it does not require human intervention or equipment operation. Common types of passive protection include fire-stopping, fire separations, equipment spacing, use of noncombustible construction materials, use of low flame-spread/smoke-development rated materials, substation grading, provision of crushed rock around oil-filled equipment, etc. The degree of passive protection for a building structure would be based on the occupancy of the area and the required structural integrity. The structural integrity of a building is critical in order to preserve life and property. The premature structural failure of a building before the occupants can evacuate or the fire department can suppress the fire is a major concern. Building and electrical codes will provide some of the criteria for structural fire resistance. IEEE 979 includes recommendations on these measures relative to substation design.

2.7.8 Active fire protection:

Active fire protection measures are automatic fire protection measures that warn occupants of the existence of fire and extinguish or control the fire. These measures are designed to automatically extinguish or control a fire at an earliest stage without risking life or sacrificing property. The benefits of these systems have been universally identified and accepted by building and insurance authorities. Insurance companies have found significant reduction in losses when automatic suppression systems have been installed. An automatic suppression system consists of an extinguishing agent supply, control valves, a delivery system, and fire detection and control equipment. The agent supply may be virtually unlimited (such as with a city water supply for a sprinkler system) or of limited quantity (such as with a water tank supply for a sprinkler system). Typical examples of agent control valves are deluge valves, sprinkler valves, and halo control valves. The agent delivery systems are a configuration of piping, nozzles, or generators that apply the agent in a suitable form and quantity to the hazard area (e.g., sprinkler piping and heads). Fire detection and control equipment can be either mechanical or electrical in operation. These systems can incorporate a fire detection means such as sprinkler heads, or they can use a separate fire detection system as part of their operation. These active fire protection systems detect a fire condition, signal its occurrence, and activate the delivery system. Active systems include wet, dry, and pre-action sprinklers, deluge systems, foam systems, and gaseous systems. Detailed descriptions of each of these systems, code references, and recommendations on application are covered in IEEE 979.

2.7.9 Manual fire protection:

Manual measures include items such as the various types of fire extinguishers, fire hydrants, hose stations, etc. requiring active participation by staff or the fire department to detect, control, and extinguish a fire. Portable fire equipment is provided for extinguishing incipient-stage fires by building occupants. Since the majority of fires start small, it is an advantage to extinguish them during their incipient stage to ensure that potential losses are minimized.

2.7.10 Fire Protection Selection:

Fire protection measures can be sub divided into life safety and investment categories.

2.7.11 Life safety measures:

Life-safety measures are considered to be mandatory by fire codes, building codes, or safety codes. As such, the codes mandate specific types of substation fire protection, with very little flexibility in their selection.

2.8 The functions of Substation:

1. To change voltage from one level to another.
2. To regulate voltage to compensate for system voltage changes.
3. To switch transmission and distribution circuits into and out of the grid system.
4. To measure electric power quantity flowing in the circuits.

5. To connect communication signals to the circuits.
6. To eliminate lightning and other electrical surges from the system.
7. To connect electric generation plants to the system.
8. To make interconnections between the electric systems of more than one utility.

