LECTURE NOTES

ON

REACTIVE POWER MANAGEMENT AND CONTROL

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UNIT – I

LOAD COMPENSATION

Load Compensation

It is necessary to manage the reactive power to improve the power factor and the quality of supply Load compensation is the major player in it. The main objectives in load compensation are:

Improved voltage profile

- Power factor improvement
- Balanced load

.• It is important to maintain the voltage profile within +-5% of the rated value.

Load compensation is the management of reactive power to improve power quality i.e. V profile and pf. Here the reactive power flow is controlled by installing shunt compensating devices (capacitors/reactors) at the load end bringing about proper balance between generated and consumed reactive power.

This is most effective in improving the power transfer capability of the system and its voltage stability. It is desirable both economically and technically to operate the system near unity power factor.

This is why some utilities impose a penalty on low pf loads. Yet another way of improving the system performance is to operate it under near balanced conditions so as to reduce the flow of negative sequence currents thereby increasing the system's load capability and reducing power loss.

The main reason for voltage variation is unbalanced parameters in the generation side and consumption side. If the reactive power that is being consumed is greater than what is being generated then there is a definite chance of increased voltage levels. But if both of them are equal then the coltage levels become flat. Hence in order to maintain a flat voltage profile we have to determine the active power transfer capability of the system and the necessary reactive power to be compensated has to be carried out using shunt compensating elements i.e either a capacitor or an inductor.

Power factor correction

An unity power factor is desirable for better economic and technical operation of the system. Usually p.f correction means to generate reactive power as close as possible to the load which requires it rather than generate it at a distance and transmit it to the load, as this results not only in large conductor size but also in increased losses.

Loads on electric power systems include two components, namely, real power and reactive power. Real power is exclusively generated at generating stations while reactive power can be generated either by generating plants or at the load site through capacitors. When the reactive power is supplied by power plants, the size of system components like generators, transformers, transmission and distribution lines and protective equipments will be much larger than existing size, and hence it is not economically feasible. The application of shunt capacitors can diminish these conditions by decreasing the reactive power demand on generators.

Load Compensation:

Load balancing

A very important concept of load compensation is load balancing. It is desirable to operate the three phase system under balanced condition as unbalanced operation results in flow of negative sequence current in the system and is highly dangerous especially for rotating machines.

An ideal load compensator would perform the following functions,

- It would provide controllable and variable reactive power almost instantaneously as
- required by the load. It should operate independently in all three phases.
- It should maintain constant voltage at its terminal.

Harmonic distortion

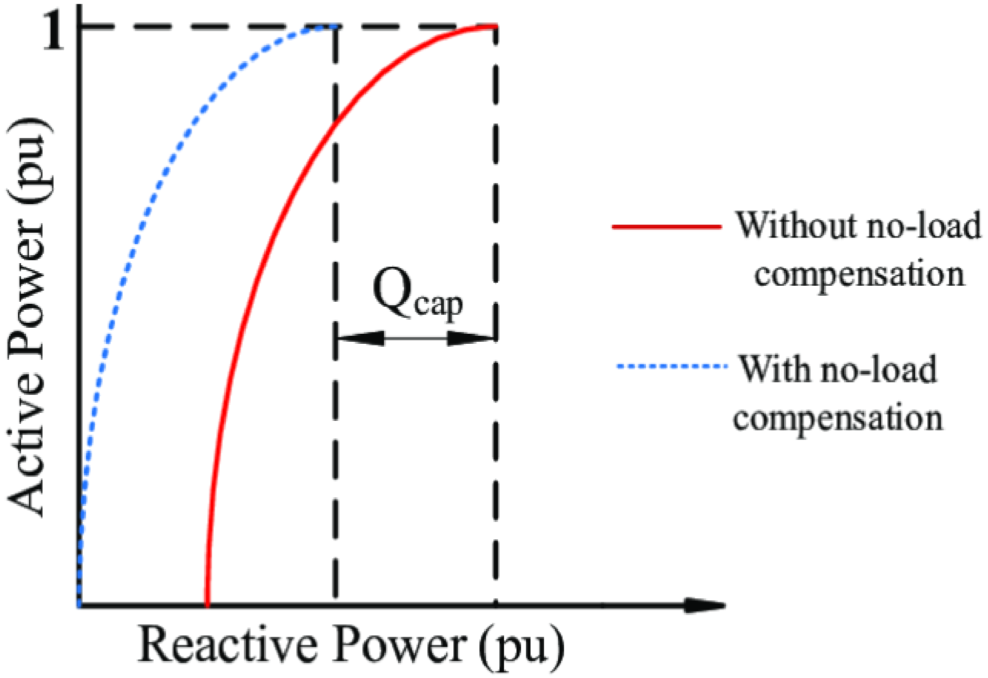
Harmonic distortion is the change in the waveform of the supply voltage from the ideal sinusoidal waveform. It is caused by the interaction of distorting customer loads with the impedance of the supply network. Its major adverse effects are the heating of induction motors, transformers and capacitors and overloading of neutrals. Power factor correction capacitors can amplify harmonics to unacceptable values in the presence of harmonic distortion. Standards specify the major harmonic voltages which can occur on the network, 5% total harmonic distortion being typical.

Power system harmonics

Power system harmonics are integer multiples of the fundamental power system frequency. Power system harmonics are created by non linear devices connected to the power system. High levels of power system harmonics can create voltage distortion and power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors. Active power filters Active power filters are simply power electronic converters specifically designed to inject harmonic currents to the system. Active power capabilities include:

- Eliminating voltage and current harmonics
- Reactive power compensation
- Regulating terminal voltage
- Compensating the voltage flickering

Reactive power characteristics



UNIT – II

STEADYSTATE REACTIVE POWER COMPENSATION IN TRANSMISSION SYSTEM

A power system engineer has been encountering in the distribution & transmission of power, a variety of problems such as voltage variations with load, poor power factor, large losses, electromagnetic and electromechanical oscillations followed by disturbances, supply voltage distortions due to harmonics generated by non-linear loads, interference with communications and so on. Their intensities may differ but all these problems exist in the main transmission, sub-transmission and distribution networks. The undertakings strive to provide un-interruptible supply with quality, minimize losses to conserve energy [31] and operate the system with timely actions in an attempt to overcome the adverse effects due to internal defects and external causes. In recent times the complexities in operation and control have increased due to a large variety of highly non-linear loads and electronic controllers. The primary concern in the thesis work undertaken is related to reactive power compensation, voltage control and energy conservation in a distribution system. In this chapter the conventional methods employed for reactive power compensation, their relative merits and demerits, desirable features of an advanced compensator in a distribution system are highlighted.

VAR Compensation:

Reactive power compensation by appropriate means has become the most economically attractive and effective solution technically for both traditional and new problems at different voltage levels in a power system. VAR compensation near load centre has gained more importance in recent times. It limits the flow of load reactive current in lines and feeders, boosts the voltage, reduces KVA demand and leads to both energy conservation and cost savings. Fig 3.1(a) & (b) show a typical distribution transformer feeding inductive loads and three a winding transformer at a receiving station requiring shunt reactive power COMPENSATION.

The desirable characteristic features of a shunt compensator are as mentioned below.

- Reactive power compensation of the load for power factor improvement.
- Stepless control of reactive power continuously matching with the prevailing load requirements from time to time.

- Maintenance of rated voltage at the point of common coupling within a narrow range irrespective of the load acting during the day.
- Reduction in the main line / feeder current, the losses and to conserve energy, throughout the day.
- Capacity to absorb line charging KVAr in very high voltage system under light load conditions.
- In case the loads introduce harmonics, the compensator should provide bypass paths for dominant harmonics and reduce the distortion levels.
- Under disturbed conditions the compensator is expected to act fast enough and damp out the oscillations.

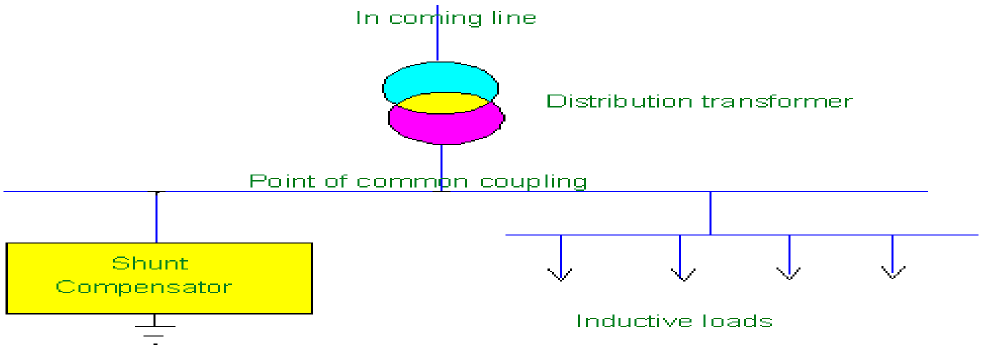
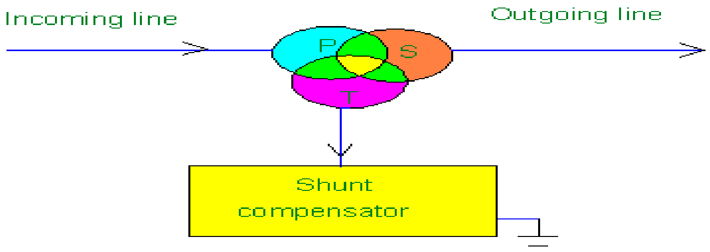


Fig. 3.1 (a) Schematic diagram showing a shunt compensator on a distribution transformer



Shunt compensation

Traditional Methods of VAR Compensation:

This section deals with the conventional methods employed for reactive power compensation and voltage control.

Synchronous Phase Modifier:

This is an ideal source having the capacity either to absorb or inject reactive power. However, it has got number of limitations as pointed out in section 1.5 (performance requirement). There are proven alternative methods of compensation available which are practically equivalent to SPM at low cost, more reliable, fast in response and giving trouble free service.

Shunt Capacitors:

The use of shunt capacitors in conventional way through mechanical switches has the following advantages:

- Overall cost is very low.
- The installation is simple requiring no strong foundations.
- Incur negligible losses
- Less maintenance problems
- More reliable in service with long life.

However, notable short coming are:

- Not possible to vary reactive power matching with load demand continuously (only step variation).
- There exist a possibility for harmonics, if present, to get amplified.
- There also exists a scope for series / parallel resonance phenomenon to occur, which requires being investigated prior hand.
- Hence the choice of a suitable compensator scheme calls for detailed study and careful design before implementation.

Series Capacitors:

A capacitor bank can be interposed is a line to partially neutralize the line reactance. Such an arrangement has the following attractive features.

- It automatically provides reduction in line voltage drop with increased loads.
- It increases the power handling capacity of a line by reducing the transfer reactance.
- It reduces voltage flicker and damp out transient oscillations.
- Quite effective in maintaining the voltage profile.

However, it poses serious problems during faults, prone for resonance phenomenon, complexity in control and likely to give rise to sub-synchronous oscillations. Hence the series capacitors can be installed after careful study only. They are employed widely in HV lines and somewhat uneconomical for distribution networks, as the requirements in both cases differ widely.

Static VAR Compensator:

This essentially consists of capacitor bank in suitable steps (operated through mechanical switches / thryristors) and thyristor controlled reactor across it of the size of minimum step. This combination yields step less variation of reactive power over the entire range. When SVC is applied at a receiving station it is possible to absorb line charging KVAr produced under light load conditions. This will enable to avoid

over voltage phenomenon under light loads. The main theme of this thesis work is application of multilevel advanced static VAR compensator with a closed loop controller on a distribution transformer. The notable features of SVC are[32, 33]

- Close matching of load reactive power
- Maintenance of power factor near unity
- Voltage control and reduction in losses However, SVC has the following limitations.

- Switching of capacitor bank steps require appropriate coordination.
- Complexity in the control of TCR.
- Generation of harmonics through TCR control

Harmonic Filters:

Most loads consume reactive power, highly non-linear and generate harmonics. The twin problems, reactive power compensation and harmonics reduction are carried out using shunt passive filters. These are tuned LC circuits to provide low impendence paths for dominant harmonics. They are quite effective in reducing the total harmonic distortion levels. An appropriately designed filter scheme can provide low impendence paths for harmonics and inject reactive power at fundamental frequency. The tuning reactor in every filter also serves the purpose of limiting inrush / outflow currents during switching operations. A filter scheme consisting of 2/3 selectively tuned filters for lower order dominant harmonics and a high pass filter can meet the most commonly encountered requirements in

LT and HT applications. It is possible to choose the appropriate filter scheme at the point of common coupling depending on the load, its pattern of variation, harmonics present, reactive power compensation at fundamental frequency so as to improve the power factor, relieve the system from adverse effects due to harmonics and improve the quality of power supply.

