POWER QUALITY

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DEFINITION

- The <u>IEEE</u> defines POWER QUALITY as the ability of a system or an equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

  PQ mainly deals with
  1. Continuity of the supply.
  2. ”Quality” of the voltage.

SCOPE

- For economic operation of a power system, the level of power quality should be properly maintained. PQ is a vast concept concerning optimization. The adverse effects due to over voltages, also the losses incurred due to the under voltages have to be seriously dealt. Also, nonlinear loads introduce harmonics in the system which have their own adverse effects including power factor reduction.
  Hence, power quality provides a good platform to deal with all these problems.

Power Quality Events

- The major problems in the power sector that need a treatment of quality upgradation are termed as power quality events.
  Power Quality provides the solutions to all these problems in a very efficient and optimized way.
  These problems, if not mitigated would cause heavy economic as well as technical disturbances.

BLACKOUTS

It is short or long term loss of electric power to an area.

CAUSES:

- Faults at power stations.
- Damage to electric transmission lines, substations or other parts of the distribution system.
- Short circuit, or the overloading of electricity mains.

EFFECTS:

- Total loss of power to an area.
- Tripping of substations.
- Under certain conditions, a network component shutting down can cause current fluctuations in neighboring segments of the network leading to a cascading failure of a larger section of the network. This may range from a building, to a block, to an entire city, to an entire electrical grid.

BROWNOUTS

A brownout is an intentional or unintentional drop in voltage in an electrical power supply system.

CAUSES:

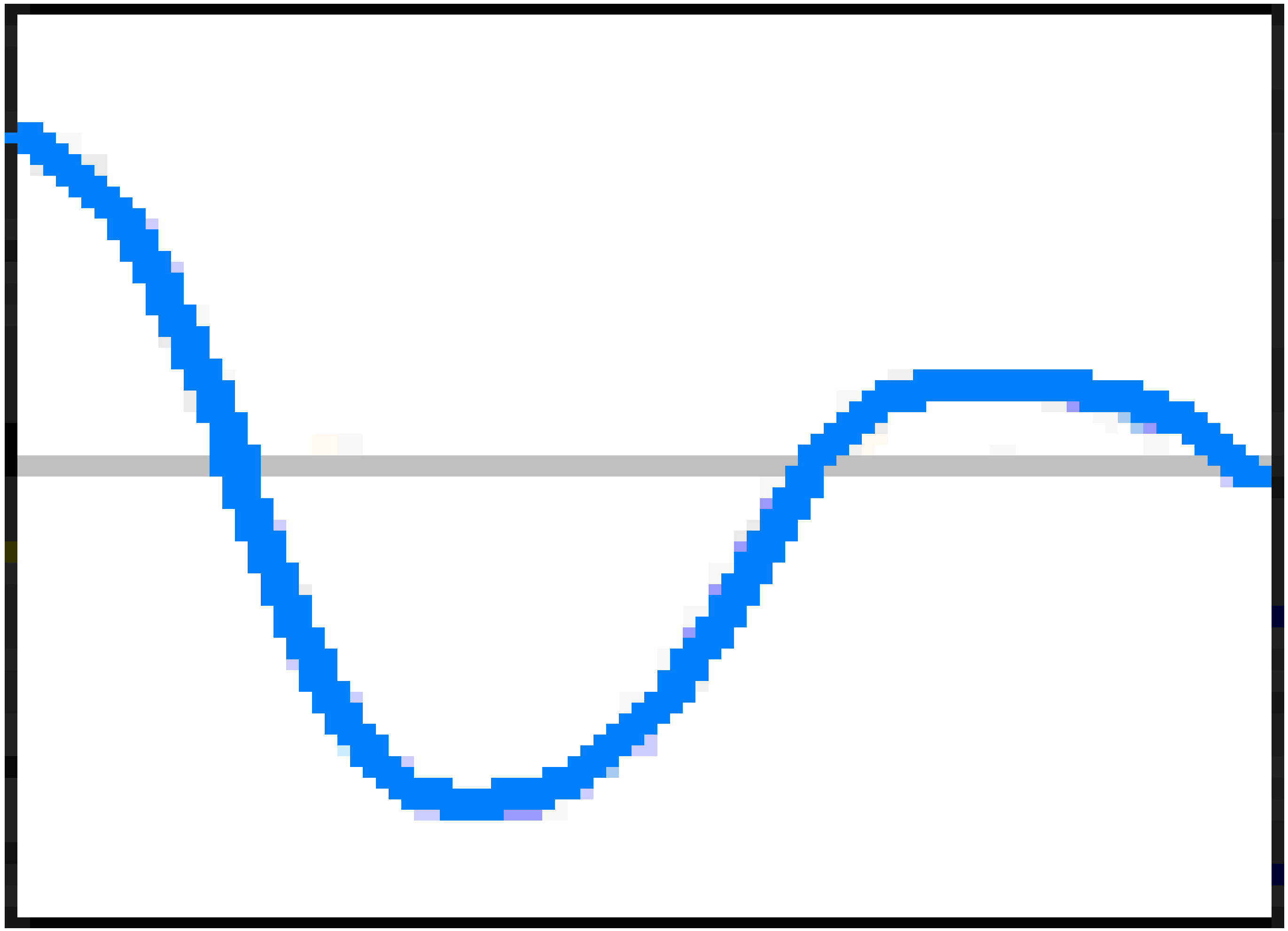
- Use of excessive loads causes reduction in voltage which in turn causes brownouts.

EFFECTS:

- Unexpected behavior in systems with digital control circuits.
- The system can experience glitches, data loss and equipment failure.

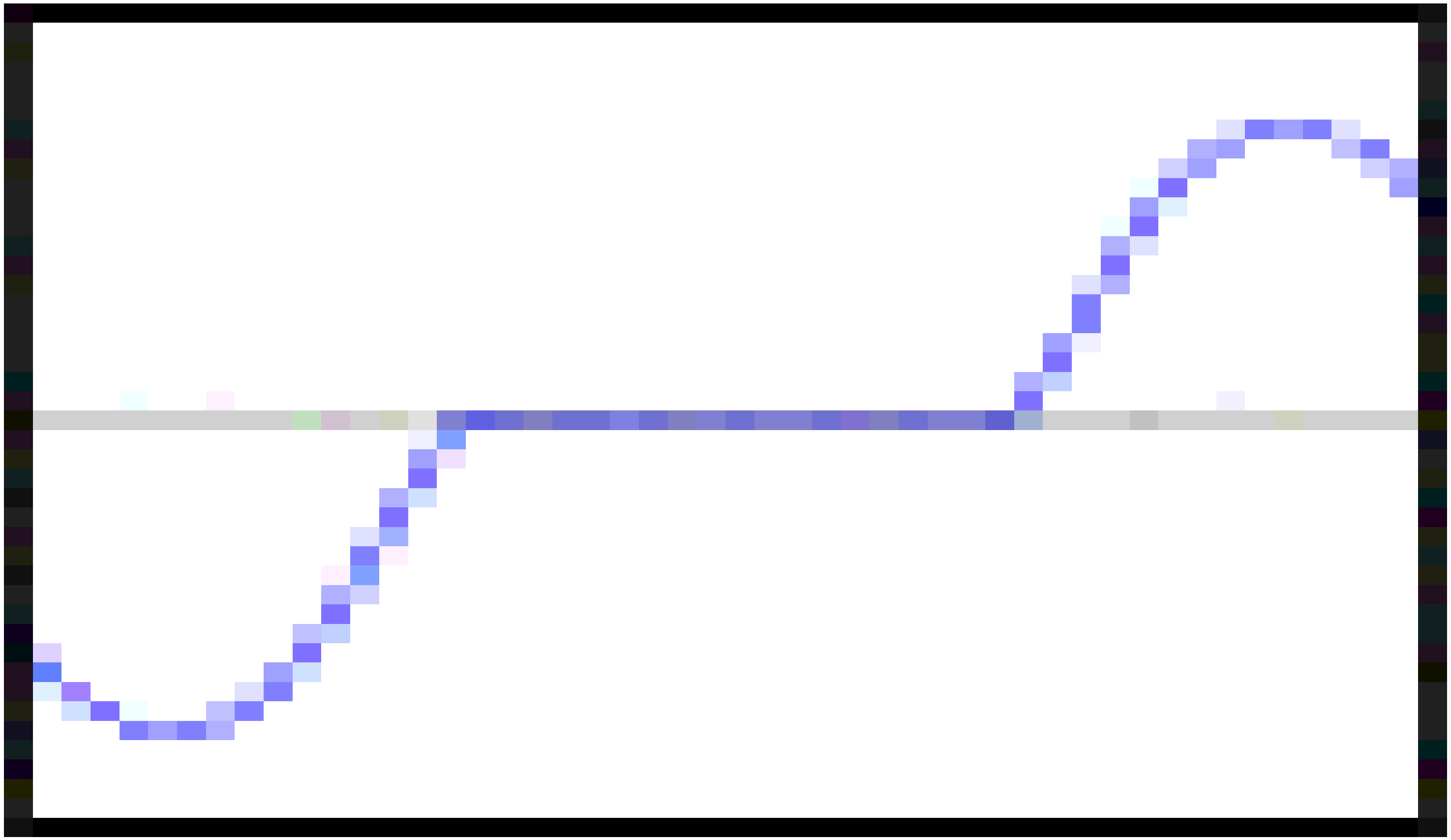
Voltage Sag (or dip)

- **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.