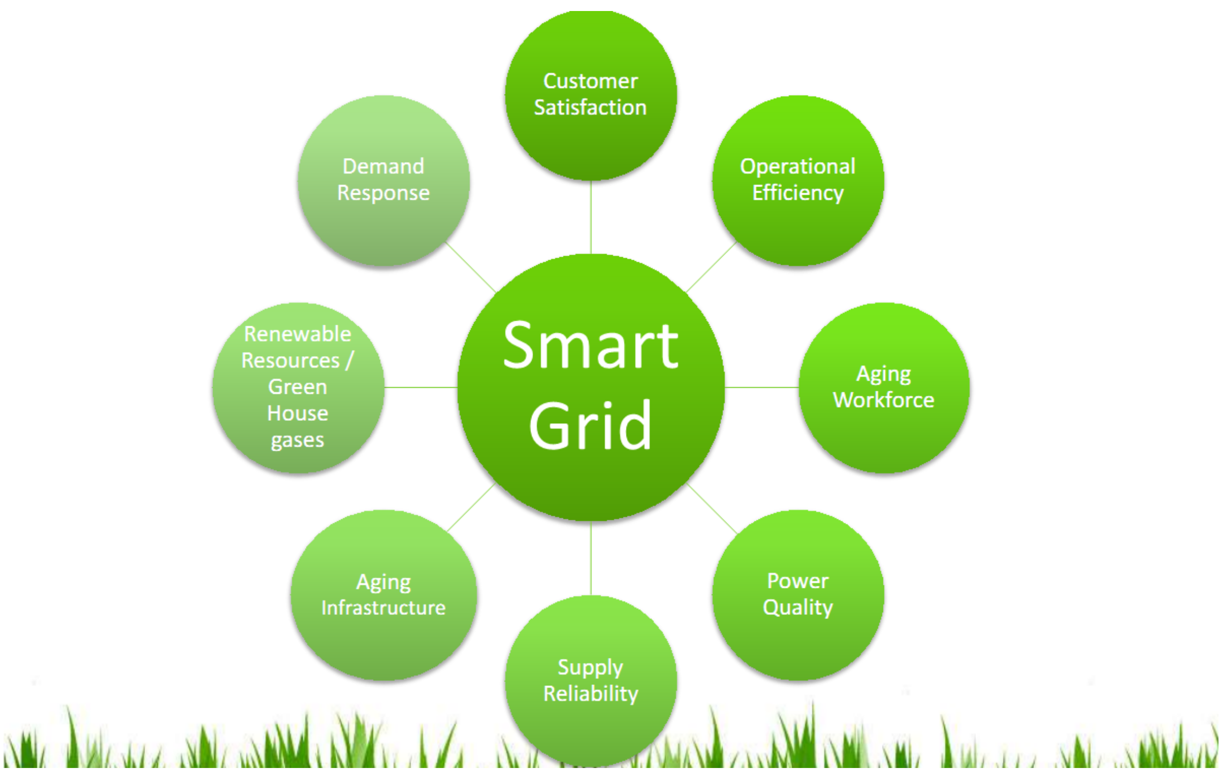
CHAPTER 3

TOWARDS A SMARTER GRID

3.1 Smart Grid:

It’s an optimized grid with more extensive monitoring and communication systems, two-way flow of power and information, electricity storage facilities and a larger portion of distributed and renewable generation.

In other words, “It’s an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers, and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.” (EU Report, 27)



3.2 Smart Grid Control Center Applications:

The smart electric transmission and distribution grid functionalities are centrally performed at the control center by several control centers or electric utility applications that include SCADA, DMS, EMS, Automated Meter Reading (AMR), Network Integration System (NIS), and Geographic Information System (GIS).

3.2.1 Concept of Operations:

The typical roles of persons involved with SCADA based monitoring and control operations are SCADA Manager, SCADA Information security officer, SCADA system administrator, SCADA operator, SCADA engineer/developer, field maintenance worker, and external user (via remote access). The external users are contractors, consultants, SCADA vendors (maintenance and emergency access), and Managed Security Solution Provider (MSSP). The latter usually performs the SCADA cyber security monitoring which is outsourced to them by the utility. In case of not outsourcing this task, cyber security monitoring is done by the Security Incident Manager. The SCADA manager is responsible for ensuring that corporate policies are followed. The information security officer is responsible for ensuring that the security policy is followed and performs audits. The administrator is responsible for system activities like maintenance, expandability, and performance. The control center operator is responsible for performing operational functions like electric substation monitoring and control. The maintenance workers perform the field work assigned to them by the control center operator, the scheduler, or the dispatcher.

3.2.2 System Activities and Performance:

In addition to the electric network management system activities, the SCADA also serves as a source of important operating data required for effective management of the utility's business. The SCADA system performance is based on its availability, maintenance, response time, security and expandability. The high availability of the SCADA system and the continuous operation assurance are attained by introducing reliability as well as redundancy of the hardware and software. In case of damage to the primary master station, for example, due to events like natural disasters, the back-up/emergency, master station takes over the system operation. The system is in normal state when the load and operating constraints are satisfied. In such occasions the main system performances are met. It switches to the emergency state when the operation conditions are not completely satisfied. In the emergency state the response time might be slow and the system performance is allowed to degrade but the basic functionalities (e.g., alarm and status change operations) are retained. The system's access level is restricted for different group of workers (Access Authorization). For example, the operators are generally provided with complete access to display and control functions for specific Areas of Responsibility (AoR), while the maintenance staff may only have access to display functions. The system maintenance involves hardware/software repair using diagnostic tools (debugging, corrections), updates (patch management, antivirus protection), tests and preventive maintenance. It can be expanded with new points, functions and equipment depending on the functional and standardization needs. The limitations (e.g., physical space) and downtime are considered important factors during expansion.

3.2.3 Operational Functions:

The main operational functions of the real-time SCADA system includes: data acquisition and processing, basic network monitoring, device and sequence control, network and device tagging, and alarms and events management.