The advantages of shunt passive filters are:

- These are of relatively low cost, less complex, easy to operate and reliable.
- Reduction in total harmonic distortion levels and improvement in the quality of power supply.
- These have long life compared to active filters.
- Reactive power compensation and associated benefits similar to the use of shunt capacitors.
- Reduction in metering errors, communication interference, and heating of electrical apparatus.

The limitations in their application are:

- Capacitors and Reactors are to be specially designed.
- Every filter in the scheme has to be provided with protection and control arrangement.
- The scope for possible series / parallel resonance exists and should be avoided by careful study before implementation.
- These do not offer 100% solution for harmonic suppression similar to active filters.
- Their performance is subject to parameter variations, ageing etc. and precise tuning not possible.

Advanced Compensators:

The conventional techniques of reactive power compensation have been dealt in the above sections. As seen, each method has its own merits and limitations. Number of improvement have been brought out over the years with the increased usage of high power rated thyristors and advanced control techniques. There has been a growing tendency to increase the number of functions to be carried out by a compensator, either series, shunt or hybrid type. This section deals with the requirements of a compensator and reviews the advances that have taken place in the recent past.

Role of series / shunt Compensator:

Consider a transmission line with sources at either end, provided with shunt and series compensator separately.

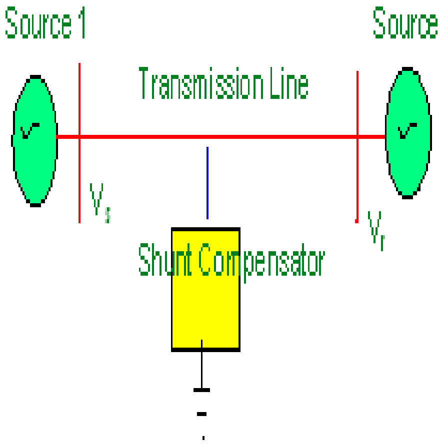


Fig 3.2 (a) Shunt Compensator

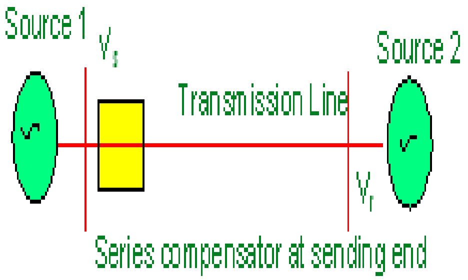


Fig 4.2 (b) Series Compensator

A shunt compensator provided say at the middle of a line (Fig. 3.2 (a)) if effectively controlled can maintain the voltages V_s and V_r equal irrespective of the directions of P & Q flows. This type of ideal compensator doubles the power handling capability, improves the power factor and maintains good voltage profiles. However, it is difficult to practically realize fully such a condition of operation. It is quite effective in providing reactive power compensation, improves steady state performance and damps out the transient oscillations during disturbances. It is usually a fast acting static VAR compensator.

On the other hand a series compensator interposed in the transmission line as shown in fig. 3.2 (b) either at sending end or somewhere in the line is quite effective to provide partial neutralization of line impedance and to reduce the voltage drop in the line. This improves the power handling capability of the line and damps out electromagnetic oscillations. However, as compared to shunt compensator, series compensator is complex to control and protect, costly and must be carefully designed to avoid sub synchronous oscillations. Both the methods have their own attractive features and limitations. It has been established that a combination of shunt and series compensators called hybrid scheme works out well. To have a understanding of the advanced compensator in the modern power systems, consider the following case as shown in fig. 3.3

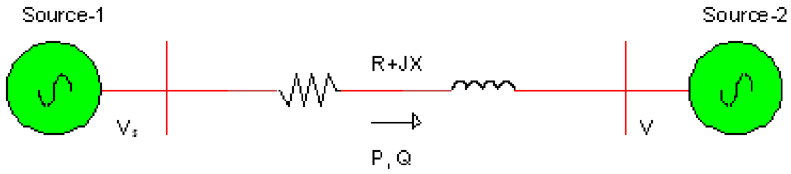


Fig - 3.3 Simplified Schematic Diagram of a Line between Two Sources

Under simplify conditions of operation (neglecting shunt paths). It is well known that, the relative magnitude difference between □ V_s□ and □ V_r□ determines the direction and magnitude of reacting power flow in the line. On the other hand the relative phase angle displacement between V_s and V_r will determine the direction and magnitude of real power flow. For example, if □ V_s□ > □ V_r□ and V_s leads V_r then both P & Q flow from source- 1 to source-2. If □ V_s□ < □ V_r□ and still leads V_r then P flows from soucr-1 to source-2 and Q flows from source-2 to source-1. This clearly indicates that the magnitude of P & Q and their directions of flow depend on the voltage magnitudes and their phase angles. To have an understanding of the influence of voltage control in its magnitude and direction, consider a situation with nominal values of V_s, V_r and P_0, Q_0 in the line subject to incremental changes in voltage deviation and phase angle difference. This obviously gives rise to four quadrant operation with coordinate axis around 'O' point corresponding to the nominal values. Fig 3.4 and table

3.1 gives the four quadrant operation for incremental values in □ □ V□ ,□ □ , □ P, □ Q.

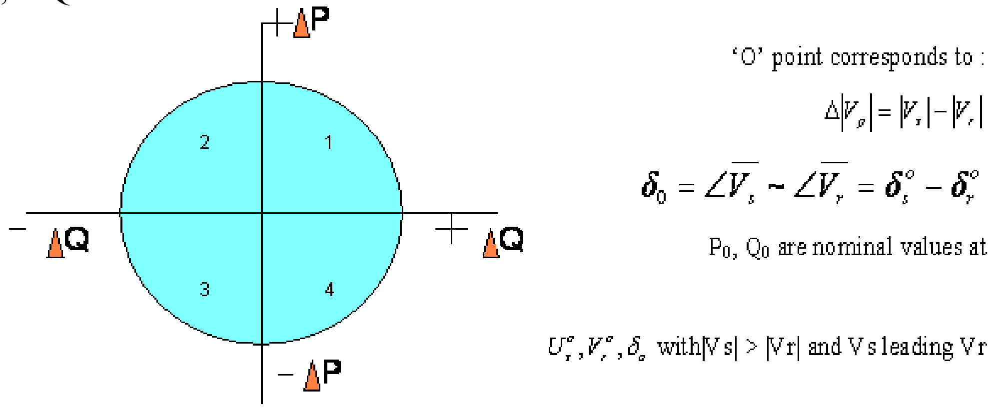


Fig - 3.4 Four Quadrant Operations For Incremental P & Q

uadrant	□V_1□	□	P	Q

Table 3.1. Four quadrant operation for incremental changes in and the corresponding changes in □ P and □ Q.

A variety of compensating devices both in series and shunt forms have been developed over the years to achieve complete control on a voltage profile, the magnitude and directions of both P and Q flows. The schemes in vogue are STATCOM, power conditioners, energy sourced inverters, in phase and quadrature boosters and so on. The detailed

treatment of this advanced compensators is outside the scope of present work.

Requirements of Advanced Compensator for distribution Systems:

In recent years lot of developments have taken place in FACT devices (flexible AC transmission) for their applications in interconnected power systems. However, that much attention was not paid to the compensators in the distribution system. It is in this perspective attempt is made to develop an advanced shunt compensator as could be made applicable on mass scale for the distribution transformers. The work proposed aims at developing a static VAR compensator with the following technical features:

- To design a static VAR compensator with capacitor bank in five binary sequential steps.
- To design a thyristor controledl reactor of KVAr capacity equal to the lowest size of capacitor bank step.
- To design an electronic feedback controller with high gain and low time constant for fast response.
- To sense the reactive power requirement as per the prevailing load, at periodical intervals.
- To coordinate the switching ON and OFF operations of the capacitor bank steps with

permissible time delays from OFF state to ON state.

- To initiate operation through feedback controller for obtaining reactive power from the compensator.
- To continuously monitor the reactive power injection, voltage condition and to maintain the power factor near unity.

The advantages contemplated with the use of above mentioned static VAR compensator on a distribution transformer are as mentioned below:

- Control of voltage and maintenance of power factor
- Reduction in feeder losses and conservation of energy
- Relief in tariff and reduction in maximum demand.
- Flexibility in control and reliability in operation.
- Limited generation of harmonics from TCR and reduction in phase unbalance.
- Minimization of neutral currents / potentials.
- Improvement in the quality of power supply.

Conclusions:

The desirable features of a compensator, types with specific reference to static VAR compensation, series and shunt types and four quadrant operation for P and Q changes through voltage angle and magnitude control are dealt in this chapter. The requirements of a typical compensator are outlined.

UNIT – III

REACTIVE POWER COORDINATION

Flexible alternating current transmission systems (FACTS) technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines. The Unified Power Flow Controller (UPFC) is a second generation FACTS device which enables independent control of active and reactive power besides improving reliability and quality of the supply. This paper describes the real and reactive power flow control through a transmission line by placing the UPFC at the sending end of an electrical power transmission system. The power flow control performance of the UPFC is compared with that of the other FACTS device called Static Synchronous Series Compensator (SSSC). Simulations are carried out in Matlab/Simulink environment to validate the performance of the UPFC.

In today’s highly complex and interconnected power systems, there is a great need to improve electric power utilization while still maintaining reliability and security. While power flows in some of the transmission lines are well below their normal limits, other lines are overloaded, which has an overall effect on deteriorating voltage profiles and decreasing system stability and security. Because of all that, it becomes more important to control the power flow along the transmission lines to meet the needs of power transfer. On the other hand, the fast development of solid-state technology has introduced a series of power electronic devices that made FACTS a promising pattern of future power systems.

Power flow between two buses of a lossless transmission line is given by :

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin \delta_{ij} \qquad ($$

where, V_i and δ_i are the i^{th} bus voltage magnitude

angle, V_j and δ_j are the j^{th} bus voltage magnitude

It is clear that the power flow is a function of transmission line impedance, the magnitude of the sending end and receiving end voltages and the phase angle between voltages. By controlling one or a combination of the power flow arrangements, it is possible to control the active, as well as, the reactive power flow in the transmission line. With FACTS technology, such as Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) etc., bus voltages, line impedances and phase angles in the power system can be regulated rapidly and flexibly. These FACTS controllers are based on voltage source converters. Thus, FACTS can facilitate the power flow control, enhance the power transfer capability, decrease the generation cost, and improve the security and stability of the power system .

A Static Synchronous Series Compensator (SSSC) is a member of FACTS family which is connected in series with a power system. It consists of a solid state voltage source converter which generates a controllable alternating current voltage at fundamental frequency. When the injected voltage is kept in quadrature with the line current, it can emulate as inductive or capacitive reactance so as to influence the power flow through the transmission line [3]-[5]. While the primary purpose of a SSSC is to control power flow in steady state, it can also improve transient stability of a power system.

The UPFC is a member of the FACTS family with very attractive features [7]. The UPFC is able to control, simultaneously or selectively, all the parameters affecting power flow in the transmission line (voltage, impedance, and phase angle) [8]. It is recognized as the most sophisticated power flow controller currently, and probably the most expensive one. The UPFC, which consists of a series and a shunt converter connected by a common dc link capacitor, can simultaneously perform the function of transmission line real/reactive power flow control in addition to UPFC bus voltage/shunt reactive power control

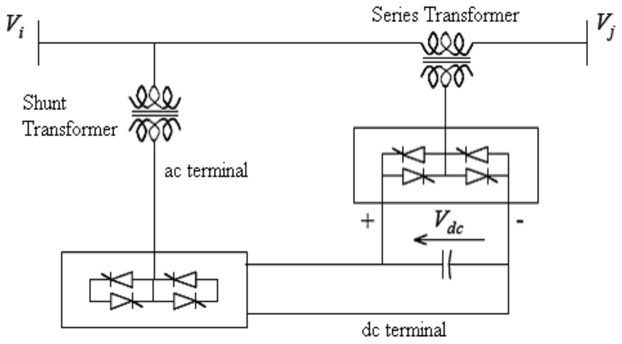
FACTS CONTROLLERS

The basic principles of the following FACTS controllers, which are used in the single machine infinite bus system under study, are discussed briefly.