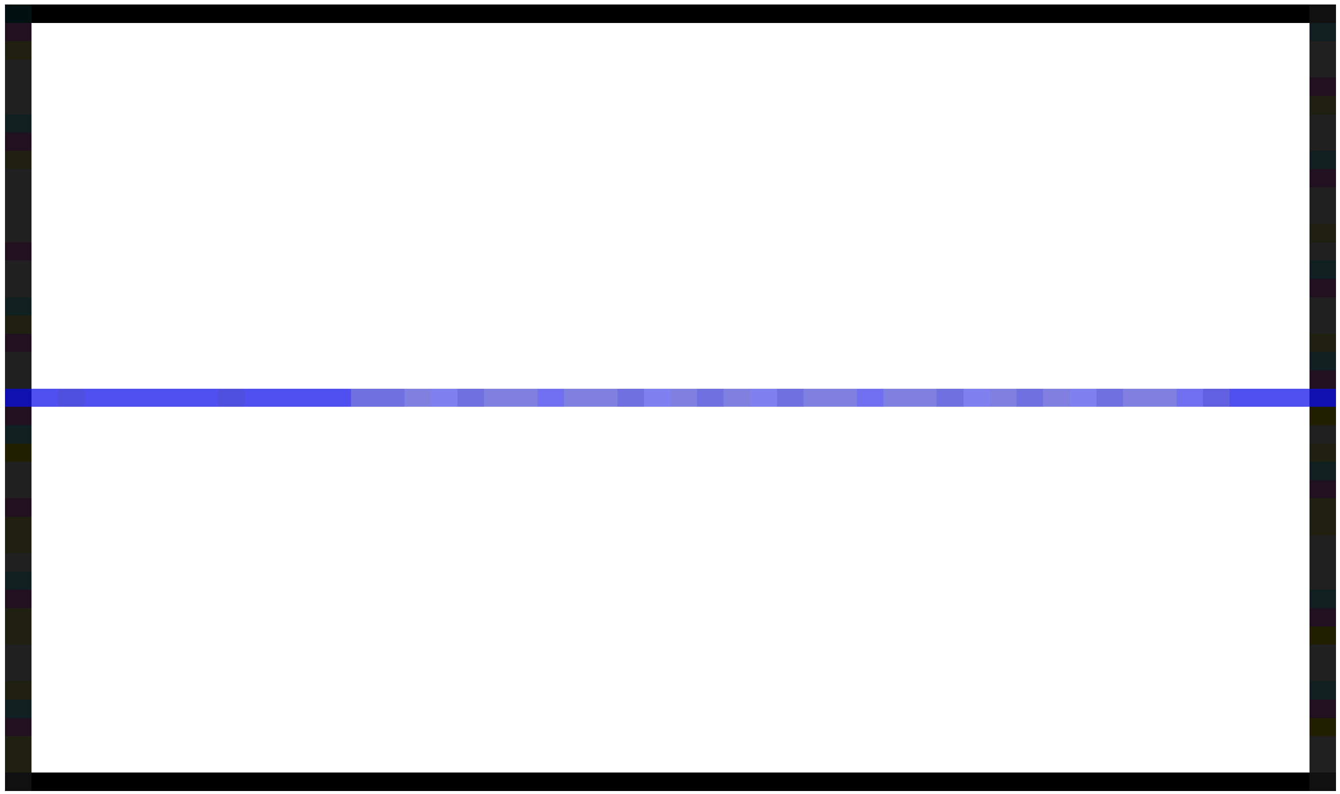
Very Short Interruptions

- **Description:** Total interruption of electrical supply for duration from few milliseconds to one or two seconds.
- **Causes:** Mainly due to the opening and automatic enclosure 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 Spikes

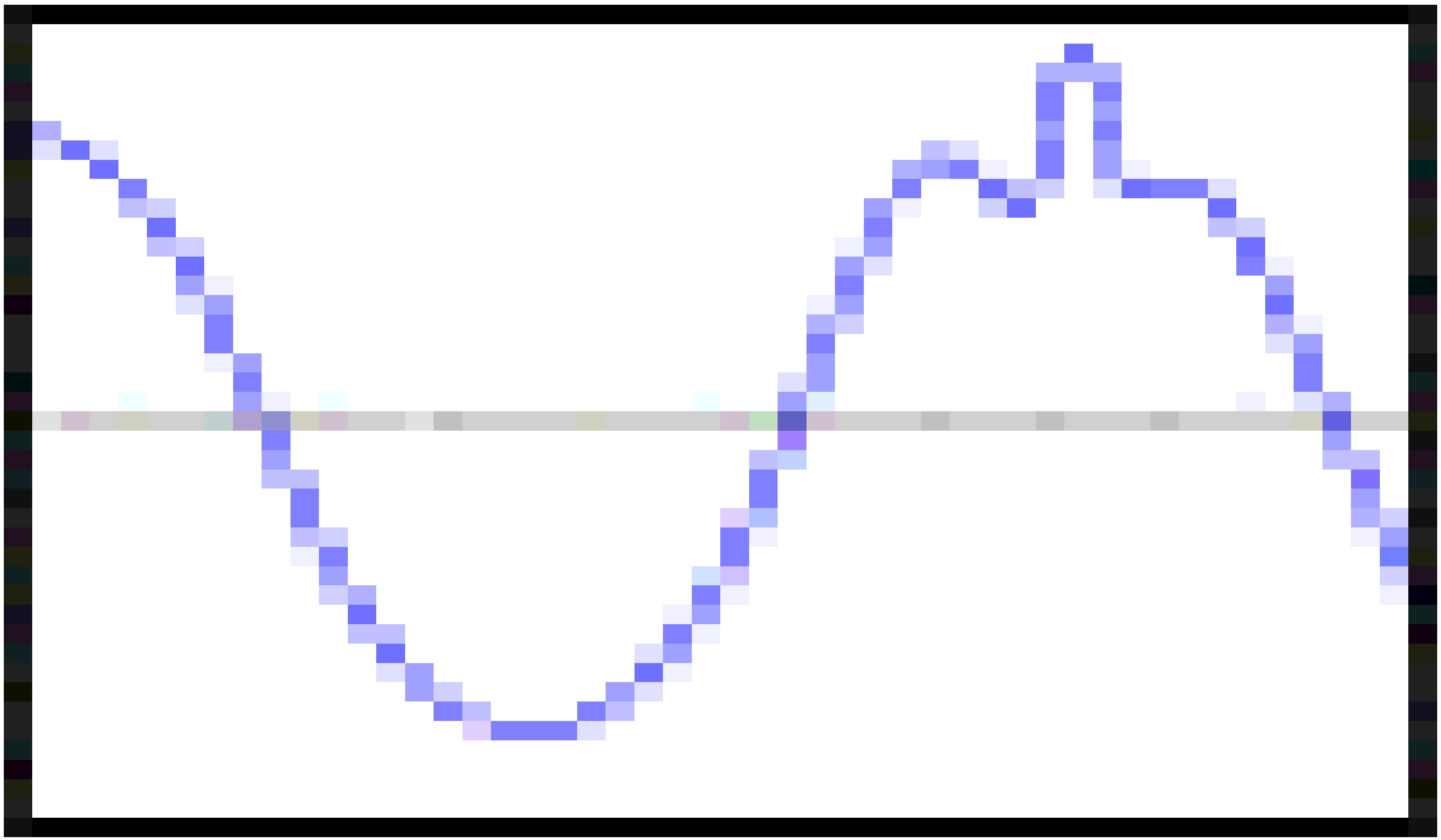
- In electrical engineering, spikes are fast, short duration electrical transients in voltage.

CAUSES:

- Lightning strikes
- Power outages
- Tripped circuit breakers
- Short circuits

EFFECTS:

- Voltage spikes may be created by a rapid buildup or decay of a magnetic field, which may induce energy into the associated circuit.