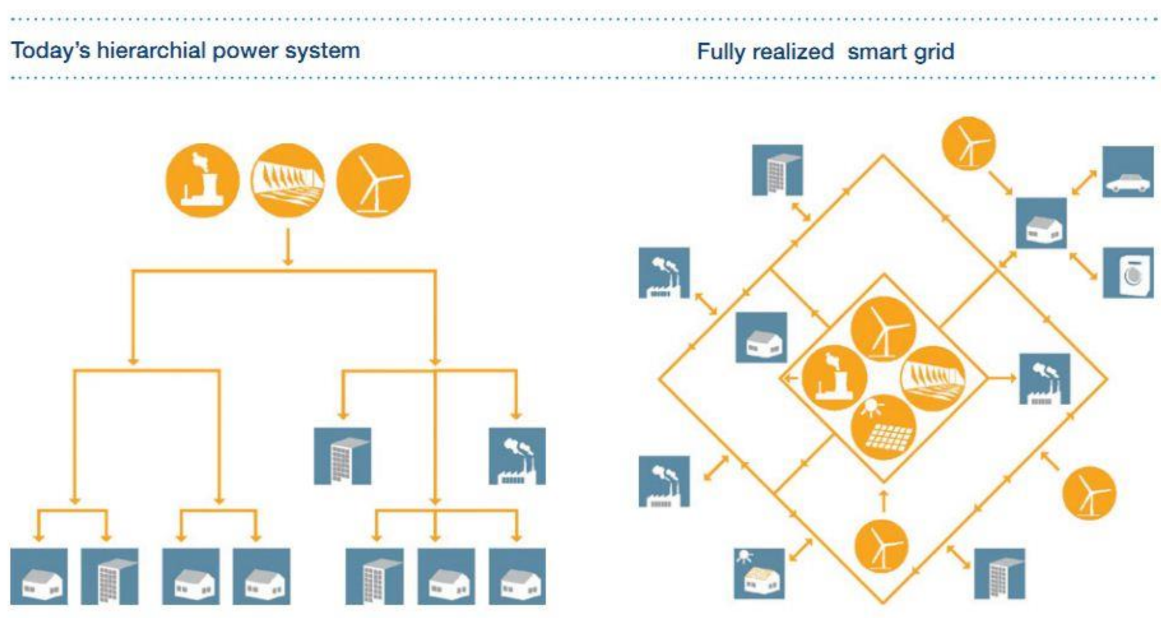
Particularly, the DMS includes applications (tools) that perform the following functions: network topology monitoring, demand response and load management, load and generation forecasting, switching procedures, fault management, outage management, trouble call management, work management, crew management, customer information, and asset management. Moreover, the Energy Management System (EMS) performs remote and local control and supervision of transmission systems.

3.3 Current Power System vs. Smart Grid:

The table below provides a concise summary of some of the differences as they appear in various parts of current grid and smart grid:

	Current Grid	**Smart Grid**
Generation	Centralized	Centralized and distributed
Reliability	Prone to failures and cascading outages essentially reactive	Automated, pro-active protection & prevents outages
Metering	Electromechanical	Digital "Smart Meters"
Communic-ation System	None or one-way typically not real-time	Two-way & real-time
Restoration after disturbance	Manual	Self-healing

