THE

TRAINING REPORT

ON

ELECTRICAL POWER GENERATION AND DISTRIBUTION SYSTEM

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ABSTRACT

This report provides a comprehensive analysis of the electrical power generation and distribution system at Oil And Natural Gas Corporation Limited’s Corporate office Deendayal Urja Bhawan, Vasant Kunj, New Delhi. ONGC is a leading oil and gas exploration and production company in India, and the efficient and reliable supply of electrical power is critical to its operations.

The report begins by outlining the importance of electrical power in the oil and gas industry, emphasizing its significance in supporting the various processes and equipment involved. It highlights the need for a robust power generation and distribution system to ensure uninterrupted operations and minimize downtime.

The next section focuses on the power generation infrastructure. It explores the different sources of electrical power, including grid supply, Generators supply and renewable energy sources. The report examines the installed capacity, efficiency, and reliability of these power generation units, as well as their compliance with environmental regulations.

The report then delves into the distribution system. It discusses the network layout, including Electric panels, transformers, Air circuit Breakers, and distribution lines, and evaluates their adequacy in meeting the power demand of various facilities and equipment. Special attention is given to the system's resilience, redundancy, and protection mechanisms to ensure the safety of personnel and equipment.

In conclusion, the report provides an overview of the electrical power generation and distribution system, highlighting its strengths, challenges, and potential areas for improvement. The findings aim to assist ONGC in enhancing the reliability, efficiency, and sustainability of its power infrastructure, thus ensuring uninterrupted operations and maximizing productivity.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF ONGC's DEENDAYAL URJA BHAWAN

Deendayal Urja Bhawan, situated in Vasant Kunj, New Delhi , India is the flagship office complex of the Oil and Natural Gas Corporation (ONGC), India's largest oil and gas exploration and production company. The building stands as a testament to ONGC's vision of sustainability, energy efficiency, and architectural excellence.

Deendayal Urja Bhawan, the corporate office of Oil and Natural Gas Corporation (ONGC), was inaugurated by Prime Minister Narendra Modi on 25th September 2017. It is named after Pandit Deendayal Upadhyaya, a prominent leader of the Bharatiya Jana Sangh (predecessor of the Bharatiya Janata Party) and a proponent of integral humanism. The inauguration of Deendayal Urja Bhawan marked a significant milestone for ONGC, providing the company with a state-of-the-art corporate office facility.

(Fig 1.1 Inauguration of Deendayal Urja Bhawan by Prime Minister Narendra Modi)

Prime Minister Shri Narendra Modi dedicated ONGC's iconic Corporate Office, Deendayal Urja Bhavan during the nationwide launch of PM Saubhgya Yojna – Government's flagship initiative to provide electricity connection to the last mile.
The Prime Minister also unveiled the statue of Pandit Deendayal Upadhyaya at the ONGC premises in the presence of Shri Dharmendra Pradhan, Minister (P&NG), Shri R K Singh Minister of State (IC) (PN&RE), K D Tripathi, Secretary (MoPNG) and Shri Dinesh K Sarraf, CMD, ONGC.

The Deendayal Urja Bhawan has been awarded the highest LEED(Leadership in Energy and Environmental Design) Platinum Rating by U.S. Green Building Council. The ONGC building is a symbol of harmony between Energy & Ecology. It is an environmentally sustainable building that has been designed, constructed and operated to minimize the total environmental impact by reducing energy consumption, water conservation and recycling waste. The project has been registered as a CDM (Clean Development Mechanism) Project with the United Nations Framework Convention on Climate Change (UNFCCC).

1.1.1 Architecture and Design

Deendayal Urja Bhawan is an architectural marvel that combines modern design elements with a strong focus on environmental sustainability. The building's design incorporates green building concepts, utilizing natural lighting, ventilation, and energy-efficient systems to minimize its environmental impact.

Key Features

- **Energy Efficiency:** Deendayal Urja Bhawan incorporates several energy-saving measures, such as solar panels, energy-efficient lighting fixtures, and intelligent building management systems. These features contribute to reduced energy consumption and a lower carbon footprint.

- **Sustainable Landscaping:** The surrounding landscape of Deendayal Urja Bhawan is designed to be environmentally friendly. It includes indigenous plants, rainwater harvesting systems, and water-efficient irrigation methods, promoting water conservation and biodiversity.

- **Amenities and Facilities:** The building houses state-of-the-art amenities and facilities to cater to the needs of ONGC employees and visitors. These include spacious conference rooms, auditoriums, a cafeteria, recreational spaces, and ample parking facilities.

- **Accessibility:** Deendayal Urja Bhawan is designed to be accessible to all, with features such as ramps, elevators, and barrier-free pathways. It adheres to universal design principles, ensuring a comfortable and inclusive environment for everyone.

- **Green Building Certification:** The complex has achieved prestigious green building certifications, such as Leadership in Energy and Environmental Design (LEED), which recognize its commitment to sustainable practices and energy efficiency.

(Fig 1.2 ONGC's Deendayal Urja Bhawan)

1.2 FUNCTIONS OF DEENDAYAL URJA BHAWAN

Deendayal Urja Bhawan is designed to serve as the administrative and operational hub for the company. It houses various departments and divisions responsible for managing ONGC's oil and gas exploration, production, refining, and marketing activities. The office serves as a central point for decision-making, coordination, and strategic planning related to ONGC's operations in India and abroad.

Key functions of Deendayal Urja Bhawan include:

- **Corporate Management:** The office accommodates the senior management team, including the Chairman and Board of Directors, who oversee the overall functioning of ONGC and formulate business strategies.

- **Administrative Operations:** It provides administrative support for day-to-day operations, including human resources, finance, legal affairs, and public relations.

- **Technical and Exploration Activities:** The office houses experts and professionals responsible for conducting geological surveys, seismic studies, drilling operations, and other technical activities related to oil and gas exploration.

- **Project Management:** Deendayal Urja Bhawan facilitates project planning, execution, and monitoring for various ongoing and upcoming projects undertaken by ONGC, such as oil and gas field development, infrastructure construction, and research initiatives.

- **Coordination and Collaboration:** The office serves as a platform for coordination and collaboration with government agencies, international partners, stakeholders, and other oil and gas companies in India and abroad.

- **Knowledge and Information Management:** It houses libraries, research facilities, and data centers to manage crucial information, research findings, and technical knowledge related to the oil and gas sector.

1.3 IMPORTANCE OF CONTINUOUS ELECTRIC POWER

For the proper functioning of all the tasks at this office; an uninterrupted and continuous electric power supply is required. Below points are verifying the importance of proper electric power supply:

- **Uninterrupted Operations:** ONGC's corporate office serves as the nerve center for the company's activities, including critical decision-making, coordination, and communication. A continuous power supply ensures uninterrupted functioning of essential services like computer systems, servers, communication networks, and other infrastructure, enabling smooth operations and efficient workflow.

- **Data Security and Management:** ONGC deals with vast amounts of data, including confidential and sensitive information related to oil and gas exploration, production, financials, and strategic planning. A power outage can lead to data loss, corruption, or disruption of critical systems. Continuous power supply with appropriate backup mechanisms ensures the security and integrity of valuable data.

- **Communication and Connectivity:** ONGC's corporate office requires uninterrupted communication and connectivity with various internal and external stakeholders, including government agencies, partner companies, and field operations. A reliable power supply ensures that communication lines, such as telephones, video conferencing systems, and internet connectivity, remain operational, facilitating effective collaboration and decision-making.

- **Emergency Preparedness:** In the event of emergencies or unforeseen situations, a continuous power supply becomes even more critical. It enables the corporate office to function as a command center for crisis management, ensuring that essential services like emergency response systems, security systems, and disaster recovery plans remain active and accessible.

- **Employee Productivity and Comfort:** A continuous power supply creates a conducive work environment for employees, avoiding disruptions and downtime due to power outages. It helps maintain comfortable working conditions, including air conditioning, lighting, and other necessary amenities, which directly impact employee productivity and morale.

- **Business Reputation:** ONGC is a leading public sector enterprise and a key player in the oil and gas industry. A reliable and continuous power supply at its corporate office reflects professionalism, reliability, and stability. It enhances the company's reputation among stakeholders, investors, and the public, demonstrating a commitment to operational excellence.

1.4 SOURCES OF ELECTRICAL POWER

After knowing the importance of reliable and quality electric power supply, now let us see how this continuous power supply is being delivered to the whole building.

The Power Plant of Deendayal Urja Bhawan is handling this task.To avoid disturbances and blackouts in electric power supply offered by Regular Electricity utilities, an uninterrupted power supply is being generated in the Power plant of the building. Power plant engineers are maintaining the plant for its proper functioning.
To operate all the electric appliances in the building, there are three major sources of electric power:

1. Gas Generators(GG) - 2x1400 KVA
2. BSES(Bombay Suburban Electric Supply)-11 KV
3. Diesel Generators(DG) - 2x2500 KVA

The primary power source is Gas Generator ; BSES is an emergency power supply i.e. when GG is not able to provide the power then BSES will provide. DGs (Diesel Generators) will provide the electric power when neither GGs nor BSES is able to provide electric power.

We will discuss these sources of electric power in later chapters.

1.5 POWER DISTRIBUTION SYSTEM

After generation of electric power it has to be distributed to all the loads at DUB (Deendayal Urja Bhawan). There is a detailed LD (Line Diagram) of the Power System Layout. LD will help in visualizing all the interconnections of loads and sources.
Main power supply is distributed in different electric panels.Then, the supply from these panels is going to the loads of the building. We will see in detail about the power distribution in the next chapters.

CHAPTER 2
ELECTRIC POWER SOURCES

As we discussed earlier there are three main sources of electric power namely Gas Generators, BSES and Diesel Generators. Although there is another source i.e. Solar power plant which is capable of producing a total of 300 KW power.
In this chapter we are going to study about all these sources of electricity in great detail. We will see the working and construction of the Generators and the Transformers(Which are using the BSES power supply), and the layout of the solar power plant installed on the top roof of the building.

2.1 Gas Generators

Gas generators are the primary sources of electric power in power plant. There are *two* Gas Generators available at the plant and each generator is having a power generation capacity of *1400 KVA*.These are manufactured by CUMMINS.
As the name suggests Gas is being used as fuel in these generators. This gas is supplied by IGL(Indraprastha Gas Limited). The gas used is PNG(Piped Natural Gas). This is mainly Methane gas which is supplied through mild steel and polyethylene pipes.This is a colorless, non-toxic, non-corrosive and odorless gas.

Now an electric generator consists of two major components i.e. Engine and Alternator.Engine is doing the job to rotate the shaft of alternator to produce electricity.

2.1.1 Gas Engine

The engine is playing an important role in the working of the generator.Engine will rotate the rotor of alternator.There are many types of engines available in the market but here Gas engine is used in power plant.
This engine is a *four stroke engine*.Let us discuss the parts of a four stroke engine:

Piston
In an engine, a piston transfers the expanding forces of gas to the mechanical rotation of the crankshaft through a connecting rod.

Crankshaft
A crankshaft is a part that converts the reciprocating motion to rotational motion.

Connecting Rod
It transfers motion from a piston to a crankshaft, acting as a lever arm

Flywheel
The flywheel is a rotating mechanical device that is used to store energy.

Inlet and Outlet Valves
It allows us to enter fresh air with fuel & to exit the spent air-fuel mixture from the cylinder.

Spark Plug
It is a device that delivers electric current to the combustion chamber, which ignites the air-fuel mixture leading to the abrupt gas expansion.

(Fig 2.1 Gas Generator Installed at Power Plant of DUB of capacity 2500 KVA)

- **Four Stroke Engine Cycle**

The one cycle of a four stroke engine completes after completion of 4 stages during the working of a four stroke engine.The four stages are explained below:

1. **Suction/Intake Stroke**

Intake stroke occurs when the air-fuel mixture is introduced to the combustion chamber. In this stroke, the piston moves from TDC (Top Dead Center – the farthest position of the piston to the crankshaft) to BDC (Bottom Dead Center – the nearest position of the piston to the crankshaft.) The movement of the piston towards the BDC creates a low-pressure area in the cylinder. The inlet valve remains open in this stroke.The intake valve then closes, and the air-fuel mixture is sealed in the cylinder.

2. **Compression Stroke**

In compression stroke, the trapped air-fuel mixture is compressed inside the cylinder. During the stroke, the piston moves from BDC to TDC, compressing the air-fuel mixture. The momentum of the flywheel helps the piston move forward. Compressing the air-fuel mixture allows more energy to be released when the charge is ignited. The charge is the volume of compressed air-fuel mixture trapped inside the combustion chamber ready for ignition. The inlet and outlet valves are closed in this stroke to ensure that the cylinder is sealed, resulting in compression.

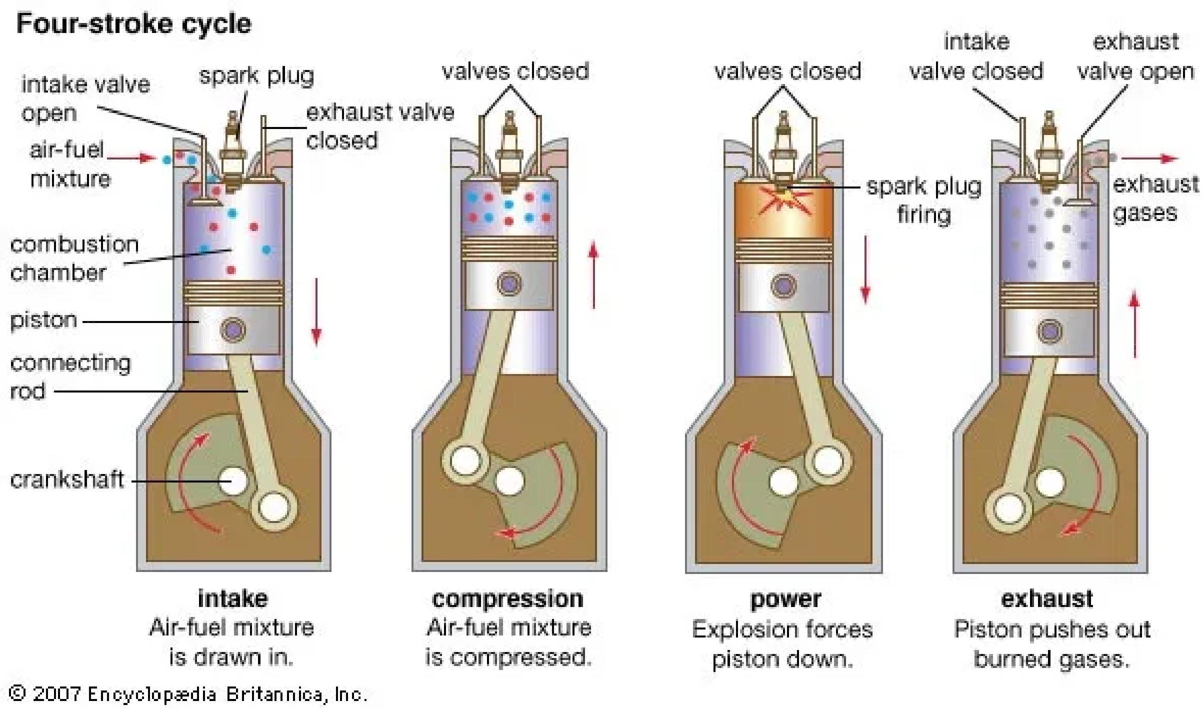
3. **Power/Combustion Stroke**

The second rotation of the crankshaft begins when it completes a full rotation during the compression stroke.In this stroke,both intake and exhaust valve remains closed.The power stroke occurs when the compressed air-fuel mixture is ignited with the help of a spark plug. Ignition or Combustion is the rapid, oxidizing chemical reaction in which a fuel chemically combines with oxygen in the atmosphere and releases energy in the form of heat. The hot expanding gasses force the piston head away from the cylinder head.

4. **Exhaust Stroke**

As the piston reaches BDC during the power stroke, combustion is complete, and the cylinder is filled with exhaust gasses. The exhaust valves open during this stroke, and the inertia of the flywheel and other moving parts push the piston back to TDC, forcing the exhaust gasses through the open exhaust valve. At the end of the exhaust stroke, the piston is at TDC, and one operating cycle has been completed.

One complete cycle completes when two rotations of the crank-shaft are completed.Therefore, it takes two complete cycles of crank-shaft to complete one engine cycle.



(Fig 2.2 Four Stroke Engine Cycle)

- **Turbo Charger**

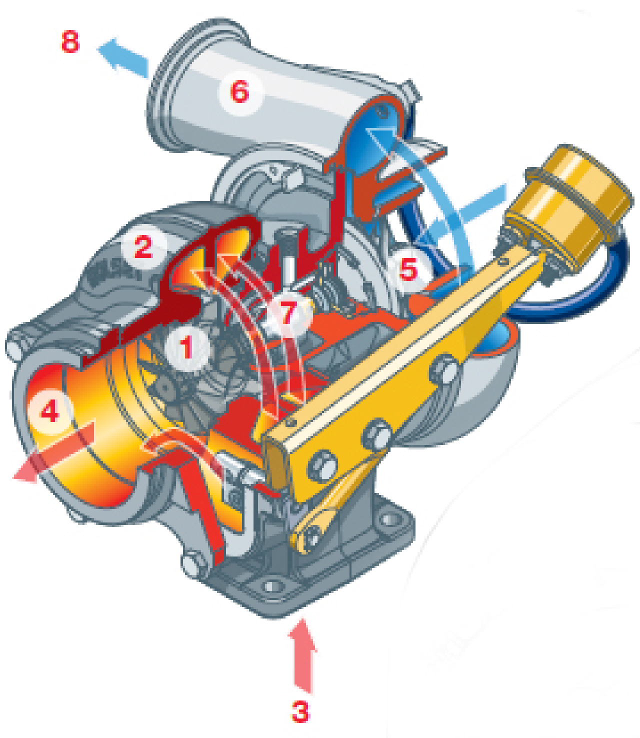
A significant difference between a turbocharged engine and a traditional naturally aspirated engine is the air entering a diesel engine is compressed before the fuel is injected. This is where the turbocharger is critical to the power output and efficiency of the diesel engine.