Voltage Swell

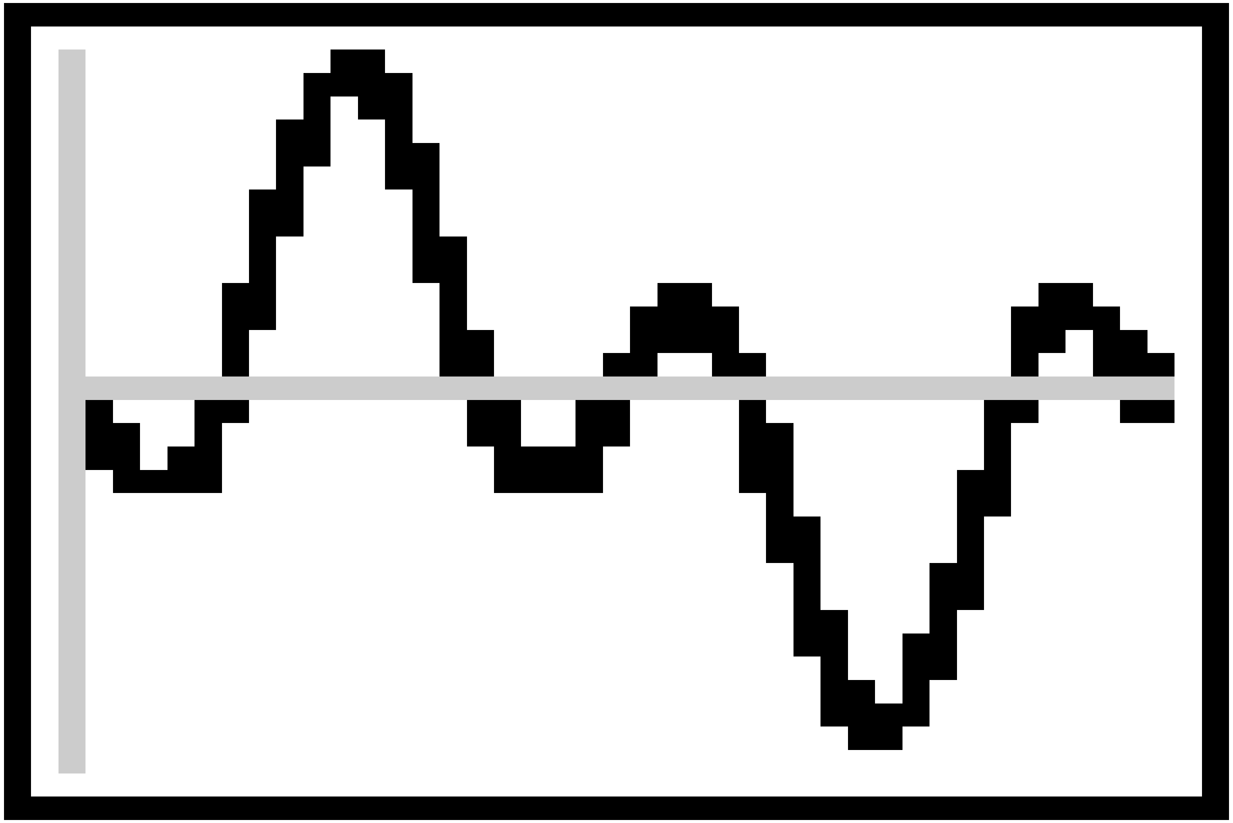
- **Description**: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.
- **Causes:** Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during 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

- **Description:** 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.

- **Causes:** *Classic sources: electric machines working above the knee of the magnetization curve (magnetic* saturation), arc furnaces, welding machines, rectifiers, and DC brush motors.
- *Modern sources: all non-linear* loads, such as power electronics equipment including ASDs, switched mode power supplies, data processing equipment, high efficiency lighting.

- **Consequences:** Increased probability in occurrence of resonance, neutral overload in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, errors in measures when using average reading



VOLTAGE SURGES

- It is a voltage rise that endangers the insulation of electric equipment.

TYPES :

1. Lightning surges.
2. System-generated surges.

CAUSES:

1. Shutdown of heavily loaded circuits.
2. Necessary commutation of a high-powered network (e.g. Pf correction).
3. Switching events such as the connection or disconnection of a current and short-circuiting to ground.

EFFECTS:

- Computers and other sensitive electronic equipment can seriously be damaged by such an over-voltage surge.
- Temporal fluctuations produce parity errors and interrupts protection systems.

FLICKERING

- It is a visible change in brightness of a lamp due to rapid fluctuations in the voltage of the power supply.

CAUSE:

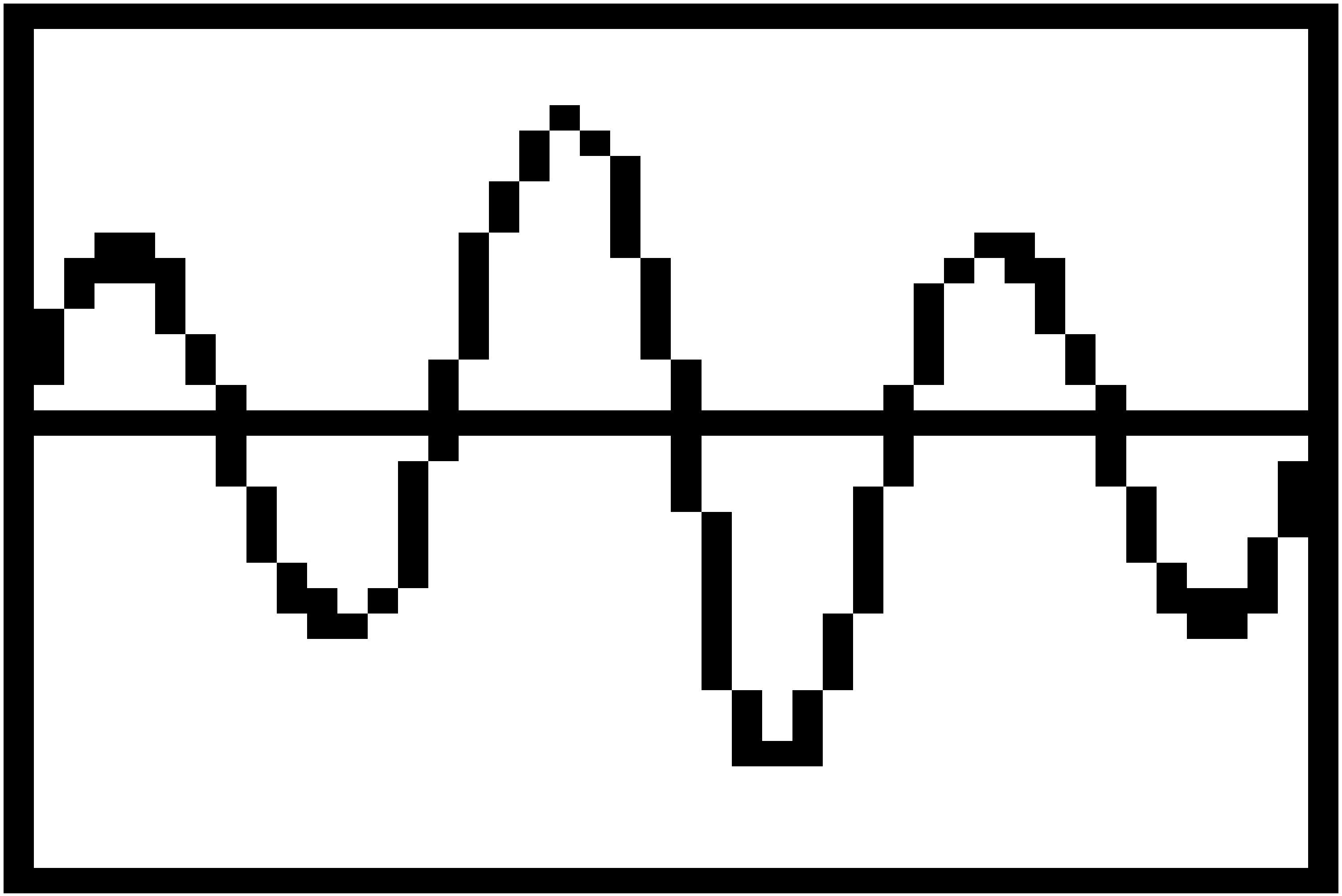
- It increase as the size of the changing load becomes larger with respect to the prospective short circuit current available at the point of common connection.