3.3.1 Comparison in regards of structure:

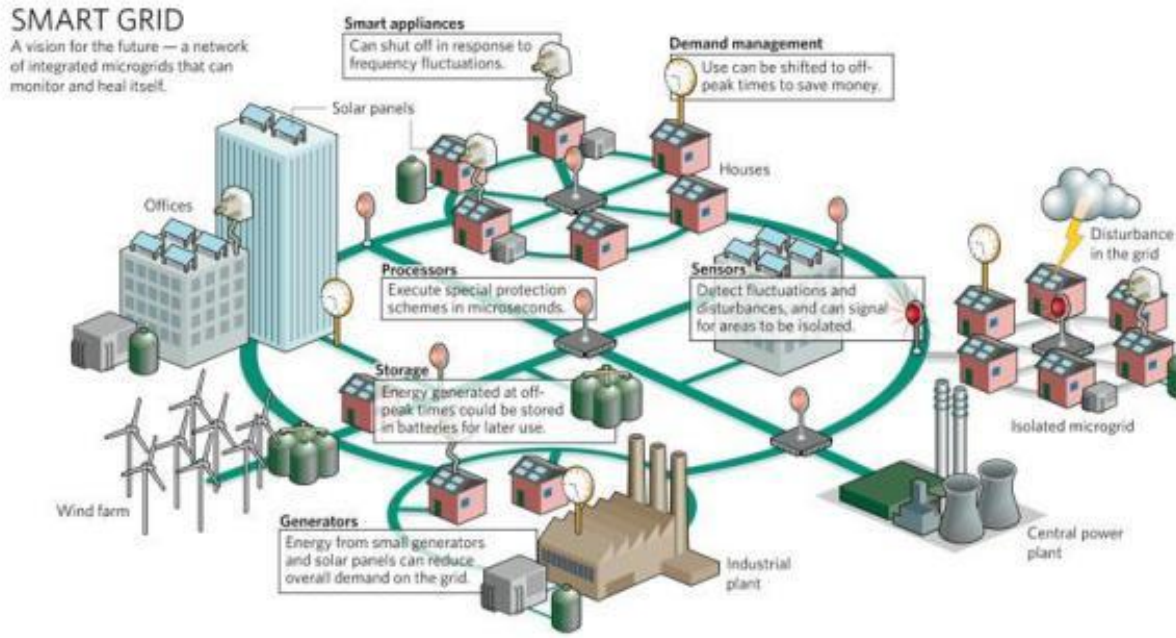


3.3.2 Problems with the Current Grid*:*

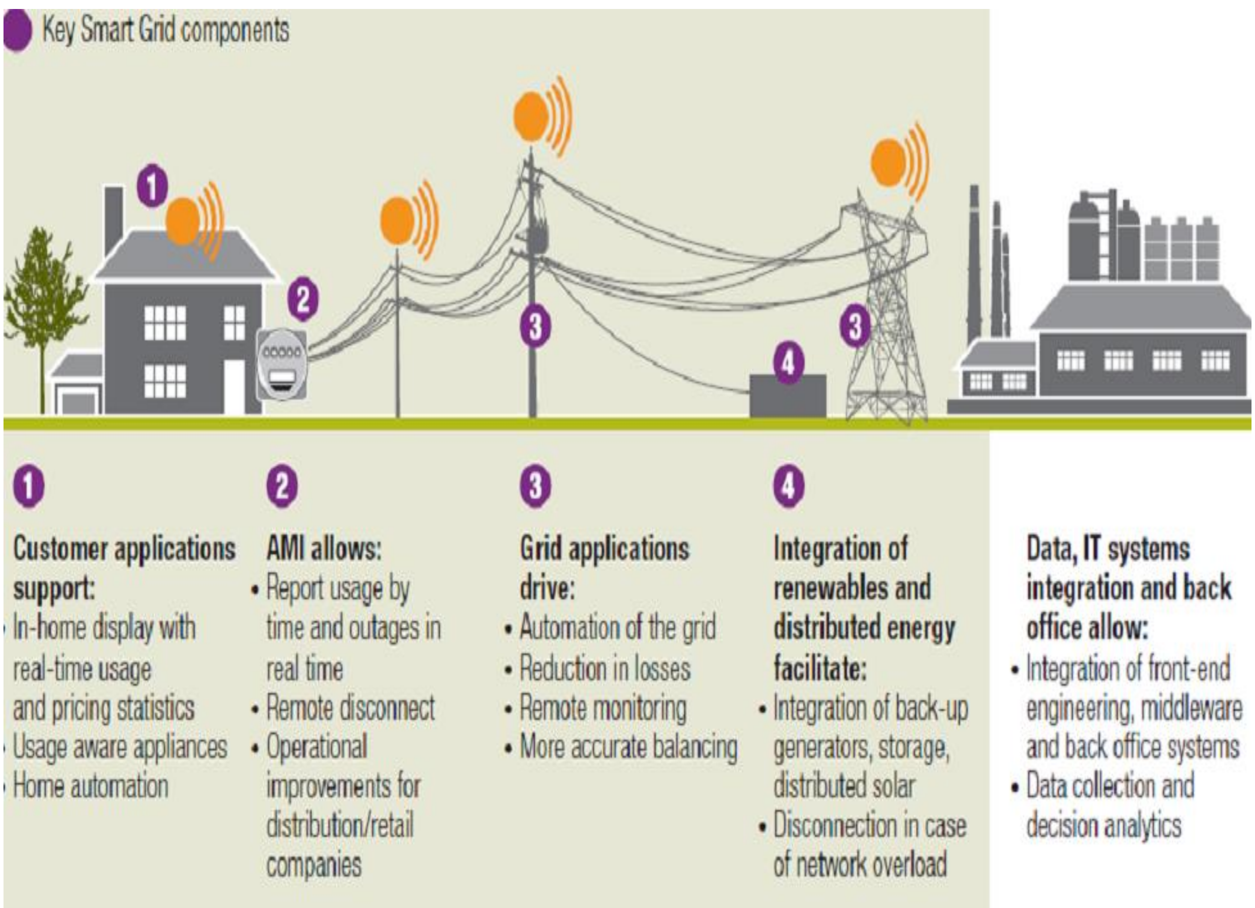
Presently, the grid is facing a multitude of challenges that can be outlined in four categories. First there are infrastructural problems due to the fact that the system is outdated and unfit to deal with increasing demand. As a result, network congestions are occurring much more frequently because it does not have the ability to react to such issues in a timely fashion. Ultimately such imbalances can lead to blackouts which are extremely costly for utilities especially since they spread rapidly due to the lack of communication between the grid and its control centers. A second flaw is the need for more information and transparency for customers to make optimal decisions relative to the market, so as to reduce their consumption during the most expensive peak hours. Finally, a third problem is the inflexibility of the current grid, which can't support the development of renewable energies or other forms of technologies that would make it more sustainable. In particular, the fact that renewable sources such as wind and solar are intermittent poses a significant problem for a grid that does not disseminate information to control centers rapidly. All of these problems are addressed by the smart grid through improved communications technology, with numerous benefits for both the supply and demand sides of the electricity market. (Li et al., 2010)