It is the job of the turbocharger to compress more air flowing into the engine's cylinder. When air is compressed the oxygen molecules are packed closer together. *This increase in air means that more fuel can be added for the same size naturally aspirated engine*. This then generates increased mechanical power and overall efficiency improvement of the combustion process. Therefore, the engine size can be reduced for a turbocharged engine leading to better packaging, weight saving benefits and overall improved fuel economy.

- **Working of Turbocharger**

A turbocharger is made up of two main sections: the turbine and the compressor. The turbine consists of the turbine wheel (1) and the turbine housing (2). It is the job of the turbine housing to guide the exhaust gas (Exhaust gas from the engine) (3) into the turbine wheel. The energy from the exhaust gas turns the turbine wheel, and the gas then exits the turbine housing through an exhaust outlet area (4).

The compressor also consists of two parts: the compressor wheel (5) and the compressor housing (6). The compressor's mode of action is opposite that of the turbine. The compressor wheel is attached to the turbine by a forged steel shaft (7), and as the turbine turns the compressor wheel, the high-velocity spinning draws in air and compresses it. The compressor housing then converts the high-velocity, low-pressure air stream into a high-pressure, low-velocity air stream through a process called diffusion. The compressed air (8) is pushed into the engine, allowing the engine to burn more fuel to produce more power.



1.The turbine wheel
2.The turbine housing
3.Exhaust gas
4.Exhaust outlet area
5.The compressor wheel
6.The compressor housing
7.Forged steel shaft
8.Compressed air

(Fig 2.3 Construction of Turbocharger)

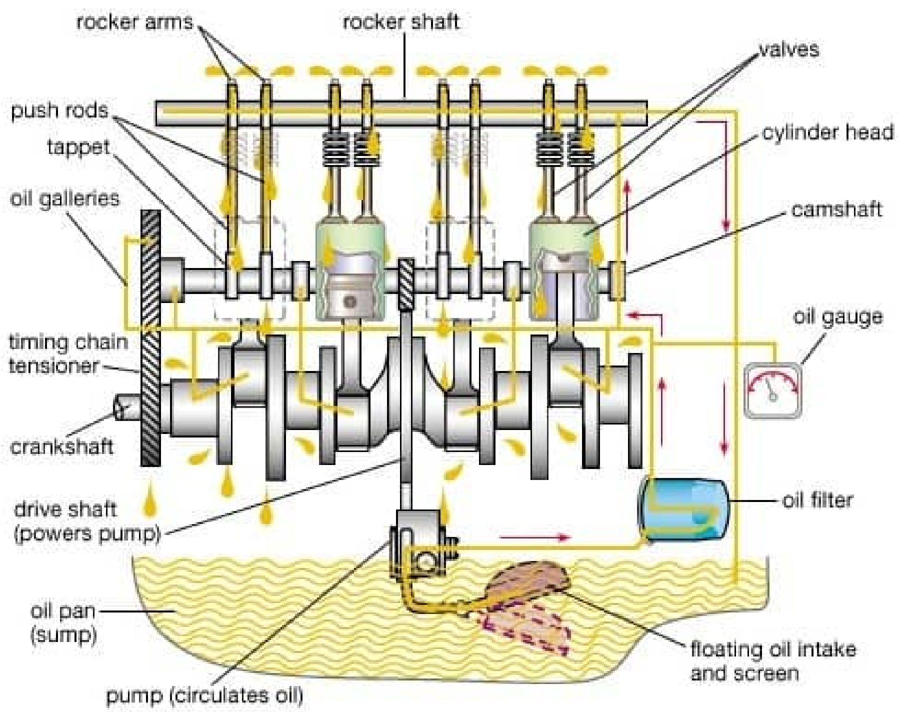
- **Engine Lubrication System**

Engine lubrication is the process in which robing metal parts are separated by the flow of lubricating substance between them.Lubricants are available in liquid, solid or gas, but the liquid is the most common form of lubrication used in engines.

Functions of Engine Lubricating System

- The primary purpose of engine lubrication is to minimize wear by securely closing the clearance between moving parts such as shafts, bearings, etc. Lubrication also avoids the moving parts not to come in direct contact with each other.

- Oil serves as a cleaning agent in an engine as it moves the dirt particle to the oil pan. Smaller particles are filtered out by the oil filters while larger ones are retained in the oil pan.
- Another purpose of engine lubrication is that it serves as a cooling system. Lubricating oil cools the moving parts of the engine and transfers the heat to the Coolant (this coolant will transfer its own heat in heat exchangers).



(Fig 2.4 General Lubrication System Of Engine)

Major Parts of Engine Lubricating System

- **Oil pan/sump:** An oil sump is a reservoir in the shape of a bowl that stores the engine oil. With the sump, the oil circulates within the engine. The part is located below the crankcase which is beneath the engine, making the oil to be easily removed through the bottom.Bad roads often cause damage to the oil pan. This is why the sump is made with hard material and features a stone guard at it underneath. This sump guard withstands any hits from the uneven ground or bad road.

- **Oil Pump:** The oil pump is a component that helps to push the lubricating oil to all the moving parts in the engine. It’s located at the bottom of the crankcase, close to the oil sump. It supplies oil to the oil filter before sending it further.Oil pumps can eventually stop working, which may lead to damages to the engine. It can be caused by small particles inside the lubricating oil, which choke the oil pump and galleries.To avoid this problem, changing engine oil and filter is very necessary within some period of time.

- **Oil filter:** The oil filter helps to keep small particles, separating them from the oil so that clean oil can flow to the engine parts. The oil pump allows the oil flow through the oil filter to the galleries before reaching the engine parts.

- **Oil Galleries:** The function of oil galleries in the engine lubrication system is to circulate oil quickly to reach all moving parts in automobiles. So, the performance of an oil gallery determines how fast your engine parts receive oil.The oil galleries are a series of interconnected passages that transfers oil to parts that require it.These passages are big and small holes drilled inside the cylinder block. The bigger holes are connected to the smaller ones until it reaches the cylinder head and overhead camshafts.

- **Oil cooler:** An oil cooler is a device that works as a radiator as it cools down the hot oil. Coolers transfer the heat from the engine oil to the engine coolant using its fins. Oil coolers stabilize the temperature of the engine oil, keep its viscosity under control, prevent the engine from overheating, minimize wear and tear as well as retaining the lubricant quality.

With this we have completed details about the Engine of the generator.Now further we will discuss one very important system known as *Heat Exchanger(HE).*The HE is used to reduce the temperature of engine components.

Starting The Engine

To produce the electricity,the first task is to start the engine.Now starting the engine is a very important task.Such a heavy engine we cannot start by hand, isn't it.To start the engine there is *DC starter motor* installed.This is a heavy duty motor.This motor works on 24V DC.Once this motor gets command to start it simply rotates the shaft of the engine and the 4-stroke engine cycle starts hence engine starts.This is a DC motor and DC supply is required to start the motor.

To get DC supply we are having 8 batteries arrangement.2-2 batteries are connected in series and 4 sets are made,then these are connected in parallel configuration.Each battery is rated as 12V,180AH.Thus we get 24V supply.

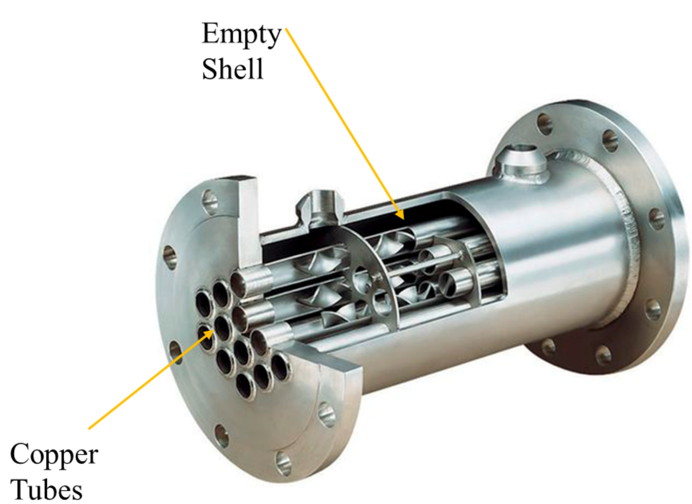
For GGs engine there is only one starter motor installed but for DGs engine,3 starter motors are installed.One more thing is these batteries will discharge after some time of usage.So to charge it we are having battery charger.This battery charger is basically converting Ac supply to DC.

2.1.1.1 Heat Exchanger

A heat exchanger is a device that allows the heat to be transferred from one fluid or medium to another.As we know there is a great amount of heat generated during the operation of the engine.In this section we will study how exactly heat exchanger works.The heat exchanger used here is of *shell and tube* type.

(Fig 2.5 Heat Exchanger)

The above figure shows how shell and tube type HE looks like.There are copper tubes aligned parallel to the axis of the HE. There are gaps between consecutive copper tubes.That space is called Shell as we can see in the figure below cross sectional view of HE;



(Fig 2.6 Shell and Tube construction of Heat Exchanger)

Before going into details of the working of Heat Exchanger let us first study about *Coolant.*

- **Coolant:** Coolant is a fluid playing an important role in the cooling process.The coolant is going inside the engine and reaching every critical part of the engine i.e. hot parts and carrying their heat out of the engine.The HE is actually having the job of cooling down this coolant which is carrying the heat from the engine.

Working of Heat Exchanger

Here's a general overview of how coolant flows and exchanges heat within an engine:

- **Coolant Pump:** The coolant pump, also known as the water pump, is typically driven by the engine's crankshaft or auxiliary belt. It circulates the coolant throughout the cooling system. The pump draws coolant from the radiator or coolant reservoir and pushes it into the engine.

- **Engine Block:** The coolant enters the engine block through an inlet port and flows through passages that are strategically located around the cylinders and other areas prone to heat generation. These passages allow the coolant to come into contact with the hottest parts of the engine, such as the cylinder walls, combustion chambers, and exhaust ports.

- **Cylinder Head:** The coolant also flows into the cylinder head through dedicated passages. The cylinder head houses the intake and exhaust valves, as well as the combustion chambers. The coolant circulates around these areas to absorb heat.

- **Heat Transfer:** As the coolant flows through the engine block and cylinder head, it absorbs heat from the hot engine components, including the cylinder walls, pistons, valves, and cylinder head itself. This heat transfer occurs through conduction, where the hot metal surfaces transfer their heat to the coolant.

Before going ahead, let me clear one thing; there are two HEs installed for each GG,called HTA(High Temperature Ambient) and LTA(Low Temperature Ambient) respectively.Both are doing the same job but the difference is that the coolant which enters into HTA heat exchanger is having a higher temperature than that of LTA heat exchanger’s coolant.This arrangement is just for better cooling.

Now after absorbing heat from the engine, coolant enters into the shell of the HE.And after being cool it comes out of HE and again goes into the engine to cool it and this cycle of coolant is going on.*But the question arises how this coolant gets cooled inside HE*.And the answer to this question is discussed below:

As we know hot coolant enters into the shell of the heat exchanger.And to absorb the heat from this coolant, cold water(called Raw Water) enters into the copper tubes and here the heat exchange takes place.Copper pipes are good heat conductors.Cold water is flowing inside these tubes and coolant is flowing in shell.So, copper tubes are submerged in hot coolant.Thus heat from coolant goes into the water flowing through copper tubes and cold coolant comes out of HE and on the other hand, hot water comes out of the HE and goes for cooling.

Now cooling of this water is again an interesting process.The mechanism which cools down this water is called *Cooling Tower*.

Cooling Tower

Cooling Tower is the mechanism which is cooling the water coming from HE(this water is carrying heat of the coolant).After absorbing heat from coolant, Raw water goes to the cooling tower.Here it exchanges its heat with environment air.Let us see working of cooling tower in detail:

Working of Cooling Towers

Here's a step-by-step explanation of how cooling towers work:

- **Hot water enters the cooling tower:** Hot water, which has absorbed heat from an industrial process or a power plant's condenser, enters the cooling tower through inlet pipes.

- **Distribution system:** The hot water is evenly distributed over the top of the cooling tower through a distribution system. This system can consist of nozzles, sprayers, or a series of pipes with perforations.

- **Water flow over the fill**: The hot water then flows over a large surface area called the fill. The fill is typically made of PVC (polyvinyl chloride) or other materials and is designed to maximize the contact between the hot water and the air.

- **Airflow:** Simultaneously, a fan called CT Fan (cooling tower fan) creates an upward draft of air through the cooling tower. The airflow can be natural (caused by wind) or mechanical (driven by fans). The airflow is essential for the cooling process.

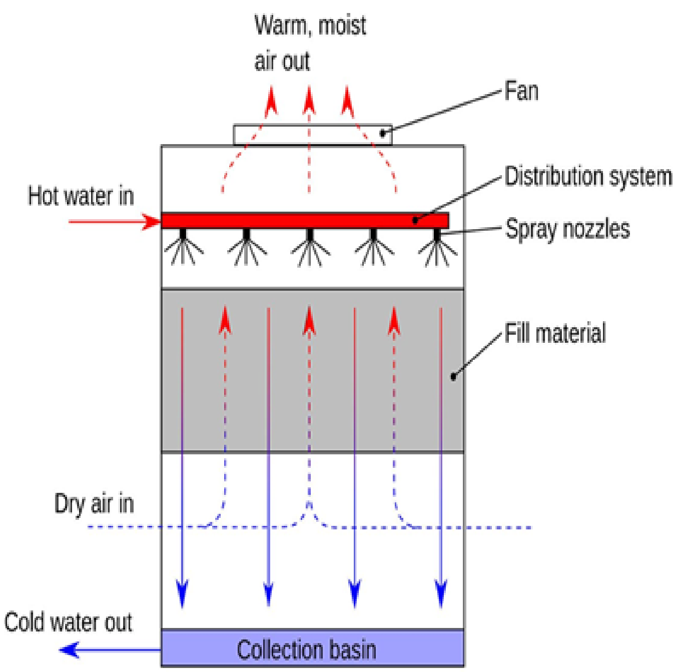
- **Evaporation:** As the hot water flows over the fill, it is exposed to the moving air, promoting evaporation. Heat is transferred from the water to the air as a result of this evaporation process. The water loses a portion of its heat and some of it evaporates into steam.

- **Heat dissipation:** The heat energy transferred from the water to the air during evaporation is dissipated into the atmosphere. The warmer air rises and is discharged through the top of the cooling tower.

- **Coldwater collection:** The cooled water, now at a lower temperature, collects at the bottom of the cooling tower in a basin or sump.

- **Recirculation:** A pump called Raw Water Pump returns the cooled water from the basin to the Heat Exchanger and the cycle repeats.

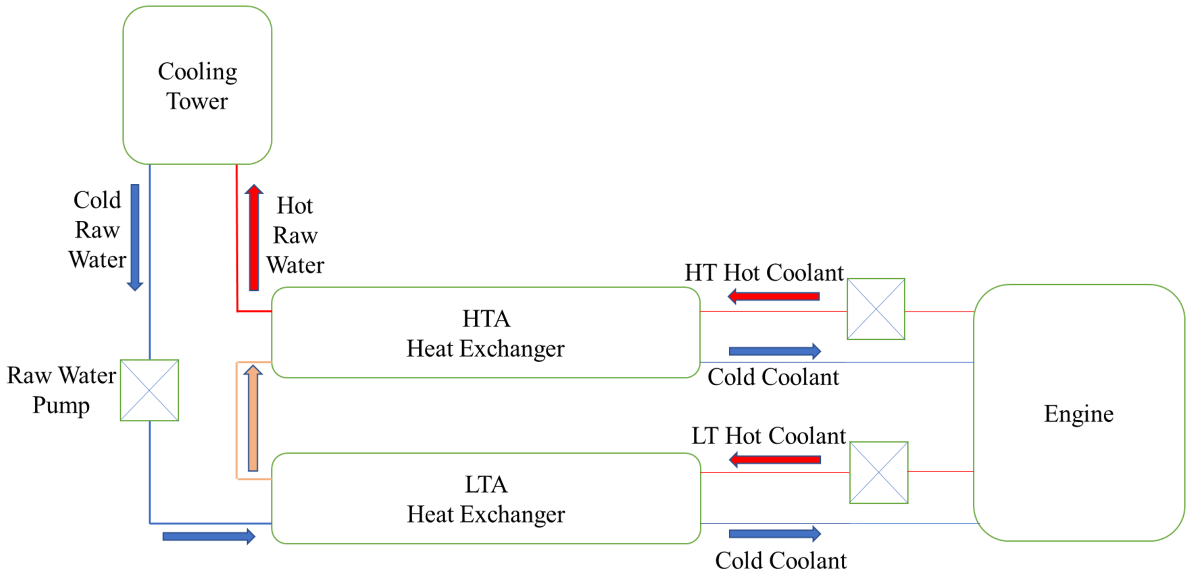
- **Makeup water supply:** To compensate for evaporation losses and maintain a constant water level, makeup water is added to the cooling tower system.



(Fig 2.7 Cooling Tower)

Heat Exchanger Cycle

To summarize whatever we have studied about the working of Heat Exchanger, let us see the complete cycle of the heat exchanger.



(Fig 2.8 Block Diagram of cooling system of GGs)

With this we are done with the Engine part of the generator, now we are going to start about the Alternator part of the generator.

