PROJECT REPORT-
SUMMER TRAINING
PROGRAM
ELECTRICAL SECTION
ONGC

33KV SUBSTATION AND AUTOMATIC POWER FACTOR CONTROLLER

Image Source:- TLT Photography

SUBMITTED BY:
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INDEX

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OIL AND NATURAL GAS CORPORATION (ONGC)

Oil and Natural Gas Corporation Limited (ONGC) was incorporated on June 23, 1993. It is an Indian public sector petroleum company. It is a Fortune Global 500 Company ranked 335th and contributes 77% of India’s crude oil production and 81% of India’s natural gas production.
The Oil and Natural Gas Corporation (ONGC) has demonstrated that it is India's most dependable energy solution supplier. With 330 oil and gas discoveries, ONGC has discovered six out of India's seven producing basins and established more than 6 billion tonnes of in-place hydrocarbon reserves in domestic basins. ONGC is India's largest transnational firm, with a presence in 24 countries and a commitment to international investment. In 2007, ONGC Videsh Limited (OVL), the company's fully owned subsidiary, sourced more than six million tonnes of equity oil and oil equivalent gas. It was identified as the largest profit-making PSU in India in a survey conducted by the Government of India for the fiscal year 2019–20. Platts ranks it seventh among the Top 250 Global Energy Companies. In March 2003, the Corporation bought a controlling share in Mangalore Refinery and Petrochemicals Limited (MRPL) and transformed it into India's finest refinery in terms of tonnes of capacity used and energy efficiency. For its production and drilling facilities, ONGC is putting in place an enterprise-wide supervisory control and data acquisition (SCADA) system. As one of India's eight key industries, the oil and gas industry has a significant impact on how other major sectors of the economy make decisions.

Source:- Marketfeed.news

The need for oil and gas is expected to increase in the coming years, making the industry very attractive to investors. The Indian government has implemented a number of initiatives in order to meet the rising demand. Many areas of the economy, including natural gas, petroleum products, and refineries, have been granted 100% Foreign Direct Investment (FDI) by the government.

HISTORY OF ONGC

1947 – 1960

The only oil firms producing oil in undivided India prior to independence were the Assam Oil Company in the north-east and the Attock Oil Company in the north-west. The majority of Indian sedimentary basins were judged unsuitable for oil and gas production. the government understood the necessity of oil and gas for fast economic growth and its strategic role in defense after independence. As a result, when the Industrial Policy Statement of 1948 was drafted, the growth of the country's hydrocarbon sector was deemed critical.
As part of Public Sector Development, the Government of India decided in 1955 to exploit oil and natural gas resources in various parts of the nation. In 1955, the Ministry of Natural Resources and Scientific Research established an Oil and Natural Gas Directorate with this goal in mind. The department was founded by a group of geoscientists from India's Geological Survey.

Mr. K D Malviya, the then Minister of Natural Resources, led a team to different nations to study the oil business and enable the training of Indian specialists to explore prospective oil and gas reserves. Foreign specialists from the United States, West Germany, Romania, and the former Soviet Union visited India and provided assistance to the administration. Finally, the visiting Soviet specialists put out a detailed plan for the 2ndFive Year Plan's geological and geophysical surveys and drilling activities (1956-57 to 1960-61).
The Government of India passed the Industrial Policy Resolution in April 1956, which classified the mineral oil sector as a Schedule "A" industry, with the state's exclusive and exclusive responsibility for its future growth.

Soon after the Oil and Natural Gas Directorate was established, it became clear that the Directorate's limited financial and administrative capabilities would make it impossible for it to perform effectively. As a result, the Directorate was elevated to the status of a commission with expanded powers in August 1956, although remaining under the control of the government. An act of Parliament transformed the Commission into a statutory entity in October 1959, enhancing the commission's powers even more. The Oil and Natural Gas Commission's main responsibilities, as defined by the Act, were to "plan, promote, organize, and implement programmes for the development of petroleum resources, as well as the production and sale of petroleum and petroleum products produced by it, and to perform such other functions as the Central Government may from time to time assign to it." The statute also defined the actions and measures that ONGC must follow to accomplish its purpose.

1961 – 1990

Since its inception, ONGC has been changing India's perception of oil and gas by converting the country's restricted upstream capabilities into a vast viable playing field. Since 1959, ONGC has had a presence in almost every area of India as well as in other territories. In Assam, ONGC discovered fresh resources and formed a new oil province in the Cambay basin (Gujarat).

With the discovery of Bombay High (now known as Mumbai High) in 1970, ONGC moved its operations offshore. This finding, together with the later discovery of massive oil resources in the Western offshore, resulted in the discovery of a total of 5 billion tonnes of hydrocarbon in the nation. However, ONGC's most significant achievement is its self-sufficiency and development of core competency in exploration and production activities at a worldwide competitive level.

Post-1990

Off the coast of Mumbai, ONGC's HAL Dhruv chopper began operations. Following the implementation of economic policy liberalization after 1990, partial disinvestments of government equity in Public Sector Undertakings were sought. As a consequence, ONGC was reorganized as a limited company, and 2 percent of shares were disinvested through competitive bidding after the business of the former Oil and Natural Gas Commission was converted to that of Oil and Natural Gas Corporation Ltd in 1993. Employees of ONGC were given 2% of the company's stock in exchange for their services. Another significant step forward was achieved in March 1999, when ONGC, Indian Oil Corporation (IOC), and Gas Authority of India Ltd. (GAIL) agreed to have cross-holdings in each other's shares (Project Report 9). As a result, the government sold 10 percent of its ONGC stock to IOC and 2.5 percent to Gail. As a result, the government's stake in ONGC has decreased to 84.11 percent. Mangalore Refinery and Petrochemicals Ltd were acquired by ONGC in 2002-03.

Talisman Energy's 25 percent share in the Greater Nile Oil project was purchased by ONGC Videsh Limited (OVL), ONGC's international asset business, in 2003.
ONGC found a huge oil field in the Persian Gulf off the coast of Iran in 2009, with up to 1 billion barrels of heavy crude reserves. ONGC has also agreed to invest $3 billion in Iran to collect 1.1 billion cubic feet of natural gas from the Farzad B gas field.

ONGC sought a 2000-acre piece of land in Dahan in 2011 to handle offshore gas. In 2012, ONGC Videsh participated in deep-sea drilling off the northern coast of Cuba alongside Statoil ASA (Norway) and Repsol SA (Spain). On August 11, 2012, ONGC reported that it has discovered a significant oil find in the D1 oilfield off India's west coast, which will allow it to increase the field's output from about 12,500 to 60,000 barrels per day (BPD).

OVL agreed to buy Conoco Phillips' 8.4% interest in the Kashagan oilfield in Kazakhstan for about $5 billion in November 2012, making it ONGC's biggest acquisition to date. The acquisition is contingent on the permission of the governments of Kazakhstan and India, as well as the waiver of pre-emption rights by other Caspian Sea partners.

Source: ONGC-India

MISSION AND VISION OF ONGC

To be the global leader in integrated energy business through sustainable growth, knowledge excellence, and exemplary governance practices.

World Class

- Dedicated to excellence by leveraging competitive advantages in R&D and technology with involved people.
- Imbibe high standards of business ethics and organizational values.
- Abiding commitment to safety, health, and environment to enrich the quality of community life.
- Foster a culture of trust, openness, and mutual concern to make working a stimulating and challenging experience for our people.
- Strive for customer delight through quality products and services.

Integrated in Energy Business

- Focus on domestic and international oil and gas exploration and production business opportunities.
- Provide value linkages in other sectors of the energy business.
- Create growth opportunities and maximize shareholder value.

Dominant Indian Leadership

Retain a dominant position in the Indian petroleum sector and enhance India's energy availability.

OBJECTIVES OF ONGC

- To develop and sustain core values.
- To develop business leaders for tomorrow.
- To provide job contentment through empowerment, accountability, and responsibility.
- To build and upgrade competencies through virtual learning, opportunities for growth, and providing challenges in the job.
- To foster a climate of creativity, innovation, and enthusiasm.
- To enhance the quality of life of employees and their families.
- To inculcate a high understanding of ‘Service’ to a greater cause

GLOBAL RANKING

Oil and Natural Gas Corporation Limited (ONGC) has moved 37 spots to 160th place on the 2019 Fortune Worldwide 500 list, demonstrating its growing global reach. The energy maharana was ranked 197 on Fortune's list last year. This is ONGC's highest Fortune rating to date. After Reliance Industries Limited (RIL) and Indian Oil Corporation, ONGC is rated third in the Indian Fortune club (IOC).

ONGC's overall income for the year is $61420.40, a significant rise of 19.9% over the previous year. It is noteworthy for an upstream energy firm like ONGC to have grown its turnover by 19.9% compared to 17.7% for downstream energy company IOC, resulting in a revenue increase from $65.9 billion to $77.6 billion.

ONGC's global rating has improved across a variety of platforms. ONGC was number 220 on the Forbes Global 2000 list in 2019, with a total market capitalization of $29.6 billion.
ONGC was ranked #1 in the world in the category "Oil and Gas Exploration and Production" in the PLATTS 250 ranking for 2018. In 2018, it was ranked 21st overall in the PLATTS 250 Global Companies rating.