3.4 The Conceptual Model:

Instead of completely replacing the current grid, the transition to a smart grid is simply a significant revamping of it with technologies such as meters, sensors and synchrophasors. When added to the existing infrastructure, these inventions will provide massive amounts of data about consumption, voltage, the health of infrastructure and many other aspects of the electricity supply to the control centers. More importantly, it is the rate of communication that is revolutionary: the synchrophasors report data up to 30 times a second, as opposed to the rate of once every two to four seconds with present day instruments. With improved communications, the smart grid resolves many of the problems listed above, and provides benefits to consumers and suppliers. The analysis of this website uses an economic supply and demand framework to understand the incentive structure for the smart grid, looking at the benefits to producers and consumers. (Economist, 2010)



3.4.1 Key Smart Grid components figure:



CHAPTER 4

IUT SUBSTATION (11 KV/400 V)

4.1.1 Introduction:

- IUT substation receives power at 11 KV (from the Board bazar substation) and convers the receiving power to 400 V.
- There are two generators in IUT substation.
  1. Bangla-cat generator
  2. Cross-world generator
- It is responsible for supplying the required power through various feeders at one voltage level.
- Effective policies must be enacted to ensure that management of generated power is made efficient and free pressures from various quarters that affect pricing, uses and distribution that debilitate the industry today.

4.1.2 Transformer:

- Incoming: **11 KV**
- Outgoing: **400 V**
- Frequency: **50 Hz**
- Rate capacity: **2000 KVA**
- Rate Voltage: **11 KV**
- Rate Current: **2782 A**
- For H.T: **105 A**
- For L.T: **3000 A**

4.2 Types of Transformers:

Transformers are constructed so that their characteristics match the application for which they are intended. The differences in construction may involve the size of the windings or the relationship between the primary and secondary windings. Transformer types are also designated by the function the transformer serves in a circuit, such as an isolation transformer.

4.2.1 Distribution Transformer

Distribution transformers are generally used in electrical power distribution and transmission systems. This class of transformer has the highest power, or volt-ampere ratings, and the highest continuous voltage rating. The power rating is normally determined by the type of cooling methods the transformer may use. Some commonly-used methods of cooling are by using oil or some other heat-conducting material. Ampere rating is increased in a distribution transformer by increasing the size of the primary and secondary windings; voltage ratings are increased by increasing the voltage rating of the insulation used in making the transformer.

4.2.2 Power Transformer:

Power transformers are used in electronic circuits and come in many different types and applications. Electronics or power transformers are sometimes considered to be those with ratings of 300 volt-amperes and below. These transformers normally provide power to the power supply of an electronic device, such as in power amplifiers in audio receivers.

4.2.3 Control Transformer:

Control transformers are generally used in electronic circuits that require constant voltage or constant current with a low power or volt-amp rating. Various filtering devices, such as capacitors, are used to minimize the variations in the output. This results in a more constant voltage or current.

4.2.4 Auto Transformer:

The auto transformer is generally used in low power applications where a variable voltage is required. The auto transformer is a special type of power transformer. It consists of only one winding. By tapping or connecting at certain points along the winding, different voltages can be obtained.

4.2.5 Isolation Transformer:

Isolation transformers are normally low power transformers used to isolate noise from or to ground electronic circuits. Since a transformer cannot pass DC voltage from primary to secondary, any DC voltage (such as noise) cannot be passed, and the transformer acts to isolate this noise.

4.2.6 Instrument Potential Transformer:

The instrument potential transformer (PT) steps down voltage of a circuit to a low value that can be effectively and safely used for operation of instruments such as ammeters, voltmeters, watt meters, and relays used for various protective purposes.

4.2.7 Instrument Current Transformer:

The instrument current transformer (CT) steps down the current of a circuit to a lower value and is used in the same types of equipment as a potential transformer. This is done by constructing the secondary coil consisting of many turns of wire, around the primary coil, which contains only a few turns of wire. In this manner, measurements of high values of current can be obtained.