2.1.2 Alternator

An alternator is an electrical device to generate alternating current (AC). The primary function of an alternator is to convert mechanical energy into electrical energy. It accomplishes this through the principle of electromagnetic induction. The alternator consists of a rotor, a stator.

Construction of Alternator

- **Stator:** The stator is the stationary part of the generator and is made up of a cylindrical core made of a stack of laminated iron sheets. The core reduces magnetic losses and provides a path for the magnetic flux. Around the core, there are slots that hold the stator windings. The stator windings consist of insulated copper or aluminum conductors.

- **Armature Winding:** The stator windings are arranged in a specific pattern to produce a rotating magnetic field when supplied with alternating current. The number of poles and the winding configuration determine the frequency and voltage output of the generator. The ends of the stator windings are connected to the terminal box for external connections.

- **Rotor:** The rotor is the rotating part of the generator and is mounted on a shaft. The rotor is also made up of a laminated iron core, similar to the stator, to reduce magnetic losses. In synchronous generators, the rotor has field windings. The field windings consist of coils of wire that are energized by a direct current (DC) source. The DC source can be provided through slip rings or a brushless excitation system.

- **Field Winding:** The excitation system supplies the DC current to the rotor field windings. In older generators, the excitation is typically provided through slip rings and brushes, where the DC current is transferred from an external source to the rotor windings. In modern generators, a brushless excitation system is commonly used, which eliminates the need for slip rings and brushes. Instead, the excitation current is supplied to the rotor windings through a stationary exciter, which uses solid-state rectifiers and a rotating magnetic field to induce the current in the rotor.

- **Bearings and Shaft:** The generator rotor is mounted on bearings that allow it to rotate smoothly on a shaft. The bearings support the rotor's weight and handle the mechanical forces and stresses during operation. The shaft is connected to the mechanical prime mover, such as a steam turbine or a gas engine, which provides the mechanical input to drive the generator.

Why is Armature winding preferable on the stator rather than rotor?

There are a lot of reasons that makes it preferable to have armature winding on stator.Let us discuss these one by one:

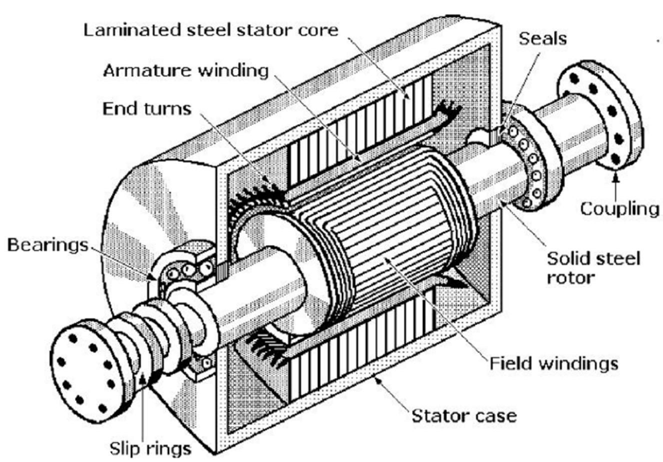
- If we will place 3-phase armature winding on the rotor then we have to use slip-rings to take the supply out of the machine at the terminals of the alternator.And if we keep field winding on the rotor then we have to use only 2 slip-rings.So, it is economical to have armature winding on the stator.
- Now, if we have armature winding on the rotor, then we have to use 3 slip-rings due to which heat loss will be more as compared to field winding on the rotor.
- As we are going to generate high voltages at the armature winding, then we have to provide better insulation.So, if we keep the armature on the rotor then in order to provide better insulation,the rotor will become heavier and we can’t rotate it at higher speed.
- We know armature winding will carry heavy current,so it will be heated up.Therefore it is necessary to cool it down.For cooling purposes,it is good to have armature winding on the stator rather than the rotor.

All the above facts are showing why we should keep the armature winding on the stator.

Working of Alternator

When the engine is running, the alternator is driven by a belt connected to the engine crankshaft. The rotating rotor, which is typically mounted on the same shaft as the engine's pulley, spins inside the stationary stator. The rotor contains a coil of wire called the field winding.This field winding is carrying a DC current of 3.2 Amp and excitation voltage of 63V. This DC current in the winding will produce a constant magnetic field.

As the rotor spins, the magnetic field produced by the field winding cuts across the stator windings, which are stationary and positioned around the rotor. This relative motion induces an alternating current in the stator windings.Then this produced emf in the armature winding is taken out at the terminals of the alternator.



(Fig 2.9 Construction of Alternator)

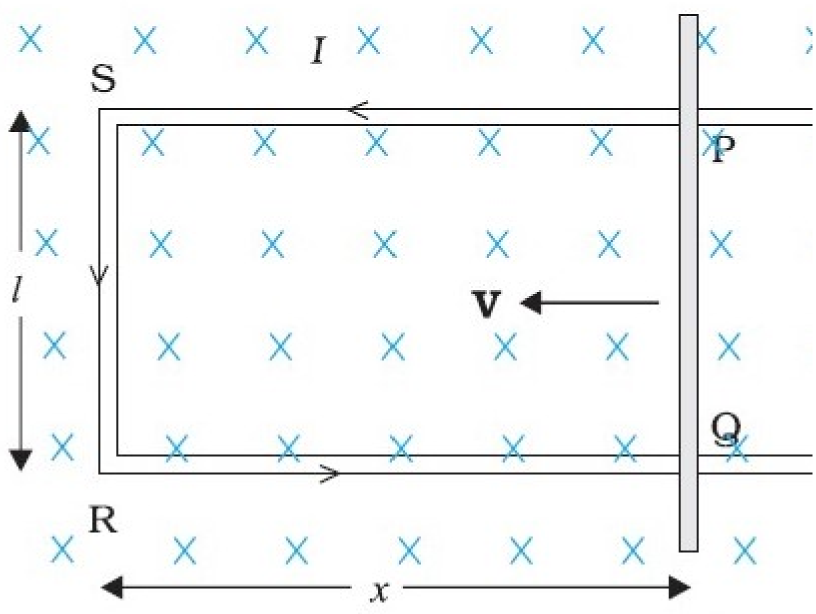
EMF Production

In this portion we are going to see how exactly AC EMF is being generated at the terminals of Alternator.We have already studied the concept of *Motional EMF.*

- **Motional EMF:** When a conductor of some length ‘l’ is moving with a velocity ‘v’ inside the the magnetic field ‘B’, then the emf across the conductor length is induced and its magnitude is determined as below:

An emf induced by the motion of the conductor across the magnetic field is a motional electromotive force. The equation is given by E = -vlB. This equation is true as long as the velocity, field, and length are mutually perpendicular. The minus sign associated with Lenz's law.

For us to understand the motional electromotive force, let us make a particular setup. Let us take a rectangular coil, a metal rod of length L, moving with velocity V, through a magnetic field B. There is a magnetic field at some location.
Length, velocity and magnetic field should always be at a right angle with each other. The direction of the magnetic field is going inside. Assume the metal rod is frictionless that means there is no loss of energy due to friction and we apply a uniform magnetic field. The conductor rod is moved with a constant velocity and placed in the magnetic field.



(Fig 2.10 Motional EMF)

Rating of Gas Generators

Manufacturer	**Cummins Power Generation**
Rated KVA	**1925**
Rated KW	**1540**
Power Factor	**0.80**

Frequency	**50 HZ**
RPM	**1500**
Rated Voltage	**415 V**
Excitation Voltage	**63 V**
Excitation Current	**3.2 A**
Ambient Temperature	**40 (degree Celsius)**
No. of Phases	**3**
Winding Connection	**Star**

Although GGs are capable of producing 1925 KVA but these are derated to generate 1400 KVA; this is due to the fact that GGs are installed in the basement,so there is not proper ventilation to run GGs at 1925 KVA.

2.2 Diesel Generator

Diesel Generator is another power source available in the power plant.There are *two* Diesel Generators available at the plant and each generator is having a power generation capacity of *2500 KVA*.These are manufactured by CUMMINS.
As the name suggests Diesel is being used as fuel in these generators. This diesel is stored in a 20,000 L Diesel Tank.From this tank diesel is first coming to the 1000 L tanks with the help of a HSD(high speed diesel) pump.There are two 1kL tanks placed nearby the DGs.Then from these 1kL tanks diesel is being provided to the engine.

Now, all the construction and working of the DGs is the same as the GGs,just the difference in rating of the alternator.So to understand the working and construction of DGs engine and alternator refer to section 2.1.

(Fig 2.11 Diesel Generator Installed at Power Plant of DUB of capacity 2500 KVA)

Rating of The Diesel Generators

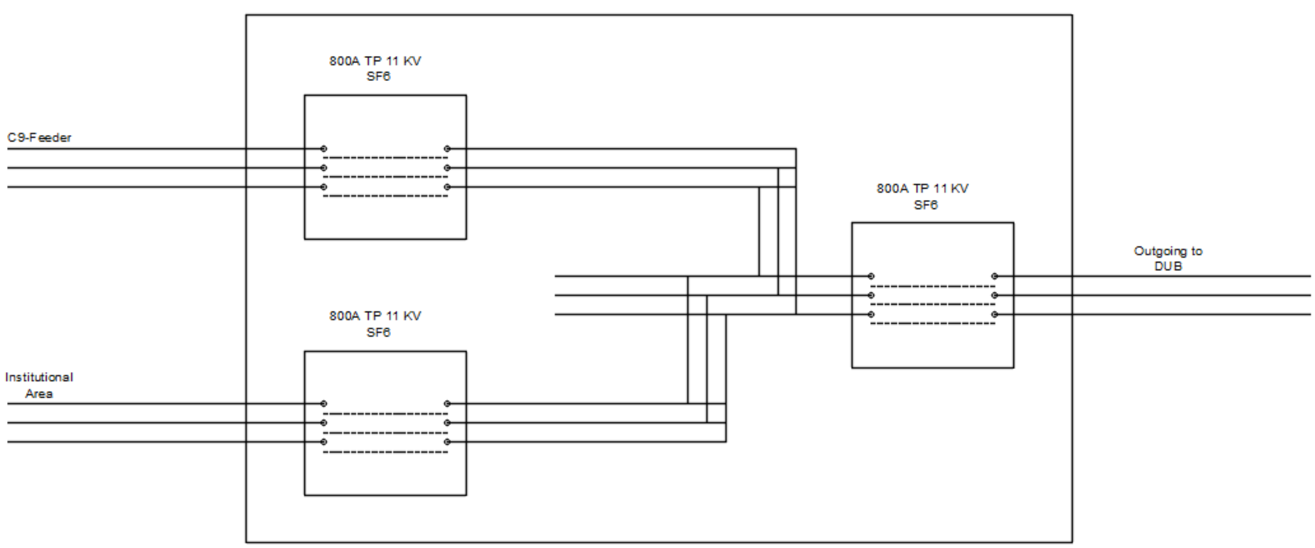
Manufacturer	**Cummins Power Generation**
Rated KVA	**2750**
Rated KW	**2500**
Power Factor	**0.80**
Frequency	**50 HZ**
RPM	**1500**
Rated Voltage	**415 V**
Excitation Voltage	**63 V**
Excitation Current	**3.2 A**
Ambient Temperature	**40 (degree Celsius)**
No. of Phases	**3**
Winding Connection	**Star**

Although DGs are capable of producing 2750 KVA but these are derated to generate 2500 KVA; this is due to the fact that DGs are installed in the basement,so there is not proper ventilation to run DGs at 2750 KVA.

2.3 BSES(Bombay Suburban Electric Supply)-11KV

BSES is a Utility which is supplying quality electric power to the consumers.BSES is supplying electric power to DUB via two *11KV* Sub-Stations namely ‘C9 Vasant Kunj’ and ‘Institutional Area’.From these sub-stations feeders are coming at DUB.But at a time only one feeder is supplying electric power.This is possible due to a special arrangement of incoming feeders called RMU(Ring Main Unit).This is nothing but a connection of incoming feeders and outgoing supply.Let us discuss it in more detail:

- **Ring Main Unit(RMU):** This a special arrangement of incoming feeders(i.e. C9 and Institutional Area) and outgoing supply to the DUB.There are basically breakers which are controlling the supply.The basic diagram is shown in the picture below.When breaker of C9 feeder is ON then breaker of Institutional area is OFF and vice-versa.Both of them cannot be ON at the same time because there is interlocking in these breakers.This whole setup is placed inside the building of DUB.



(Fig 2.12 RMU Connections)

This is how the 11KV supply is coming at DUB.Outgoing of the RMU is going to HT(High Tension) Meter,which is having a job of measuring the consumption of electric power.

- **HT Meter(High Tension Meter):** This is a meter which simply measures the amount of electricity consumed by DUB.But the main thing is there are no such meters which can directly measure 11KV volts and high currents.So, for this purposes we are using ‘Potential Transformers(PT)’ and ‘Current Transformers(CT)’.The arrangement of CT and PT allows us to calibrate such meters that can indirectly measures such higher voltages and currents.Let us see how this works:

  Current Transformer: These are devices that measure alternating current. They are widely used to measure high magnitude currents.

  A current transformer essentially lowers (steps down) a high current to a lower, safer level that you can manage properly. It steps down the current to be measured so that you can measure it with an average range ammeter.

  Potential Transformers: On the other hand, potential transformers, also known as voltage transformers, steps down the high voltages to a lower one that we can simply measure using our conventional meters.

  The HT Meter installed here has PTR(Potential Transformation Ratio) of 11000/110V and CTR(Current Transformation Ratio) of 300/5A.

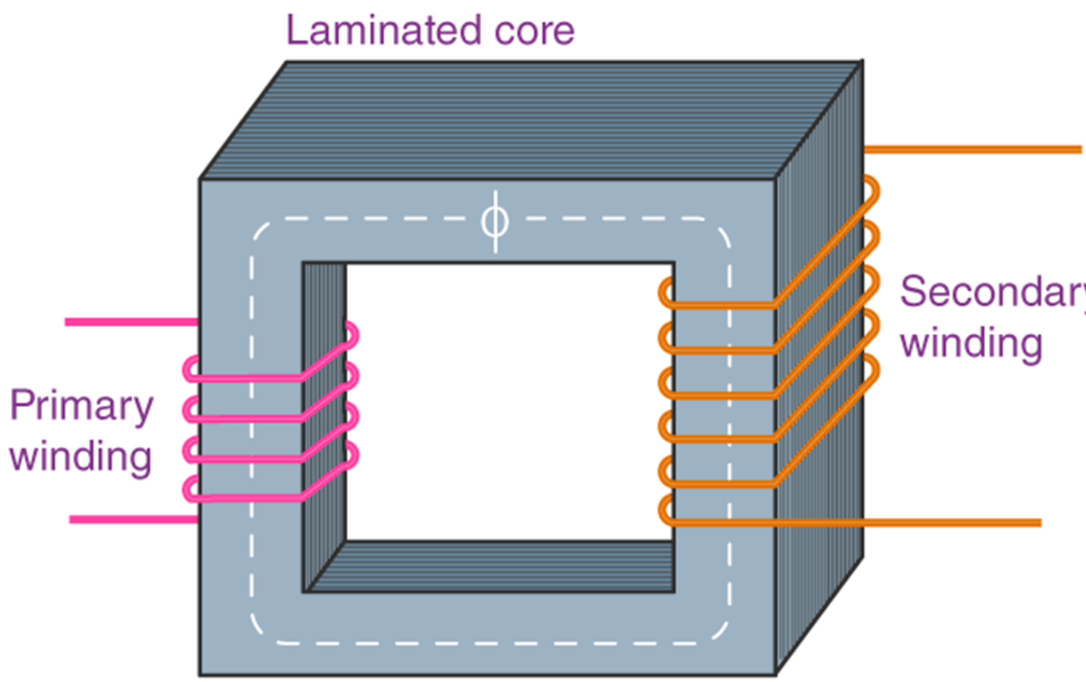
As we know BSES will provide 11KV supply,but at DUB only 415V is required.So, for that purpose there are two Transformers installed at power plant.Let us study about these transformers now:

Transformers

In order to convert 11KV to 415V, Transformers are being used.There are two 2500 KVA transformers installed.These are manufactured by VOLTAMP.These are three phase transformers.The primary supply to these transformers is 11KV and secondary supply is 415V. This 415V is then supplied to the next panels.

Construction of Three Phase Transformers

- **Core:** The core of a three-phase transformer is typically made of laminated steel sheets. These sheets minimize eddy current losses and improve the efficiency of the transformer. The core provides a low-reluctance path for the magnetic flux generated by the windings.



(Fig 2.13 Internal Construction of a Single Phase Transformer)

- **Windings:** There are two types of windings in a three-phase transformer: primary windings and secondary windings.

- **Primary Windings:** The primary windings are connected to the primary three-phase power source. They are typically arranged in a delta (Δ) or wye (Y) configuration.

- **Secondary Windings:** The secondary windings are connected to the load or the receiving end. Like the primary windings, they can be connected in a delta or wye configuration, depending on the application.

- **Cooling System:** Three-phase transformers generate heat during operation, and it is crucial to dissipate this heat to prevent overheating. Cooling systems, such as oil or air, are employed to maintain the temperature within safe limits. Oil-cooled transformers are more common for higher power ratings.

(Fig 2.14 Transformer(2500 KVA, 11KV/415V, 3-Phase) installed at Power plant of DUB)

Working of Three Phase Transformer

When three-phase power is supplied to the primary windings, a changing magnetic field is generated in the transformer core. This magnetic field induces voltage in the secondary windings, which is then transferred to the load.