EFFECTS:

1. Filament of lamp can be damaged.
2. Reduction in life of electrical equipment

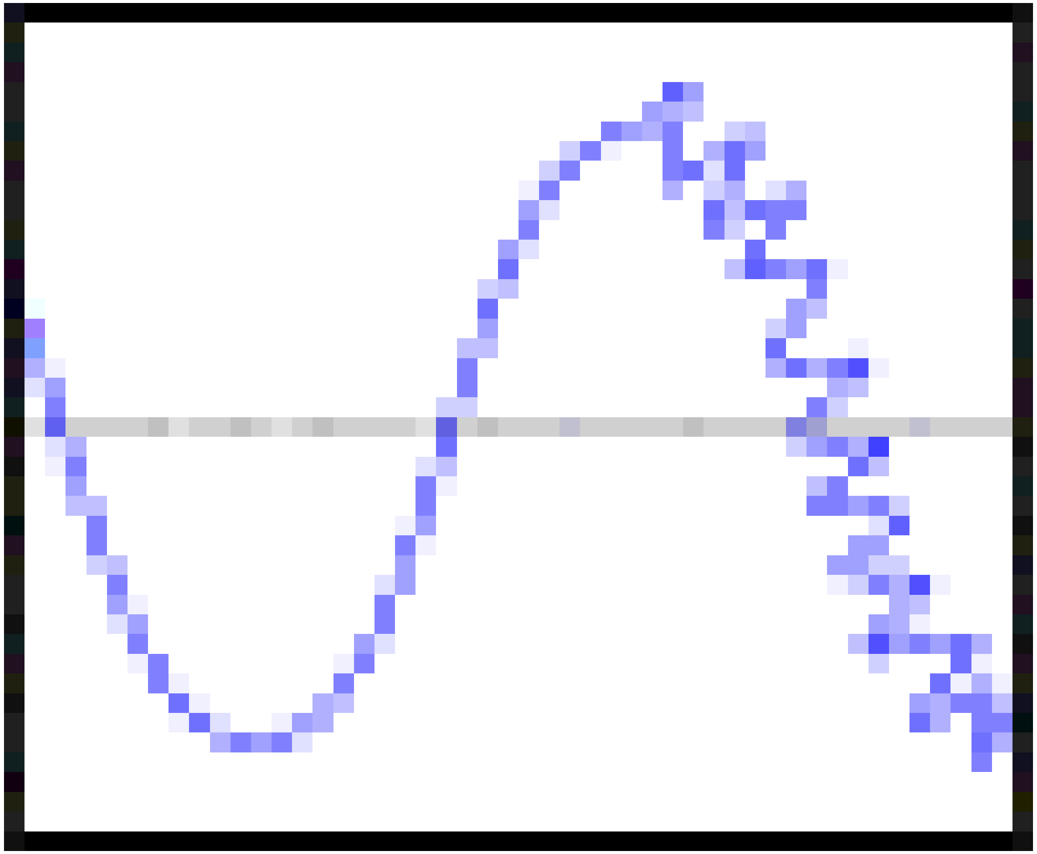
Voltage Fluctuation

- **Description:** Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz.
- **Causes:** Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads.
- **Consequences:** 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.



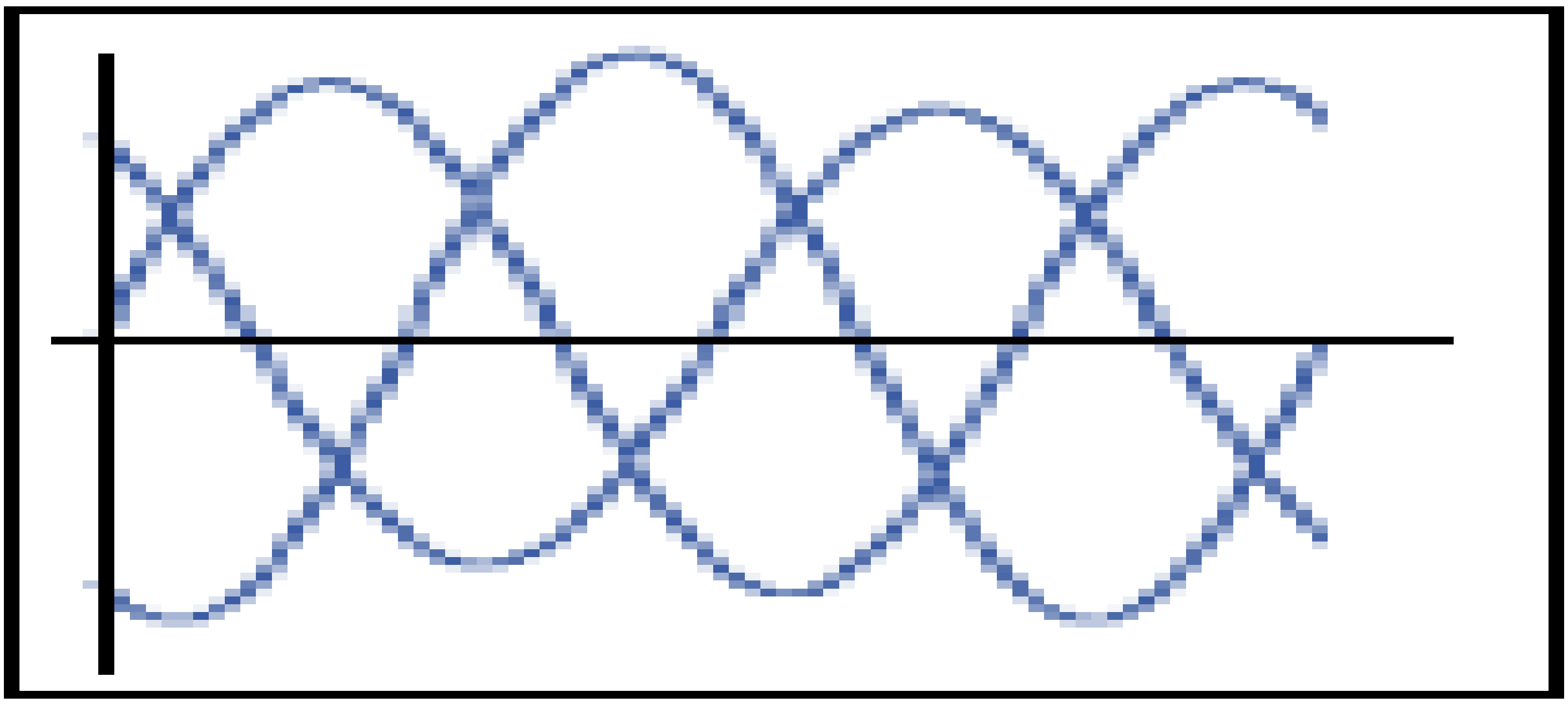
Noise

- **Description:** 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.