A current transformer should always be short-circuited when not connected to an external load. Because the magnetic circuit of a current transformer is designed for low magnetizing current when under load, this large increase in magnetizing current will build up a large flux in the magnetic circuit and cause the transformer to act as a step-up transformer, inducing an excessively high voltage in the secondary when under no load.

4.2.8 Transformer Types Summary:

Distribution transformers are generally used in power distribution and transmission systems.

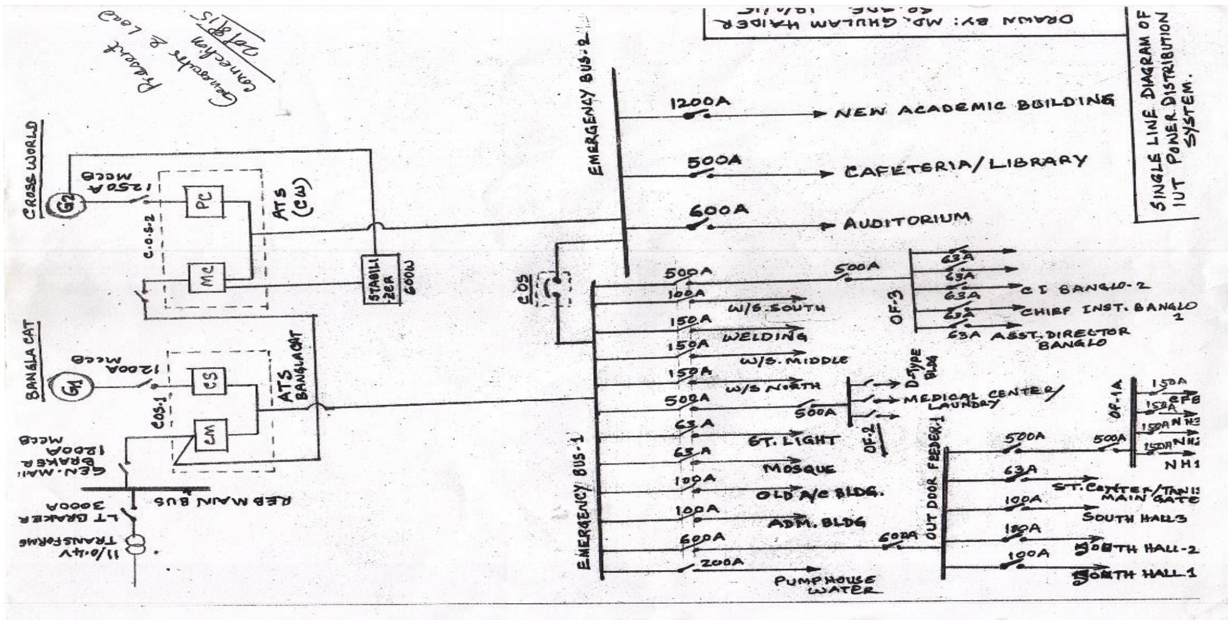
Power transformers are used in electronic circuits and come in many different types and applications. Control transformers are generally used in circuits that require constant voltage or constant current with a low power or volt-amp rating. Auto transformers are generally used in low power applications where a variable voltage is required. Isolation transformers are normally low power transformers used to isolate noise from or to ground electronic circuits. Instrument potential and instrument current transformers are used for operation of instruments such as ammeters, voltmeters, watt meters, and relays used for various protective purposes.

4.2.9 Circuit Breaker in IUT Substation:

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow.