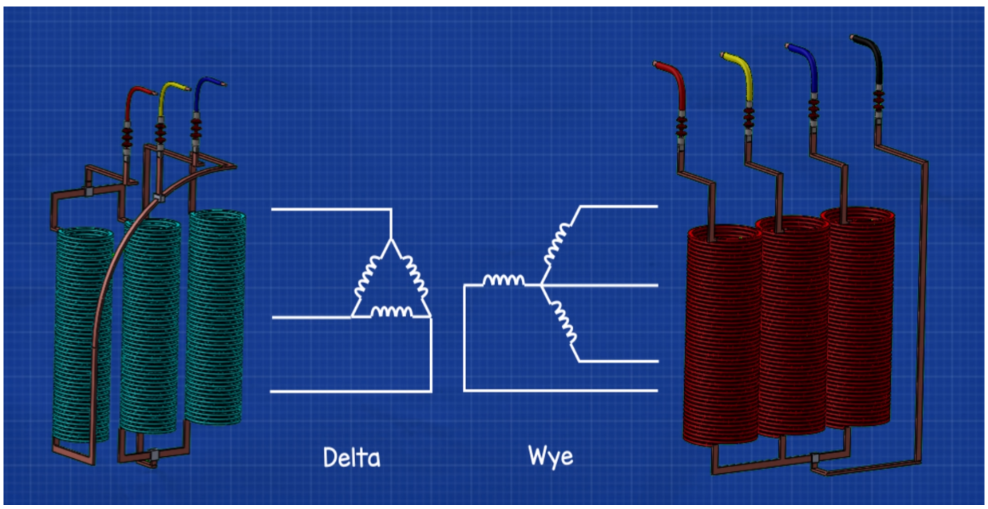
The operation of a three-phase transformer is similar to that of a single-phase transformer. However, the key difference lies in the configuration and connection of the windings. The winding arrangement can be:

- **Delta-Delta (Δ-Δ):** Both the primary and secondary windings are connected in a delta configuration. This connection is commonly used in industrial applications where a balanced three-phase load is required.

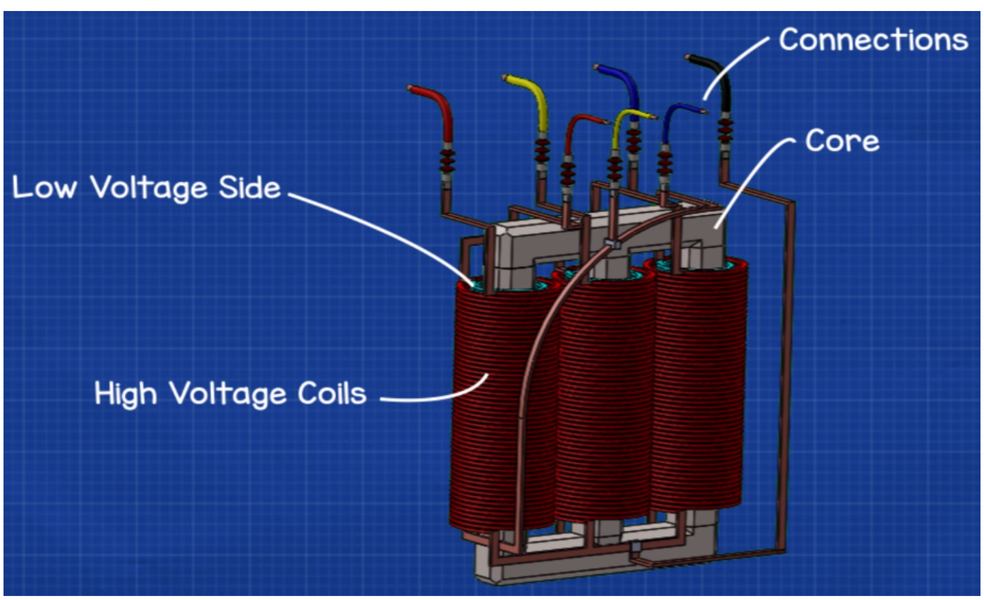
- **Wye-Wye (Y-Y) or Star-Star:** Both the primary and secondary windings are connected in a wye configuration. This connection is commonly used in commercial and residential applications where a neutral connection is necessary.

- **Delta-Wye (Δ-Y):** The primary winding is connected in a delta configuration, while the secondary winding is connected in a wye configuration. This connection allows the transformation of voltages from a higher level to a lower level.

In case of step down distribution transformers, the most commonly used winding connection is Delta-Way or Delta-Star connection.In the power plant of DUB the same connections are used.



(Fig 2.15 Star-Delta Connections of Secondary and Primary Windings of Transformer)



(Fig 2.16 Actual Connections of Windings of Transformer)

With this we are done with construction and working of a three-phase transformer.Now let us discuss some other components installed with the transformer:

- **Tap Changer:** This is a device used to raise or lower down the output voltage of the transformer according to our need.The tap-changer does its task simply by changing the number of turns involved(in the circuit) in the primary windings of the transformer.To operate tap-changer we have to do it manually.We need to use tap-changer when there is not proper voltage coming at the primary windings of the transformer.

  Mathematically,
  Let us say V1-N1,V2-N2 are the voltages and number of turns of windings on primary and secondary sides respectively.Therefore, if I have a fixed primary side voltage V1 and I want to change my output voltage V2 by changing number of turns in the primary winding using tap-changer then we have the following relation using which we can do the task:

$$\frac{V1}{V2} = \frac{N1}{N2}$$

$$V2 = \frac{N2}{N1} V1$$

  According to this, if I want to raise the voltage V2 then I have to reduce the number of turns in primary winding and vice-versa.

Types of Tap-Changer

There are two types of tap-changers,ON-LINE and OFF-LINE.

- **ON-LINE:** These tap-changers are designed to be operated in even the working condition of the transformer,there is no need to shut down the transformer to use the tap-changer.
- **OFF-LINE:**These tap-changers are designed to be operated in only the off condition of the transformer,we have to shut down the transformer to use this tap-changer.

(Fig 2.17 Tap-Changer Installed with Transformer)

2.4 Solar Power Plant

Solar power plant is another source of electric power for DUB.This is the most eco-friendly power source.There are two set of solar plants, each of 150 KW power generation capacity.So, total 300 KW is being generated by solar power plant.This solar power plant is installed on the rooftop of the building.This source of power cannot handle the total load of the DUB but it is helping other power sources by sharing some amount of load.Now let us discuss how actually solar plant produces electricity:

Solar cell (Its construction and working)

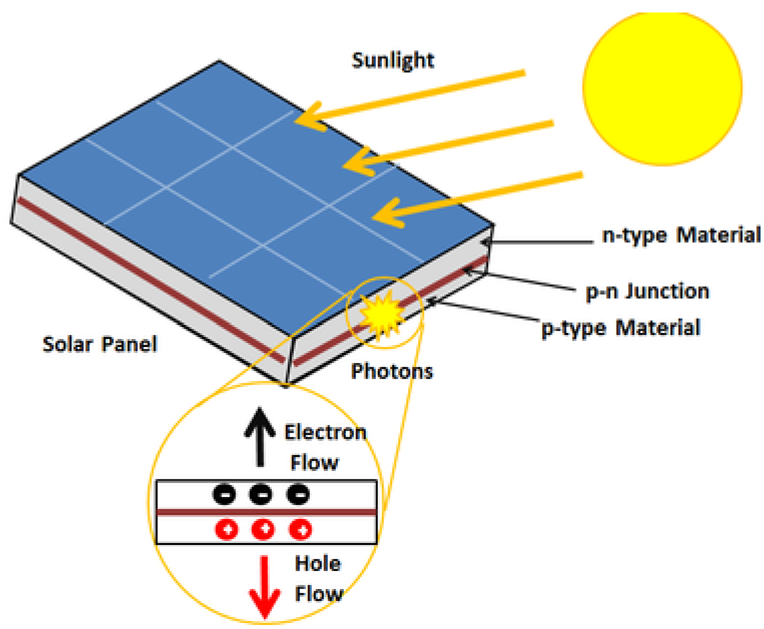
A solar cell, also known as a photovoltaic (PV) cell, is a device that converts sunlight directly into electrical energy through a process called the photovoltaic effect. It is the fundamental building block of solar panels and plays a crucial role in harnessing solar energy for various applications. Here's an explanation of the construction and working principles of a solar cell:

Construction of Solar Cell

- **Semiconductor Material:** Solar cells are typically made of a semiconductor material, most commonly silicon. Silicon is abundant, cost-effective, and possesses desirable electronic properties for solar cell applications.

- **P-N Junction:** The silicon material is doped with impurities to create a P-N junction. Doping involves adding specific atoms to the silicon crystal lattice, altering its electrical properties. The P-N junction consists of two regions within the semiconductor material: the P-type (positive) region and the N-type (negative) region.

- **Electrical Contacts:** Metal contacts are placed on the top and bottom layers of the cell. These contacts allow the extracted electrical current to flow out of the solar cell and be utilized for external applications.



(Fig 2.18 Construction of Solar Cell)

Working of Solar Cell

- **Absorption of Photons:** When sunlight (composed of photons) strikes the solar cell, the photons are absorbed by the semiconductor material, typically silicon. The energy from the photons excites the electrons present in the silicon atoms, causing them to move from the valence band to the conduction band.

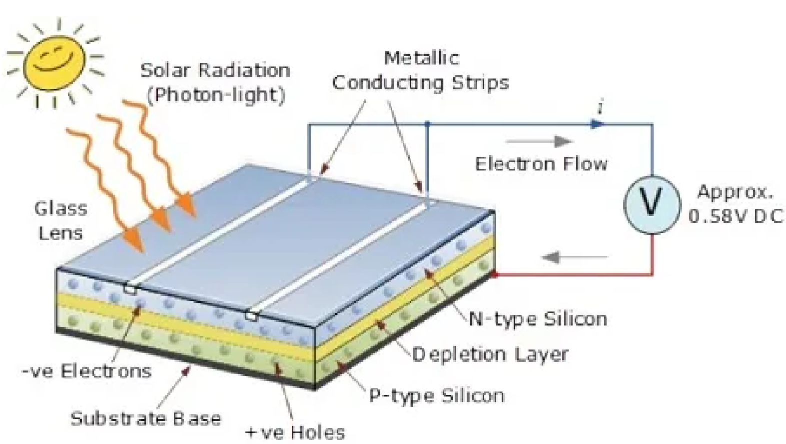
- **Generation of Electron-Hole Pairs:** The excitation of electrons creates "electron-hole" pairs. Electrons are negatively charged, while the resulting holes are positively charged vacancies left behind in the valence band.

- **Separation of Charges:** Due to the P-N junction, the electron-hole pairs get separated. Electrons are drawn towards the N-side, which has an excess of negative charge, while holes are attracted to the P-side, which has an excess of positive charge. This separation creates an internal electric field at the junction.

- **Electron Flow:** The separated electrons and holes create a voltage difference between the two sides of the cell, leading to the flow of electrons from the N-side to the P-side. This flow of electrons generates an electric current, which can be harnessed for various applications.

- **External Circuit:** To utilize the generated electric current, the solar cell is connected to an external circuit, typically through the metal contacts. The current flows through the circuit, powering electrical devices or charging batteries.

- **Continuous Operation:** As long as sunlight is present and the circuit is closed, the solar cell continues to convert solar energy into electrical energy. The process is self-sustaining and environmentally friendly, as it does not involve any moving parts or the burning of fossil fuels.



(Fig 2.19 Working of Solar Cell)

Converting DC to AC

Solar power plants generate alternating current (AC) electricity by converting the direct current (DC) output from solar panels.Here's a detailed explanation of how solar power plants produce AC supply:

- **Solar Panel Array:** The solar power plant consists of a large array of solar panels, which are made up of multiple interconnected solar cells. Each solar panel generates DC electricity when exposed to sunlight.
- **DC Combiner Box**: The DC electricity from multiple strings of solar panels is combined in a DC combiner box. The combiner box collects the DC output from several strings and feeds it into the inverter system.

- **Inverter Operation:** The inverter system receives the combined DC electricity and performs the following functions:

1. **Conversion to AC:** The inverter converts the DC electricity into AC electricity, which is the standard form of electrical power used in most electrical devices and the power grid.
2. **Synchronization:** The inverter synchronizes the frequency and voltage of the AC electricity it produces with the local power grid or the desired electrical specifications.
3. **Power Conditioning:** The inverter also performs power conditioning functions, such as ensuring a smooth and stable AC output, correcting power factor, and protecting against grid faults or fluctuations.

- **Monitoring and Control:** Solar power plants incorporate monitoring and control systems to monitor the performance, efficiency, and output of the solar panels, inverters, and other components. These systems enable operators to optimize the plant's performance, detect faults, and ensure smooth operation.

This is how the whole setup is working and ultimately the solar power plant is delivering AC supply to the loads.

With this we covered all the sources of electric power sources available at DUB.In the next chapter we will see how the sources are feeding the supply to the loads through electric panels.

CHAPTER 3
ELECTRIC POWER DISTRIBUTION

In this chapter we are going to discuss about the distribution of the electric power to the loads.We are going to see how exactly electric power is going from power sources and reaching the loads of DUB.We will see in later sections about electric panels that are playing a vital role in power distribution.In order to visualize this,line diagrams are used which will clarify the doubts.

Before starting the discussion on the electric panels,let us firstly discuss about the *circuit breakers*,their types and working.This is necessary to understand the construction and working of the circuit breakers because these are being used everywhere in every panel.

3.1 Circuit Breakers

Circuit breakers are electrical devices designed to protect electrical circuits and connected devices from damage caused by excessive current, short circuits, or electrical faults. They serve as safety devices that automatically interrupt the flow of electrical current when abnormal conditions occur in a circuit.There are many types of circuit breakers available,but mainly four types of circuit breaker are used there at DUB power plant:

- ACB(Air Circuit Breaker)-More than 800 Amps.
- SF6 Breaker(Sulphur Hexafluoride)-From 11KV to 800KV
- MCCB(Molded Case Circuit Breaker)-From 25 Amps to 630 Amps.
- MCB(Miniature Circuit Breaker)-From 1 Amps to 100 Amps.

Actually circuit breakers are having the same task but the different types are used for different levels of currents and voltages.The most common circuit breaker with which we have to deal is ACB. Let us study ACB in great detail.

ACB(Air Circuit Breaker)

ACB stands for Air Circuit Breaker. It is a type of circuit breaker in which electrical contacts are placed in air only. ACBs are commonly used in low-voltage electrical systems for the protection and control of power distribution. Let's dive into its construction and working in detail:

Construction of ACB

- **Frame:** The ACB is housed in a frame that provides structural support and protection. The frame also contains the operating mechanism and various control components.

- **Contacts:** The ACB consists of a pair of stationary and moving contacts. The stationary contacts are fixed within the frame, while the moving contacts are attached to the operating mechanism.

- **Arc Chute:** The arc chute is an essential component in an ACB. It is designed to quickly extinguish the electric arc that is generated when the circuit is interrupted. The arc chute consists of a series of metal plates or grids arranged in a zigzag pattern. These plates create a magnetic field that forces the arc to move and split into smaller arcs, thereby aiding in arc extinction.

- **Operating Mechanism:** The operating mechanism is responsible for opening and closing the contacts of the ACB. It can be either manual or motor-operated, depending on the size and application of the ACB. The operating mechanism includes mechanisms like springs, latches, trip coils, and other control elements.

- **Trip Unit:** The trip unit is an integral part of the ACB and is responsible for sensing overcurrent, short circuit, and other faults. It consists of protective relays, current transformers, and other components that monitor the electrical parameters of the circuit. When a fault is detected, the trip unit sends a signal to the operating mechanism to open the contacts.

- **UV Coil (Under Voltage Coil):**The UV coil is an electromagnetic coil that is energized by a control circuit in the ACB. It functions to monitor the voltage level of the power supply. When the voltage drops below a predetermined threshold, indicating an under-voltage condition, the UV coil is de-energized. This causes the trip signal to be activated, leading to the tripping of the ACB. The UV coil is a protective feature that prevents the ACB from remaining closed and potentially causing damage or unsafe conditions during low voltage situations.

- **Shunt Coil:**The shunt coil is another electromagnetic coil found in an ACB. It is responsible for assisting in the arc extinguishing process when the breaker trips and interrupts the current flow. When a fault occurs and the trip signal is initiated, the shunt coil is energized. This produces a magnetic field that aids in deflecting and splitting the electric arc formed between the separating contacts. The magnetic field generated by the shunt coil helps accelerate the arc extinction process by directing the arc into the arc chute, where it is rapidly cooled and extinguished.

- **Closing Coil:**The closing coil in an ACB is an electromagnetic coil that is energized to close the contacts and restore the circuit connection after a fault has been cleared or during the normal operation of the breaker. When the closing coil is energized by a control signal, it generates a magnetic field that attracts the moving contacts towards the stationary contacts, bringing them into contact and allowing current to flow through the breaker. The closing coil is typically controlled by a manual or automatic closing mechanism.

- **Tripping Coil:**The trip signal is sent to the trip coil. When the trip coil receives the signal, it is energized. This means that a current flows through the coil, creating a magnetic field around it.The magnetic field generated by the energized trip coil interacts with the operating mechanism of the ACB. The operating mechanism typically consists of springs, latches, and other components that hold the contacts in the closed position.

Now let us see the operating mechanism of the ACB where *spring charging* is being done.Spring charging is very important for the working of ACB.If the spring is uncharged,then ACB will not work.

Spring Charging(or Compressing) Mechanism

The spring charging system in an Air Circuit Breaker (ACB) is responsible for storing and releasing the energy in a spring,required to operate the operating mechanism and close or open the contacts of the breaker. It ensures that the operating mechanism has sufficient power to perform its intended function. Here's an overview of how the spring charging system works:

- **Spring Charging Mechanism:** The spring charging system typically consists of a motor, a set of springs, and associated gears and mechanisms. The motor drives the mechanism that charges or compresses the springs.Although there is also a handle using which we can manually charge the spring.