Unified Power Flow Controller (UPFC)

The UPFC is made out of two voltage-source converters (VSCs) with semiconductor devices having turn-off capability, sharing a common dc capacitor and connected to a power system through coupling transformers. The basic structure of UPFC is shown in Fig.1. The shunt converter is primarily used to provide the real power demand of the series converter at the common dc link terminal from the ac power system. It can also generate or absorb reactive power at its ac terminal, which is independent of the active power transfer to (or from) the dc terminal. Therefore, with proper control, it can also fulfill the function of an independent advanced static VAR compensator providing reactive power compensation for the transmission line and thus executing indirect voltage regulation at the input terminal of the UPFC.

The series converter is used to generate a voltage at the fundamental frequency with variable amplitude and phase angle, which is added to the ac transmission line by the series connected boosting transformer. The inverter output voltage injected in series with the line can be used for direct voltage control, series compensation, phase shifting, and their combinations. This voltage source can internally generate or absorb all the reactive power required by the different type of controls applied and transfers active power at its dc terminal. The reactive power is generated/absorbed independently by each converter and does not flow through the dc link [14]-[15]. The dc link provides a path to exchange active power between the converters. The series converter injects a voltage in series with the system voltage through a series transformer. The power flow through the line can be regulated by controlling the magnitude and angle of the series-injected voltage. The injected voltage and line current determine the active and reactive power injected by the series converter. The converter has a capability of electronically generating or absorbing the reactive power. However, both the series and shunt converters can independently exchange reactive power with the ac system. However, the injected active power must be supplied by the dc link, in turn taken from the ac system through the shunt converter. When the losses of the converters and the associated transformers are neglected, the overall active power exchange between the UPFC and the ac system becomes zero [16]-[17].



Configuration of UPFC

Static Synchronous Series Compensator (SSSC)

The SSSC is one of the most recent FACTS devices for power transmission series compensation. It can be considered as a synchronous voltage source as it can inject an almost sinusoidal voltage of variable and controllable amplitude and phase angle, in series with a transmission line. The injected voltage is almost in quadrature with the line current. A small part of the injected voltage that is in phase with the line current provides the losses in the inverter. Most of the injected voltage, which is in quadrature with the line current, provides the effect of inserting an inductive or capacitive reactance in series with the transmission line. The variable reactance influences the electric power flow in the transmission line. The basic configuration of a SSSC is shown in Fig.2.

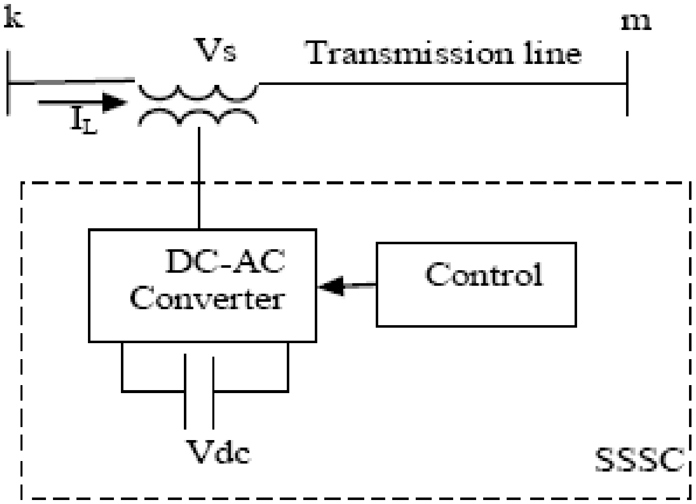


Fig. 2 Simplified diagram of a SSSC

POWER SYSTEM MODEL

Consider a single machine infinite bus (SMIB) system with series FACTS devices as shown in Fig.3. Here, the series FACTS devices such as UPFC (combination of STATCOM and SSSC) and SSSC are equipped between bus-2 and bus-3. The UPFC installed between bus-2 and bus-3 effectively controls the power flow from sending end to receiving end. Here, V_S and V_R are assumed to be sending and receiving end voltages. This model assumes that sending end corresponds to a power plant while the receiving end to an electric power network, i.e., SMIB system. The system data are given in [18]-[19].

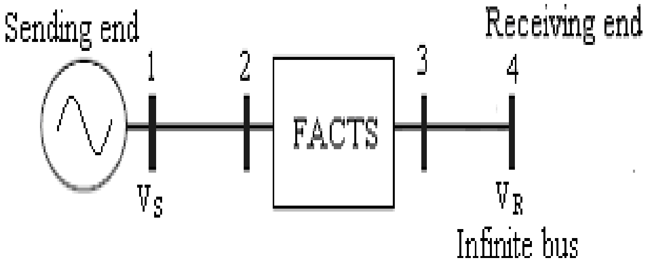


Fig. 3 SMIB system with FACTS device

CONCLUSION:

In this study, the Matlab/Simulink environment is used to simulate a simple single machine infinite bus (SMIB) power system with UPFC connected to a three phase three wire transmission system. The control and performance of UPFC intended for installation on a transmission line is presented. Simulation results show the effectiveness of UPFC on controlling the power angle oscillations and real and reactive power flow through the line. From the simulation results, it is inferred that there is an improvement in the real and reactive power flow through the transmission line with UPFC when compared to the system without UPFC and with SSSC.

Power Quality Terms

Active filter: Consists of a number of power electronic devices for eliminating harmonic distortion.

Common mode voltage: The noise voltage that appears equally from current carrying conductor to ground.

Coupling: A circuit element, or elements, or a network that may be considered common to the input mesh and the output mesh and through which energy may be transferred from one to another.

Crest factor: A value reported by many power quality monitoring instruments representing the ratio of the crest value of the measured waveform to the root mean square of the fundamental.

Critical load: Devices and equipment whose failure to operate satisfactorily jeopardizes the health or safety of personnel, and/or results in loss of function, financial loss, or damage to property deemed critical by the user

Harmonic (component): Integer multiple of fundamental frequency.

Harmonic content: The quantity obtained by subtracting the fundamental component from an alternating quantity.

Harmonic distortion: Periodic distortion of the sine wave.

Harmonic filter: On power systems, a device for filtering one or more harmonics from the power system. Most are passive combinations of inductance, capacitance, and resistance. Newer technologies include active filters that can also address reactive power needs.

Causes of low power quality

The most common types of Power Quality problems are presented below along with their description, causes and consequences:

1. Voltage sag (or dip)
2. Very short interruptions
3. Long interruptions
4. Voltage spike
5. Voltage swell
6. Harmonic distortion
7. Voltage fluctuation
8. Noise
9. Voltage Unbalance

Voltage sag (or dip)

Description: A decrease of the normal voltage level between **10% and 90%** of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute.

Causes: Faults on the transmission or distribution network (most of the times on parallel feeders). Faults in consumer’s installation. Connection of heavy loads and start-up of large motors.

Consequences: Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.

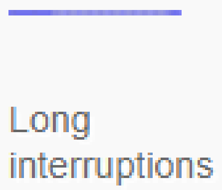
Very short interruptions

description: Total interruption of electrical supply for duration from few milliseconds to one or two seconds.

Causes: Mainly due to the opening and automatic reclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover.

Consequences: Tripping of protection devices, loss of information and malfunction of data processing equipment. Stoppage of sensitive equipment, such as ASDs, PCs, PLCs, if they’re not prepared to deal with this situation.

Long interruptions

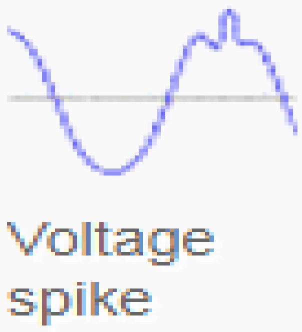


Description: Total interruption of electrical supply for duration greater than 1 to 2 seconds

Causes: Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices.

Consequences: Stoppage of all equipment.

Voltage spike

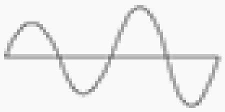


Description: Very fast variation of the voltage value for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts, even in low voltage.

Causes: Lightning, switching of lines or power factor correction capacitors, disconnection of heavy loads.

Consequences: Destruction of components (particularly electronic components) and of insulation materials, data processing errors or data loss, electromagnetic interference.

Voltage swell



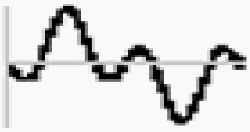
Voltage swell

Description: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.

Causes: Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

Consequences: Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

Harmonic distortion

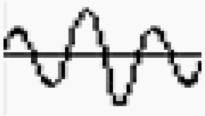


Harmonic distortion

<u>Description:</u> Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency.

<u>Causes:</u> Classic sources: electric machines working above the knee of the magnetization curve (magnetic saturation), arc furnaces, welding machines, rectifiers, and DC brush motors.

Voltage fluctuation



Voltage fluctuation

<u>Description:</u> Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz.

<u>Causes:</u> Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads.

<u>Consequences:</u> Most consequences are common to undervoltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.

Noise

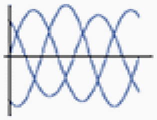
Noise

<u>Description:</u> Superimposing of high frequency signals on the waveform of the power-system frequency.

Causes: Electromagnetic interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause.

Consequences: Disturbances on sensitive electronic equipment, usually not destructive. May cause data loss and data processing errors.

Voltage Unbalance



Voltage Unbalance

Description: A voltage variation in a three-phase system in which the three voltage magnitudes or the phase-angle differences between them are not equal.

Causes: Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault).

Consequences: Unbalanced systems imply the existence of a negative sequence that is harmful to all three- phase loads. The most affected loads are three-phase induction machines.

Equipment to solve Power Quality problems

Manufacturers have developed a range of equipment to help consulting engineers and facility personnel address specific power-quality issues. In some cases, the options are pretty cut and dried, while situations may require a bit more thought.

- *Transients*. Transient voltage surge suppressors are the best option for protecting against transients in a power system.
- *Voltage sags and interruptions.* The best choice here depends on extent of any interruption. Uninterruptible power supplies and other energy-storage options could do well with shorter-term sags or interruptions, but back-up generators or self-generation equipment is needed when longer

outages are encountered. Other solutions could include static transfer switches and dynamic voltage restorers with energy storage. Schneider Electric's MGE Galaxy 5000 series.

- *Harmonics.* Active filters are the recommended solution for harmonic mitigation, thanks to their flexibility and high correction performance. Alternative approaches could involve passive filters, multi-pulse arrangement transformers or harmonic correction at the equipment level (for example, by integrating harmonic filtering into variable speed drives). The AccuSine power-correction system from Schneider Electric offers a complete harmonic-filtering solution.
- *Power factor*. Reducing power factor requires producing reactive energy as close as possible to connected loads. Installing capacitors on the network, such as Schneider Electric's VarSet LV capacitor banks, is the easiest and most common way to achieve this goal.

What Is Undervoltage? How Can I Protect My Equipment?

ndervoltage occurs when the average voltage of a three-phase power system drops below intended levels, and is sometimes referred to as a brown-out. Electromechanical devices, including three phase motors and pumps, are designed to be operated at very specific voltage levels. If these devices are allowed to operate at reduced voltage levels they will draw higher currents. The increase in current causes increased heat in the winding and coils of the equipment damaging the critical insulation protecting them. Operating in Under voltage conditions can drastically reduce the life of the electromechanical equipment and lead to premature failure.

Undervoltage conditions are usually be caused by undersized or overloaded utility and facility transformers. During peak demand periods and/or when the utility is experiencing problems, the demand for power exceeds the capability of the transformer and as a result the voltage drops. These conditions can occur without warning and provide no obvious indications. To protect motors and equipment, use a three-phase monitor relay, also known as a phase failure relay, as a cost-effective solution to prevent costly damage from under voltage.

A three-phase monitor relay, with undervoltage protection, cans shutdown equipment when undervoltage occurs preventing damage. A clear indication of the fault present is provided by these relays for rapid troubleshooting and reduced downtime.

Three-phase motors and other equipment are commonly used in a variety of industries:

- HVAC
- Mining
- Pumping
- Elevator
- Crane
- Lift
- Generator
- Irrigation
- Petro-Chem
- Wastewater
- Industrial Machinery
- And more

Macromatic offers three-phase monitor relays (phase failure relays) specifically engineered for detecting undervoltage issues. Learn more about protecting equipment and preventing expensive repairs with Macromatic's Three-Phase Monitor Relays.