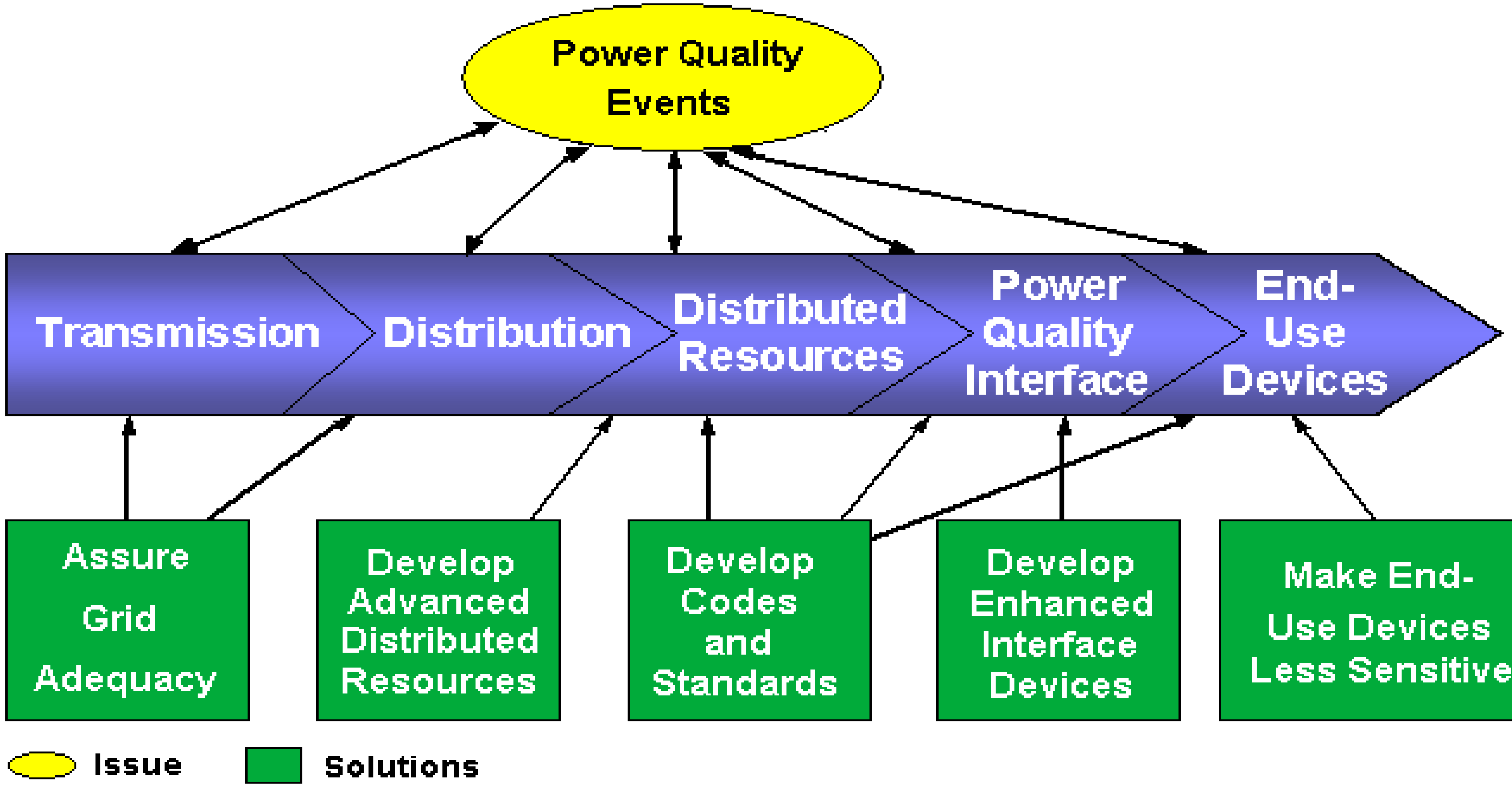


Voltage Unbalance

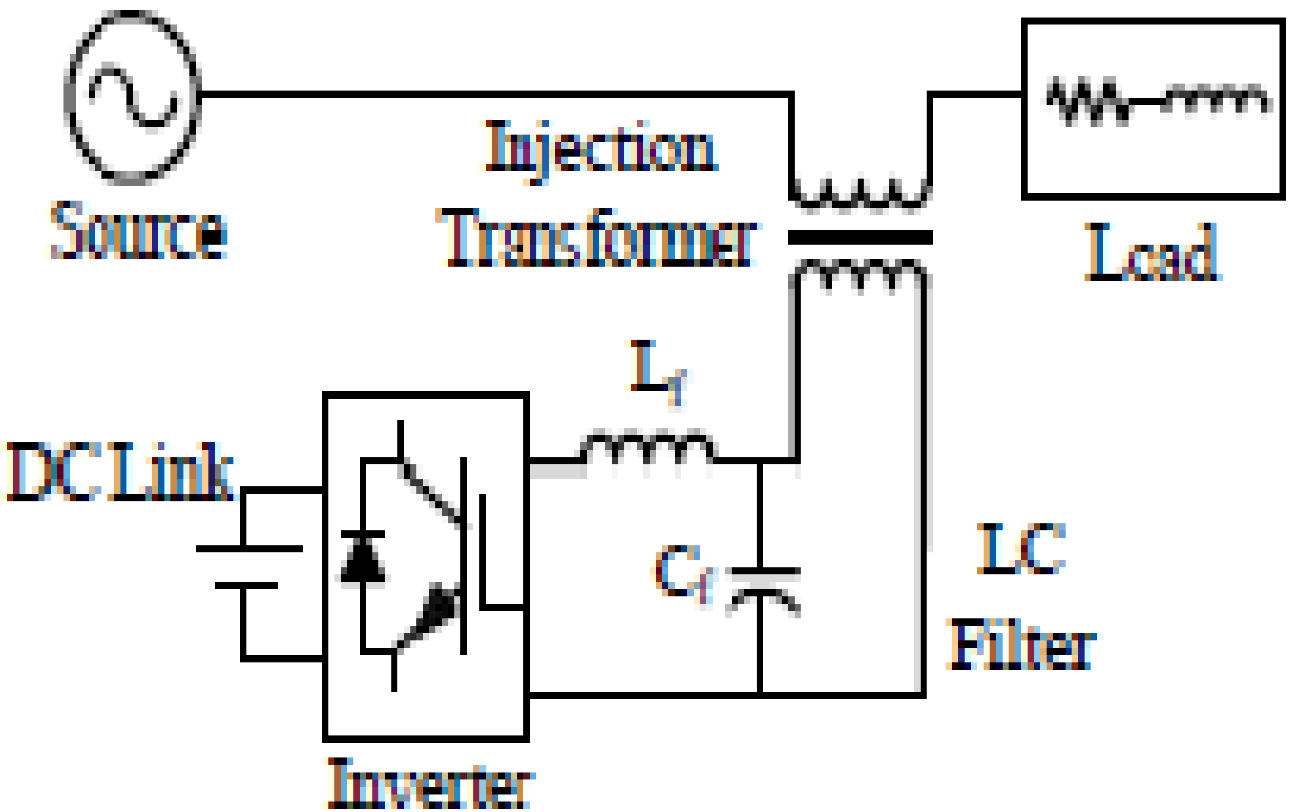
- **Description:** A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences between them are not equal.
- **Causes:** Large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases 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.



MITIGATION TECHNIQUES

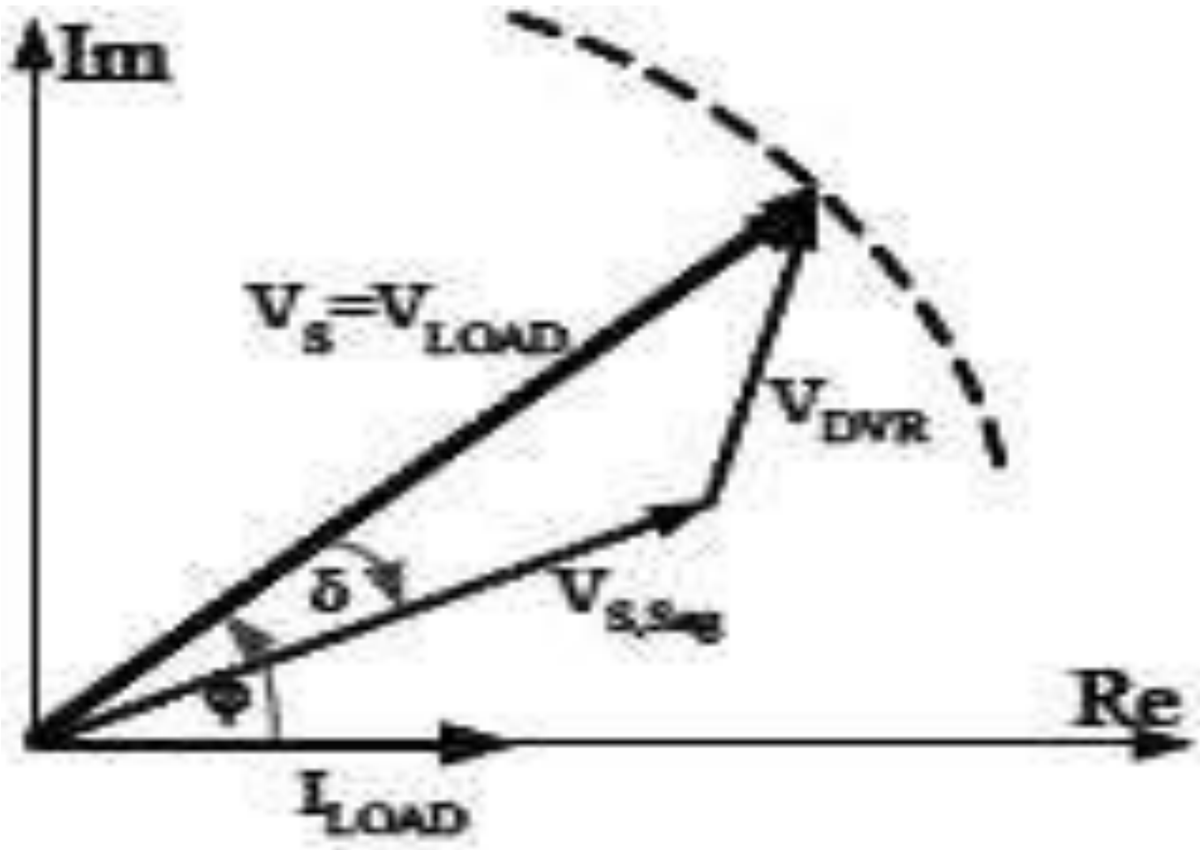


DYNAMIC VOLTAGE RESTORER



- **The Dynamic Voltage Restorer (DVR)**, also referred to as the Series Voltage Booster (SVB) or the Static Series Compensator (SSC), is a device that utilizes solid state (or static) power electronic components, and is connected in series to the utility primary distribution circuit. The DVR provides three phase controllable voltage, whose vector (magnitude and angle) adds to the source voltage to restore the load voltage to pre-sag conditions.