- **Charging the Springs:** When the ACB is in the "charged" state, the springs are compressed and store potential energy. The motor is engaged, causing the mechanism to rotate and compress the springs. This process involves transferring mechanical energy from the motor to the springs, building up the potential energy within the springs.

- **Energy Storage:** As the springs are compressed, they store potential energy, which is converted from electrical energy supplied by the motor. The amount of energy stored depends on the characteristics of the springs and the design of the charging mechanism.

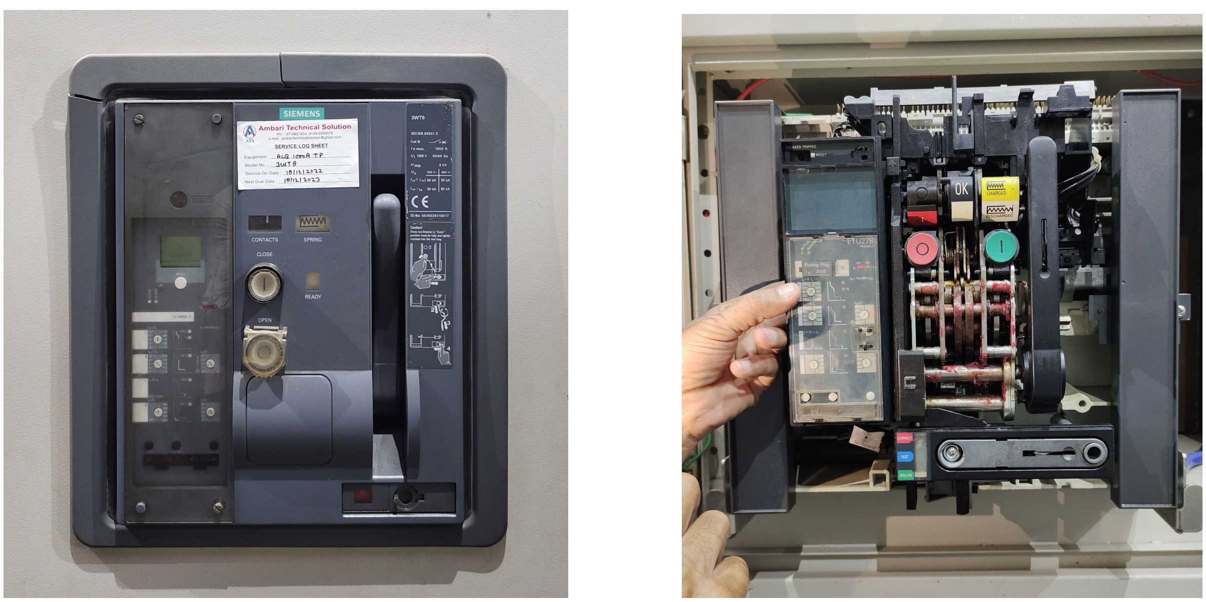
- **Operating the ACB:** When it is time to close or open the contacts of the ACB, the potential energy stored in the charged springs is used. The control system, usually operated manually or automatically, triggers the release of the stored energy to actuate the operating mechanism.

- **Energy Release:** The control system disengages the latch or trigger mechanism that holds the compressed springs. Once released, the potential energy stored in the springs is rapidly converted into kinetic energy.

- **Contact Operation:** The kinetic energy generated by the released springs is used to drive the operating mechanism. It moves the contacts either to the closed position (for making electrical connections) or to the open position (for interrupting current flow).

- **Recharging the Springs:** After the contacts are closed and opened once, the spring charging system engages again to recharge the springs.That means by charging the spring one time ACB can be ON and OFF one time.The motor drives the mechanism to compress the springs, restoring the potential energy within them.

For the sake of knowledge I want to mention here that a single ACB costs around 5-6 lacs Rs.



(Fig 3.1 Outer and Inner view of ACB installed in panels)

Working of ACB

- **Normal Operation:** In normal operation, the ACB allows the electrical current to flow through its closed contacts. The moving contacts are held against the stationary contacts under the force of the operating mechanism.

- **Fault Detection:** When a fault occurs in the circuit, such as an overcurrent or short circuit, the protective devices connected to the ACB sense the abnormal conditions. The trip unit receives signals from these protective devices or directly monitors the electrical parameters.

- **Tripping Process:** Upon detecting a fault, the trip unit initiates the tripping process. It sends a signal to the operating mechanism, which releases the latch holding the moving contacts. The energy stored in the springs of the operating mechanism is then released, causing the contacts to separate rapidly.

- **Arc Interruption:** As the contacts separate, an electric arc is formed due to the interruption of the current. The arc is directed into the arc chute, where it is rapidly cooled and extinguished. The plates or grids in the arc chute create a magnetic field that deflects and splits the arc, aiding in its extinction.

- **Circuit Isolation:** Once the arc is extinguished, the contacts are fully open, and the circuit is effectively isolated. This prevents the fault current from flowing further and protects the connected electrical equipment.

  The trip coil, also known as the tripping coil, is an essential component in an Air Circuit Breaker (ACB) that is responsible for initiating the tripping action. It works in conjunction with the trip unit, which detects faults and sends a signal to the trip coil to initiate the tripping process. Let's explore the working of the trip coil in more detail:

  The trip unit continuously monitors the electrical parameters of the circuit, such as current, voltage, and frequency. It is designed to detect abnormal conditions, including overcurrent, short circuits, or other fault conditions.

  When a fault is detected by the protective relays in the trip unit, it generates a trip signal. The trip signal indicates that the ACB needs to interrupt the current flow and isolate the faulty circuit.

  The trip signal is sent to the trip coil. When the trip coil receives the signal, it is energized. This means that a current flows through the coil, creating a magnetic field around it.

The magnetic field generated by the energized trip coil interacts with the operating mechanism of the ACB. The operating mechanism typically consists of springs, latches, and other components that hold the contacts in the closed position.

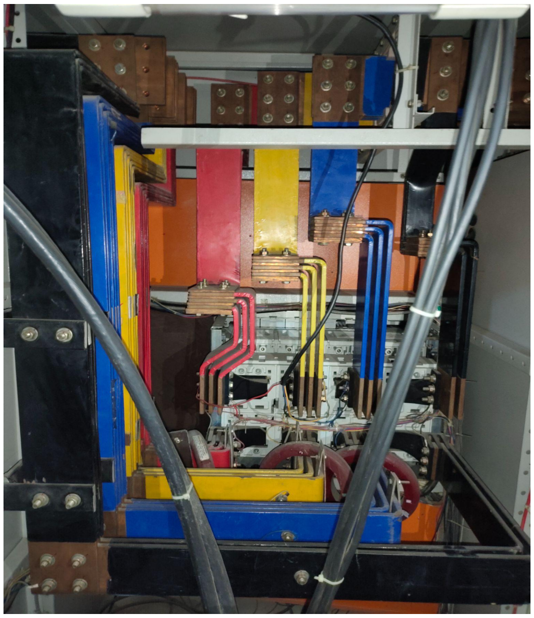
The magnetic field produced by the trip coil acts on the latch mechanism, causing it to release. This action disengages the latch holding the moving contacts, allowing them to move rapidly.

Once the latch is released, the moving contacts separate from the stationary contacts under the force of springs or other mechanisms. This separation interrupts the current flow and isolates the faulty circuit from the power supply.

As the contacts separate, an electric arc is formed due to the interruption of the current. The ACB is equipped with an arc chute, which helps in rapidly cooling and extinguishing the arc by deflecting and splitting it into smaller arcs.

Once the arc is extinguished, the contacts remain open, ensuring the circuit is effectively isolated. This prevents the fault current from continuing to flow, protecting the electrical system and equipment.

- **Resetting and Closing:** After the fault is cleared and the circuit is restored to normal conditions, the ACB can be manually or automatically reset. The operating mechanism is engaged to close the contacts, allowing the current to flow again.



(Fig 3.2 Backside View of ACB)

With this we are done with the construction and working of ACBs.In the same manner any other breaker will work, just their voltage and current handling capacities are different,so according to that their design and cost is varying.Next we are moving towards the electrical distribution panels.Let us see how the electricity is going from sources of electric power to the loads, through electric panels.

3.2 ATS(Automatic Transfer Switch)

In order to study electrical panels, it is necessary to study ATS because it is a very important device that is being used in panels.

In the field of electrical engineering, ATS stands for Automatic Transfer Switch. An Automatic Transfer Switch is an electrical device that automatically switches the power supply between two sources, typically the utility power and a backup power source, such as a generator or an uninterruptible power supply (UPS).

The primary purpose of an ATS is to provide a seamless transition of power supply in the event of a power outage or when there is a need to switch between different power sources. When the utility power supply fails or falls below a certain threshold, the ATS detects the change and quickly transfers the load from the utility power to the backup power source. Once the utility power is restored or stable again, the ATS transfers the load back to the utility power and returns to its normal operation.

(Fig 3.3 Inside view of ATS)

Construction of ATS

- **Power Input Terminals:** The ATS has terminals for connecting the utility power source and the backup power source, such as a generator or UPS.

- **Load Terminals:** These terminals are used to connect the electrical load, such as lights, appliances, or machinery, to the ATS.

- **Control Circuitry:** The control circuitry consists of sensors, relays, timers, and logic controllers that monitor the power sources and control the switching operation.

- **Transfer Switch Mechanism:** The transfer switch mechanism is responsible for physically connecting the power sources to the load. It typically consists of electromechanical switches, such as contactors or relays, that make or break the electrical connections.

Working of ATS

- **Normal Power Supply:** When the utility power supply is available and within acceptable voltage and frequency ranges, the ATS maintains the load connection to the utility power. The transfer switch remains in a position that allows power to flow directly from the utility to the load.

- **Power Failure Detection:** If the utility power fails or deviates from acceptable parameters, the ATS control circuitry detects the power interruption or anomaly through sensors. This triggers the transfer process.

- **Source Monitoring:** The ATS continuously monitors the backup power source, such as a generator or UPS. It checks parameters like voltage, frequency, and stability to ensure it is ready to assume the load.

- **Transfer Activation:** Once the ATS confirms the readiness of the backup power source, it activates the transfer switch mechanism. The transfer switch moves to disconnect the load from the utility power and connects it to the backup power source.

- **Backup Power Supply:** With the transfer switch in position, the backup power source begins supplying power to the load. The ATS continuously monitors the backup power to ensure its stability and quality.

- **Utility Power Restoration:** When the utility power is restored and stabilizes within acceptable parameters, the ATS control circuitry verifies its reliability.

- **Transfer Back to Utility:** The ATS initiates the transfer switch mechanism again, disconnecting the load from the backup power source and reconnecting it to the utility power.

- **Standby Mode:** Once the load is safely reconnected to the utility power, the ATS returns to its standby mode, ready to detect and respond to future power interruptions or anomalies.

This is all about an ATS.Now let us study about other devices being used in panels.

3.3 DOL(Direct Online) Starter

Starters are another very important devices that are used to start the motors.DOL starter is very commonly used.Let us study what it is and how it works.

A DOL starter, also known as a Direct-On-Line starter, is a type of motor starter used to start and control induction motors. It is one of the simplest and most commonly used methods for starting motors in various industrial applications.

Construction of DOL starter

- **Contactor:** A contactor is an electromechanical switch used to control the flow of electric current to the motor. It typically consists of a coil and contacts that open and close to control the power circuit.

- **Thermal Overload Relay:** This component protects the motor from excessive heat and overload conditions. It monitors the current flowing through the motor and activates when it exceeds the set limits, thus disconnecting the motor from the power supply.

- **Start Button:** The start button is used to initiate the motor's starting sequence. When pressed, it energizes the contactor coil, closing the contacts and allowing current to flow to the motor.

- **Stop Button:** The stop button is used to halt the motor's operation. When pressed, it de-energizes the contactor coil, opening the contacts and cutting off the power supply to the motor.

Working of a DOL Starter

- **Motor at Rest:** Initially, the motor is at rest, and the start and stop buttons are in the open position. The contactor is also in the open position, interrupting the power supply to the motor.

- **Starting Sequence:** When the start button is pressed, current flows through the control circuit and energizes the contactor coil. This causes the contactor's contacts to close, connecting the motor to the power supply.

- **Full Voltage Applied:** With the contacts closed, the full voltage from the power supply is directly applied to the motor windings. As a result, the motor receives the maximum starting torque, allowing it to accelerate quickly.

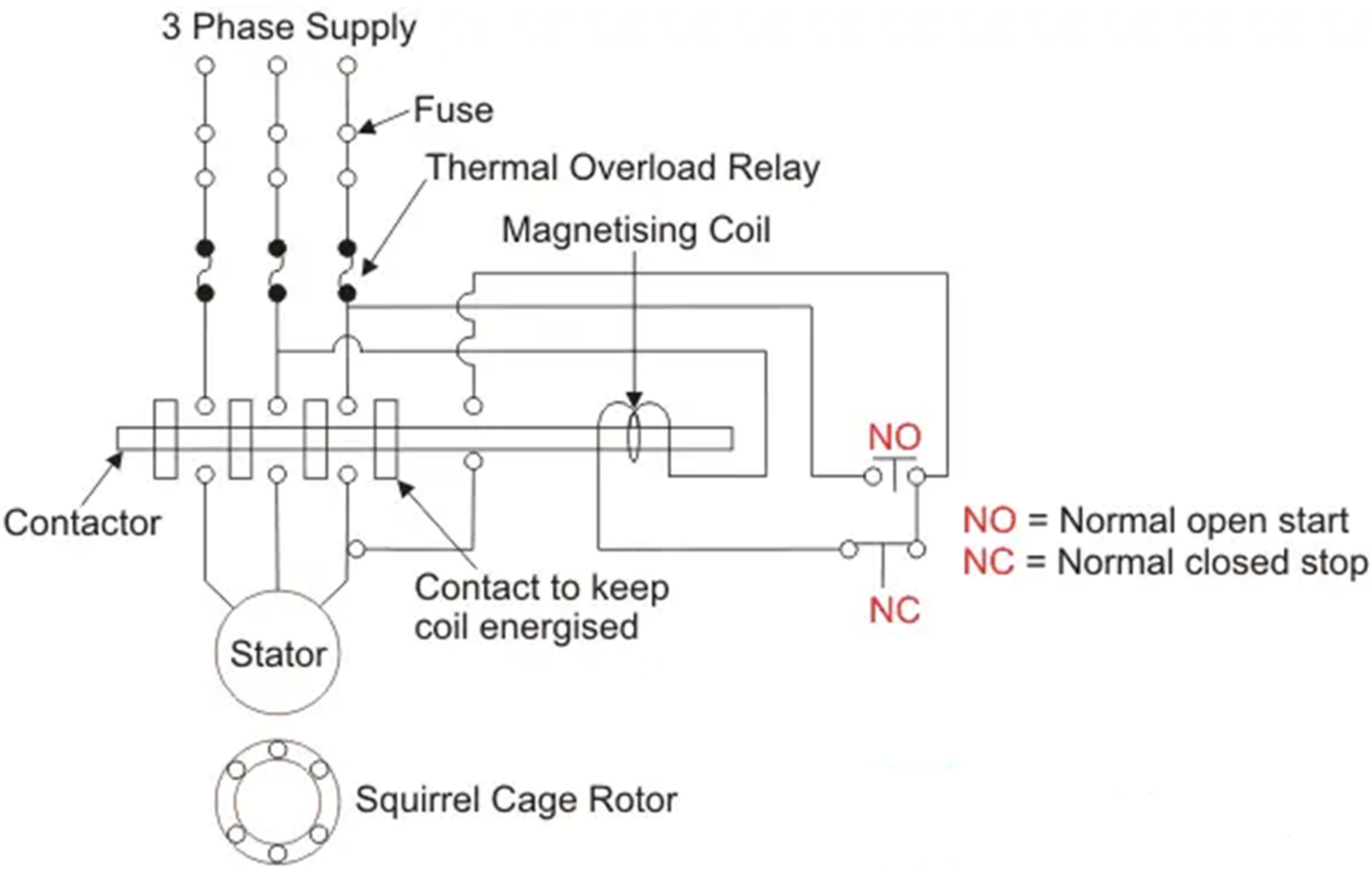
- **Running Condition:** Once the motor reaches its operating speed, the start button is released. However, the contactor remains closed, maintaining the connection between the motor and the power supply.

- **Overload Protection:** The thermal overload relay is connected in series with the motor. It continuously monitors the motor's current. If the current exceeds the set limit due to an overload or fault, the thermal overload relay activates and disconnects the motor from the power supply, providing protection against damage.

- **Stopping the Motor:** To stop the motor, the stop button is pressed. This de-energizes the contactor coil, opening the contacts and cutting off the power supply to the motor, bringing it to a stop.