Electromagnetic interference (**EMI**), also called **radio-frequency interference** (**RFI**) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction.[1] The disturbance may degrade the performance of the circuit or even stop it from functioning. In the case of a data path, these effects can range from an increase in error rate to a total loss of the data.[2] Both man-made and natural sources generate changing electrical currents and voltages that can cause EMI: ignition systems, cellular network of mobile phones, lightning, solar flares, and auroras (northern/southern lights). EMI frequently affects AM radios. It can also affect mobile phones, FM radios, and televisions, as well as observations for radio astronomy and atmospheric science.

Electromagnetic interference can be categorized as follows:

- Narrowband EMI or RFI interference typically emanates from intended transmissions, such as radio and TV stations or mobile phones.

- Broadband EMI or RFI interference is unintentional radiation from sources such as electric power transmission lines.[4][5][6]

Conducted electromagnetic interference is caused by the physical contact of the conductors as opposed to radiated EMI, which is caused by induction (without physical contact of the conductors). Electromagnetic disturbances in the EM field of a conductor will no longer be confined to the surface of the conductor and will radiate away from it. This persists in all conductors and mutual inductance between two radiated electromagnetic fields will result in EMI.

UNIT – IV

DEMAND SIDE MANAGEMENT

Supply side management:

Supply-side management (SSM) refers to actions taken to ensure the generation, transmission and distribution of energy are conducted efficiently.

- This has become especially important with the deregulation of the electricity industry in many countries, where the efficient use of available energy sources becomes essential to remain competitive.

- Utility companies may look at means of modifying their load profile to allow their least efficient generating equipment to be used as little as possible.

- Why it is necessary?

– To Ensure sustained availability of reliable energy

– To Meet increasing electricity demand

– To reduce environmental impact of energy production and supply

***Important point-There is balance between supply & demand side.**

Resources and resource preparation

1.Clean coal technology

2.Fuel substitution

Power generation and energy conversion

1. Proper maintenance
2. Data and performance monitoring
3. Combustion control
4. Upgradation of generation unit

Transmission and distribution

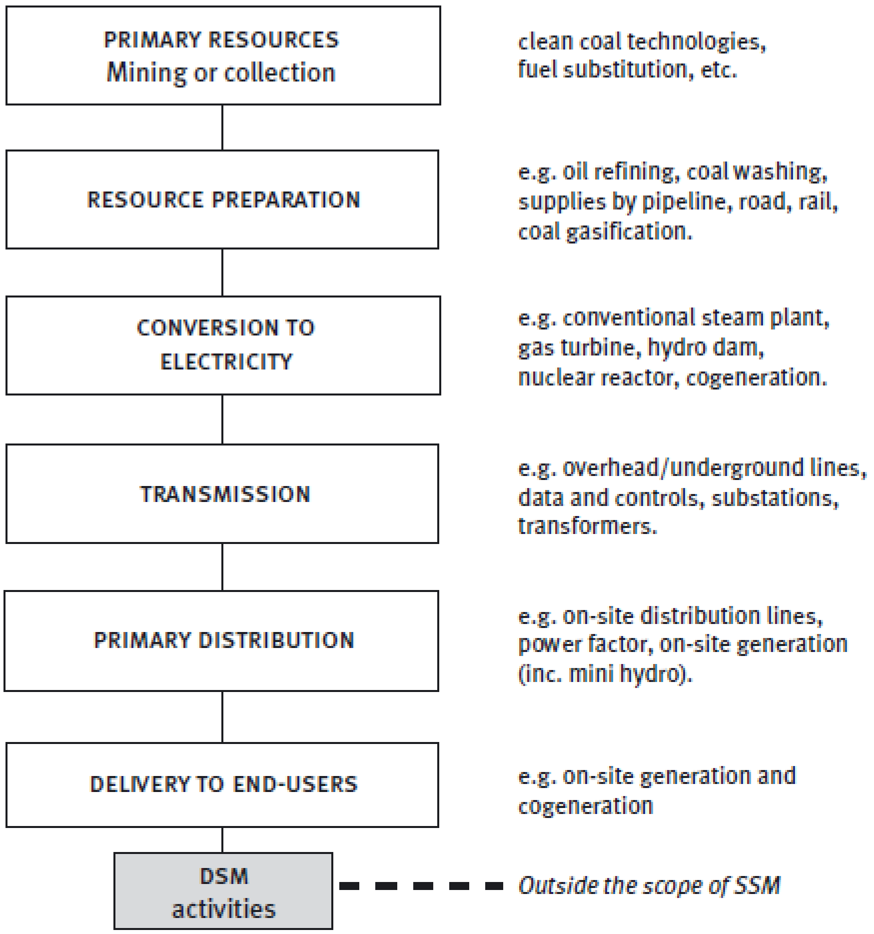
1. Transmission lines
2. Data monitoring and control

3. Load aggregation

4. Facts

Supply side measures

Simplified electricity supply chain



Up gradation of generation units

•Upgrading generating units can improve reliability, increase output and reduce environmental impacts from electricity generation.

•Typical improvements are the installation of new and improved burners, extra flue gas heat recovery, additional heat recovery from hot blow down water, as well as modernization of instruments and combustion control systems.

•For very old power plants, it may be justified to replace the old equipment completely with a new generation plant designed and built to the best modern efficiency standards.

There are a large number of possible measures to adopt to raise the operating efficiency of an existing power plant.

•Implementation depends on the type of plant, the technology currently used, the level of maintenance, and many such factors that are site-specific.

•It is therefore impossible to estimate the potential improvements without a careful analysis of the actual plant and the costs involved.

• However, it is possible to make very rough estimates of the typical range of figures that might be encountered in practice

Load aggregation

•Electric load aggregation is the process by which individual energy users band together in an group to secure more competitive prices that they might otherwise receive working independently.

Benefits-

1. **Increased Buying Power-**Through load aggregation, companies can enhance their purchasing power by taking advantage of load diversity among multiple facilities as a means of improving the overall load factor of the group.

2.Improved Load Factor-Load factor is the ratio of electricity consumption to peak demand (expressed as a percentage) for each billing period.

• A high load factor means power usage is relatively constant and it is beneficial to utility because the billing is done on basis of maximum demand.

FACTS devices

•This offers ways of attaining an increase of power transmission capacity at optimum conditions, i.e. at maximum availability, minimum transmission losses, and minimum environmental impact. Plus, of course, at minimum investment cost and time expenditure.

•Important devices power transmission involving FACTS and Power Quality devices:

•SVC (Static Var Compensators),

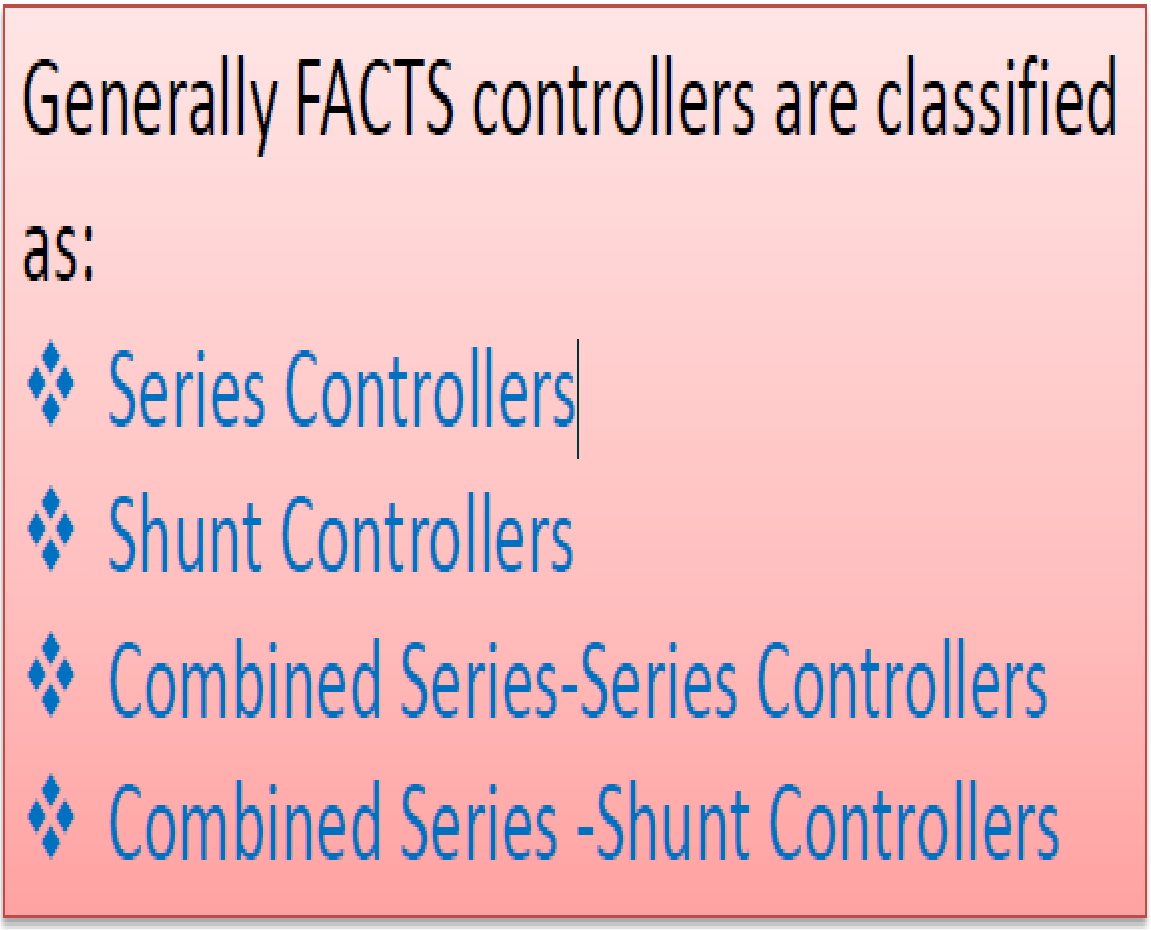
•Thyristor-Controlled Series Capacitors (TCSC) and Statcom.

•PST (Phase-shifting Transformers),

•IPC (Interphase Power Controllers),

•UPFC (Universal Power Flow Controllers),

•and DVR (Dynamic Voltage Restorers).



Generally FACTS controllers are classified as:

- Series Controllers
- Shunt Controllers
- Combined Series-Series Controllers
- Combined Series -Shunt Controllers