ACHIEVEMENTS OF ONGC

- ONGC has been ranked at 198 by the Forbes Magazine in their Forbes Global 200 list for the year 2007.
- ONGC has featured in the 2008 list of Fortune Global 500 companies at position 335.
- ONGC is ranked as Asia’s best Oil and Gas Company, as per a recent survey conducted by US-based magazine Global Finance.
- 2nd biggest E&P company, as per the Platts Energy Business Technology (EBT) Surveys 2004.
- Ranks 24th among Global Energy Companies by Market Capitalization in PFC Energy 50 (December 2004).
- Economic Times 500, Business Today 500, Business Baron 500, and Business Week Recognizes ONGC as the most valuable Indian Corporate, by Market Capitalization, Net worth, and Net Profits.
- It was conferred with 'Maharatna' status by the Government of India in November 2010. The Maharatna status to select PSUs allows more freedom in decision-making.
- In 2011, ONGC was ranked 39th among the world's 105 largest listed companies in 'transparency in corporate reporting' by Transparency International making it the most transparent company in India.
- In April 2013, it was ranked at 155th place in the Forbes Global 2000 for 2012.
- ONGC was ranked as the Most Attractive Employer in the Energy sector in India, in the Randstad Awards 2013.
- ONGC received the ‘Golden Peacock Award 2013’ for its HSE practices.
- In February 2014, FICCI conferred it with Best Company Promoting Sports Award.
- In May 2014, ONGC was accorded with FORTUNE World's Most Admired Company.
- In June 2014, ONGC was ranked 217th in the world and 3rd in India in the Newsweek Green Ranking, the world’s most recognized assessment of corporate environmental performance.

ONGC TODAY

- The only Indian company in Fortune Magazine's list of the World's Most Admired Companies for 2007 is ONGC. ONGC is ranked 9th in the mining industry for crude oil output.
- In the prestigious Forbes Global 2000, ONGC is ranked 239th overall and No. 1 among Indian companies.
- ONGC Videsh Limited (OVL), the company's abroad subsidiary, has projects in Vietnam, Russia, Sudan, Iraq, Iran, Libya, Myanmar, Syria, Qatar, Egypt, Cuba, Sao Tome & Principe, Brazil, Nigeria, and Columbia. OVL is currently involved in 29 E&P projects in 15 countries. OVL is the operator in 14 of the existing 29 projects and the joint operator in two others in nine countries.
- ONGC had the largest net profit of any Indian business, at Rs. 156.429 billion. In the 2006-07 financial year, it had a net value of Rs. 614 billion. In the same time span, it has contributed about Rs. 286 billion to the exchequer.
- ONGC presently has a committed staff of over 40,000 experts working for it.
- Through a partnership with SAP AG, ONGC has one of the largest ERP deployments in Asia.
- Today, ONGC employs one of the world's Top Ten Virtual Reality Interpretation facilities.

Fig. ONGC in Vietnam Source:- Business standards

SOME FACTS ABOUT ONGC

ONGC India (Oil and Natural Gas Corporation Limited) is Asia's greatest oil and gas company. According to the Platts Energy Business Technology (EBT) Survey 2004, it is the second-largest E&P firm (and first in terms of profitability). In the PFC Energy 50, it is ranked 24th among global energy companies by market capitalization (December 2004). Up till March 2004, ONGC was rated 17th. Previously, the stock values had decreased little due to external factors.

Activities

Everyone at ONGC India is responsible for safeguarding the environment, our people's health, and the safety of our communities throughout the world. Our dedication to excellence is ingrained in everything we do, and finding a cost-effective solution is critical to our long-term success.

ONGC's commitment to environmental and safety concerns is exemplified by the fact that a distinct institute, the Institute of Petroleum Safety, Health, and Environment Management (IPSHEM), was established in 1989 to address these challenges. The safety policy of Oil and Natural Gas Corporation Limited (ONGC) aims to ensure safe and healthy working conditions while enlisting the active participation of all employees. ONGC's development efforts are based on strong environmental principles and include necessary environmental protections.

ONGC Represents India's Energy Security:

ONGC has composed India's hydrocarbon tale on its own, using the following methods:

- ONGC has built 6 billion tonnes of in-place hydrocarbon reserves with more than 300 oil and gas finds; in fact, ONGC has discovered 5 of the 6 producing basins: out of these in-place hydrocarbons Ultimate Reserves are 2.1 billion metric tonnes (BMT) of oil plus equivalent gas (O+OEG) on domestic acreage.
- From 115 fields, the company has produced 685 million metric tonnes (MMT) of oil and 375 billion cubic meters (BCM) of natural gas.

INSTITUTES OF ONGC

In the oil and gas industry, as well as other connected industries, ONGC undertakes institutional research and development. Separate institutions have been formed to carry out particular operations in important areas like exploration, drilling, reservoir management, production technology, ocean engineering, safety, and environmental protection. These institutes are organized into nine R&D centers that are all run independently. ONGC's exploration and production activities are supported by R&D institutes with highly experienced and trained people.

1. Keshav Dev Malviya Institute of Petroleum Exploration (KDMIPE), Dehradun.
2. Institute of Drilling Technology (IDT), Dehradun.
3. ONGC Academy, Dehradun.
4. Institute of Reservoir Studies (IRS), Ahmedabad.
5. Institute of Oil and Gas Production Technology (IOGPT), Mumbai.
6. Institute of Engineering and Ocean Technology (IEOT), Mumbai.
7. Institute of Petroleum and Safety Environment Management (IPSEM), Margao.
8. Institute of Bio-Technology and Geotectonic, Guwahati.

SUBSTATIONS

A substation is a component of an electrical transmission, distribution, and generating system. Substations change the voltage from high to low or vice versa, as well as conduct a variety of other vital tasks. Electric power may pass via numerous substations at varying voltage levels between the producing station and the customer. Transformers may be used in a substation to change voltage levels between high transmission voltages and lower distribution voltages, or to link two transmission voltages. An electrical utility may own and run a substation, or a big industrial or commercial client may own and operate one. Substations are often unattended, relying on SCADA for remote monitoring and control.

STEP DOWN TRANSFORMERS:-

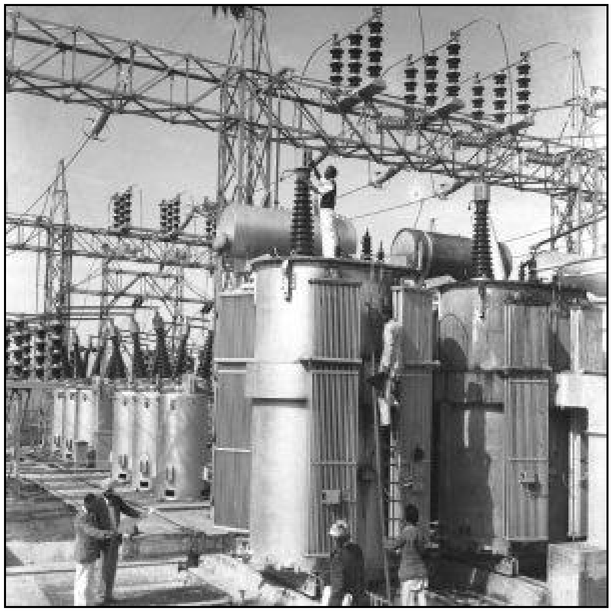
The transformer is a device that transmits electrical energy from one circuit to another via a magnetic field medium with no frequency change. The transformer's primary and secondary are magnetically linked. In a step-down transformer, the primary has more windings than the secondary, resulting in a lower secondary voltage than the primary voltage. Because there are no moving components, this system is very efficient and requires very little maintenance and monitoring. Windings are constructed around a central laminated core of the transformer. Fins, radiators, a conservator, and a silica gel breather are included in this tank.

Source:- MISTRAS Group

TYPES OF SUBSTATIONS:

The substations may be classified in numerous ways, such as by nature of duties, service rendered operating voltage, importance, and design.

Step-up or Primary Substations:- This sort of substation receives its power from a nearby power plant. It makes use of a huge power transformer to boost the voltage level for transmission much farther places. A transmission bus to transmission lines can be used to transmit power in this substation. This substation may potentially cause a disruption in the incoming power to the generating facility. The received electricity can be used to deliver power to the plant's operating machinery. Circuit breakers for switch generation, as well as transmission circuits in and out of operation, are included in a substation.



Step-up substation, Source:- elprocus.com

Primary Grid Substations:- The value of primary stepped-up voltages is reduced by this substation. The principal grid substation's output serves as the subsidiary substations' input. The secondary substation is used to scale down the input voltage so that it may be sent at a lower voltage.

Distribution Substation:- A distribution substation is a device that transmits power from an area's transmission system to its distribution system. Because connecting energy customers directly to the main transmission network are uneconomical unless they use a lot of power, the distribution station lowers the voltage to a level acceptable for local distribution. A distribution substation's input usually consists of at least two transmission or sub-transmission lines. The input voltage might be 115 kV or whatever is available in the location. A variety of feeders are produced as a result of the output. Depending on the size of the region serviced and the practices of the local utility, distribution voltages are generally medium voltage, ranging from 2.4 kV to 33 kV. The feeders go above (or below in certain circumstances) and supply power to the distribution transformers at or near the customer's location.

Transformer Substations:- Transformers are placed in these types of substations to convert power from one voltage level to another as needed.

Converter Substations:- Substations may be associated with HVDC converter plants, traction current, or interconnected non-synchronous networks. These stations have power electronic equipment that can modify the frequency of the current or convert it from alternating to direct current or the other way around. Rotary converters used to alter frequency to link two systems; such substations are now uncommon.

Switching Substations: A switching substation is one that has no transformers and solely operates at one voltage level. Collector and distribution stations are occasionally employed in switching substations. In the event of a failure, they are sometimes utilized to divert current to backup lines or to parallelize circuits.

Collector Substation:- A collector substation may be required for dispersed generating installations like as wind farms. Although power flows in the other direction, from several wind turbines up into the transmission grid, it looks like a distribution substation.
The collector system is typically operated at 35 KV for construction cost savings, and the collector substation steps up voltage to a grid transmission voltage. If required, the collector substation can additionally provide power factor adjustment, metering, and wind farm control. A collector substation can also house an HVDC converter station in specific circumstances.