(Fig 3.4 DOL Starter)

Power and Control Wiring of DOL starter



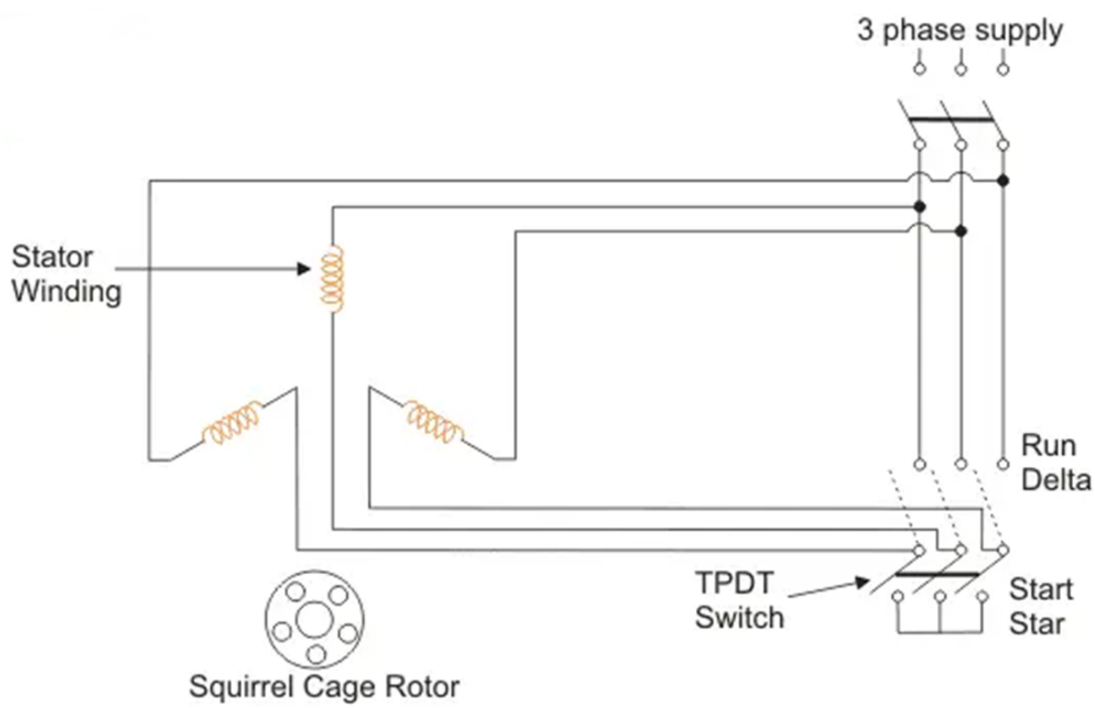
(Fig 3.5 Power and Control Wiring of DOL starter)

This is how DOL starter works.Now let us see another important type of starter called Star-Delta Starter.

3.4 Star-Delta Starter

A star delta starter is a type of reduced voltage starter. We use it to reduce the starting current of the motor without using any external device or apparatus. This is a big advantage of a star delta starter, as it typically has around 1/3 of the inrush current compared to a DOL starter.

The starter mainly consists of a TPDP switch which stands for Triple Pole Double Throw switch. This switch changes stator winding from star to delta. During starting condition stator winding is connected in the form of a star. Now we shall see how a star delta starter reduces the starting current of a three-phase induction motor.

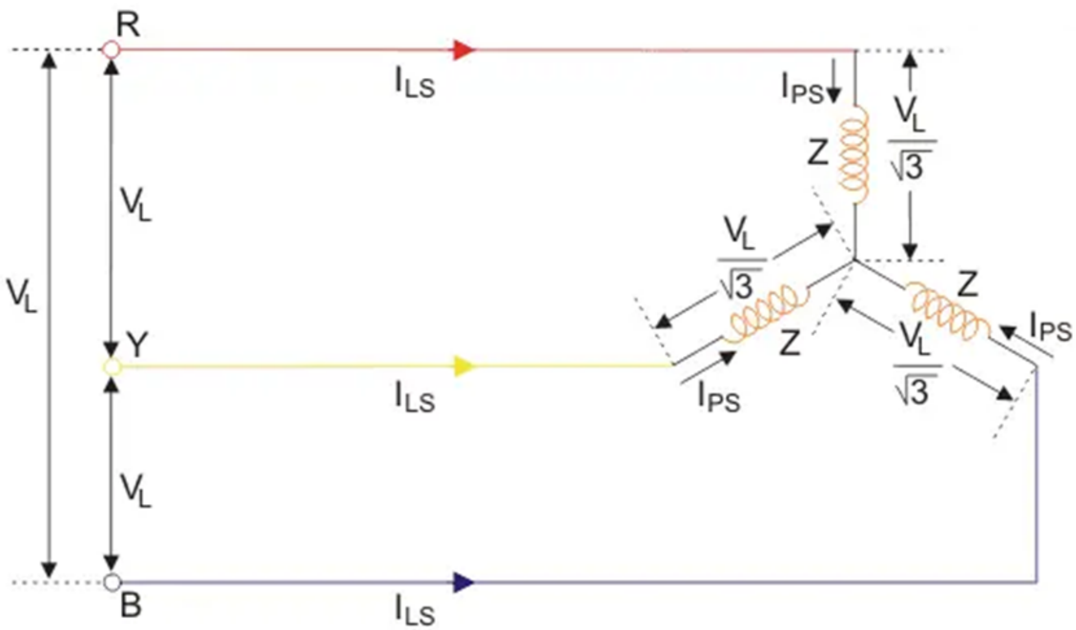


(Fig 3.6 Power and Control Wiring of Star-Delta Starter)

For that let us consider,

V_L = Supply Line Voltage, I_{LS} = Supply Line Current and, I_{PS} = Winding Current per Phase and Z = Impedance per phase winding at stand still condition.

Now, let us consider the situation where the motor gets started with star connected stator winding from three phase supply points,



(Fig 3.7 Star Connection of the Starter)

As the winding is star connected, the winding current per phase (I_{PS}) equals the supply line current (I_{LS}).

$$I_{PS} = I_{LS}$$

As the winding is star connected, the voltage across each phase of the winding is

$$\frac{V_L}{\sqrt{3}}$$

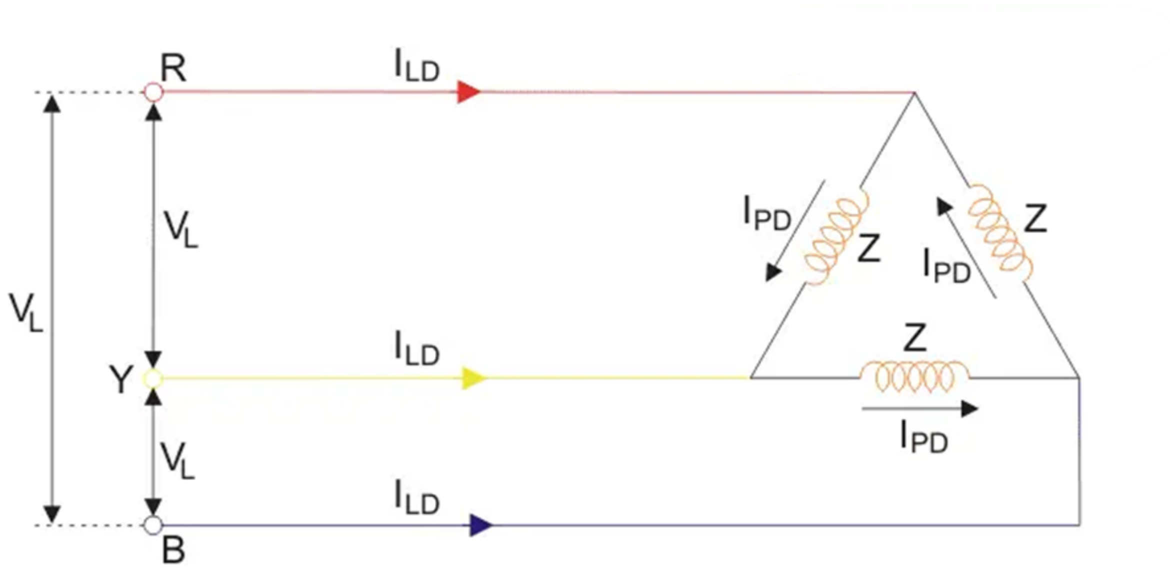
Hence, the winding current per phase is

$$I_{PS} = \frac{V_L}{\sqrt{3}Z}$$

Since here, the winding current per phase (I_{PS}) equals to the supply line current (I_{LS}), we can write,

$$I_{PS} = \frac{V_L}{\sqrt{3}Z} \Leftrightarrow I_{LS} = \frac{V_L}{\sqrt{3}Z}$$

Now, let us consider the situation where the motor gets started with delta connected stator winding from same three phase supply points,



(Fig 3.8 Delta Connection of Starter)

Here, I_{LD} = Supply Line Current and, I_{PD} = Winding Current per Phase and Z = Impedance per phase winding at stand still condition.
As the winding is delta connected, supply line current (I_{LD}) is root three times of the winding current per phase (I_{PD})

$$I_{LD} = \sqrt{3}\, I_{PD}$$

As the winding is delta connected, the voltage across each phase of the winding is

$$V_L$$

Hence, the winding current per phase is

$$I_{PD} = \frac{V_L}{Z}$$

Now, we can write,

$$I_{LD} = \sqrt{3}\ I_{PD} = \frac{\sqrt{3}\ V_L}{Z}$$

Now, by comparing supply line currents drawn by an induction motor with star and delta connected winding, we get

$$\frac{I_{LD}}{I_{LS}} = \frac{\frac{\sqrt{3}\ V_L}{Z}}{\frac{V_L}{\sqrt{3}\ Z}} = 3 \Rightarrow I_{LS} = \frac{1}{3} I_{LD}$$

Thus we can say that the starting current from the mains in case of star delta is one-third of direct switching in the delta. Again, we know that the starting torque of an induction motor is proportional to the square of the voltage applied to the winding per phase.

$$\frac{Starting\ torque\ in\ star\ connected\ stator\ winding\ motor}{Starting\ torque\ in\ delta\ connected\ stator\ winding\ motor}$$
$$= \frac{\left(\frac{V_L}{\sqrt{3}}\right)^2}{{V_L}^2} = \frac{1}{3}$$

The equation shows that the star delta starter reduces the starting torque to one-third of that produced by the DOL starter.

With this we are done with both the starters and now we are ready to continue our discussion on electric panels.So in next section we are going to discuss the electrical panels which are distributing the source supply to all the loads in the building.

3.5 Distribution Electric Panels

Electric panels, also known as distribution panels or electrical distribution boards, are an integral part of electrical systems in buildings and industries. They are designed to receive electrical power from a main power source and distribute it to various circuits, appliances, and equipments. Electric panels serve as a centralized control and distribution point for electrical power. Here are some key aspects and components of electric panels:

- **Main Power Input:** Electric panels receive power from the main power supply, typically through a main circuit breaker or a main switch. The main power input is usually connected to the utility power grid or an onsite power generation system.

- **Circuit Breakers or Switches:** Electric panels contain multiple circuit breakers or switches, each dedicated to a specific circuit or group of circuits. These devices provide overcurrent protection and can be manually operated to control the power supply to individual circuits.

- **Busbars:** Busbars are conductive bars or strips that distribute electrical power within the electric panel. They act as a common connection point for the incoming and outgoing electrical conductors. Busbars ensure efficient and organized power distribution within the panel.

- **Terminal Blocks:** Terminal blocks provide connection points for electrical wires within the panel. They enable the secure and organized termination of incoming and outgoing electrical conductors, allowing for easy installation, maintenance, and modification of circuits.

- **Control and Monitoring Components:** Electric panels may include control and monitoring components, such as control relays, timers, voltage meters, and ammeters. These components enable the monitoring, control, and measurement of electrical parameters within the panel.

- **Panel Enclosure:** Electric panels are enclosed in a cabinet or enclosure made of non-conductive materials, typically metal or plastic. The enclosure provides physical protection, prevents accidental contact with live components, and offers a degree of electrical insulation.

- **Labels and Indicators:** Electric panels are often equipped with labels, markings, and indicators that provide information about circuit identification, voltage ratings, safety precautions, and other relevant details. These labels help electricians and maintenance personnel easily identify and troubleshoot electrical circuits.

(Fig 3.9 Example of an Electric Panel)

There are many distribution panels installed in the building,but we are going to see the panels installed only in the power plant of the DUB.There are around 11 main electric panels that we are going discuss.In this section I will be explaining only about the incoming of the panels and outgoing of the panels.

To visualize the connections of a panel it is recommended to refer to the Line Diagram attached with this report file.So let us start with our first panel i.e. GG Sync Panel;

3.5.1 GG Sync Panel

After generation of 3-phase electric power in the alternators of GGs the supply goes into the GG sync panel with the help of a busbars.3-phase supply from both GG1 as well as GG2 is coming in this panel.These are called incomers to this panel.There are ACBs installed in both the incoming supply lines and the outgoing of ACBs is going to the common busbar installed inside the panel.

There is a bus-coupler(ACB only) which divides the common busbar in two parts.This helps in synchronizing operation of both the GGs.Also, it is not always needed to run both the GGs,in case of low demand of electric supply.So, in that case using this bus-coupler we can run all the loads connected to this panel using only a single GG.

Next,there are only two outgoings from this panel and both are going to next electric panel called the Duplex *Panel.*Let us study that.

3.5.2 Duplex Panel

This is the next important panel.This is important because it is the main panel which is feeding the supply to the other panels.

Supply from two sources is coming to the panel i.e. GGs and BSES(means power transformers).Gas Generators are feeding the Duplex panel with the help of GG Sync Panel and Transformers are feeding the Duplex panel with the help of Consumer HT Panel.

There are two parallel busbars, one for GGs and one for Transformers.Both the busbars are divided in two parts using bus-couplers.So,supply from GG1 and GG2 is going to each side of the Generator busbar(each side means,one side left to the bus-coupler and one to the right).Similarly, supply from TRF1 and TRF2 is going to both each side of the Transformer busbar.

Now to give supply from Duplex panel to the other panels, ATS are being used.One supply source to ATS is from GG and other is Transformer.GGs are the primary source of electricity and Transformers are emergency source of electricity for ATS.So, as soon as GGs are giving supply ATS will give the same in its output.But when GGs are not available the ATS will transfer the load to the Transformer supply.

So, to see all the loads connected to this panel refer to the LD(line diagram) attached.Before going to the panels connected to the Duplex panel,let us first discuss some other panels.

3.5.3 Consumer HT Panel

This is the panel where the 11 KV 3-phase supply from BSES is coming.In this panel this incoming supply is divided into two 11 KV 3-phase supply.Each of this two supply is then going into the TRF1 and TRF2 respectively.From the Transformers the supply steps down to 415V. Then two busbars are carrying the outgoings of the Transformers to the Duplex Panel.

3.5.4 DG Panel

After generation of 3-phase electric power in the alternators of DGs the supply goes into the DG sync panel with the help of a busbars.3-phase supply from both DG1 as well as DG2 is coming in this panel.These are called incomers to this panel.There are ACBs installed in both the incoming supply lines and the outgoing of ACBs is going to the common busbar installed inside the panel.

There is a bus-coupler(ACB only) which divides the common busbar in two parts.This helps in synchronizing operation of both the DGs.Also, it is not always needed to run both the DGs,in case of low demand of electric supply.So, in that case using this bus-coupler we can run all the loads connected to this panel using only a single DG.

With this we are done with all the panels where the supply from the main electricity sources is going directly.

Now, any other panel we will discuss have two incomers;one from the Duplex Panel and other from the DG panel.

- Main NLPP Wing-A(Normal Lighting and small Power Panel Wing-A)
- Main NLPP Wing-B(Normal Lighting and small Power Panel Wing-B)
- Miscellaneous Power Panel
- Main PAC power Panel
- Fire Emergency Panel
- HVAC Power Panel
- Data Center Panel

To know about the outgoings of these panels please refer to the line diagram of the complete power generation and distribution system.

With this we are done with this chapter.In next chapter we will look at two major applications of Electricity at the DUB i.e. HVAC system and Electric Lifts.

CHAPTER 4
HVAC SYSTEM & ELECTRIC ELEVATORS

In the previous chapters we have seen how the electricity is being produced and how it is delivered to the loads of the building.Now in this chapter we are going to look at two important applications of the electric power(at DUB).These are HVAC(Heating Ventilation and Air Conditioning) system & Electric Lifts.

These systems are providing a huge amount of service to the employees and other staff.HVAC system is basically to keep the building cool in Summer and warm in winter & Lifts we are all familiar with.Let us see how these systems are working.

4.1 HVAC(Heating Ventilation and Air Conditioning) System

HVAC stands for Heating, Ventilation, and Air Conditioning. It refers to the technology and systems used to provide comfortable and healthy indoor environments. HVAC systems are commonly used in residential, commercial, and industrial buildings to regulate and control temperature, humidity, and air quality.

Here's a breakdown of each component of an HVAC system:

- **Heating:** HVAC systems provide heating to maintain a comfortable temperature during colder periods. Common heating methods include furnaces, boilers, heat pumps, and electric heaters.

- **Ventilation:** Ventilation is the process of exchanging indoor and outdoor air to maintain air quality. It involves the removal of stale air, odors, and contaminants and the introduction of fresh air. Ventilation systems use fans, ductwork, and vents to distribute air throughout the building.

- **Air Conditioning:** Air conditioning is the process of cooling and dehumidifying indoor air. It helps maintain comfortable temperatures during hot weather. Air conditioning systems typically use refrigeration cycles and compressors to remove heat from indoor air and expel it outdoors.

- **Control Systems:** HVAC systems employ control systems to regulate and maintain desired conditions. These systems monitor and adjust temperature, humidity, and air distribution based on user settings and environmental conditions.

Now,let us first understand how *air conditioning* is done in the whole building.This process is done using a system called *Chiller.*Chiller is a device that does the job of providing chilled water as a medium to take heat from the desired room and make it cool.In next section we will see how this is done.

Before discussing about the chiller,let us first discuss about *Refrigeration Cycle.Refrigeration* cycle is the process of heat exchange in many stages.So, let us first discuss this.

4.1.1 Refrigeration Cycle

The refrigeration cycle is a thermodynamic cycle that is used in refrigeration and air conditioning systems to transfer heat from a cooler environment to a warmer environment. It involves the circulation of a refrigerant through various components, where it undergoes phase changes and absorbs and releases heat.