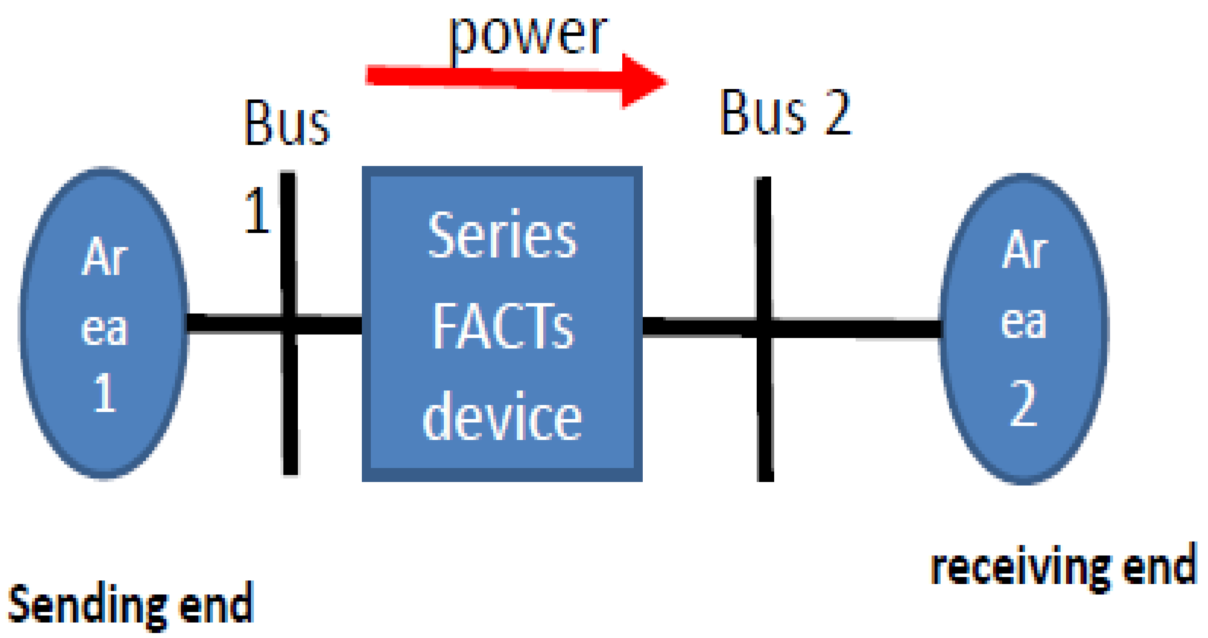


Figure 3 Two-area power system with series FACTS device

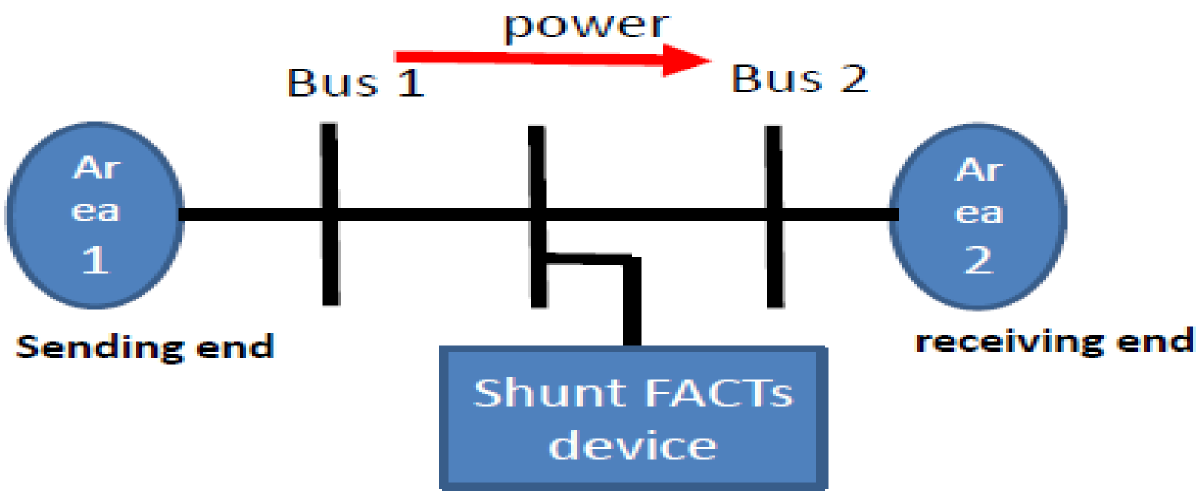


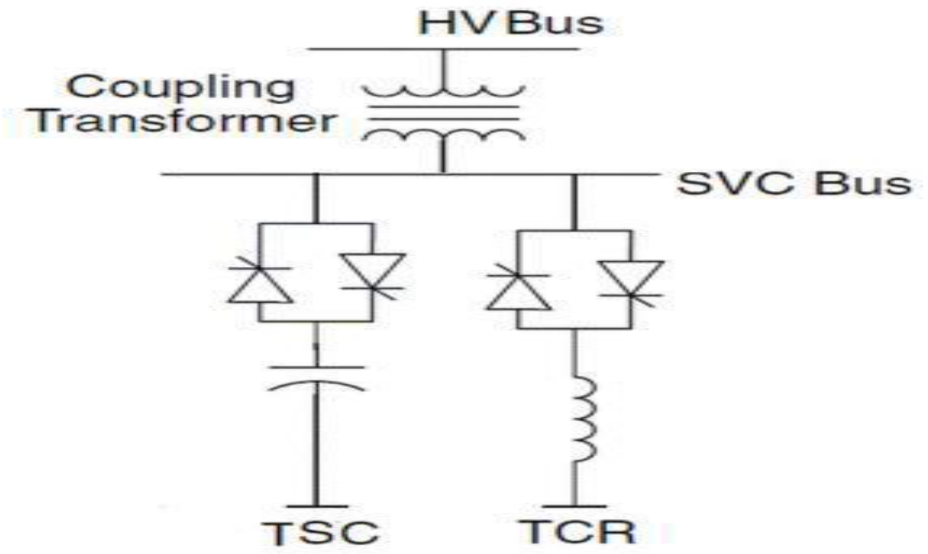
Figure 4 Two-area power system with shunt FACTS device

Facts are available in

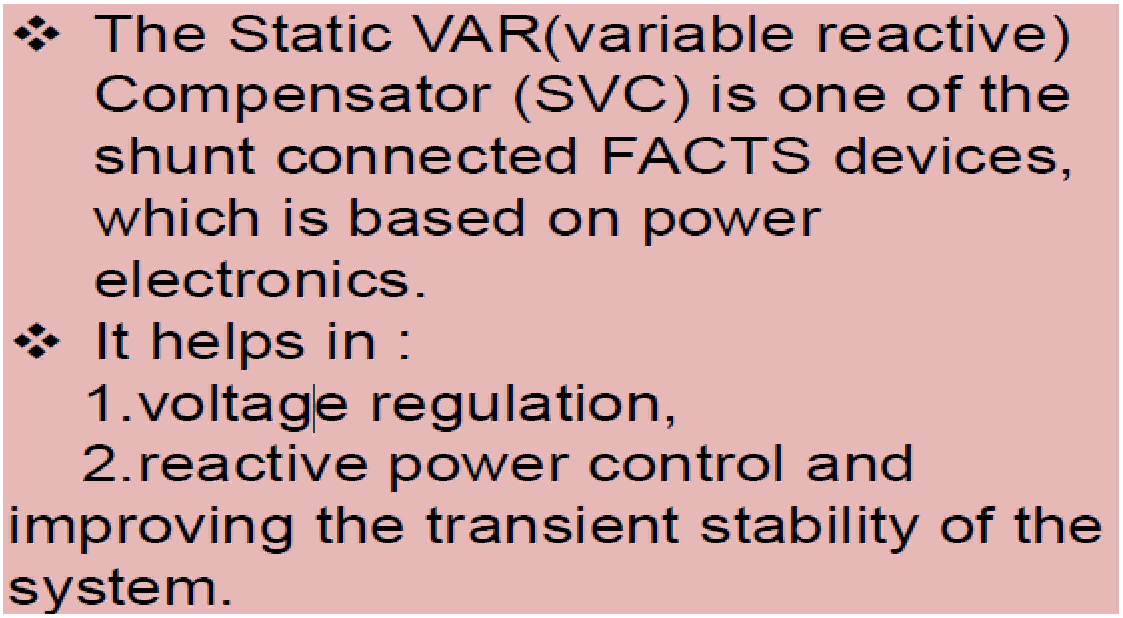
•Shunt compensator

1.Shunt capacitive compensator- for PF improvement of line.

2.Shunt inductive compensator-for charging the transmission line or used when there is very low load at receiving end.



STATIC VAR COMPENSATOR (SVC)



- The Static VAR(variable reactive) Compensator (SVC) is one of the shunt connected FACTS devices, which is based on power electronics.
- It helps in :
  1.voltage regulation,
  2.reactive power control and improving the transient stability of the system.

Types of common SVCs are

- Thyristor –controlled reactor(TCR)
- Thyristor –switched reactor(TSR)
- Thyristor –controlled capacitor (TCC)
- Thyristor –switched capacitor (TSC)
- Mechanically switched capacitor/ reactor(MSC/MSR)

Series compensator-used for insertion of reactive power element in transmission lines.

1. fixed series capacitors(FSC)
2. thyristor controlled series compensation

A. thyristor controlled series capacitor(TCSC)

B. thyristor controlled series reactor(TCSR)

C. thyristor switched series capacitor(TSSC)

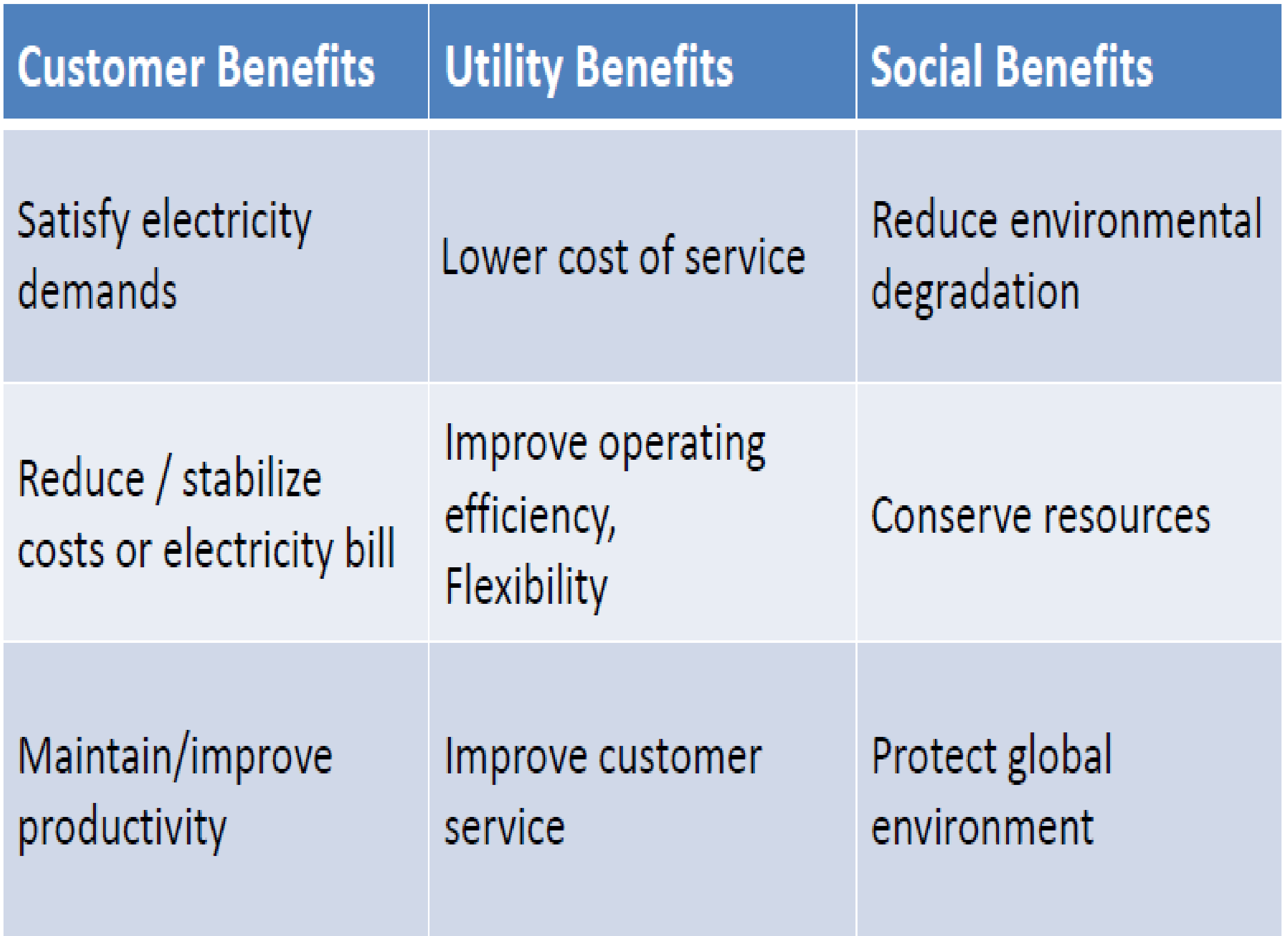
D. thyristor switched series reactor(TSSR)

Demand Side management

- It is also called as **Energy Demand Management**.
- The modification of consumer demand for energy through various methods such as financial incentives and education is termed as **Demand Side Management.**
- The main goal of demand side management is to **encourage the consumer to use less energy during peak hours**, or to move the time of **energy use** to **off-peak times** such as night time and weekends.