Transmission Substation:- The main aim of a transmission substation is to link multiple transmission lines. The simplest situation is when the voltage on all transmission lines is the same. In such instances, the substation is equipped with high-voltage switches that allow lines to be connected or disconnected for maintenance purposes.
Transmission substations are available in a variety of configurations, from simple to sophisticated. A small switching station' might consist of little more than a bus and a few circuit breakers. With numerous voltage levels and a huge number of sensing and control equipment, the biggest transmission substations may span a vast area (several acres/hectares) (capacitors, relays, switches, breakers, voltage, and current transformers).

Mobile substation:- A mobile substation is a transportable substation with a transformer, breakers, and buswork installed on a self-contained semi-trailer that can be pulled by a vehicle. They are small enough to drive on public highways and are employed as a backup in the event of a natural disaster or conflict. Mobile substations are often rated far lower than permanent substations, and they can be built in many pieces to accommodate road traffic restrictions.

Pole Mounted Substations:- Substations of this type are built to distribute power across the community. For transformers with capacities of up to 25 KVA, 125 KVA, and over 125 KVA, single stout pole or H-pole and 4-pole constructions with suitable platforms are used.

COMPONENTS USED IN SUBSTATIONS

Power Transformers:- The power transformer's primary function is to step-up transmission voltage at the generating unit and step-down transmission voltage at the distribution unit. Oil-immersed, naturally cooled, 3-phase transformers are often used for ratings up to 10MVA (Mega-volt-Amperes). Similarly, air blast cooled transformers are utilised for greater over 10MVA (Mega-volt-Amperes). Such kind of transformer functioned at the full-load condition, and when it is at light load condition then the transformer will be detached. As a result, the power transformer's efficiency is highest when it is fully loaded.

Current Transformer:- The measuring of alternating electric currents is done with a current transformer (CT). When the current in a circuit is too large to be applied directly to measuring equipment, a current transformer provides a reduced current that is precisely proportional to the circuit's current and may be linked to measuring and recording devices. A current transformer protects the measuring equipment from the monitored circuit's potentially excessive voltage. In the electrical power sector, current transformers are frequently employed in metering and protective relays.

Lightning Arrestors:- A lightning arrestor is a device that protects the insulation and conductors of a power or telecommunications system from the harmful effects of lightning. A lightning arrester typically has a high-voltage and a ground terminal. When a lightning surge (or switching surge, which is similar) travels up the power line to the arrester, the surge's current is redirected through the arrestor, and in most circumstances, to earth.

Instrument Transformer:- The primary function of an instrument transformer is to reduce high currents and voltages to a safe and realistic level. These figures may be computed using standard tools. The voltage and current ranges are 110 V and 1A (or) 5A, respectively. This transformer also serves to activate the protective relay (AC type) by supplying both current and voltage. Voltage transformers and current transformers are the two types of transformers available.

Isolator:- A disconnector, disconnect switch, or isolator switch is used in electrical engineering to guarantee that an electrical circuit is entirely de-energized for servicing or maintenance. These switches are used in electrical distribution and industrial applications where machinery's source of driving power has to be withdrawn for adjustment or maintenance. In electrical substations, high-voltage isolation switches are used to isolate apparatus such as circuit breakers, transformers, and transmission lines for maintenance. The disconnector is generally only used for safety isolation and not for regular circuit management.

Wave-Trapper:- The high-frequency signal is trapped by the wave-trapper, which is placed on the incoming lines. The current and voltage signals are interrupted by this signal (wave) from the distant station. The high-frequency signal is tripped and directed to the telecom board by this component.

Bus Coupler:- A bus coupler is a device that couples two buses together without interrupting electricity or causing dangerous arcs. Circuit breakers and isolators are used to do this.

Insulator:- In substations, the insulator is utilised to both insulate and fix the bus-bar systems. There are two types of insulators: post type and bushing type. The ceramic body of a post type insulator is made of ceramic, while the insulator's top is made of cast iron. It has a direct connection to the bus bar. The second type of insulator (bushing) has a ceramic shell body, as well as higher and lower locating washes for fitting the bus-bar position.

Circuit-Breaker:- When a system mistake occurs, this sort of electrical switch is utilised to open or close the circuit. It has two movable components, both of which are normally closed. When a system fault occurs, the relay sends a signal to the circuit breaker, which causes their pieces to be moved independently. As a result, flaws in the system become apparent. There are different types of circuit breakers which are:-

- **Low-voltage circuit breakers**:- Miniature Circuit Breaker (MCB) and Molded Case Circuit Breaker are two low-voltage (less than 1,000 VAC) kinds that are often used in home, commercial, and industrial applications (MCCB).

- **Thermal magnetic circuit breakers**:- The electromagnet responds instantly to significant surges in current (short circuits) while the bimetallic strip responds to less severe but longer-term over-current circumstances in thermal magnetic circuit breakers, which are the kind used in most distribution boards. The circuit breaker's thermal section has a "inverse time" reaction characteristic, which means it trips the circuit breaker sooner for greater overcurrents.

- **Magnetic circuit breakers** :- A solenoid (electromagnet) is used in magnetic circuit breakers, and its pulling force rises as the current increases. In certain cases, electromagnetic forces are used in addition to solenoid forces.

- **Vacuum circuit breakers**:- Generator circuit breakers can handle rated currents of up to 6,300 A. These breakers stop the flow of electricity by generating and dissipating an arc in a vacuum container.

- **Air circuit breakers**:- Generator circuit breakers have a rated current of up to 6,300A and greater. Trip features, such as customizable trip thresholds and delays, are frequently entirely modifiable. Electronically operated in most cases, however certain versions have a microprocessor-controlled electronic trip unit built in. Frequently used in big industrial plants for main power distribution, where the breakers are placed in draw-out enclosures for ease of maintenance.

Capacitor Bank:- Capacitors are integrated into this device and may be linked in series or parallel. The major purpose of this is to store electrical energy in the form of electrical charges. This bank pulls main current, which boosts the system's PF (power factor). The capacitor bank serves as a source of reactive power, reducing the phase gap between the current and the voltage. They will increase the power supply's ripple current capacity and eliminate the system's unnecessary features. The capacitor bank is an effective approach for maintaining power factor and correcting power-lag issues.

DESIGN AND LAYOUT OF SUBSTATIONS

A power engineer's major concerns are dependability and cost. A good design tries to find a balance between the two in order to provide enough reliability without paying excessive costs. The station's architecture should also allow for easy expansion if necessary. Installation of equipment with appropriate clearances for electrical safety, as well as access to maintain huge apparatus such as transformers, need sufficient land space. Where land is limited, such as in cities, gas-insulated switchgear may save money in the long run. Due to load increase or planned transmission expansions, the site must have capacity for extension.

The substation's environmental consequences, including as drainage, noise, and road traffic, must be considered. It is necessary to build a grounding (earthing) system. To safeguard passers-by during a transmission system short-circuit, the overall ground potential rise and the gradients in potential during a fault (called "touch" and "step" potentials) must be computed. The location of the substation must be relatively close to the distribution region to be supplied. Passers-by must not be allowed access to the site, both to protect people from electric shock or sparks and to prevent the electrical system from malfunctioning due to vandalism.

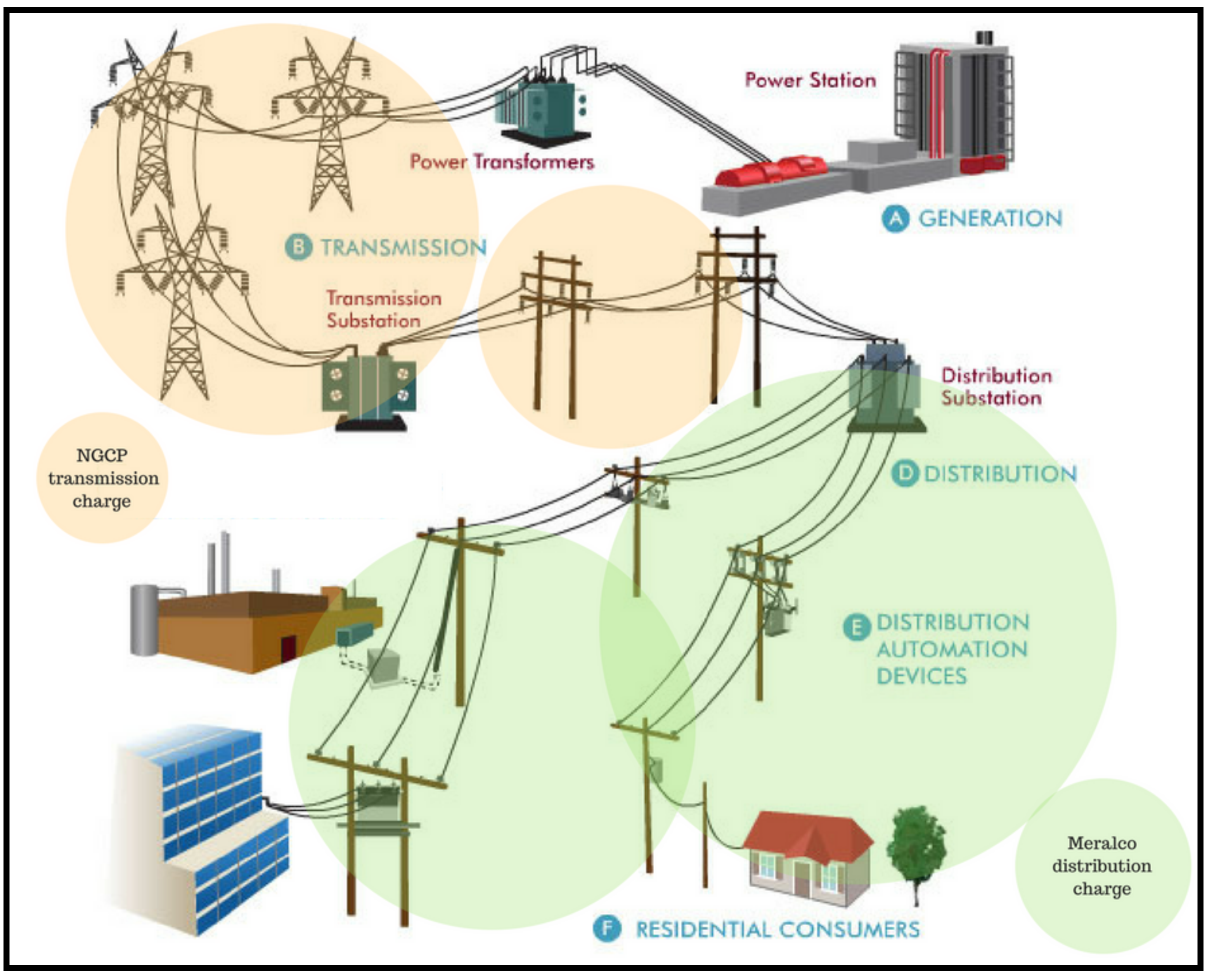
The development of a one-line diagram, which illustrates in simplified form the switching and protection arrangement necessary, as well as the incoming supply lines and outbound feeders or transmission lines, is the first stage in developing a substation layout. Many electrical utilities create one-line diagrams with major components (lines, switches, circuit breakers, and transformers) organised on the page in the same way that the apparatus would be put out in the real station.