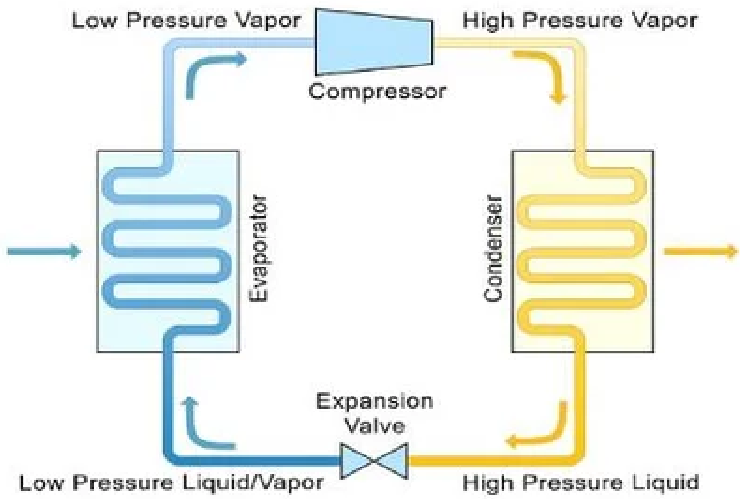
The basic components of a refrigeration cycle are as follows:

- **Evaporator:** The low-pressure refrigerant mixture from the expansion valve enters the evaporator, which is another heat exchanger. The evaporator is usually located in the space or area that needs to be cooled. As the warm air from the space flows over the evaporator coils, the refrigerant absorbs heat from the air, causing it to evaporate into a low-pressure vapor. This vapor is then drawn back into the compressor to start the cycle again.

- **Compressor:** The compressor is the heart of the refrigeration system. It is usually an electric motor-driven pump that increases the pressure and temperature of the refrigerant vapor. The compressor draws low-pressure refrigerant vapor from the evaporator and compresses it into a high-pressure, high-temperature vapor.

- **Condenser:** The high-pressure, high-temperature refrigerant vapor leaving the compressor flows into the condenser. The condenser is a heat exchanger that facilitates the transfer of heat from the refrigerant to the surrounding environment. In most cases, the condenser is cooled by air or water, which causes the refrigerant to condense into a high-pressure liquid.

- **Expansion Valve or Throttle Valve:** After leaving the condenser, the high-pressure liquid refrigerant passes through the expansion valve or throttle valve. This valve is a small opening or restriction in the refrigerant line that causes a drop in pressure and allows the refrigerant to expand rapidly. As a result, the refrigerant undergoes a phase change from a high-pressure liquid to a low-pressure mixture of liquid and vapor.



(Fig 4.1 Refrigeration Cycle)

Before going ahead let us discuss about refrigerant.

Refrigerant

A refrigerant is a substance or a mixture of substances used in refrigeration and air conditioning systems to transfer heat by undergoing phase changes. It is the working fluid that circulates through the various components of the refrigeration cycle, absorbing heat from a low-temperature environment and releasing it to a higher-temperature environment.

Refrigerants have specific thermodynamic properties that make them suitable for use in refrigeration systems. They should have a low boiling point and a high latent heat of vaporization, meaning they can easily change from a liquid to a vapor state and absorb a significant amount of heat during this phase change. They should also have good heat transfer properties and low viscosity to facilitate efficient heat transfer in the system.

Over the years, various refrigerants have been used in different refrigeration systems. In the past, commonly used refrigerants were chlorofluorocarbons (CFCs), such as Freon-12 (R-12), and hydrochlorofluorocarbons (HCFCs), such as R-22. However, these refrigerants have been found to have adverse effects on the ozone layer and contribute to global warming. As a result, international agreements, such as the Montreal Protocol, have led to the phase-out of these ozone-depleting substances.

Currently, the most common refrigerants used are hydrofluorocarbons (HFCs) and hydrofluoro-olefins (HFOs). Some examples include:

- **R-410A:** This is a widely used HFC refrigerant in air conditioning systems. It has good thermodynamic properties and does not harm the ozone layer. However, it has a high global warming potential (GWP).

- **R-134a:** Another HFC refrigerant commonly used in automotive air conditioning systems. It has a lower GWP compared to R-410A but is still considered a greenhouse gas.

- **R-32:** This is an HFC refrigerant with a lower GWP than R-410A. It is gaining popularity due to its lower environmental impact and improved energy efficiency.

- **R-1234yf:** An HFO refrigerant used as a replacement for R-134a in automotive air conditioning systems. It has a significantly lower GWP and is considered more environmentally friendly.

- **Ammonia (NH3):** Although not an HFC or HFO, ammonia is a natural refrigerant that has been used for many years in large industrial refrigeration systems. It has excellent thermodynamic properties and zero ozone depletion potential (ODP) and GWP. However, it is toxic and requires strict safety precautions.

The refrigerant used in the chiller at DUB is R-134a.

Now with this we are done with the refrigeration cycle.Now we will continue our discussion on Chiller.Let us study how exactly the chiller plant is working and what is its construction.

4.1.2 Chiller

A chiller is a refrigeration system that is specifically designed to cool large spaces or equipment by removing heat from the surroundings. It typically consists of several key components and operates based on the principles of the refrigeration cycle. Here is an overview of the construction and working of a typical chiller:

Construction of Chiller

- **Compressor:** The chiller contains a compressor, which is responsible for compressing the refrigerant vapor, raising its pressure and temperature.

- **Condenser:** After leaving the compressor, the high-pressure, high-temperature refrigerant vapor enters the condenser. The condenser is a heat exchanger that facilitates the transfer of heat from the refrigerant to the external environment (either air-cooled or water-cooled). As a result, the refrigerant condenses into a high-pressure liquid.

- **Expansion Valve:** The high-pressure liquid refrigerant then flows through the expansion valve, which is a small opening or restriction. This valve causes a drop in pressure and allows the refrigerant to expand rapidly, leading to a decrease in its temperature and pressure.

- **Evaporator:** The low-pressure liquid refrigerant from the expansion valve enters the evaporator, which is another heat exchanger. The evaporator is usually located in the space or area that needs to be cooled. As warm air from the space passes over the evaporator coils, the refrigerant absorbs heat from the air, evaporating into a low-pressure vapor. The cool air is then circulated back into space.

(Fig 4.2 Chiller Installed at DUB)

Working of Chiller

The working principle of a chiller follows the basic refrigeration cycle, which involves the transfer of heat from a lower-temperature environment (the evaporator) to a higher-temperature environment (the condenser). Here are the steps involved:

Refrigerant Compression: The compressor draws low-pressure refrigerant vapor from the evaporator and compresses it, raising its pressure and temperature. This process requires mechanical work and increases the energy of the refrigerant.

Heat Rejection: The high-pressure, high-temperature refrigerant vapor leaves the compressor and enters the condenser. In the condenser, the refrigerant transfers heat to the surrounding environment (either through air or water). As a result, the refrigerant condenses into a high-pressure liquid.

Expansion and Cooling: The high-pressure liquid refrigerant flows through the expansion valve, where its pressure drops suddenly. This causes the refrigerant to rapidly expand, reducing its temperature and pressure. The low-pressure liquid refrigerant then enters the evaporator.

- **Evaporator:** The evaporator contains the refrigerant in liquid form.And inside the evaporator there are copper tubes installed parallel to each other.Evaporator is basically a shell and tube structure(as we discussed in Heat Exchanger of the GGs).The copper tubes are immersed in the refrigerant.These copper tubes are carrying the normal water.This water is being circulated in the copper tubes and going to the coil of an AHU(Air handling Unit) and returning back.We will discuss about AHU later.

  This water circulation is maintained via electric pumps.There are two types of pumps i.e. primary and secondary.The secondary pumps are carrying the water from the evaporator to the AHU and primary pumps are carrying the water from the AHU to the evaporator.

  Now the refrigerant present in the evaporator is having very low temperature.Which cools down the water in the copper tubes.So this chilled water is going to the AHU's coil.A blower is passing the air through this coil of AHU(which is carrying chilled water),here air exchange its heat with this chilled water and thus air becomes cool and water becomes warm.Then the chilled air is supplied to the specified rooms of the building,and warm water is coming back to the evaporator to exchange its heat and again become chilled.When hot water returns to the evaporator,the refrigerant absorbs the heat from the hot water and changes its phase from liquid to low pressure vapor.This low pressure vapor refrigerant is then going to the next important part of the chiller called *Compressor*.

Before going further let us first discuss about AHU.

AHU(Air Handling Unit)

AHU stands for Air Handling Unit. It is an integral component of heating, ventilation, and air conditioning (HVAC) systems used to condition and distribute air within a building or a specific space. An AHU is responsible for handling the supply, filtration, cooling or heating, and distribution of air throughout the HVAC system.

The main components of an AHU typically include:

- **Blower:** The blower, also known as a fan, is responsible for drawing in air from the surrounding environment or the return air ducts and moving it through the AHU. It helps in creating the necessary airflow for conditioning and distributing air.

- **Filters:** Air handling units are equipped with filters to remove dust, particles, and contaminants from the incoming air. Filters improve indoor air quality by capturing pollutants and preventing them from entering the occupied space.

- **Heating and Cooling Coils:** AHUs may include both heating and cooling coils to condition the air to the desired temperature. Heating coils, typically using hot water or steam, warm up the air during colder seasons, while cooling coils, utilizing chilled water or refrigerant, cool down the air during warmer seasons.

- **Humidifier/Dehumidifier:** In some cases, an AHU may be equipped with a humidifier to add moisture to the air, or a dehumidifier to remove excess moisture, depending on the requirements of the space and the climate conditions.

- **Dampers:** Dampers are used to control and regulate the flow of air within the AHU. They can adjust the amount of outside air intake, mix the return air with fresh air, or control the airflow to different sections or zones of the building.

- **Control System:** AHUs are typically equipped with a control system that monitors and regulates various parameters, such as temperature, humidity, and air volume. The control system ensures that the AHU operates according to the desired setpoints and coordinates with other components of the HVAC system.

The working of an AHU involves the following steps:

- **Air Intake:** The AHU draws in air from the outside environment through outdoor air intakes or from the return air ducts connected to the occupied space.

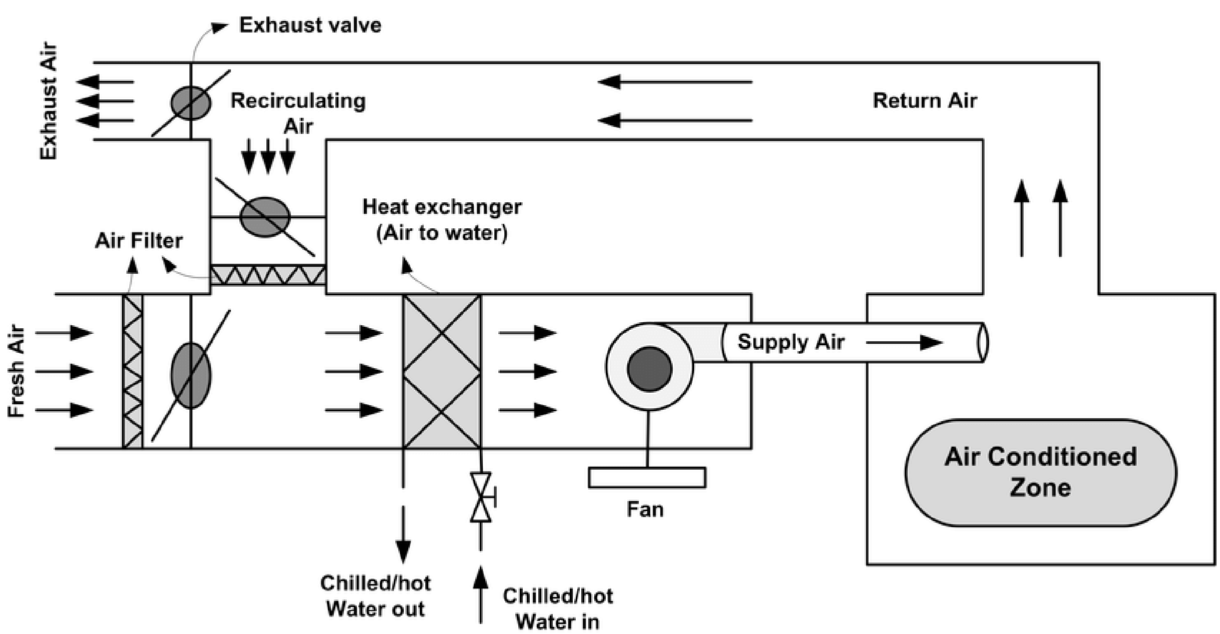
- **Filtration:** The incoming air passes through filters within the AHU, removing dust, pollutants, and other airborne particles, improving air quality.

- **Conditioning:** The air passes through the heating and cooling coils, where it is either heated or cooled to achieve the desired temperature setpoint.

- **Humidification/Dehumidification:** If required, the AHU may introduce moisture or remove excess moisture from the air to maintain the desired humidity level.

- **Mixing and Distribution:** The conditioned air is mixed with the return air or fresh air, depending on the requirements, and is then distributed through ductwork to the various areas or zones of the building.

- **Exhaust:** In some cases, an AHU may include an exhaust system to remove stale or contaminated air from specific areas, such as restrooms or kitchens.



(Fig 4.3 Block Diagram of AHU)

- **Compressor:**Low pressure vapor from evaporator enters into the compressor.This compresses the low pressure vapor refrigerant into very high pressure high temperature vapor.Then this high pressure high temperature vapors are entering into the *condenser* unit of the chiller.

- **Condenser:**Condenser is the another important unit of the chiller.When high temperature high pressure vapor of the refrigerant enters into the condenser,it comes in the contact of the low temperature water(which is flowing inside the copper tubes).Condenser is also a shell and tube type structure.Copper tubes are there inside which the cool water is flowing and in the shell, high pressure high temperature vapor refrigerant is flowing.Here,the heat exchange takes place between high temperature refrigerant and low temperature water.This heat exchange takes place without change in temperature but then question rises,where extra heat goes.This heat released by the refrigerant is utilized in phase change.This is called latent heat.

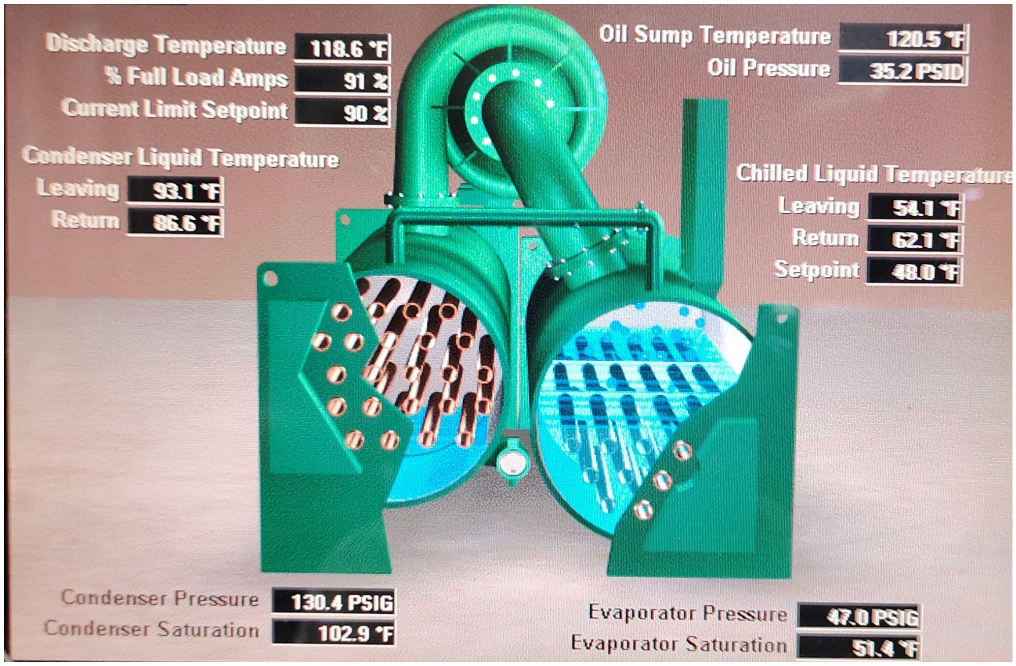
  Latent heat refers to the heat energy absorbed or released by a substance during a phase change without a change in temperature. It is the energy required to change the state of a substance from one phase to another, such as from a solid to a liquid (melting) or from a liquid to a gas (vaporization).

  When a substance undergoes a phase change, the energy supplied or released is used to break or form intermolecular bonds between its particles rather than to raise or lower the temperature of the substance. This is why there is no change in temperature during the phase transition.

  When The heat exchange takes place, high temperature high pressure vapor refrigerant releases its heat and changes its phase to liquid.And water absorbs this heat and becomes hot.Then this water is going to the *Cooling Towers* to be cooled.Thus the circulation of water from condenser to the the cooling towers is maintained by the CT pumps.