Definition - DSM (Demand Side Management) is the **'Scientific control of usage and demand of Electricity, for achieving better load factor and economy, by the Licensee/Supplier'.**

Benefits of Demand Side Management



Customer Benefits	Utility Benefits	Social Benefits
Satisfy electricity demands	Lower cost of service	Reduce environmental degradation
Reduce / stabilize costs or electricity bill	Improve operating efficiency, Flexibility	Conserve resources
Maintain/improve productivity	Improve customer service	Protect global environment

The barriers for DSM

i) Monopoly power market structure.

ii) No competition which leads to traditional and inefficient tariff structure.

iii) Lack of creating awareness among consumers about the efficient use of energy.

iv) Lack of energy efficient environment.

v) Huge gap between supply and demand of energy.

vi) Lack of proper incentive schemes to consumer on using energy efficient appliances and utility to implement DSM solutions.

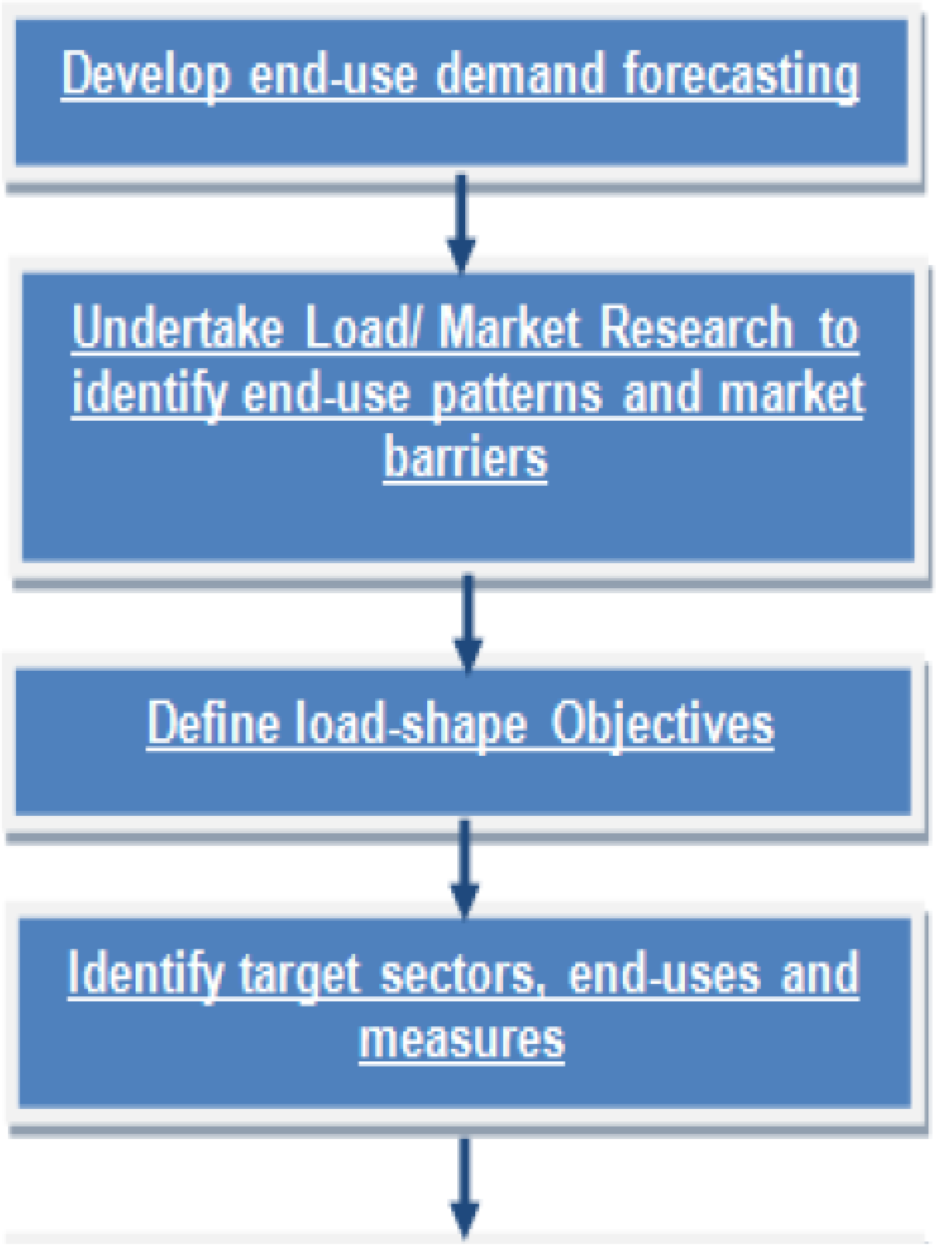
vii) Power system reliability, quality and stability is not able to keep itself in standard position.

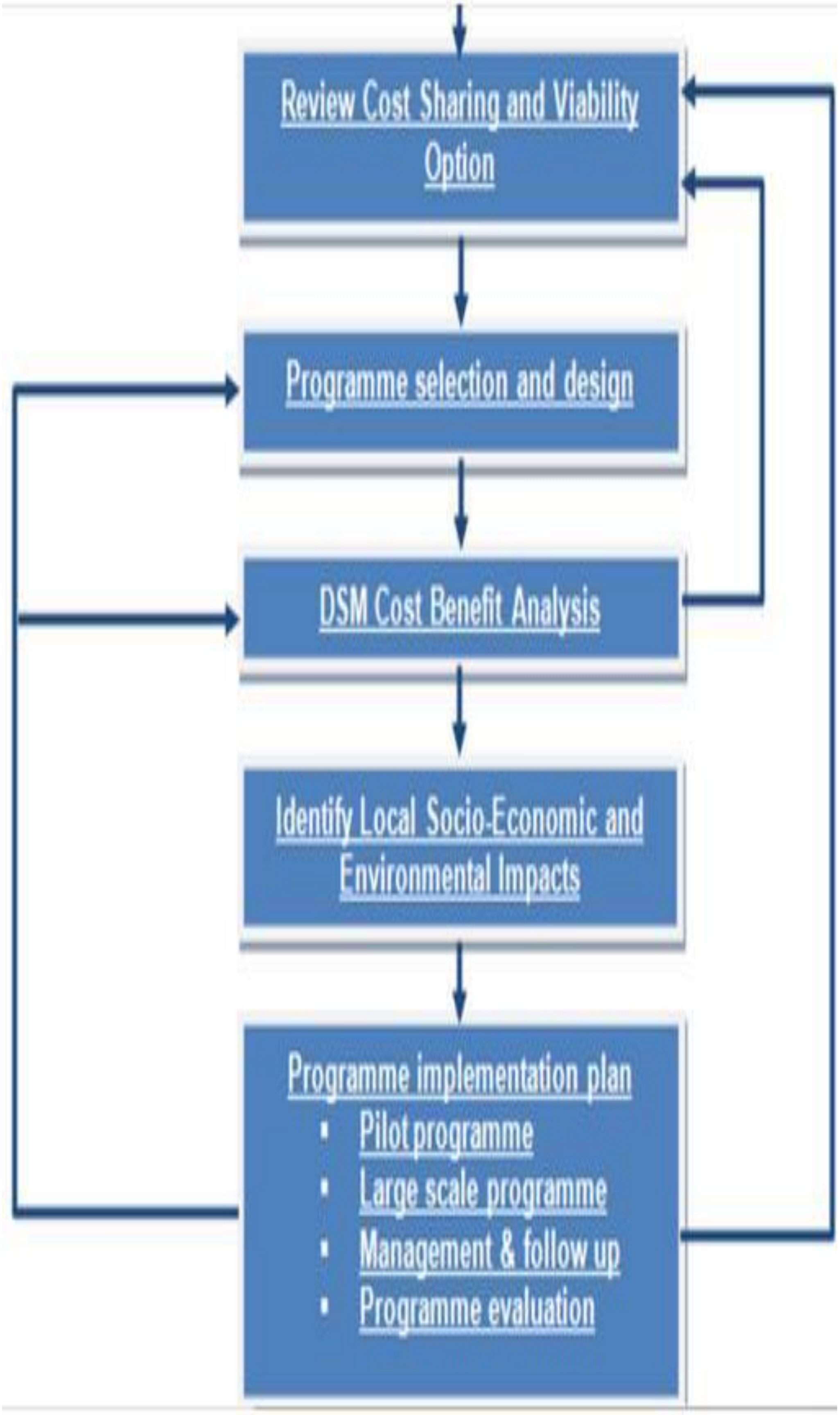
Implementation of DSM

Initiative from the consumer side is very important for successful DSM
•The scope of DSM includes

1. Load shifting/ Load management
2. Energy conservation
3. Increased electrification

Planning &implementation of DSM




Review Cost Sharing and Viability Option
Programme selection and design
DSM Cost Benefit Analysis
Identify Local Socio-Economic and Environmental Impacts
Programme implementation plan
Pilot programme
Large scale programme
Management & follow up
Programme evaluation

Planning & Implementation of DSM

1. Develop end-use Demand forecasting

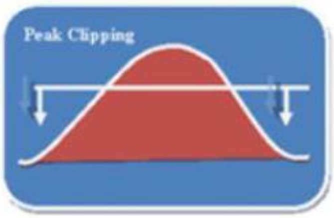
- **Forecasting by end-use** is an essential pre-requisite for effective DSM planning and implementation.
- Mid- and long-term forecasts of **power demand variations** play a very important role in the development of a DSM programme.
- **Demand forecasting** is an exercise that every electricity-generating company **should carry out regularly** in order to assess its **future equipment requirements.**

2. Undertake Load/ Market Research to identify end-use patterns and market barriers

- To design effective DSM programmes it is important to know **how electricity is used** and what **barriers** are **preventing customers from using efficient technologies.**
- Load research should be undertaken to estimate load curves for each sector or region, using **local sub-metering**, **customer bill analysis** and **customer surveys**.
- Major areas of interest to **DSM programmes** include the **residential, commercial, industrial, and public utility sectors.**
- Market research is needed to understand the target market, **identify barriers and evaluate possible solutions.**

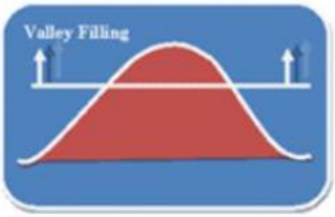
3. Define load-shape objectives

Peak Clipping



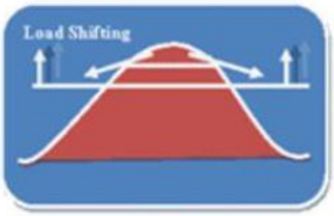
- Reduction in peak demand
- Controlling the equipments
- Controlled tariff rate

Valley filling



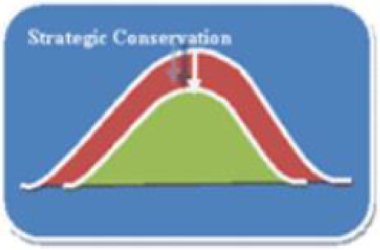
- Increasing load during off peak hours
- Building off peak loads

load shifting



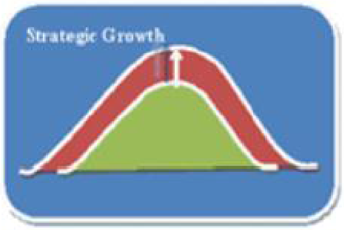
- Demand shift to off peak
- Shift peak load to off peak hours
- Popular applications include use of storage water heating, storage space heating, and coolness storage.

Strategic conservation



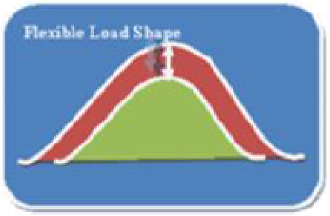
- The reduction of utility load, more or less equally, during all or most hours of the day
- Non traditional approaches to load management

strategic growth



- The INCREASE of utility load
- Load-shape change which refers to overall increase in sales

flexible load shape



- The interruptible agreements by utility to alter customer energy consumption on an as-needed basis

4. Identify target sectors, end-uses, and measures

•The **collected information** is normally useful in **determining** a typical **load curve** for each end-use.

•Find out load-curve management objectives

•**Choose sectors** and end-uses that account for the largest power consumption and **peak loads**, or will do so in the future.

•Select DSM measures which will have the largest impact on peak demand and electricity use.

5. Identify sources of financing

•In any DSM programme, **financing** is needed for individual projects undertaken by participants.

•Utilities may also require financing to cover administrative costs and cost sharing investments.

•Government/public fund is required.

6. Review Cost Sharing and Viability Options

•Cost sharing in a DSM programme should **try to maximize viability for each partner** (participant, utility, and government).

•The **wider the differences between tariffs**, the **higher the utility investment** can be, which in turn leads to a **higher participation rate**.