In the bigger stations, incoming lines nearly always include a disconnect switch and a circuit breaker; but, in rare circumstances, the lines may not have both, with either a switch or a circuit breaker being sufficient. Isolation and protection are provided by these devices. Because a disconnect switch is not rated for breaking a loaded circuit, it is nearly usually used simply for isolation, whereas a circuit breaker is frequently employed as both an isolation element and a protection device. When a substantial fault current passes through the circuit break, current transformers can be used to identify it. The amount of the current transformer's output may be used to trip the circuit breaker, causing the load provided by the circuit breaker to be disconnected from the feeding point. This attempts to isolate the failure spot from the rest of the system, allowing the system to operate with little disruption.

The lines of a particular voltage all hook into a common bus once they've passed through the switching components. This is a set of three thick metal bus bars; three bars are used in most situations since three-phase electrical power distribution is widely used across the world.

The lines of a particular voltage link to one or more buses once they pass through the switching components.

Since three-phase electrical power distribution is essentially common across the world, they are sets of bus bars, usually in multiples of three.



PRINCIPLE OF POWER FACTOR CORRECTION

POWER FACTOR is the ratio between the useful (true) power (kW) to the total (apparent) power (kVA) consumed by an item of a.c. electrical equipment or a complete electrical installation. It's a metric for how well electrical energy is transformed into productive work production. One, or unity, is the optimum power factor. Anything less than one indicates that more effort is necessary to complete the task at hand. In both the supply and distribution systems, all current flow generates losses. The most efficient loading of the supply is a load with a power factor of 1.0. A load with a power factor of 0.8, for example, results in considerably larger supply system losses and a higher consumer bill. Because losses are proportional to the square of the current, a very small increase in power factor can result in a substantial reduction in losses.

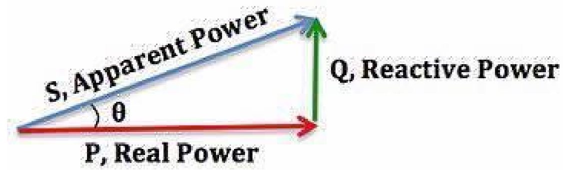
When the power factor is less than one, the "missing" power is known as reactive power, which is unfortunately required to generate the magnetising field that motors and other inductive loads require to execute their tasks. Reactive power can also be interpreted as wattless, magnetising or wasted power and it represents an extra burden on the electricity supply system and on the consumer’s bill.

A low power factor is caused by a large phase difference between the voltage and current at the load terminals, as well as a high harmonic content or a distorted current waveform. An inductive load, such as an induction motor, a power transformer, a luminaire ballast, a welding set, or an induction furnace, causes a low power factor. A rectifier, an inverter, a variable speed drive, a switched mode power supply, discharge lighting, or other electronic loads can all cause a distorted current waveform. Power factor correction equipment can improve a low power factor caused by inductive loads, but a poor power factor caused by a distorted current waveform necessitates a change in equipment design or the inclusion of harmonic filters. Some inverters are marketed with a power factor of greater than 0.95, whereas the genuine power factor is between 0.5 and 0.75. The 0.95 figure is based on the cosine of the angle between voltage and current, but it ignores the fact that the current waveform is discontinuous, which leads to higher losses.

A magnetic field is required for an inductive load to work, and producing one causes the current to be out of phase with the voltage (the current lags the voltage). The technique of correcting for the trailing current by producing a leading current by connecting capacitors to the source is known as power factor correction. The power factor is adjusted to be as near to unity as feasible by connecting a suitable capacitance.

Power Triangle:

The power triangle in vector space can be used to link the various components of AC power. Because it is a purely real component of AC power, real power extends horizontally in the î direction. Because it is a totally hypothetical component of AC power, reactive power extends in the direction of. Because complex power (and its magnitude, apparent power) is a mixture of real and reactive power, it may be computed using the vector sum of the two components. We may deduce the following mathematical connection between these elements:



Principal of Power Factor in:-

1. **Resistive Load:-**

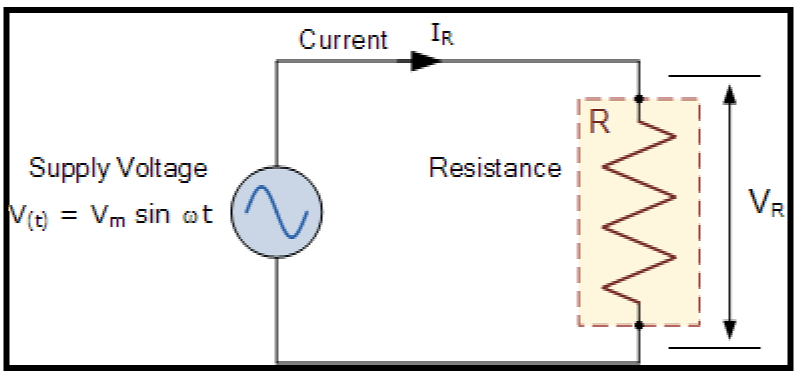


Image Source:- Electronics Tutorials

If a sinusoidal voltage source connected to a resistor, current will flow, power will be dissipated in the resistor and the resistor will heat up.

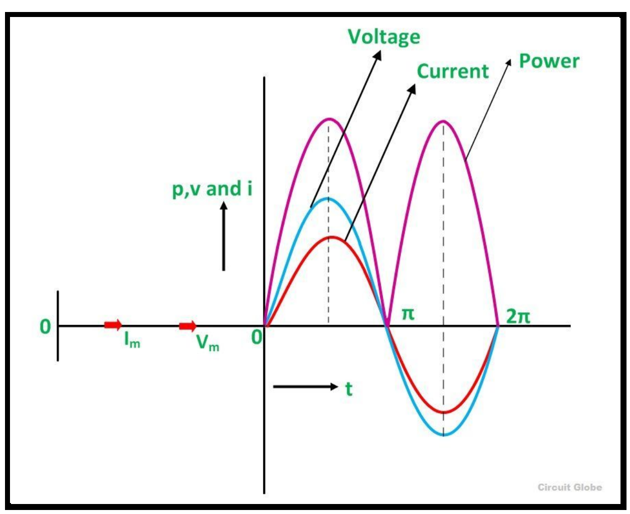


Fig. Waveforms for resistive load, Image source:- Circuit Globe

I=V/R represents current, while P=I*V or P= V2 / R represents power. The rms (root mean square) values of the voltage and current are used. The sky
blue voltage waveform is sinosidual in nature. The voltage is 1V rms giving a peak voltage of 1. 414V.
The red waveform is the current, It is 1A rms, 1. 414 A peak.
The pink waveform is the instantaneous power, i. e. the product of voltage and current from moment to moment. For example, when the current and voltage are both in their positive peaks, so the instantaneous power will be

1.414V * 1.414A= 2 watts

When both the current and voltage waveforms are at their negative peak, than the instantaneous power will be

-1.414V * -1.414A= 2 watt

That is the product of two negatives gives a positive value. The average of the power waveform is 1W.

2. Inductive Load:-

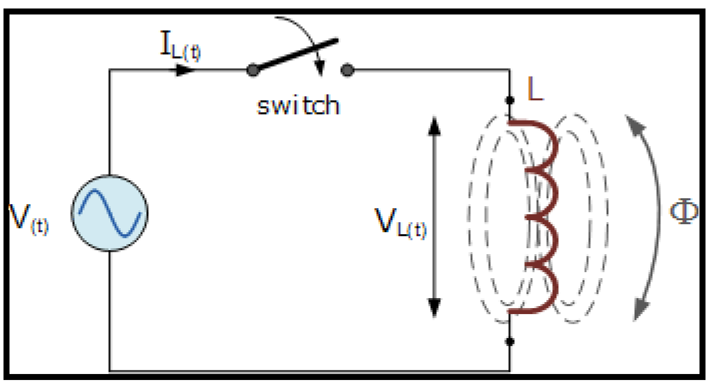


Image Source:- Electronics Tutorials

Assuming the resistor is now replaced with an inductor with a L H inductance. An inductor's current lags precisely 90 degrees after the supplied voltage.