Compensating Vector Diagram



Sag Detection Techniques

- Peak value method
- Root mean square method
- Fourier transform
- Space vector method

CONTROL TECHNIQUES

- Linear Controllers
  (Open loop or Closed loop control system)

- Non Linear Controllers
  (Sinusoidal Pulse width modulation techniques)

Harmonic Filters

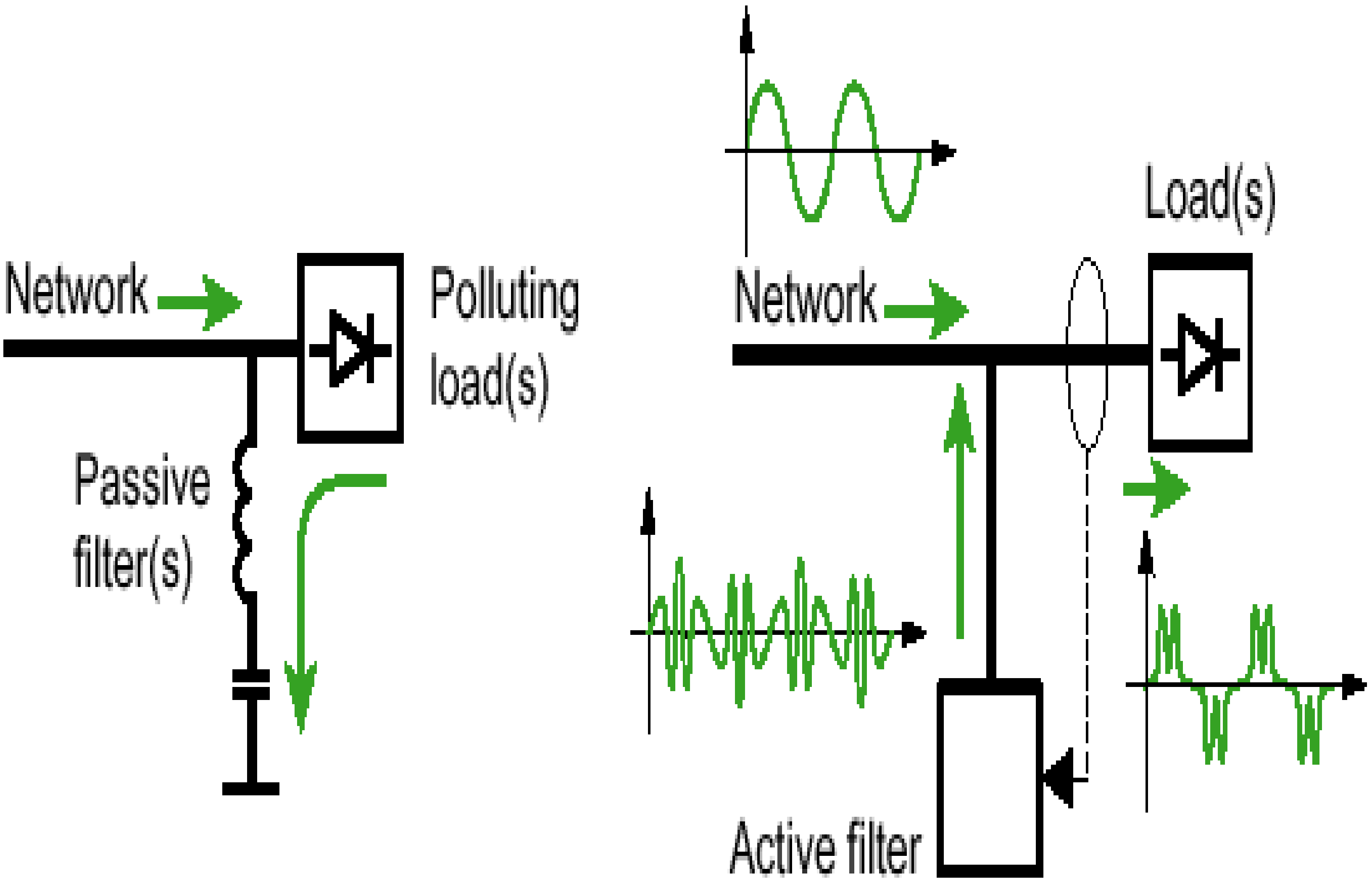
Power factor depends on:-

1. Displacement between current and voltage phasors
2. Total Harmonic distortion

   pf = displacement pf * distortion pf

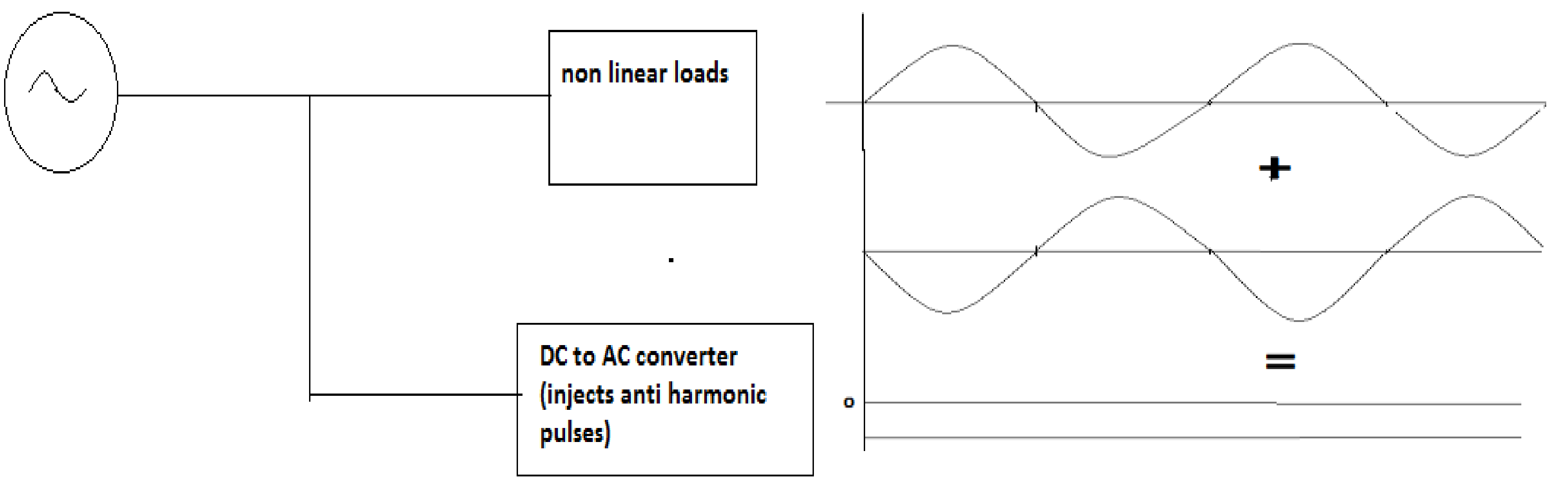
Current-voltage displacement can be minimized by using capacitor banks(to compensate the reactive power) and synchronous condensers, etc.

- Harmonic distortion can be minimized by using harmonic filters(an arrangement of linear elements).
- These elements are so arranged so as to eliminate the particular harmonics(of integral Fourier order).
- Once the harmonics are maximum filtered off, the distortion power factor(inversely proportional to the total harmonic distortion) turns unity and thus the power factor improves.