7. Programme Selection and Design

•**Identifying** a list of programmes for each customer class.

•**Formation of brief report** corresponding to that program

•Uniform reporting format is required.

8. DSM Cost/Benefit Analysis

•Based on the case study /measurement

•Calculation of financial interest

9. Identify Local Socio-Economic and Environmental Impacts

•Most DSM programmes provide **indirect economic and environmental benefits** as well as **reducing emissions** and other impacts from power supply facilities.

•Eg. employment is created in the energy services industry

10. programme Implementation Plan

•Implementation of any DSM programme requires **a core DSM staff or "cell"** within a power utility to develop a plan.

•For the programme and manage its implementation, even if consultants are hired for both aspects of the programme.

demand side management in agricultural

•Why DSM need in agriculture?

•Agriculture accounts for about 27% of electricity consumption in the country, which is increasing due to rural electrification efforts of the Government.

•The electricity is largely used in agricultural pump sets which generally have very poor efficiency. Most of the pilot projects as well as other studies project potential of 45-50% by mere replacement of inefficient pumps. Overall electricity savings (from 20 million pumps) is estimated at 62.1 billion units annually

The energy consumption is high due to-

1.improper selection and installation

2.use of high friction piping

3.Lack of proper maintenance

Options for improvement-

1.Remove of unnecessary pipe lengths

2. Remove of unnecessary bends

•3.replacement of GI pipe with PVC pipe

•4. capacitor bank for PF improvement

•5. do regular maintenance

DSM in residential sector

Residential electricity consumption contributed to about 25% of total electricity in India.

The main areas of consumption are

1. lightning

2. celling fan

3. television

4. refrigeration

5. air conditioners

DSM in commercial sector

•The main areas of consumption are

lightning
refrigeration
air conditioners

Ventilation
Heating
Water heating

DEMAND MANAGEMENT THROUGH TARIFFS (TOD)

•In India, Time of Day (TOD) tariff that was used mostly for industrial sector is now slowly being introduced for commercial sector as well.

•if you have an office or own a small business, this change in tariff can surely impact your electricity bill. It may present a chance to you to reduce your bill by altering the way you consume electricity in your office.

•Tariff structure:

1.time of day tariff
2.PF incentive & penalty/ reactive power charges.

1.Time Of Day (TOD) pricing

•Time of Day (or TOD) tariff is a tariff structure in which different rates are applicable for use of electricity at different time of the day.

•It means that cost of using 1 unit of electricity will be different in mornings, noon, evenings and nights.

• This means that using appliances during certain time of the day will be cheaper than using them during other times.

•TOD is already practicing in India for **HV installation, industries & large commercial installations**

•Gov. Should extend to other installation India for all types of load.

2. Apparent energy tariffs

•kVAh metering is a concept to replace the conventional kWh metering. It suggests that consumers must be billed as per the kVAh (apparent energy) drawl, and not as per the kWh (active energy).

• Implementation of the concept will mean that at each consumer premise a new type of meter will have to be installed, one which records kVAh.
Apparent energy, which is kVAh, contains a component called reactive energy (kVArh) whose generation is not directly related to conversion of energy resources.

•This reactive energy component may be necessary to support delivery of active energy, but it is not useful to the end consumer for conversion to any active work or output.

•Hence it may be said that apparent energy (kVAh) is not a commodity that the user wants to use and nor it is a commodity that transporters (i.e. distribution companies) transfer from generating stations.
Electricity is metered to meet two objectives (i) To account for active energy transmittals, that is, energy accounting (ii) For commercial metering, that is, to make a consumer pay for the electricity that they consumed.

•There needs to be accounting at every stage, and hence kWh is accounted for, right from the generating stations, through the transmission and distribution lines, and as delivered to end consumers, through the present kWh meters.

•All this is not possible if kVAh meters were used.

UNIT – V

USER SIDE REACTIVE POWER MANAGEMENT

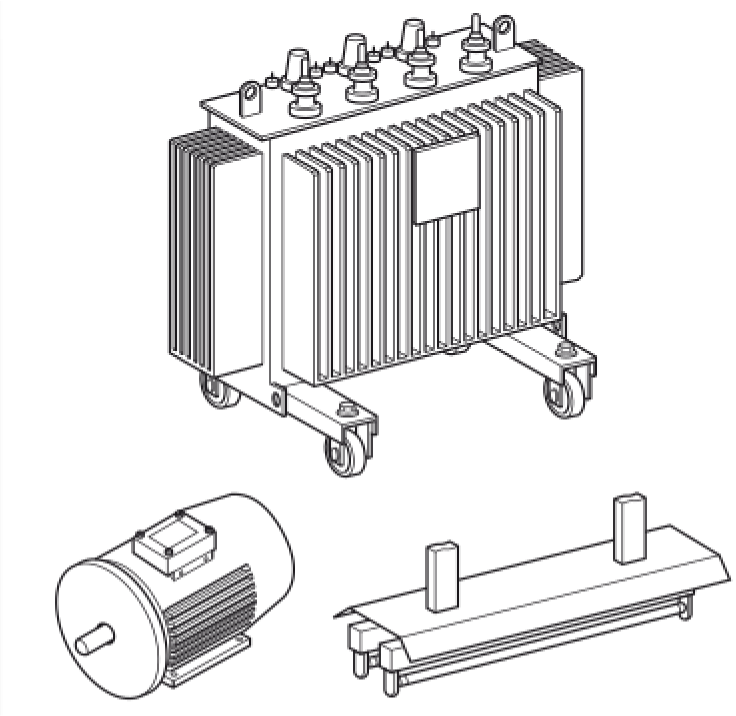
Requirements for domestic appliances

All AC equipment and appliances that include electromagnetic devices, or depend on magnetically coupled windings, require some degree of reactive current to create magnetic flux.

The most common items in this class are transformers, reactors, motors and discharge lamps with magnetic ballasts (see **Fig. L6**).

The proportion of reactive power (kvar) with respect to active power (kW) when a piece of equipment is fully loaded varies according to the item concerned being:

- 65-75% for asynchronous motors (corresponding to a Power Factor 0.8 – 0.85)
- 5-10% for transformers (corresponding to a Power Factor close to 0.995)



purpose of using capacitors:

The demand of active power is expressed in Kilo Watts (kW) or Mega Watts (MW). This power should be supplied from electrical generating station. All the arrangements in electrical pomes

system are done to meet up this basic requirement. Although in alternating power system, reactive power always comes in to picture. This reactive power is expressed in Kilo VAR or Mega VAR.
The demand of this reactive power is mainly originated from inductive load connected to the system. These inductive loads are generally electromagnetic circuit of electric motors, electrical transformers, inductance of transmission and distribution networks, induction furnaces, fluorescent lightings etc. This reactive power should be properly compensated otherwise, the ratio of actual power consumed by the load, to the total power i.e. vector sum of active and reactive power, of the system becomes quite less.

This ratio is alternatively known as electrical power factor, and fewer ratios indicates poor power factor of the system. If the power factor of the system is poor, the ampere burden of the transmission, distribution network, transformers, alternators and other equipments connected to the system, becomes high for required active power. And hence reactive power compensation becomes so important. This is commonly done by **capacitor bank**.
Let’s explain in details,
we know that active power is expressed = vIcosθ
Where, cosθ is the power factor of the system. Hence, if this power factor has got less valve, the corresponding current (I) increases for same active power P.
As the current of the system increases, the Ohmic loss of the system increases. Ohmic loss means, generated electrical power is lost as unwanted heat originated in the system. The cross-section of the conducting parts of the system may also have to be increased for carrying extra ampere burden, which is also not economical in the commercial point of view. Another major disadvantage, is poor voltage regulation of the system, which mainly caused due to poor power factor.

The equipments used to compensate reactive power.

There are mainly two equipments used for this purpose.

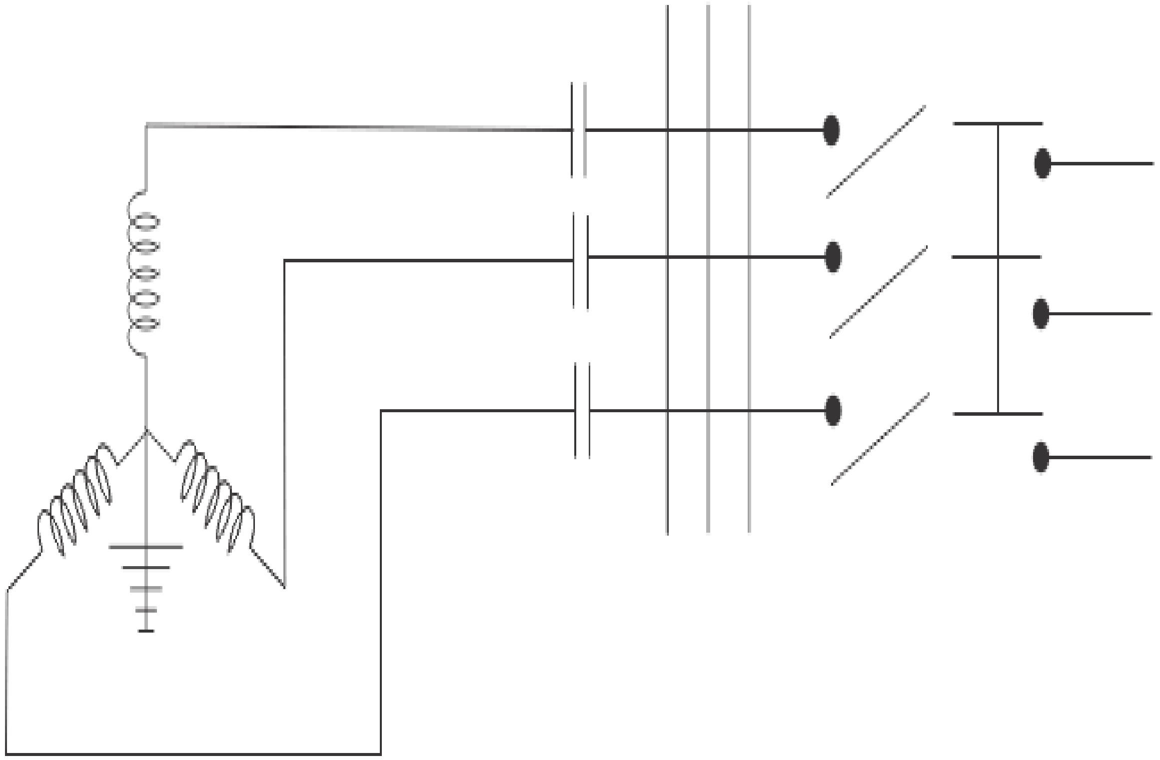
(1) Synchronous condensers

(2) Static capacitors or **Capacitor Bank**

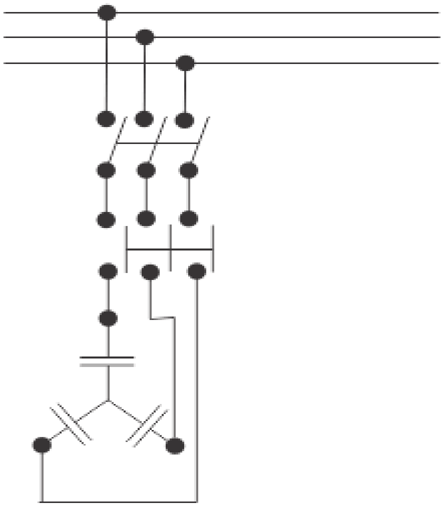
synchronous condensers, can produce reactive power and the production of reactive power can be regulated. Due to this regulating advantage, the synchronous condensers are very suitable for correcting power factor of the system, but this equipment is quite expensive compared to static capacitors. That is why synchronous condensers, are justified to use only for voltage regulation of very high voltage transmission system. The regulation in static capacitors can also be achieved to some extend by split the total capacitor bank in 3 sectors of ratio 1 : 2 : 2. This division enables the capacitor to run in 1, 2, 1 + 2 = 3, 2 + 2 = 4, 1 + 2 + 2 = 5 steps. If still further steps are required, the division may be made in the ratio 1 : 2 : 3 or 1 : 2 : 4. These divisions make the static capacitor bank more expensive but still the cost is much lower them synchronous condensers.

It is found that maximum benefit from compensating equipments can be achieved when they are connected to the individual load side. This is practically and economically possible only by using small rated capacitors with individual load not by using synchronous condensers.