The red current waveform in picture 2 illustrates this. A detailed examination of the instantaneous power waveform reveals that a negative voltage is multiplied by a positive current between the vertical lines, yielding a negative power.

The negative power indicates that energy is transferred from the inductor (load) to the voltage source during that section of the cycle.

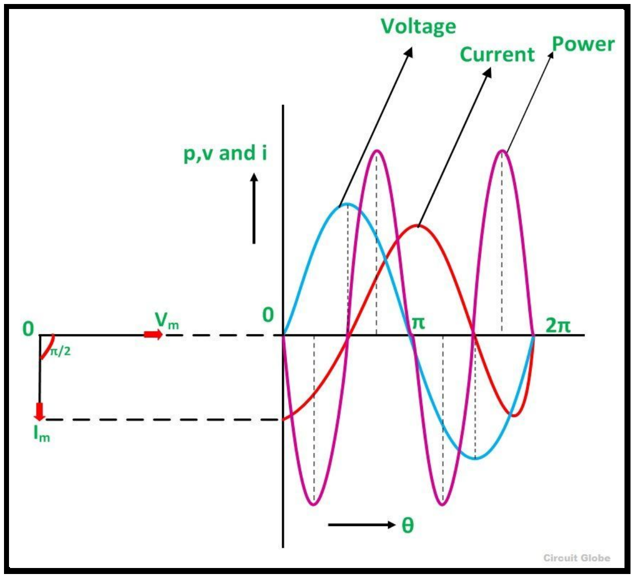


Fig. Waveforms for inductive load, image source:- Circuit Globe

An inductor is an energy storage device. The energy stored in an inductor is 0.5 * I2 * L. If the load is a perfect inductor, the negative power cancels out the positive power perfectly, resulting in zero net power dissipation.

However, the voltage remains 1V and the current remains 1A, resulting in a product that is far from zero. As a result, a 1W input does not produce 1W of heat. This is referred to as "wattles watts." Volt-Amps, or VA, is the proper word. We'll assume the circuit draws 1 volt but consumes none. The power factor of a pure inductor is 0 since it dissipates no heat.

3. **Resistive and Inductive Load:-**

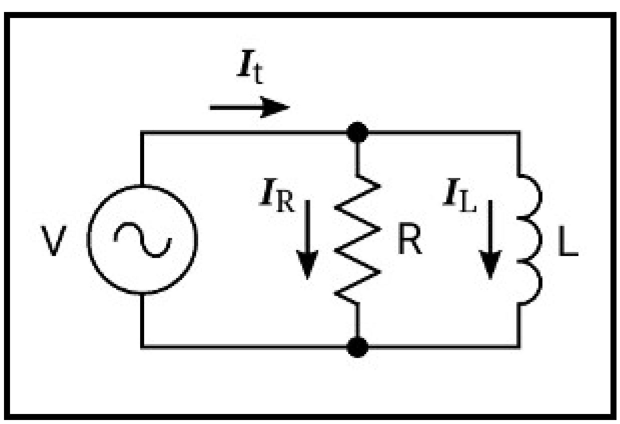


Image Source:- Electric Circuit Studio

Both the inductor and the resistor have been given the same voltage as previously. As a result, they must all be drawing the same amount of current as previously.

The resistor draws 1A in phase with the supply voltage, whereas the inductor draws 1A 90 degrees behind the voltage.

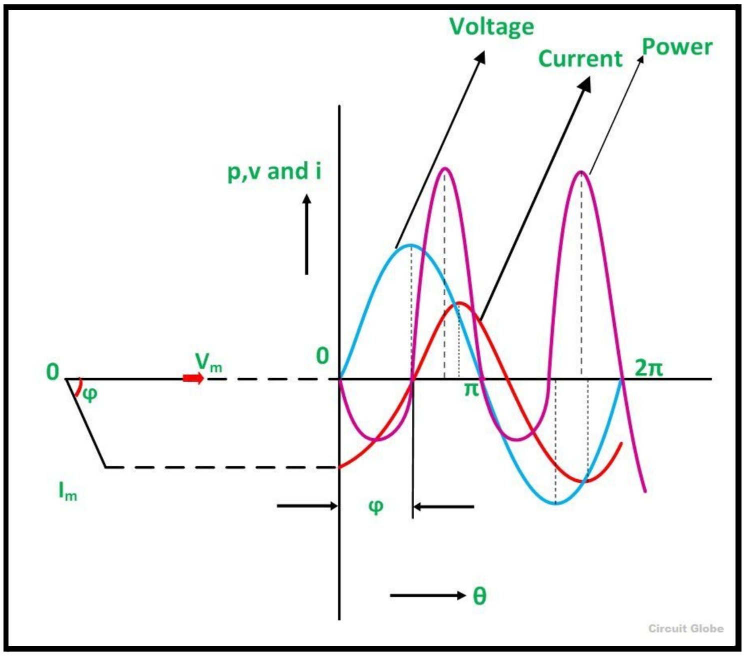


Fig. Waveforms for resistive and inductive, Image source:- Circuit Globe

The overall current is the total of these two currents from one time to the next. The overall current has a phase that is exactly half way between the two separate currents (i.e. lags the voltage by 450) and a magnitude of 1. 414A, as illustrated visually or numerically.

The input voltage is 1V and the current 1. 414A, so the input VA is 1. 414VA.

The power consumption is 1W, which is the same as the resistor alone. As a result, 1W/1. 414VA = 0. 707 is the power factor. It's also known as the Cosine of the voltage-current phase angle (Phi).

As a result, power factor is defined as the ratio of power to VA.

Causes of Low Power Factor:-

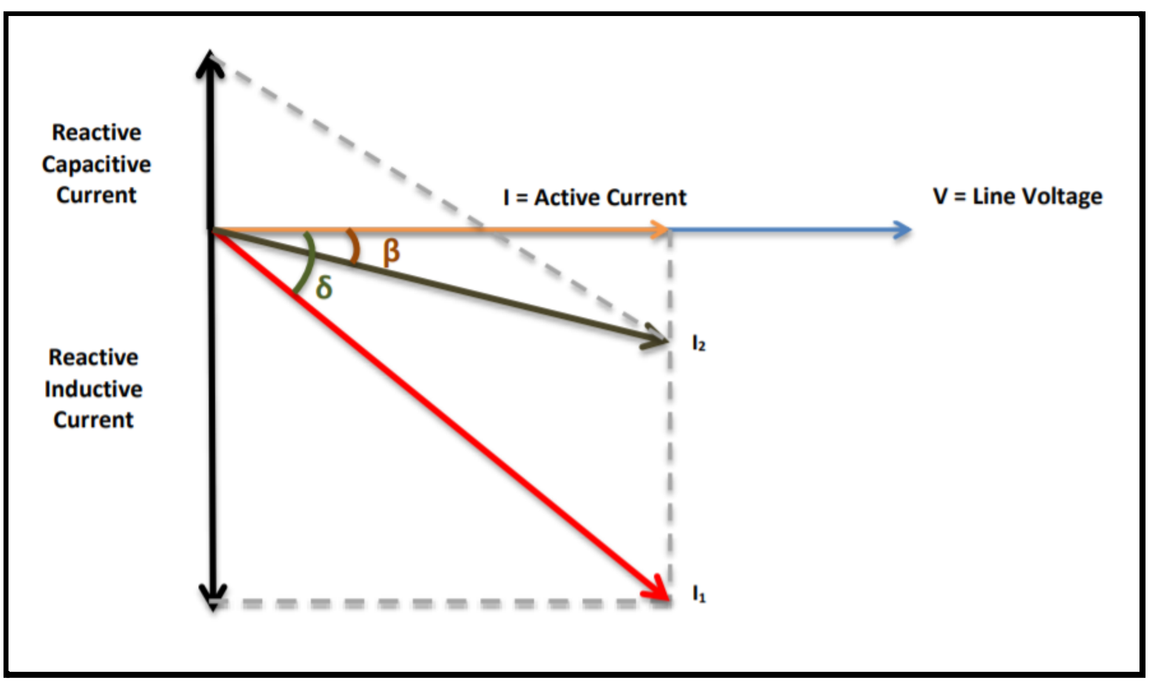
1. Single phase and three phase induction Motors(Usually, Induction motor works at poor power factor i.e. at: Full Load, pf:- 0.8 to 0.9, Small Load, pf:- 0.2 to 0.3, No load, pf tends to zero.

2. Variable Load in the Power System (As we all know, the load on the power system varies. During periods of low demand, the supply voltage is raised, which increases the magnetising current, resulting in a lower power factor.)
3. Electrical equipments which need reactive power like inductor.
4. Motors require reactive power during their operation to maintain magnetic fields.
5. Harmonic Currents
6. Non-linear loads distorts power factor.
7. Industrial heating furnaces

Disadvantages of Low Power Factor:-

1. Inefficient use of Electrical Energy
2. Large Copper (I2R) Losses
3. Large kVA Ratings of Equipment
4. Overloading of Transformer/Generator.
5. Leads to poor voltage regulation.
6. Higher temperature due to increased losses.
7. Overloading of Cables, Switchgear, Busbar etc
8. Reduces revenue to Electrical Utilities.

POWER FACTOR CORRECTION FOR LINEAR LOADS



From the above figure, For the resultant current I1 from inductor, phase angle is δ.

For the resultant current I2 from inductor and capacitor, phase angle is β.

As, $\delta > \beta$ & $\cos \delta < \cos \beta$

So in the case of combined circuit of inductor and capacitor, power factor is greater than with respect to the power factor of and inductive circuit.