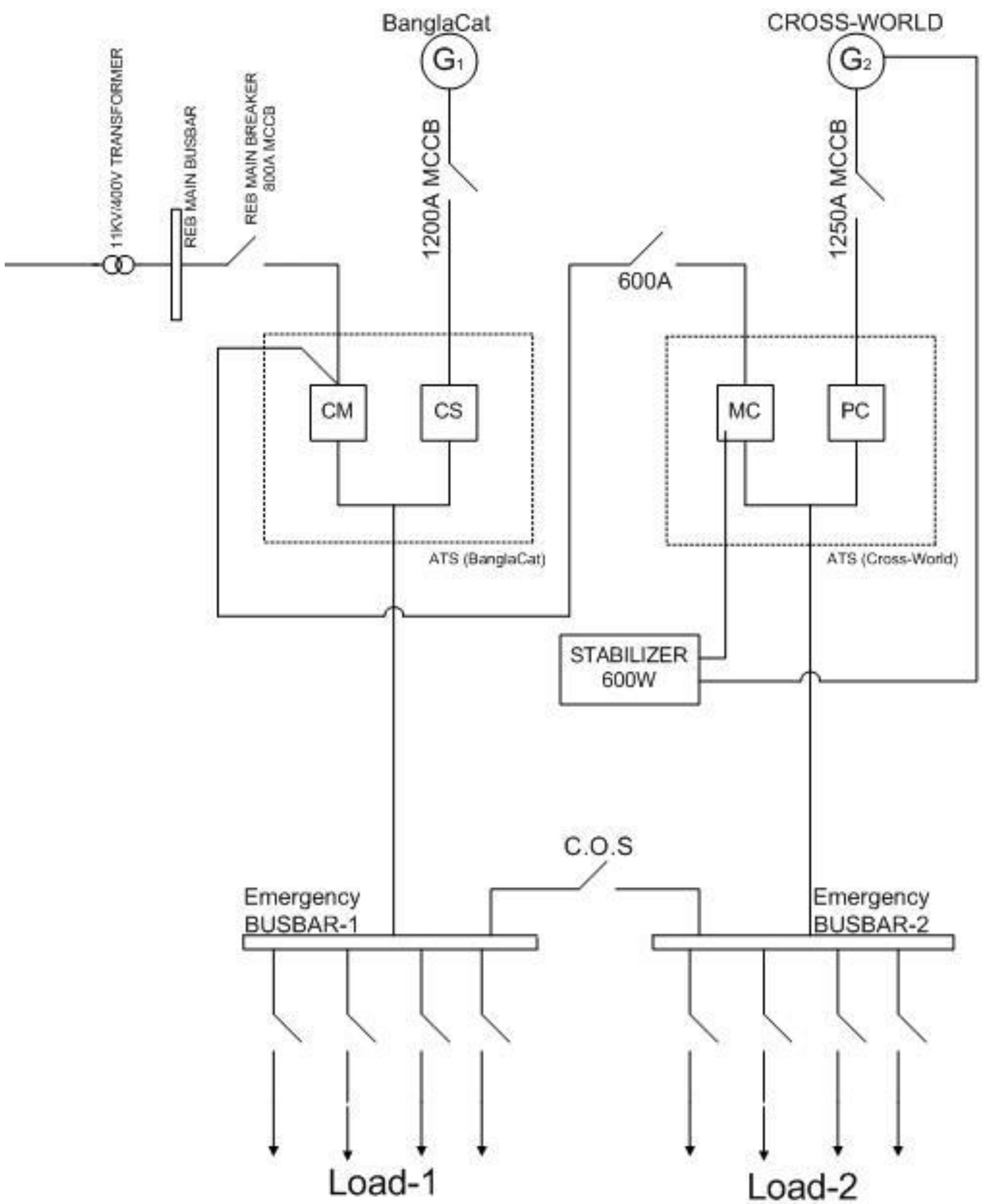
Image: One of the Circuit Breakers in the IUT Substation

4.3 Single-line Diagram with the Generators and load connection in IUT Substation:



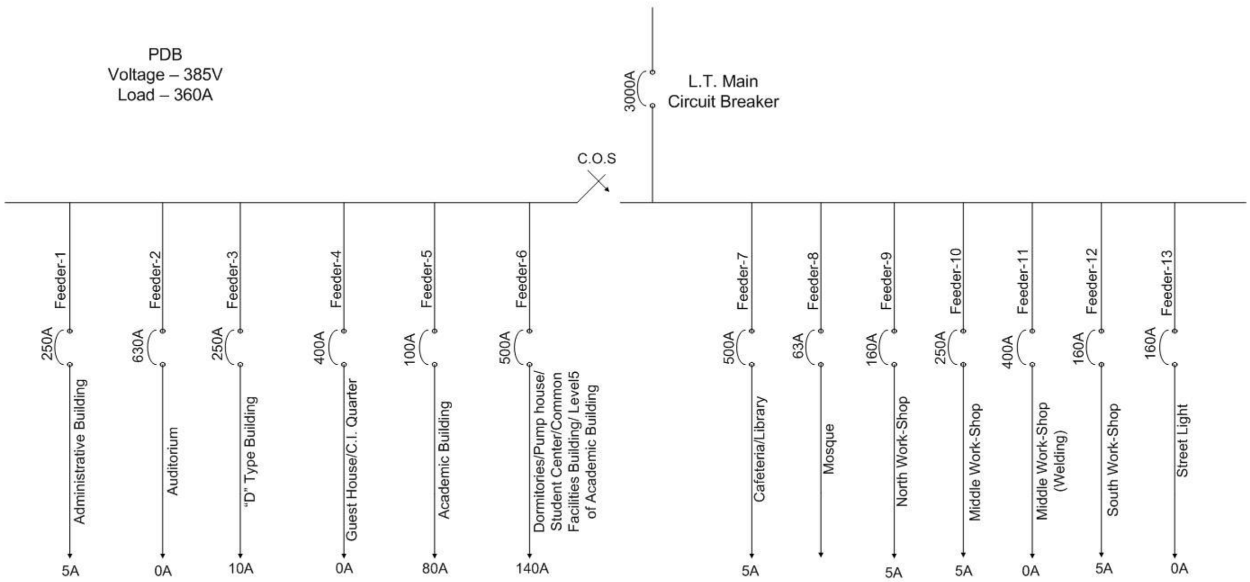
4.4 **IUT Substation diagram:** (Made using Microsoft Visio)