Network
Polluting
load(s)
Passive
filter(s)
Load(s)
Network
Active filter

Distribution Static Compensators

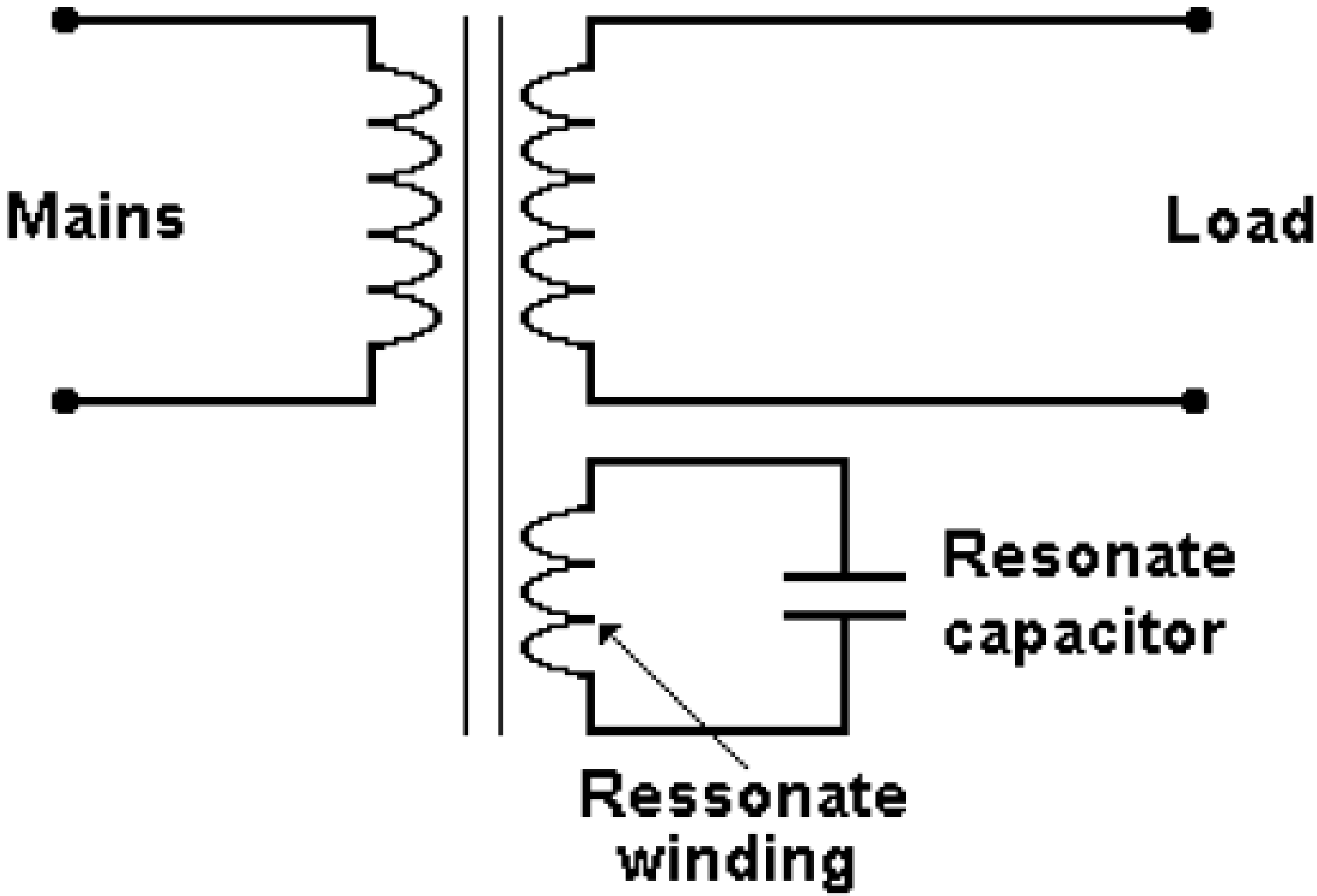
- Inject the pulses which are exactly 180 degrees out of phase of the unwanted harmonics , thus cancelling out the unwanted harmonics and yielding the output wave, very close in nature to the fundamental wave



Constant Voltage Transformers

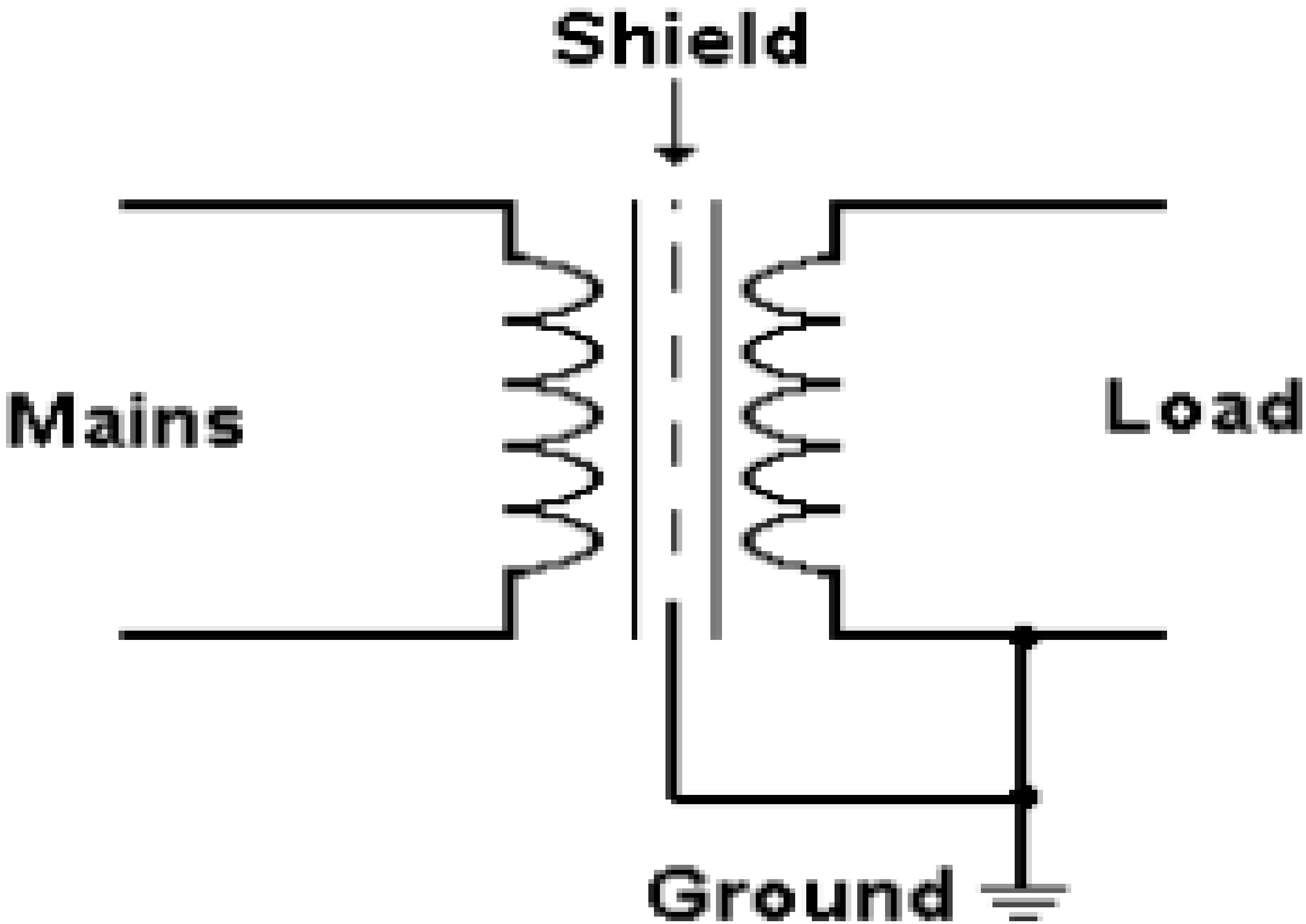
- Constant voltage transformers (CVT) were one of the first PQ solutions used to mitigate the effects of voltage sags and transients. To maintain the voltage constant, they use two principles that are normally avoided: resonance and core saturation.

- When the resonance occurs, the current will increase to a point that causes the saturation of the magnetic core of the transformer. If the magnetic core is saturated, then the magnetic flux will remain roughly constant and the transformer will produce an approximately constant voltage output. If not properly used, a CVT will originate more PQ problems than the ones mitigated. It can produce transients, harmonics (voltage wave clipped on the top and sides) and it is inefficient (about 80% at full load). Its application is becoming uncommon due to technological advances in other areas.


Mains
Load
Resonate
capacitor
Ressonate
winding

Isolation Transformers

Isolation transformers are used to isolate sensitive loads transients and noise deriving from the mains.
In some cases (Delta-Wye connection) isolation transformers keep harmonic currents generated by loads from getting upstream the transformer.
The particularity of isolation transformers is a grounded shield made of nonmagnetic foil located between the primary and the secondary. Any noise or transient that come from the source in transmitted through the capacitance between the primary and the shield and on to the ground and does not reach the load.


Shield
Mains
Load
Ground

Transient Voltage Surgé suppressors (TVSS)

Transient voltage surge suppressors are used as interface between the power source and sensitive loads, so that the transient voltage is clamped by the TVSS before it reaches the load. TVSSs usually contain a component

with a nonlinear resistance (a metal oxide varistor or zener diode) that limits excessive line voltage and conduct any excess impulse energy to ground.