POWER FACTOR CORRECTION FOR NON-LINEAR LOADS

A rectifier (such as one found in a power supply) or an arc discharge device, such as a fluorescent light, electric welding machine, or arc furnace, is an example of a non-linear demand on a power system. Because current in these circuits is stopped by a switching action, the current comprises frequency components that are multiples of the frequency of the power supply. The distortion power factor is a measure of how much a load current's harmonic distortion reduces the average power delivered to the load. Non-linear loads change the current waveform's shape from a sine wave to something else. Harmonic currents are created in addition to the original (fundamental frequency) AC current by non-linear loads. Harmonic currents can be prevented from entering the supplying system by using filters made up of linear capacitors and inductors.

The power factor only comes from the change of phase between current and voltage in linear circuits that have one frequency sinusoidal currents and voltages alone. This is "power factor of displacement." The notion can be generated to a total power factor, distortion or real power, where all harmonic components contain apparent power. In actual power systems with non linear loads, including rectifiers, various kinds of lighting, electronic arc furnaces, welding equipment, power supply switched-mode and other devices, this is of relevance.

Power factor correction in non-linear loads:-

- **Passive PFC:-** Using a filter that only passes current at line frequency(50 or 60 Hz) is the easiest approach to regulate harmonic current . The harmonic current is reduced by this filter, and the non-linear device now appears to be a linear load. The power factor may now be made close to unity by adding capacitors or inductors as needed. However, this filter necessitates large-value high-current inductors, which are bulky and costly. A passive PFC requires a bigger inductor than an active PFC, but it is less expensive. Using capacitor banks, this is a straightforward technique to rectify a load's nonlinearity. It doesn't work as well as active PFC.

- **Active PFC:-** An active power factor corrector (active PFC) is a power electronic system that improves the power factor by changing the wave form of current taken by a load. The goal is to make power factor adjusted load circuits seem entirely resistive (apparent power equals real power). Voltage and current are in phase in this scenario, and reactive power usage is zero. This allows for the most effective distribution of electrical power from the utility to the end user.
  Some types of active PFC are:
  1. Buck Converter
  2. Boost Converter
  3. Buck-Boost Converter

- **Dynamic power factor correction:-** For electrical stability during fast load fluctuations, dynamic power factor correction (DPFC), also known as "real-time power factor adjustment," is employed. Standard power factor correction is unable to adjust with the continuously changing, i.e. dynamic, electrical network, resulting in excess or under correction when electrical networks encounter fast load fluctuations, especially when non-linear loads are present.

  With semiconductors, DPFC can link capacitors or inductors to electrical networks without disrupting the network or putting excessive stress on electrical components like fuses and capacitors. The use of DPFC enhances power quality by lowering current, particularly reactive current, and providing electrical stability.

  Poor power quality results in higher electricity expenses for businesses, particularly factories, due to power quality fines. Despite the fact that PFC is accessible, few businesses utilise it since it is costly and ineffective. DPFC devices nowadays range from sampling once per wave cycle (50 Hz/60 Hz) to sampling over 8000 times per wave cycle.

ADVANTAGES OF POWER FACTOR CORRECTION

1. Reduction in KVA Demand
2. Avoid Power Factor penalties
3. Reduction in Line loss
4. Reduction in Cable / Bus – Bar Size
5. Reduction in KVAR Demand
6. Reduction in Line Current
7. Reduction in Transformer Rating

DISADVANTAGES OF FIXED CAPACITOR IN PFC

1. Not meet the require KVAr under varying loads.
2. Cause over voltage
3. Manual operation(on/off)
4. Saturation of transformer
5. Penalty by electricity authority
6. Can result leading power factor

NEED FOR AUTOMATIC POWER FACTOR CORRECTION

1. Power factor also varies as a function of the load requirements.
2. As under leading power factor under light load conditions which results in over voltages, saturation of transformers, mal-operation of diesel generating sets and penalties by electric supply authorities, APFC prevent leading power factor also.
3. Leading power factor under light load conditions (fixed compensation).
4. No manual intervention is needed.
5. Difficult to maintain a consistent power factor by use of Fixed Compensation i.e. fixed capacitors.

AUTOMATIC POWER FACTOR CORRECTION

A power-factor controller (PFC) is the interface between the AC line and the utility source that receives the power. PFCs operate as reactive power generators, providing the reactive power required to complete KW of work. A Power-factor controller (PFCprimary)'s duty is to produce a resistive load on the AC source. This means that the input current must only deviate by a scaling factor from the sinusoidal source voltage. Their waveforms must be similar, but scaled by Ohm's Law to account for the PFC's effective input resistance. The resultant current (I_G) would be proportional to the voltage, and the power source input would seem resistive, forming a current control loop controlled by the sine wave input. Because the loop will require a bipolar range to accommodate a sinusoid, a bridge rectifier will be used at the input.

The rectified sine wave (or sine magnitude), Og, is now uni-polar (assumed positive going with respect to PFC ground), but there is no storage capacitor after it. Instead, the capacitor is placed at the current-loop converter's output. This can also be explained by the trailing diagram.

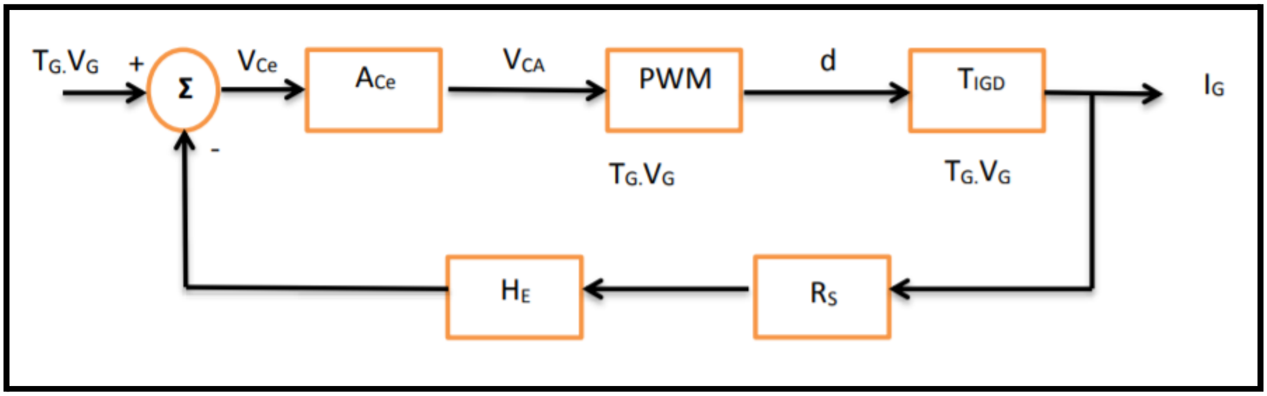


Fig. Block Diagram of Power Factor Controller

The output voltage is not controlled by the power-factor controller (PFC) conceptual design. It can also change for the sine magnitude input regulating current. If the scale-factor is electrically modified with an analogue multiplier, a second outer control loop to regulate the output voltage can be created. As a result, this system operates like this. The storage-capacitor output voltage, scaled by a voltage divider, Hv, is compared to the regulated voltage, set by a voltage reference, in the outer voltage loop. A voltage-loop error amplifier, Ave, raises its input to the multiplier if it is too low. The other input is the sine magnitude voltage, which is split first by a fixed divider, Tg, whose amplitude is raised. The current of the current control loop is now controlled by the multiplier output, which is now a bigger sine magnitude.

If the input-current instantaneous value along the sine magnitude is too low. The current-loop error amplifier's (ACE) output to the pulse-width modulator (PWM) grows, as does the PWM duty-ratio, D. The active converter switch will be on longer as a result, increasing the inductor current. As a result of the current flowing into the storage capacitor, the output voltage rises. The voltage loop reacts as a result. To conclude, the inner current loop is a scaled sine magnitude input switching trans-conductance amplifier. It's also a programmable-gain amplifier (PGA), with a voltage control loop that changes average output current I to keep output voltage Vo constant. The complete diagram of APFC is shown below.