Single-line diagram of IUT Substation 11/0.4 KV



4.5 Feeders at IUT Substation: (Made using Microsoft Visio)

Existing Loading in Different Feeders at IUT Substation



4.5 Load Tests of Emergency Generators:

A. Operation of REB & G1 when G2 OFF:

1) REB Power OFF(MCCB 800A OPEN)
2) MCCB of Emergency Generator No.2 OFF(1200A MCCB)
3) All Distribution Loads OFF.
4) Manual Change-Over-Switch ON.
5) MCCB of Emergency Generator No.1 ON(1250A MCCB)
6) ATS of Emergency Generator No.2 AUTO.
7) Load sequentially ON.
8) All loads connected.

B. Operation of REB & G2 when G1 OFF:

1) REB Power OFF(MCCB 800A OPEN)
2) MCCB of Emergency Generator No.1 OFF(1200A MCCB)
3) All Distribution Loads OFF.
4) Manual Change-Over-Switch ON.
5) MCCB of Emergency Generator No.2 ON(1250A MCCB)
6) ATS of Emergency Generator No.2 MANUAL.
7) Load sequentially ON.
8) All loads connected.

CHAPTER 5

SHORT CIRCUIT

5.1 Short circuit:

A short circuit is an abnormal connection between two nodes of an electric circuit intended to be at different voltages. These results in an excessive electric current limited only by the venin equivalent resistance of the rest of the network and potentially causes circuit damage, overheating, fire or explosion. Although usually the result of a fault, there are cases where short circuits are caused intentionally, for example, for the purpose of voltage-sensing crowbar circuit protectors.

5.2 Examples:

A common type of short circuit occurs when the positive and negative terminals of a battery are connected with a low-resistance conductor, like a wire. With low resistance in the connection, a high current exists, causing the cell to deliver a large amount of energy in a short time. A large current through a battery can cause the rapid buildup of heat, potentially resulting in an explosion or the release of hydrogen gas and electrolyte (an acid or a base), which can burn tissue, cause blindness or even death. Overloaded wires can also overheat, sometimes causing damage to the wire's insulation, or a fire. High current conditions may also occur with electric motor loads under stalled conditions, such as when the impeller of an electrically driven pump is jammed by debris; this is not a short, though it may have some similar effects. In electrical devices unintentional short circuits are usually caused when a wire's insulation breaks down, or when another conducting material is introduced, allowing charge to flow along a different path than the one intended.

5.3 Damages:

A short circuit fault current can, within milliseconds, be thousands of times larger than the normal operating current of the system. Damage from short circuits can be reduced or prevented by employing fuses, circuit breakers, or other overload protection, which disconnect the power in reaction to excessive current. Overload protection must be chosen according to the current rating of the circuit. Circuits for large home appliances require protective devices set or rated for higher currents than lighting circuits. Wire gauges specified in building and electrical codes are chosen to ensure safe operation in conjunction with the overload protection. An overcurrent protection device must be rated to safely interrupt the maximum prospective short circuit current. In an improper installation, the overcurrent from a short circuit may cause ohmic heating of the circuit parts with poor conductivity (faulty joints in wiring, faulty contacts in power sockets, or even the site of the short circuit itself). Such overheating is a common cause of fires. An electric arc, if it forms during the short circuit, produces high amount of heat and can cause ignition of combustible substances as well. In industrial and utility distribution systems, dynamic forces generated by high short circuit currents cause conductors to spread apart. Bus bars, cables, and apparatus can be damaged by the forces generated in a short circuit.

CONCLUSION

Electrical power system is a vital sector for every country. To maintain its quality, every country must give emphasis on this field and most of the country already giving. To ensure the ultimate quality every sector within the system should maintain a minimum quality. The cumulative effort from every sector can only make the system well qualified. Some of the countries are fighting with the shortage of generation; they can't give proper attention in other sectors like transmission, distribution etc. To ensure maximum use of the generated power it is must to ensure minimum loss in the transmission and distribution. Transmission and distribution sectors are affected by several problems. The identification of these problems should have the priority. In Bangladesh most of the electrical power distribution industries are facing some common problems. Their systems are not studied in a recommended time interval or even not at all. So they fail to supply quality power.

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