Noise Filters

Noise filters are used to avoid unwanted frequency current or voltage signals (noise) from reaching sensitive equipment. This can be accomplished by using a combination of capacitors and inductances that creates a low impedance path to the fundamental frequency and high impedance to higher frequencies, that is, a low-pass filter.

They should be used when noise with frequency in the kHz range is considerable.

Static VAR Compensators

Static VAR compensators (SVR) use a combination of capacitors and reactors to regulate the voltage quickly.

Solid-state switches control the insertion of the capacitors and reactors at the right magnitude to prevent voltage from fluctuating. The main application of SVR is the voltage regulation in high voltage and the elimination of flicker caused by large loads (such as induction furnaces).

SVCs are used for:

1. Increasing power transfer in long lines
2. Stability improvement (both steady state and transient) with
   fast acting voltage regulation
3. Damping of low frequency oscillations (corresponding to electromechanical modes.)
4. Control of dynamic over voltages

Characteristics of SVC

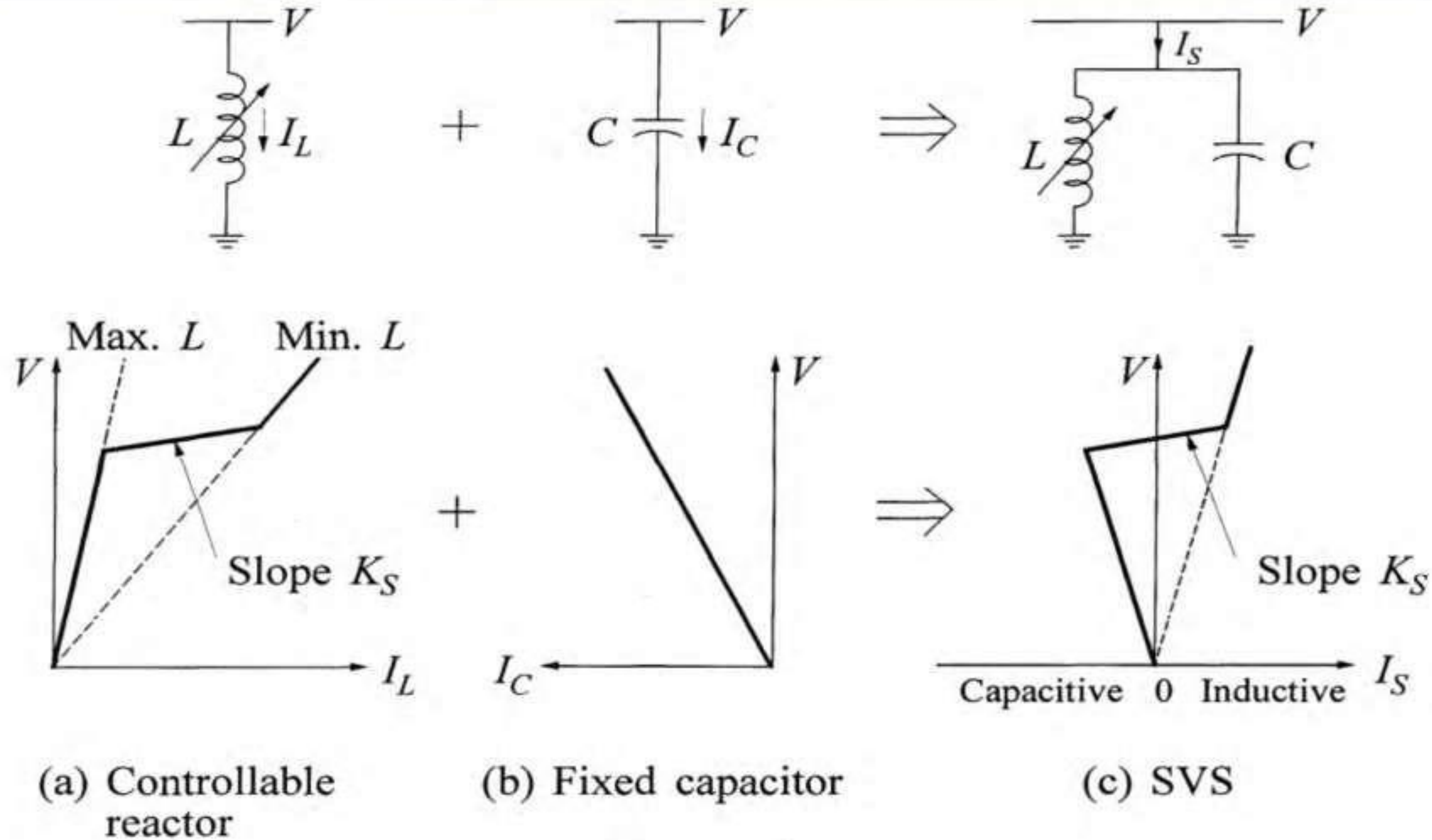
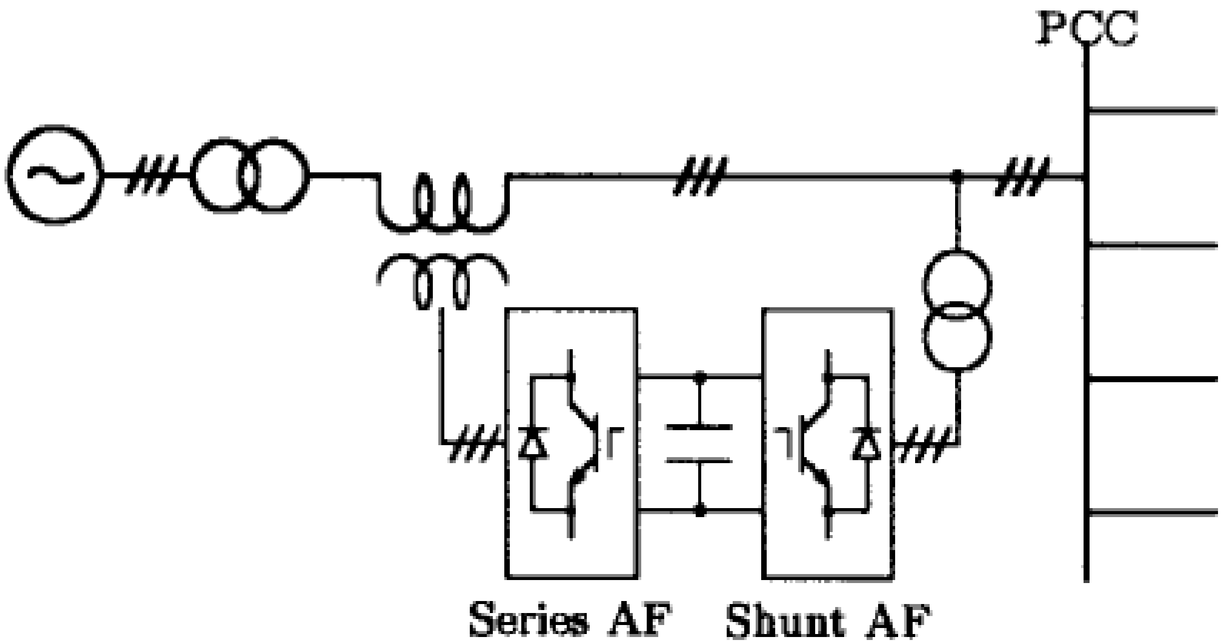


Figure 11.41 Composite characteristics of an SVS

5. Unified Power Quality Conditioner

- The integration of series-active and shunt-active filters.
- The main purpose of a UPQC is to compensate for voltage flicker/imbalance, reactive power, negative sequence current, and harmonics.
- In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems.
- A **UPQC that combines the operations of a Distribution** Static Compensator **(DSTATCOM) and Dynamic Voltage** Regulator **(DVR) together.**



General UPQC.

In short,

•Shunt active filters eliminate the harmonics,

•Whereas, Series active filters allow the passage of only the fundamental wave.

IMPACTS ON ENVIRONMENT AND SOCIETY

1. The mitigation of all the power quality related issues leads to the economic operation of the power system.

2. A technically sound quality of power will be supplied to the equipments, thereby leading to their smooth operation and ensuring a long life for them.

3. The elimination of harmonics and other issues leads to the proper operation of the system, thereby eliminating the unwanted vibrations and keeping the system stable.

4. The reactive power is compensated at an acceptable and affordable cost and thus, the system efficiency improves.
5. The power factor is improved; this leads to a heavy savage in the costs of electricity bills.

6. Above all, the problem of power pollution is eliminated.

Conclusion

- POWER QUALITY maintenance is an important aspect in the economic operation of a system.
- Various PQ problems may lead to another undesirable problems.
- Proper mitigation devices can be used to maintain the level of power quality as desired.