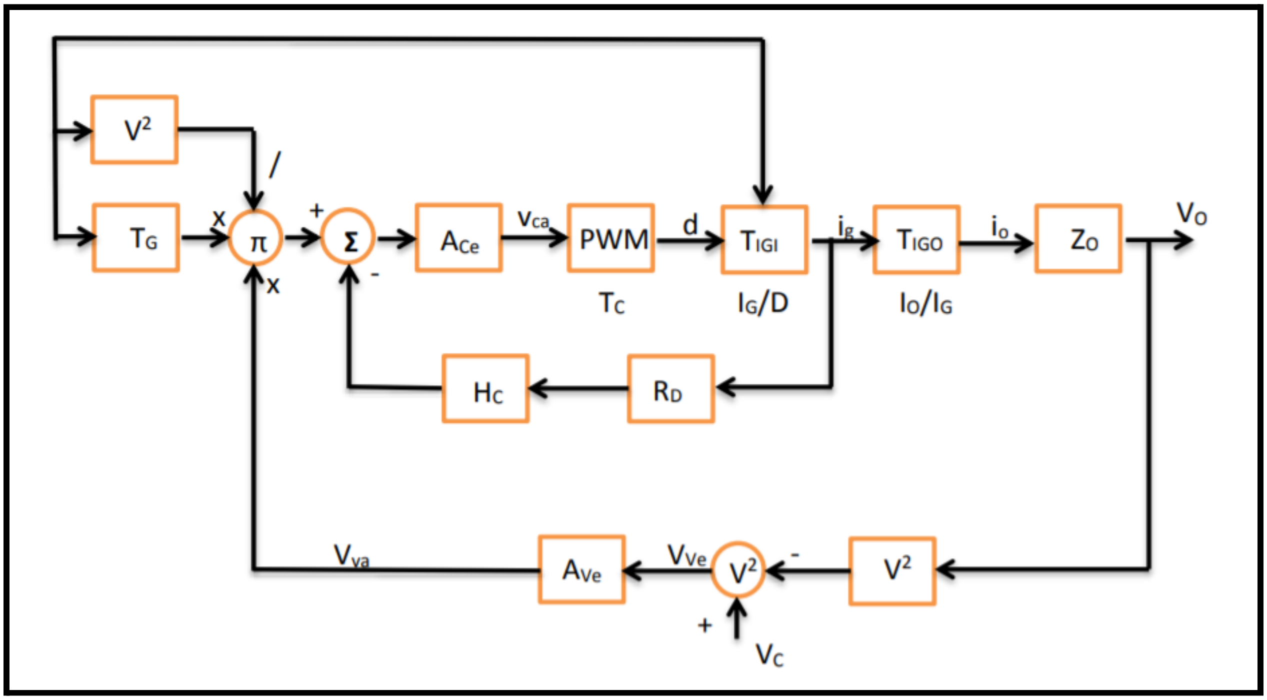


Fig. Block Diagram of Automatic Power Factor Controller

WORKING OF APFC

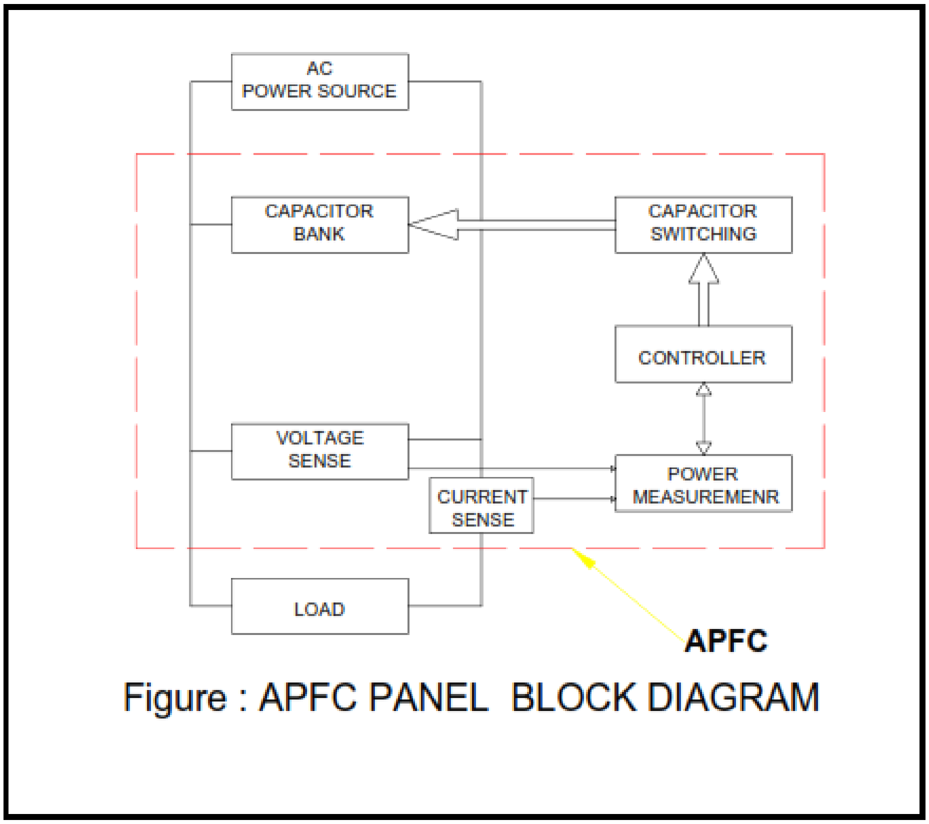


Image Source:- Heliac Enegry Private Limited

As may be seen in the APFC panel block schematic, The input of the APFC Panel is linked to the supply main terminals. The CT and PT put on line side detect the power factor. The capacitor banks are controlled by microprocessor-based APFC relays in response to line voltage and current to archive estimated power factor. The appropriate capacitor bank will run at the KVAr necessary for the APFC panel to achieve the target PF. The feedback from the switching capacitors will be checked by CT and PT after that. Finally, a PF that has been archived or targeted is loaded. To solve this challenge, we focused on the Selam Flour Factory in Debre Markos, Ethiopia. This factory has a low power factor of 0.66, which will be rectified by connecting the capacitor bank to the load in parallel. Table 1 shows the data obtained from the Selam Flour Factory for this project.
Based on the obtained data, a design for rectifying the system power factor was created, as shown in the table.

Specification of capacitors in APFC:-

- Voltage rise should be≤ 3.0% [% Voltage rise = (KVAr * %X)/(KVA)]
- Voltage rise due to series reactor and harmonics
- Degree Of Protection IP20
- Ambient temperature
- Directly connected Discharge Device (Resistor, VT) to discharge the capacitor to reduce voltage to 50 volts within one minute.
- Size of individual capacitor banks (step requirement).

DESIGN CALCULATION FOR CAPACITOR SIZE:-

Problem Statement:- Customer of electric power wants to increase his power factor to 0.92 to avoid paying power factor penalties that are being charged by the electrical utility. Calculate how much reactive power compensation / power factor correction they need to install to raise the power factor to 0.92

Table 1: Data obtained from the factory

Month	Power	Previous reading	Present reading	Average power	Consumption(Wh*cost/KWh)
January	Active(W)	39168	40695	39,931.5	16,612.5
	Reactive(VAR)	47341	43433	45,387	
Februray	Active(W)	40695	39869	40,282	16,758
	Reactive(VAR)	37869	37896	37,882.5	
March	Active(W)	43433	48373	45,903	19,096.4
	Reactive(VAR)	53064	58254	55,659	
April	Active(W)	48256	39754	44,005	18,306.7
	Reactive(VAR)	57892	40128	49,010	
May	Active(W)	39458	40916	40,187	16,718.7
	Reactive(VAR)	38654	36782	37,718	
June	Active(W)	40824	37854	39,339	16,365.6
	Reactive(VAR)	39784	34852	27,318	
July	Active(W)	39970	48251	44,110.5	18,350.6
	Reactive(VAR)	49131	49131	49,131	

August	**Active(W)**	37782	38788	38,285	15,927.1
	Reactive(VAR)	46608	47847	47,227.5	
September	**Active(W)**	38785	39970	39,377.5	16,381.6
	Reactive(VAR)	47847	49131	48489	
October	**Active(W)**	40857	42191	41,524	17,274.6
	Reactive(VAR)	49131	51652	50,391.5	
November	**Active(W)**	42191	43433	42,812	17,810.4
	Reactive(VAR)	51652	53064	52,358	
December	**Active(W)**	43433	43433	43,433	18,100.9
	Reactive(VAR)	53064	53064	53,064	

Note: Block rate for all month is 0.5778.

Solution:- From table 1 we can calculate reactive and active power to go for our next design calculation part.

Total active power (P) used = 505.8 KW in previous reading

Average = 505.8 / 12 = 41.15 KW

Total reactive power (Q) used = 544.68 KVAR in previous reading

Average = 544.68 KVAR / 12 =45.39 KVAR

Total active power (P) used = 501.9 KW in present reading

Average = 501.9 / 12 = 41.82 KW

Total reactive power (Q) used = 524.04 KVAR in present reading

Average = 524.04 KVAR / 12 = 43.67 KVAR

Supply voltage	380V
Minimum power factor	0.66
Allowed power factor	0.8
Desired power factor	0.92
Active power	41.82 KW
Frequency	50 Hz

Table 2. Electrical parameter used

Steps used in design calculations:

Step 1:- Calculate the apparent power before corrected (S in KVA)

$$P = S \times PF \quad (1)$$

Then, $S_{old} = P / Pf = 41.82\ KW / 0.66 = 63.36\ KVA$

Step 2:- The average reactive power from the above table calculation;

$Q_{old} = 44.53\ KVAR$

Step 3:- Calculate new apparent power for the desired power factor (S in KVA)

$$P = S \times PF \quad (2)$$

$S_{new} = P / PF = 41.82\ KW / 0.92 = 45.45\ KVA$

Step 4:- Calculate reactive power at desired power factor (Q new in KVAR)

$$S^2 = P^2 + Q^2 \text{, then } Q^2 = S^2 - P \quad (3)$$

$(63.36\ KVA)^2 = (41.82\ KW)^2 + Q^2_{new}$

$Q_{new} = \sqrt{}\ (45.45\ KVA\ 2 - 41.82\ KW\ 2\ ) = \sqrt{}\ (716.264)$

$Q_{new} = 17.8\ KVAR$

Step 5:- Calculate the capacitive reactive power correction needed

$$Q_{old} - Q_{new} = Q_{required} \quad (4)$$

$Q_{required} = 44.53\ KVAR - 17.8\ KVAR = 26.73\ KVAR$

Hence for per phase we divide total KVAR value for three, which means reactive power required for each phase is: = 26.73 KVAR / 3 = 8.91 KVAR

From the above calculation the total current before capacitor added is calculated as follows

$$\text{Apparent power} = V_{rms} \times I_{rms} \quad (5)$$

I_{rms} of the $S_{new} = 45.45 / 380V = 119.6\ A$

Active component of $I_{active} = I_{rms} \cos \varphi = 119.6\ A \times 0.66 = 78.93\ A$

Reactive component of current, $I_{old\ reactive} = I_{rms} \sin\varphi$, first let we find φ value.

$\varphi = \cos^{-1} (0.66) = 48.7$ degree

$\sin(48.7) = 0.75$,

then reactive component of $I_L = I \sin \varphi = 119.6\ A \times 0.75 = 89.7\ A$

The new Reactive component of the current is equal to;

$I_{new\ reactive} = I_{rms} \sin \varphi$

but $\cos^{-1}(0.92) = 23.07$ degree, so $\sin \varphi = 0.392 = 119.6A \times 0.392 = 46.88$ A

Therefore to connect the capacitor bank in star connection the capacitor line current is calculated from the difference of corrected reactive current from uncorrected reactive current.

