Power Quality (PQ)
Improvement Systems on LT distribution
Benchmarking of PQ
and
Various methods & merits.

Power Quality (PQ) Improvement Systems on LT distribution
Benchmarking of PQ and Various methods & merits.

General PQ:

Power Quality has multiple issues involved. Thus, need to have some benchmarking standards.

Very little is spoken about the LT supply installation within an industry. There is need to understand PQ requirements within an Electrical Installation.

Various type of Industries and Commercial installation has different needs for PQ. The type of equipments used too are varied nature and needs different PQ standards.

Views from Supply utility and PQ improving equipment supplier always have seen to dominate the LT supply consumer PQ standards.

Need for every electrical installation to define own standards based upon their own needs rather than governing by others.

Power Quality (PQ) Improvement Systems on LT distribution
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Benchmarking Requirements for PQ:

Factors governing PQ benchmarking are:

- **Governed by supply utility. Measured normally at point of supply (or metering point).**
- **Governed by the equipments used by consumer. The equipment specifications with regards to PQ requirements.**
- **Processes for manufacturing goods quality control within the industry. Mainly the process reliability.**
- **Other factors such as Human safety and data communication requirements.**

Benchmarking Requirements for PQ:

Various issues in PQ that are to be encountered:

- Voltage Sags and Swells.
- Momentary mains cycles loss.
- Voltage surges and High frequency noise / disturbance (sometimes called as transients or glitches)
- Current surges and high fluctuation of load current (normally reflects onto voltage problems)
- Current Harmonics and consequential Voltage Harmonics.
- Inter-harmonics on Current and Voltages.
- Neutral floating or shifting.
- Earthing Problems.
- Power Outages and effect of Auto-Reclose system.
- Power Frequency variations.

Benchmarking Requirements for PQ:

The process of benchmarking within the given installation requires activities like:

1. **Study of installation electrical distribution diagram (SLD – Single line diagram) and identify the critical points on the same where the PQ issues can be measured. i.e. identifying the points for survey.**
2. **Checking out the specifications of the equipments that are supplied from the specified points in electrical diagram that are selected for survey.**
3. **After identifying the survey points on electrical installation diagram, defined the different PQ issues that are needed to be surveyed. This should be based upon the equipment specifications too.**
4. **Check the supply utility standards and incorporate these too at PCC survey point.**

Continued -----

Benchmarking Requirements for PQ:

The process of benchmarking within the given installation requires activities like:

5. **With identified survey points, one needs to define the survey standards for every PQ issue identified. There are various point one has to consider here.**

6. **Define the right type of measurement and monitoring equipments so as to get the authentic results. The equipment may not be able to monitor all the PQ issues defined in benchmarking. One has to select the right type of equipment so that results obtained are authentic.**

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Benchmarking Requirements for PQ:

PQ Benchmarking at : XYZ Electrical Installation									
Sr. No.	Survey Point No:	PQ Issues to be surveyed for:	Instrument used	Monitoring Requirements			Load Condition	Other Load Condition	Capacitor Status
				Time frame	Data log interval	Number of events			
1.1	PCC - Transformer Incomer	Voltage Sags & Swells of more than 1min	Krykard ALM-35	24hrs	10 seconds	-Not Applicable-	Maximum and Min Load during normal 24hrs days work	-Not Applicable-	Capacitor On
1.2		Voltage Outages	On Existing Power Distribution panel - Energy Manager - Rish 12	1 year	-Not Applicable-	Count the events per year	Normal work	-Not Applicable-	Normal status
1.3		Continuous Harmonics	Krykard ALM-35	24hrs	1 min	-Not Applicable-	Maximum Load	-Not Applicable-	With capacitors ON and with capacitors OFF
1.4		Neutral Voltage (Neutral floating)	Krykard ALM-35	24hrs	10 min	-Not Applicable-	Maximum Load	-Not Applicable-	Capacitor On

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Benchmarking Requirements for PQ:

Sr. No.	Survey Point No:	PQ Issues to be surveyed for:	Requirements
1.1	PCC - Transformer Incomer	Voltage Sags & Swells of more than 1min	+10% to -15%
1.2		Voltage Outages	Less than 3 times per year.
1.3		Continuous Harmonics	V-THD% < 2% I-THD% < 8% 3rd Harmonic < 5%
1.4		Neutral Voltage (Neutral floating)	< 1.5 Volts-AC RMS value
1.5		Power Values exceeding MD and Reactive Power needs	MD-KVA < 3200 KVA kVAR < 150 kVAR
2.1	Load Point -1 on SLD	Continuous Harmonics	V-THD% < 3% I-THD% < 12%
2.2		Voltage Disturbances	HF Disturbances frequency > 1kHZ < 650Volts-peak amplitude

Benchmarking Requirements for PQ:

Once the Benchmarking Requirements are appropriately defined and the Requirement of the Equipments is defined, One can proceed with the equipment procurement.