Static Capacitor Bank



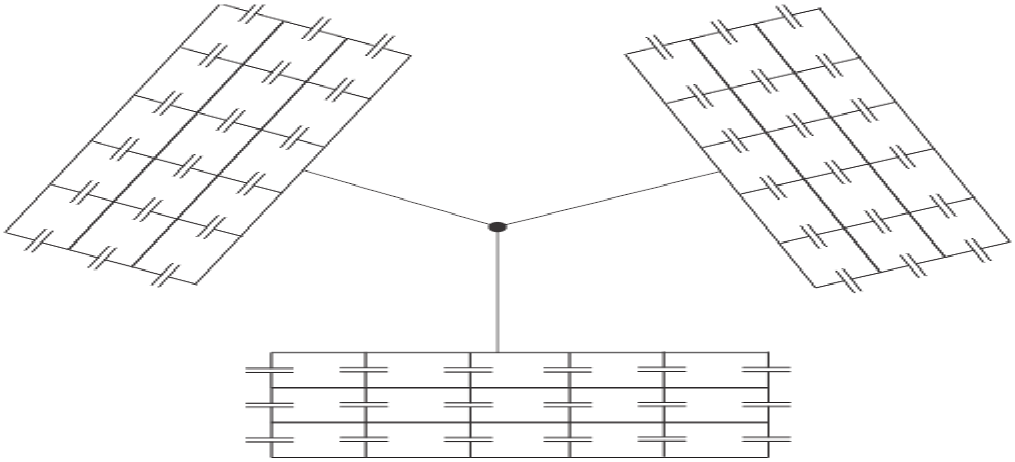
Series capacitor bank



There are some specific advantages of using shunt capacitors such as,

1. It reduces line current of the system.
2. It improves voltage level of the load.
3. It also reduces system Losses.
4. It improves power factor of the source current.
5. It reduces load of the alternator.
6. It reduces capital investment per mega watt of the Load.

Shunt Capacitor



5.4 MVAR-33 kV Bank

But it has however some drawbacks such as,

1. It has low dielectric constant.
2. The voltage distribution in the mineral oil is not uniform.
3. It is very inflammable.
4. It is subjected to oxidation.

dielectric plays a key role in categorizing the capacitors.

The factors to be considered are

- Operating voltage
- Size
- Leakage resistance
- Allowable tolerance, stability
- Prices

If a higher value of capacitance (C) is required than the increase in the cross-sectional area of dielectric or to reduce the distance of separation or to use dielectric material with stronger Permittivity.

The factors to be looked at before choosing a capacitor are

- **Stability:** The value of the capacitor changes with the time and temperature.
- **Cost:** It should be economical
- **Precision:** +/- 20% is not common
- **Leakage:** Dielectric will have some resistance and will leak for DC current.
- The Target PF and current Power Factor at site
- The Average & Maximum Demand in KVA or KW at the proposed site of installation
- Nature of Load of the Site.
- The availability of space at the site of installation, power cables etc.

Electric Traction

Electric traction systems generate various power quality problems that have an important impact on its distribution network. In this paper a DC electric traction system was modeled in order to generate the problems that its operation implicated. Once the power quality phenomena were replicated a compensation device, SVC, was added to de distribution network to improve voltage and also a filter was installed in the same node to reduce wave distortion. Finally the possible events that can appear if the original configuration of the compensator device is changed are evaluated.

Electric Arc Furnace in electric arc furnaces (EAFs). The time-varying characteristics of EAF accentuate the voltage fluctuations and produce flicker in power lines as well as neighboring loads. In order to solve this issue, quick and accurate response of SVC within a half-cycle ahead is required. This paper proposes a nonparametric approach based on lower upper bound estimation method (LUBE) to construct prediction intervals (PIs) for the reactive power in EAFs. Due to the nonlinear nature of reactive power signals in EAFs, a set of PIs are produced and combined to find an optimal aggregated PI. The proposed prediction method provides a faster-than-real-time monitoring of SVC which aims at high-speed and efficient reactive power compensation

Electric traction system

Electric traction involves the use of electricity at some stage or all the stages of locomotive movement. This system includes straight electrical drive, diesel electric drive and battery operated electric drive vehicles.

In this, electrical motors are used for producing the vehicle movement and are powered by drawing electricity from utilities or diesel generators or batteries.

t has many advantages over non-electric traction systems such as more clean and easy to handle, no need of coal and water, easy speed control, high efficiency, low maintenance and running costs, etc.

As mentioned above, electric traction systems can be self contained locomotives or vehicles that receive power from electric distribution system (substations). Self contained locomotives includes

- Battery operated electrical drives
- Diesel operated electrical drives

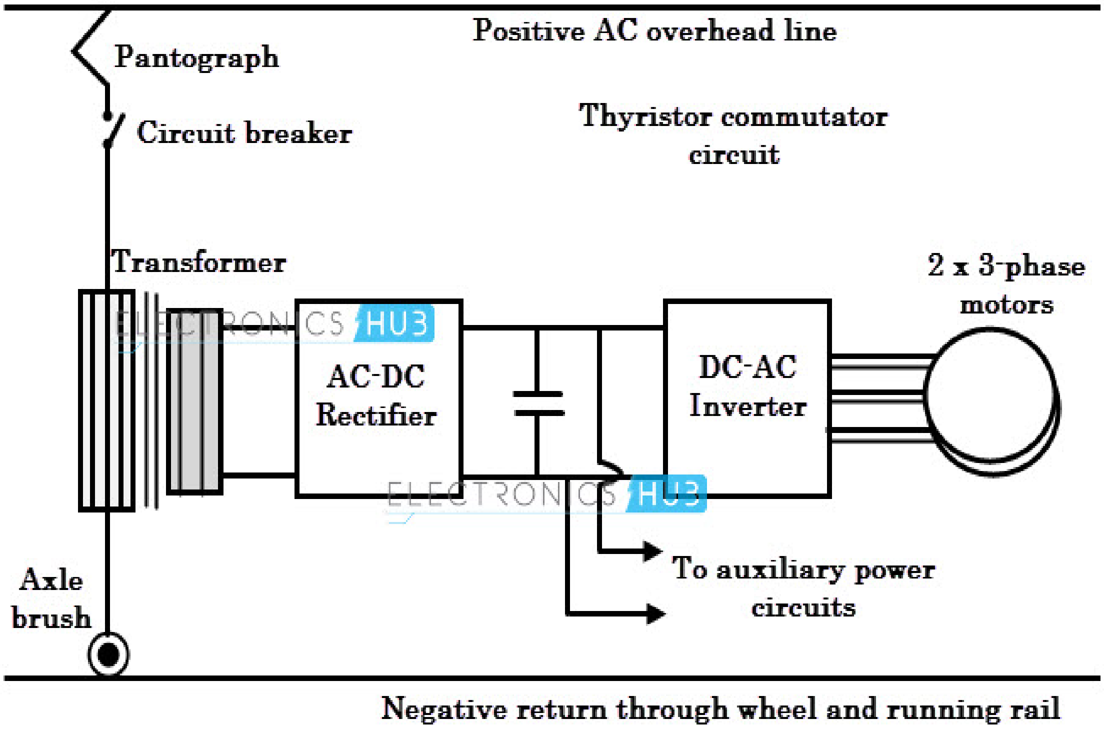
Vehicles that receives the power from substation is also referred as a third rail systems which includes

- Railway electric vehicles fed from overhead AC or DC supply
- Trolley buses or tramways supplied with DC supply (i.e., battery electric drives)

Supply Systems of Electric Traction

The way of giving the power supply to locomotive unit is generally referred as traction electrification system. Presently, there are four types of track electrification systems are available based on the availability of supply. These are

- DC traction system
- Single phase AC traction system
- Three phase AC traction system
- Composite traction system



Reactive Power in Operations

Reactive power affects power system operation in numerous ways:

1 Loads consume reactive power, so this must be provided by some source.

2 The delivery system (transmission lines and transformers) consumes reactive power, so this must be provided by some source (even if the loads do not consume reactive power). Note however that all transmission lines do provide some reactive power from their shunt line charging which offsets their consumption of reactive power in their series line losses.

3 The flow of reactive power from the supplies to the sinks causes additional heating of the lines and voltage drops in the network.

4. The generation of reactive power can limit the generation of real power. So, one primary dilemma with reactive power is that a sufficient quantity of it is needed to provide the loads and losses in the network, but having too much reactive power flowing around in the network causes excess heating and undesirable voltage drops. The normal answer to this dilemma is to provide reactive power sources exactly at the location where the reactive power is consumed. And, since strictly speaking it does not take any "fuel" to provide reactive power, it should be possible to distribute reactive power sources (such as capacitors) all around the network to avoid the problem of heating the conductors and causing voltage drops. Unfortunately, this is not practical in the extreme since there are literally millions of lines and loads connected to the grid and so this would require millions of reactive power sources - all controlled to provide exactly the right amount of reactive power at the right time - every second of every day. The best we can do in most cases is work with some type of aggregation of load (say at the feeder leaving a substation) and at terminals of major lines and transformers. This also brings up the issue of the difference between power factor control (trying to exactly provide the right amount of reactive power needed to equal that which is consumed) and voltage control (trying to keep voltage levels at exactly the right level no matter how much reactive power it takes). Reactive power is both the problem and the solution to network voltage control.

A **distribution transformer** or **service transformer** is a transformer that provides the final voltage transformation in the electric power distribution system, stepping down the voltage used in the distribution lines to the level used by the customer. [1] The invention of a practical efficient transformer made AC power distribution feasible; a system using distribution transformers was demonstrated as early as 1882.

If mounted on a utility pole, they are called **pole-mount transformers**. If the distribution lines are located at ground level or underground, distribution transformers are mounted on concrete pads and locked in steel cases, thus known as distribution tap pad-mount transformers.

Distribution transformers normally have ratings less than 200 kVA,[2] although some national standards can allow for units up to 5000 kVA to be described as distribution transformers. Since distribution transformers are energized for 24 hours a day (even when they don't carry any load), reducing iron losses has an important role in their design. As they usually don't operate at full load, they are designed to have maximum efficiency at lower loads. To have a better efficiency, voltage regulation in these transformers should be kept to a minimum. Hence they are designed to have small leakage reactance

Filter requirements

filter design is the process of creating the filter coefficients to meet specific filtering requirements. Filter implementation involves choosing and applying a particular filter structure to those coefficients. Only after both design and implementation have been performed can data be filtered. The following chapter describes filter design and implementation in Signal Processing Toolbox™ software.

The goal of filter design is to perform frequency dependent alteration of a data sequence. A possible requirement might be to remove noise above 200 Hz from a data sequence sampled at 1000 Hz. A more rigorous specification might call for a specific amount of passband ripple, stopband attenuation, or transition width. A very precise specification could ask to achieve the performance goals with the minimum filter order, or it could call for an arbitrary magnitude shape, or it might require an FIR filter. Filter design methods differ primarily in how performance is specified.

To design a filter, the Signal Processing Toolbox software offers two approaches. The first approach uses the designfilt function. As an example, design and implement a 5th-order lowpass Butterworth filter with a 3-dB frequency of 200 Hz. Assume a sample rate of 1 kHz. Apply the filter to input data.

The **electric arc furnace working principle** is based on the heat generated by an electric arc. The electric arc heating may be used in the following different ways.

By striking the arc between the charge and electrode: In this method, the heat is directly conducted and taken by the charge. The furnaces operating on this principle are known as direct arc furnace. These furnaces are used for production and refining of various grade of steel.

By striking the arc between two electrodes: In this method, the heat is transferred to the charge by radiations. The furnaces operating on this principle are known as indirect arc furnaces. These types of furnaces are used for melting of non-ferrous metals such as brass, copper and zinc.

There are two types of arc furnaces namely:

- Direct Electric Arc Furnace
- Indirect Electric Arc Furnace

Power Supply for Electric Arc Furnace

The power consumption of the arc furnaces is very high. The arc voltage is low i.e. between 50-150 V but the current required is of the order of several hundred amperes. As the heating effect is proportional to the square of the current, therefore, the higher current is essential to achieve the higher temperature.

For obtaining the required power supply a 3-phase arc furnace transformer is used. When the electrodes are short-circuited, the total input to the furnace is almost zero. On the other hand, when the electrodes are far away arc is extinguished and there is no power drawn from the supply mains.