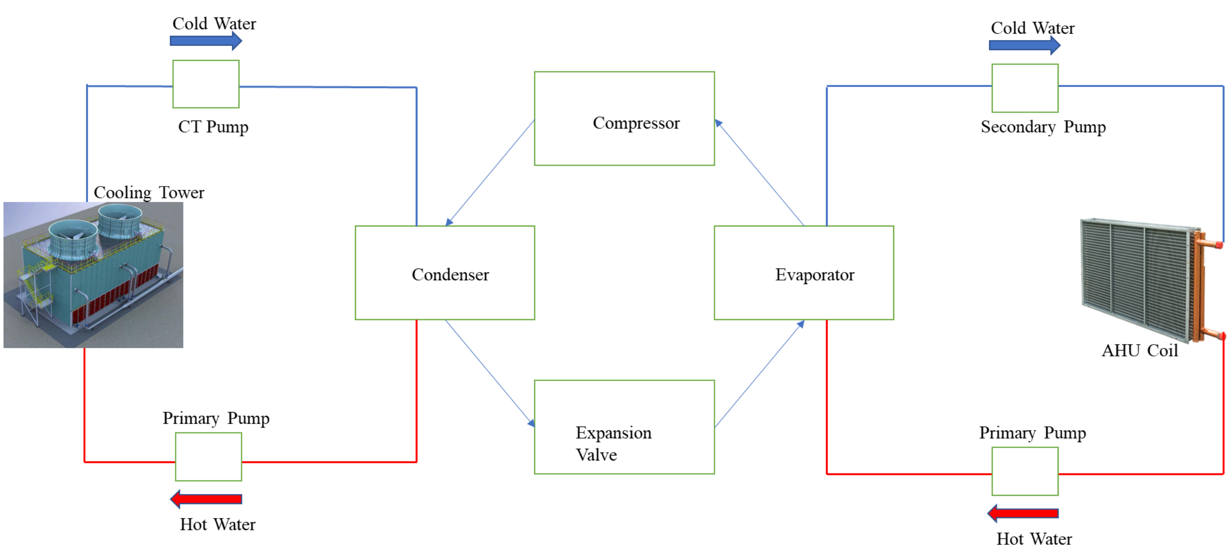
  Note:We have already learnt about the cooling towers in detail in the GGs section.Just the difference is in each cooling tower there are *two CT fans*.

- **Expansion Valve:**This is a very important part of the chiller.After changing the phase to liquid in the condenser unit,refrigerant enters into the expansion valve.This does the job of expanding the liquid refrigerant and reducing its pressure to great extent.As,the pressure drops the temperature also drops.In this process the temperature of refrigerant goes to -20 degree celsius.This is the main part that contributes into the cooling process of the the chiller.



(Fig 4.4 Chiller from Inside)

With this we are done with all the components of the chiller.Now let us visualize this via the help of a diagram to summarize all the things.



(Fig 4.5 Working of Chiller Plant)

With this we are done with the air conditioning(Chiller Plant),now we will discuss the Boiler(i.e. for heating purposes in winter weather).Let us discuss the Boiler unit.

4.1.3 Boiler(Hot Water Generator)

A boiler is an essential component of an HVAC system that is responsible for heating. It is commonly used for space heating in residential, commercial, and industrial applications. The boiler's construction and working principle can vary depending on the type and design of the boiler, but I'll provide a general overview.

Boiler is also having the similar task as chiller.It is heating the water and this hot water is then passed through the coil of same AHU in which the cold water was flowing(from chiller).And the blower will pass the air through this coil and then the air will become hot,hence the temperature of the building rises.

Construction of a Boiler

- **Shell:** The boiler's outermost layer is a sturdy metal shell that encloses all the internal components. It provides structural support and protects the boiler from external damage.

- **Burner:** The burner is responsible for mixing fuel (commonly natural gas, oil, or biomass) with air and igniting it to generate heat. It is located at the bottom of the boiler and is connected to a fuel source.

- **Combustion Chamber:** The combustion chamber is where the fuel-air mixture is ignited and combustion occurs. It is designed to provide a controlled environment for efficient combustion.

- **Heat Exchanger:** The heat exchanger is a crucial part of the boiler. It consists of metal tubes or pipes that carry the heated water or steam. The heat from combustion gasses is transferred to the water or steam in the heat exchanger.

- **Controls:** Boilers have various controls to monitor and regulate the operation of the system. This includes temperature sensors, pressure sensors, safety valves, and control panels.

Working of a Boiler

- **Combustion**: The fuel is delivered to the burner, where it mixes with air and is ignited to produce a controlled flame. The combustion process generates hot combustion gasses.

- **Heat Transfer:** The hot combustion gasses flow through the combustion chamber and come into direct contact with the heat exchanger. Heat is transferred from the gasses to the water or steam inside the heat exchanger, raising its temperature.

- **Distribution:** The hot water or steam produced in the heat exchanger is then circulated through pipes to the desired locations for space heating. In hydronic systems, water is circulated through radiators, baseboard heaters, or underfloor heating systems. In steam systems, steam is distributed to radiators or other heat emitters.

(Fig 4.6 Hot Water Generator(Boiler))

The above explained is the general working of the Boiler.Let us discuss the working of the boiler installed here at DUB.

Actually here alone the boiler is not used for heating purposes.There are heat recovery systems used,so that waste heat from other sources can be used for the heating purposes.Let us see these heat recovery units one by one.

Heat Exchanger

This is the device which is using the exhaust gas of GGs which is around 400 to 500 degree celcius hot.This exhaust gas is passed through this heat exchanger and also the water is passed through this heat exchanger.Here heat exchange takes place and water becomes very hot.

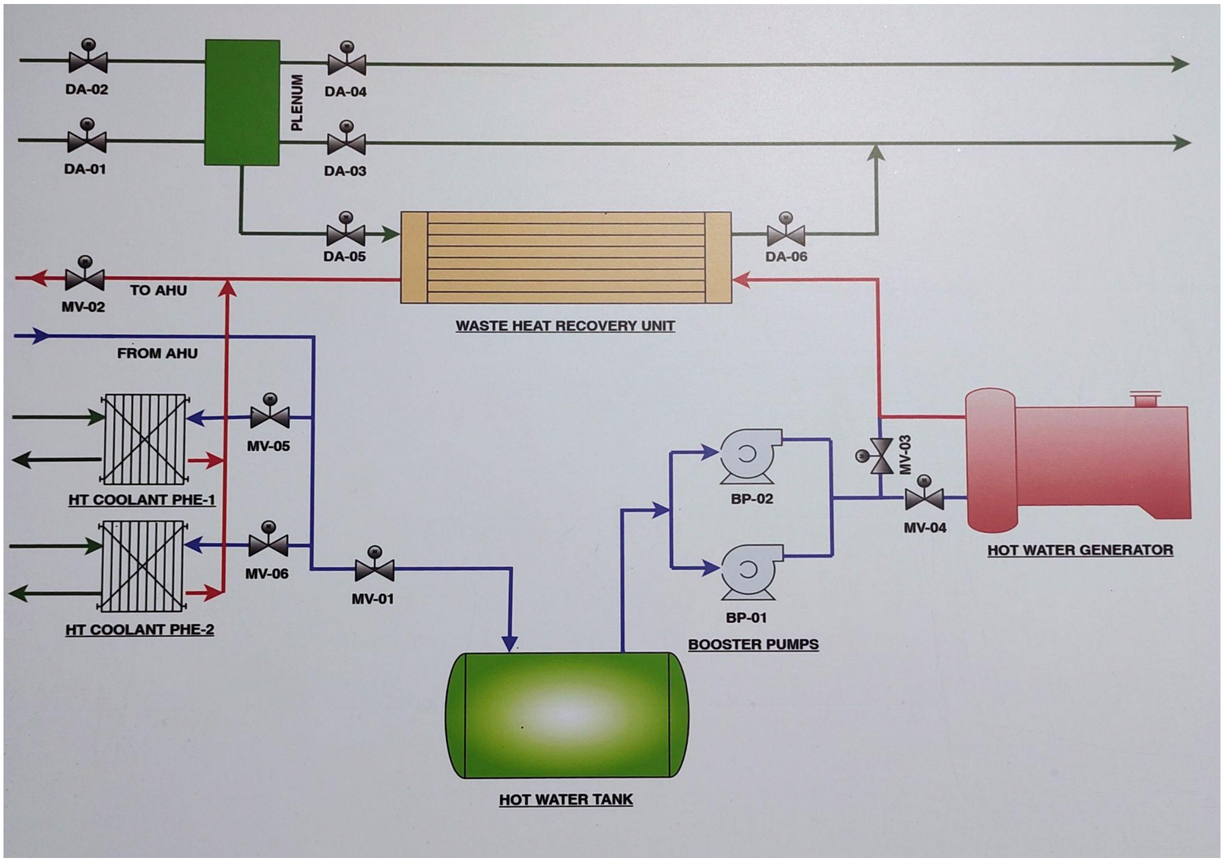
So,instead of releasing the exhaust gas directly to the environment, we are first using it to heat the water and then releasing it in the environment.

(Fig 4.7 Heat Exchanger)

PHEs(Plate Heat Exchanger)

PHE is another energy saving method,to heat the water.Actually,when GGs are in running condition,a lot of heat is generated and this heat is released to the environment using heat exchanger and cooling towers.The coolant being circulated in PHEs is taking out the heat from the GGs and this hot coolant is then used to heat up the water.

Let us study the whole process using the block diagram:



(Fig 4.8 Working of Boiler Unit)

With this we are done with our HVAC system.Now we will move to the next application i.e. *electric lifts*.

4.2 Electric Lifts

Electric lifts, also known as electric elevators or electric hoists, are vertical transportation systems that use electrical power to move people or goods between different levels of a building. They are commonly found in buildings with multiple floors and are designed to provide efficient and convenient vertical transportation.

Construction of Electric Lifts

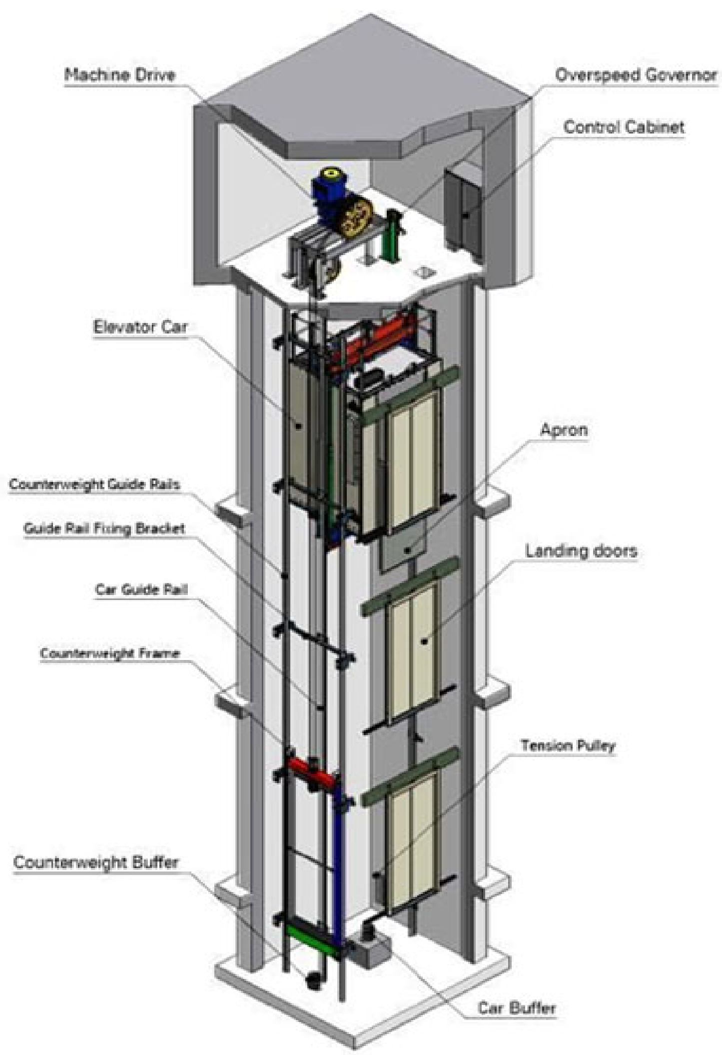
- **Carriage or Cabin:** The carriage is the enclosed space where passengers or goods are transported. It is equipped with doors for entry and exit.

- **Hoistway or Shaft:** The hoistway is a vertical shaft or well that serves as the pathway for the carriage to move up and down. It is constructed with sturdy materials such as steel or concrete to ensure structural integrity.

- **Guide Rails:** The guide rails are installed vertically within the hoistway and provide guidance for the carriage, ensuring smooth and safe movement. The carriage is equipped with rollers or shoes that run along the guide rails.

- **Electric Motor:** The electric motor is the primary power source of the lift system. It drives a traction system or a hydraulic system to move the carriage. The motor is typically located at the top of the hoistway or in a machine room adjacent to the shaft.

- **Control System:** The control system includes electrical and electronic components that regulate the operation of the lift. It consists of buttons or panels inside the cabin and on each floor to select the desired destination, and safety features such as limit switches, sensors, and emergency stop buttons.



(Fig 4.9 Construction of Electric Elevators)

Working of Electric Lifts

- **Cabin Call:** A user inside the cabin or on a particular floor presses the desired floor button to call the lift.

- **Signal Reception:** The control system receives the signal and determines the appropriate response based on the current position and direction of the lift.

- **Motor Activation:** The electric motor is activated, and its power is transmitted to the drive system.

- **Traction System:** In a traction system, the motor rotates a sheave or pulley connected to a counterweight and a set of steel ropes or belts. The ropes are attached to the carriage, and as the motor turns the sheave, the carriage moves up or down along the guide rails.

- **Hydraulic System:** In a hydraulic system, the motor drives a pump, which pushes hydraulic fluid into a cylinder. The pressure created by the fluid moves a piston, which in turn lifts or lowers the carriage.

- **Leveling and Door Operation:** Once the carriage reaches the desired floor, the control system ensures that it stops accurately, aligning the cabin floor with the floor of the building. The doors open, allowing passengers to enter or exit.

Electric Supply for motor of the lift

- **Power Source:** The power source for the electric lift is typically the building's electrical grid. The grid is connected to the main power supply, which could be a local power station or a regional electrical distribution network.

- **Electrical Distribution:** Electricity from the power source is distributed throughout the building via electrical distribution panels and wiring. These panels ensure that the required voltage and current reach various parts of the building, including the lift system.

- **Main Disconnect Switch:** At the lift's location, there is a main disconnect switch that acts as a safety measure. This switch allows the entire lift system to be disconnected from the power supply for maintenance or in case of emergencies.

- **Machine Room or Top of Hoistway:** In traditional lift setups, the electric motor is located either in a dedicated machine room adjacent to the hoistway or at the top of the hoistway itself. The motor is typically an AC induction motor or a gearless permanent magnet synchronous motor.

- **Motor Control:** The motor is controlled by a motor controller or motor drive, which is part of the control system. The motor controller receives signals from the control panel and adjusts the motor's speed and direction accordingly. It converts the electrical energy from the power supply to mechanical energy for the movement of the lift.

- **Control Panel:** The control panel is typically located in the machine room or a designated control room. It houses the electrical and electronic components necessary for the operation of the lift system. The control panel includes:

  Control Circuitry: This circuitry consists of relays, contactors, and other control devices that receive signals from the cabin and floor buttons to initiate the lift's movement. They coordinate the motor, brakes, and other components.

  Control Logic: The control logic determines the lift's behavior based on the received signals. It manages tasks such as floor selection, car dispatching, and safety protocols. The control logic ensures that the lift operates efficiently, stops accurately at each floor, and responds to user inputs.

  Safety Devices: The control panel integrates various safety devices, such as limit switches, door interlocks, and emergency stop buttons. These devices ensure the safety of passengers and prevent accidents by monitoring the lift's position, detecting obstructions, and initiating emergency procedures if necessary.

- **Power Distribution to the Motor:** Electrical power is distributed from the control panel to the motor through power cables or conductors. These cables transmit the required voltage and current to the motor, enabling its operation. The motor controller regulates the power flow to control the lift's speed and direction.

Elevators are equipped with various safety systems to ensure the well-being of passengers and prevent accidents. Here are some of the key safety systems commonly found in modern elevator installations:

- **Overspeed Governor:** The overspeed governor is a critical safety device that prevents the elevator from descending at excessive speeds. It consists of a centrifugal mechanism that detects overspeed conditions and activates the safety brakes to bring the elevator to a controlled stop.

- **Safety Brakes:** Safety brakes are designed to stop the elevator car in the event of an overspeed or a malfunction. They are typically installed on the elevator's drive system and engage when triggered by the overspeed governor or other safety devices.

- **Car Buffer:** As mentioned earlier, the car buffer is a cushioning device installed at the bottom of the elevator shaft. It absorbs the kinetic energy generated during an impact or sudden stop, preventing the elevator car from crashing into the pit at high speeds.

- **Door Sensors:** Elevator doors are equipped with various sensors to detect obstructions and prevent them from closing on passengers or objects. These sensors may use infrared beams, pressure-sensitive edges, or motion detectors to ensure safe operation and avoid entrapment.

- **Emergency Stop Button:** An emergency stop button is located inside the elevator car, allowing passengers to halt the elevator in case of an emergency. When pressed, it immediately stops the elevator and opens the doors to provide a safe exit.

- **Fire Service Operation:** Elevators often have a dedicated fire service mode that allows firefighters to control the elevator during emergency situations. This mode overrides normal operation, enables firefighter-controlled access, and ensures proper evacuation procedures.

- **Backup Power System:** In the event of a power outage, elevators are equipped with backup power systems, such as uninterruptible power supplies (UPS) or emergency generators. These systems ensure that elevators can operate temporarily and allow passengers to safely exit the car.

- **Intercom or Emergency Communication:** Elevators are typically equipped with an intercom or emergency communication system that enables passengers to communicate with building personnel or emergency services in case of an emergency or entrapment.

- **Light Curtain:** A light curtain is a safety feature installed in the elevator doorway. It uses infrared beams to create an invisible barrier across the entrance, ensuring that the doors do not close on passengers or objects that are partially or fully in the doorway.

- **Load Weighing System:** A load weighing system measures the weight of passengers and cargo inside the elevator car. This system ensures that the elevator operates within its designated weight capacity and prevents overloading, which could lead to malfunctions or unsafe conditions.

With this we are done with the electric elevators.With this we have completed this chapter.

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