The important points one need to keep in mind while deciding on the specific equipment are:

- **Equipment Features suitability.**
- **If benchmarking standards are completely met with.**
- **If benchmarking standards are met beyond the set standards, if cost of the equipment is much higher than the equipments that are able to critically meet the benchmarking.**
- **If selected equipment is causing some another PQ issue.**
- **If the Supply Utility requirements are met with. This normally one has to comply with.**
- **Equipment selected other performance issues like Reliability, Maintenance costs, Warranty standards etc.**

Power Quality (PQ)
Various Methods to improve

PQ for Industrial Benchmarking with various methods to improve.

–Tushar Mogre.

1.
Voltage Sags & Swells:

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PQ Various methods to Improve:

Voltage Sags & Swells

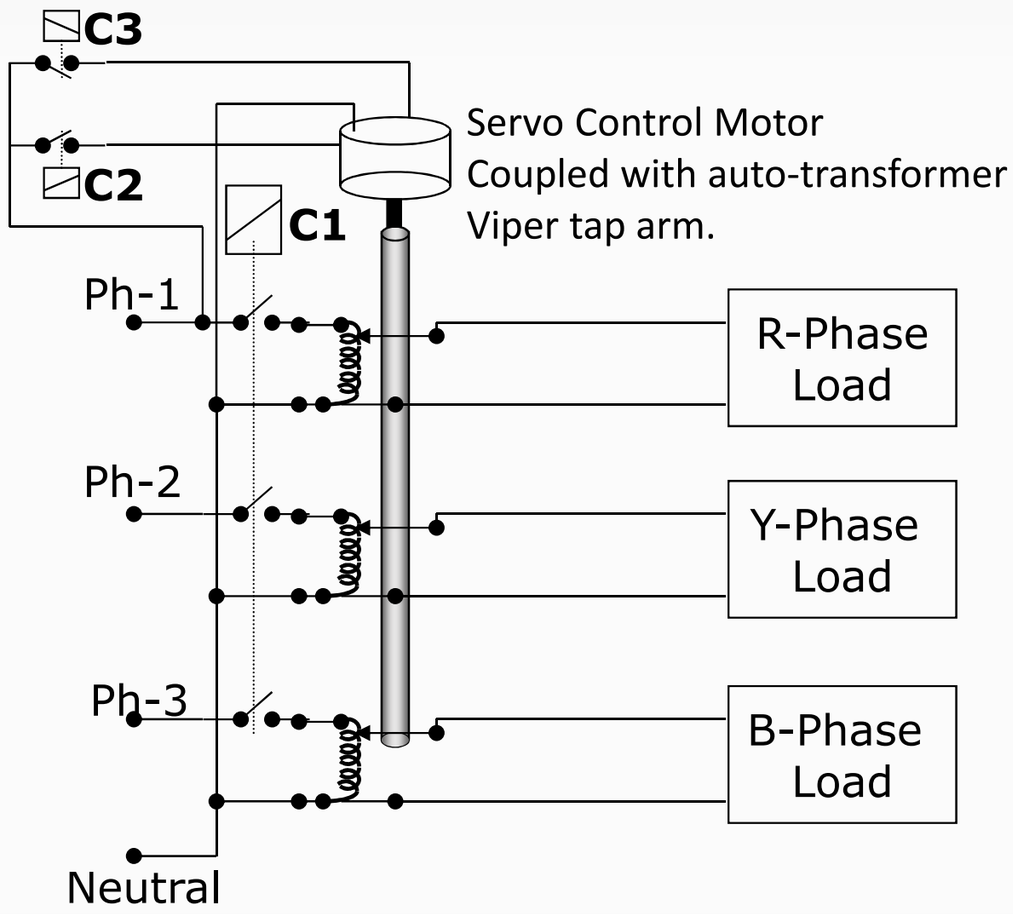
Servo Control Voltage stabilizer:

Merits:

- Good voltage regulation.
- Almost no harmonics generated.
- Moderately good efficiency.

De-merits:

- Regular maintenance.
- Correction for sudden voltage changes takes few seconds.
- Limitation on output capacity so usage is restricted to low to medium LT power requirements.