$IC = I_{old\ reactive} - I_{new\ reactive} = 89.7\ A – 46.88\ A = 42.82\ A$

$I_{CP} = V_{ph} / XC = 2\pi fcV_{ph}$ Where V_{ph} is equal to √3 times line voltage

$C = I_{cp} / 2\pi fV_{ph} = 42.82\ A / 2\pi \times 50Hz \times \sqrt{3}(380V)$

$= 207.09 \times 10^{-6}$ F

Therefore each capacitor value can be 69.03×10^{-6} Farad

To calculate capacitive reactance;

Therefore $XC = 1 / 2\pi fc$

$= 1/ 2\pi \times 50 \times 207.09 \times 10^{-6}$ Farad $= 15.37\ \Omega$

Step 6:- To calculate the inductive reactance the first thing is; we have to solve for inductor, as we have.

$XL = Q / I_{rms}^{2} = 17.8\ KVAR / (119.6)^2 = 1.24\ \Omega$

Inductance, $L = XL/2\pi \times f$ (6)

$L = 1.24\ \Omega / 2\pi \times 50\ Hz = 3.97 \times 10^{-3}$ H

We have the following for protection of capacitor bank;

Fuse:-

Size of the fuse =165% to 200% of Capacitor Charging current.

Size of the fuse=1.85 x 42.82 A

Size of the fuse= 79.2 A

Circuit Breaker:-

The circuit breaker should be sized no less than 135% of the rated capacitor current:

Rated Capacitor Current = (Q_{new} / Voltage) Amps

Rated Capacitor Current = (17.8 x 1000)/380V = 46.84 A

The breaker shall be rated to carry the current equal to 78.42 A x 135% or 63.2 A continuously in its operating environment.

Contactors for Capacitors Switching:-

An automated power factor correction system consists of numerous capacitor banks (several stages) with similar or differing ratings, each activated individually according to the power factor to be adjusted. The power of the steps to be powered is automatically determined by an electrical device, which activates the appropriate contactors. In the event of automated correction, the inrush current peak is determined by the power of the steps already in operation and can exceed 100 times the nominal current of the activated step.

I_1 = 17.8 KVAR / V

I_1 = 17.8 KVAR / 380V = 46.8 A

The contactor operating currents Ie = 46.8 A then the selected contactors' have to carry capacity of 46.8 A

Cost Analysis:-

To calculate the cost paid before corrected and after corrected we have as follows. The cost paid per KVA is 0.67 birr analyzed from the gathered data.

Before Corrected

S = 63.36 KVA per month

Per month payment = 0.67birr/KVA x 63.36 KVA = 42.45 birr/month

Per year payment = 594.41 birr

After Corrected

S = 44.53 KVA per month

Per month payment = 44.53 KVA x 0.67 birr/KVA = 29.83 birr/month

Per year payment = 358.02 birr

Saved birr = Before corrected per year – After corrected per year

Saved birr = 236.38 birr

S. No.	Status	Birr
1	Before corrected	594.41
2	After corrected	358.02
3	Saved	236.38

Table 3:- Before and After corrected data

SELECTION OF SWITCHING EQUIPMENT

- **Low Tension (LT):-**
  - Switch should be quick make and break type
  - Rating of CB, contactors, fuse and cable should be ≥ 130% of capacitor rated current.
  - For automatic switching, each step capacitor should be provided with fuse and contactor.
  - Switch-fuse units/Circuit Breakers/ Thyristors

- **High Tension (HT):-**
  - Circuit Breaker rating should be ≥ maximum operating voltage of circuit
  - Continuous current rating of CB should be ≥ 135% of rated capacitor bank current
  - HT capacitor is connected to bus by Circuit Breaker.

TYPES OF APFC PANELS:-

- **LT APFC SYSTEM:-** To achieve the set Target power factor, the Reactive Power Compensation system is designed to work automatically on LT power supply to measure, display, and connect, disconnect the required capacitor banks through Thyristor/Capacitor Duty contactor with protection of MCB/HRC Fuses and series reactors to each bank. Thyristor/Contactor Switched Automatic Power Factor System is a very accurate, well-designed system with the requisite creep age distance.

  To measure, compute, and display all electrical network characteristics, the APFC System is integrated with a sophisticated, Digital Microprocessor based relay. It precisely monitors the reactive power demand from cycle to cycle for necessary capacitors linked to switching elements / devices in the system, as well as required capacitors connected / detached from the network. The near loop rapid response multi method switching [MMS] algorithm used by APFC Controllers allows for close and accurate power factor management.

  Features:-
  - Protection to each step
  - Powder coated metallic frame structure design
  - Well ventilated design.
  - Four modes of operation.
  - Modular Structure
  - Door interlocks Facility.

Applications:

- Automobile Industries, Cement Industries, Metal Industries.
- Chemical & Fertilizer Plant, Pharmaceutical Industries.
- Windmill, Power Stations, DG Stations, Crushers.
- Railway / MES / Ordinance Workshops

- **HT APFC RELAY:-** All electrical network parameters may be measured, calculated, displayed, and stored using an intelligent high-speed DSP + Microprocessor-based device. HT CTs and PTs are used to achieve voltage and current feedback. The Intelligent Multi Method Switching (MMS) Algorithm, which is incorporated into the device, allows the user to keep a close eye on the network's reactive power requirements. For Diesel Generators and Windmill Stations, the Multi Method Switching (MMS) Algorithm allows the user to define several goal power factors. A built-in self-test feature allows you to evaluate the relay's calibration and operation without an external load. GB Control's APFC controller finds use and applications in all areas of industry, including automobile manufacturers, cement plants, chemical and fertiliser plants, metal industries, and so on. Other built-in functions, such as Over Voltage Protection, Low Voltage Protection, Under Load Protection, Over Load Protection High Temperature, and so on, ensure that the APFC System runs continuously.

- **Thyristor / Contactor S witched APFC System:-**

  LT APFC SYSTEM: - To achieve the set Target power factor, the Reactive Power Compensation system is designed to work automatically on LT power supply to measure, display, and connect, disconnect the required capacitor banks through Thyristor/Capacitor Duty contactor with protection of MCB/HRC Fuses and series reactors to each bank. Thyristor/Contactor Switched Automatic Power Factor System is a very accurate, well-designed system with the requisite creep age distance. To measure, compute, and display all electrical network characteristics, the APFC System is integrated with a sophisticated, Digital Microprocessor based relay. It precisely monitors the reactive power demand from cycle to cycle for necessary capacitors linked to switching elements / devices in the system, as well as required capacitors connected / detached from the network. The near loop rapid response multi method switching [MMS] algorithm used by APFC Controllers allows for close and accurate power factor management. The APFC Relay features a memory storage model with a capacity of 45 days on an hourly basis and a communication port of Rs 232.

PFC IMPROVEMENT WITHOUT HARMONICS PROBLEM

Harmonics are produced by a variety of nonlinear loads, the most prevalent of which are variable speed controllers and switch mode power supply in the industrial sector today. Higher current flows in the capacitors as a result of harmonics on the supply. This is because the capacitors' impedance decreases as the frequency rises. This increase in current flow through the capacitor will cause the capacitor to overheat and shorten its life. As a result, ordinary capacitors are not utilised alone in APFC to adjust the power factor. Detuning reactors are used in conjunction with power factor correction capacitors to decrease harmonic currents and guarantee that the series resonant frequency is not a harmonic of the supply frequency. Reactors are typically chosen and classed as either 5% or 7% reactors.

This implies that the capacitive reactance is decreased by 5% or 7% at the line frequency. Detuning reactors have a lower impedance, which increases current, thus the capacitance must be lowered to provide the same degree of correction. When detuning reactors are employed in systems with large harmonic voltages, the resulting voltage across the capacitors can be rather high. This demands the usage of capacitors that can withstand a high continuous voltage. Detuning reactors should not be utilised with capacitors designed for use at line voltage only. The detuning reactors have a large heat dissipation capacity. The enclosure must be adequately ventilated and cooled using forced air.

With the use of detuning reactors, APFC:-

- It provides capacitive reactance at the fundamental frequency, which is required for power factor correction.
- To avoid resonance, it has inductive reactance at all higher order dominant harmonic frequencies.

BENEFITS OF APFC:-

- Consistently high power factor under fluctuating loads.
- Automatically switch on/off relevant capacitors steps for consistent power factor.
- Protect under any internal fault
- Prevention of leading power factor
- Eliminate power factor penalty
- Lower energy consumption by reducing losses.

CONCLUSION

Any electric utility company strives for a power factor of one, or "unity power factor," since if the power factor is less than one, they must deliver more current to the consumer for a given quantity of power usage. There are more line losses as a result of this. They must also have equipment with a higher capacity than would otherwise be required. As a result, if an industrial facility's power factor is significantly off from 1, it will be penalised.
The current lags the voltage in industrial facilities, which is known as a "lagging power factor" (like an inductor). This is largely due to the presence of a large number of electric induction motors, which operate as inductors as perceived by the power supply. Capacitors, on the other hand, work in the opposite direction and can compensate for inductive motor windings. Some industrial locations will use enormous banks of capacitors solely for the aim of reducing utility company rates by bringing the power factor back to one. The target power factor was also improved much better from 0.66 to approximately 0.92 almost unity when compared to its absence, thus reducing the effect of high power bills and heavy penalties from electricity boards. We successfully examined different techniques for power factor correction for linear as well as non-linear loads in this study, finding out that the Automatic Power Factor Correction method with little human intervention is the more significant approach for power factor correction.

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