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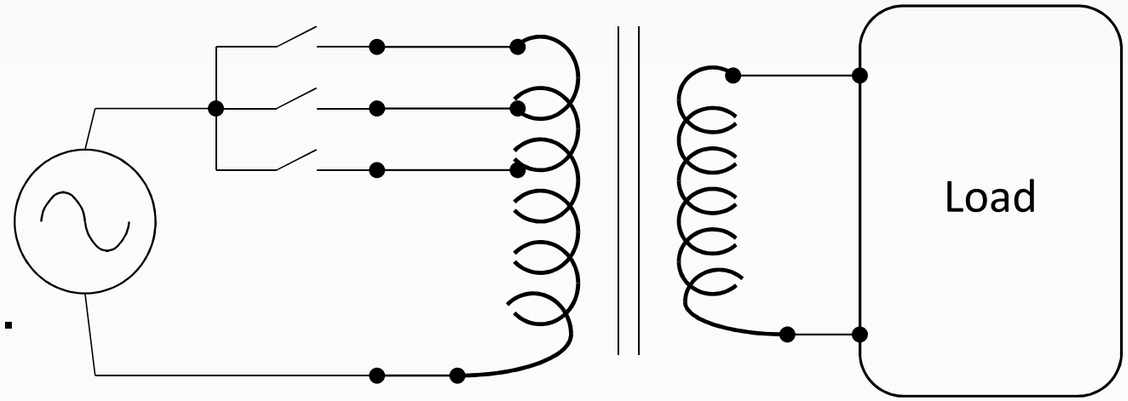
PQ Various methods to Improve:

Voltage Sags & Swells

On Load Tap Changer:

Merits:

- **Higher rated capacity control (Normally available up to 10MVA).**
- **Voltage regulation fairly good (within the difference between the tap voltage ratio).**
- **Almost no harmonics generated.**



On Load TAP Changer Transformer.

De-merits:

- **Comparatively high cost of equipment.**
- **Voltage regulation only against the input supply (utility supply) voltage variations.**
- **Voltage disturbances (transients) during the tap changing process.**
- **Regular Maintenance needed.**
- **Considered by many as "Prone to break-down".**

PQ Various methods to Improve:

Voltage Sags & Swells

CVT – Constant Voltage Transformers:

Technology uses the effect of magnetic core saturation to maintain the output voltage regulation.

Merits:

- **High speed control over voltage regulation and suitable for fast changing input voltages.**
- **Voltage regulation with regards to high speed load changes is good.**
- **No mechanical moving parts thus extremely low maintenance requirements.**

De-merits:

- **Output voltage waveform is non-sinusoidal creating harmonics issues.**
- **Transformer efficiency not good (higher core losses)**

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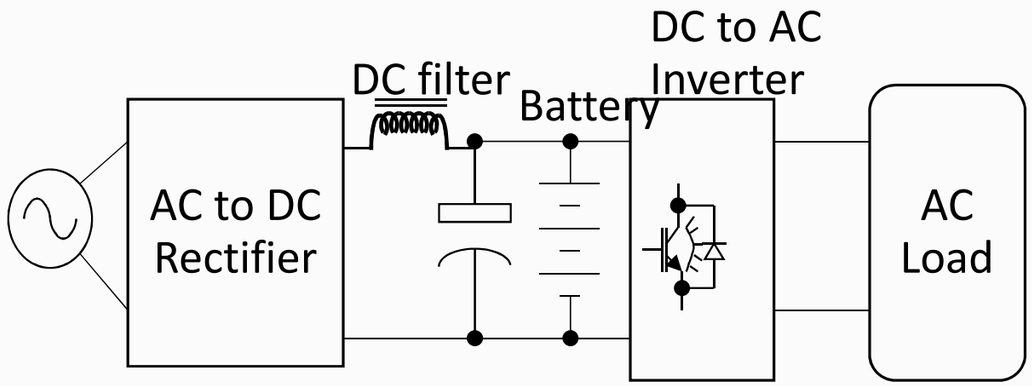
PQ Various methods to Improve:

Voltage Sags & Swells

Uninterrupted Power Supply:
(Schematic Block Diagram)



Uninterrupted Power Supply Scheme

Merits:

- Good output voltage regulation to fast changes in input voltages as well as for fast changes in loads.
- Suitable for other PQ issue like Cycle Loss, Power Outages and Voltage transients etc.
- Fairly good output sinusoidal waveform.

De-merits:

- High cost of equipment.
- Efficiency is not good as compared to other methods.
- Backup battery needs regular maintenance.
- Output surge current handling capacity is poor.
- Generates Harmonics on supply system from where it draws the power. (unless special design features to reduce harmonics are incorporated).

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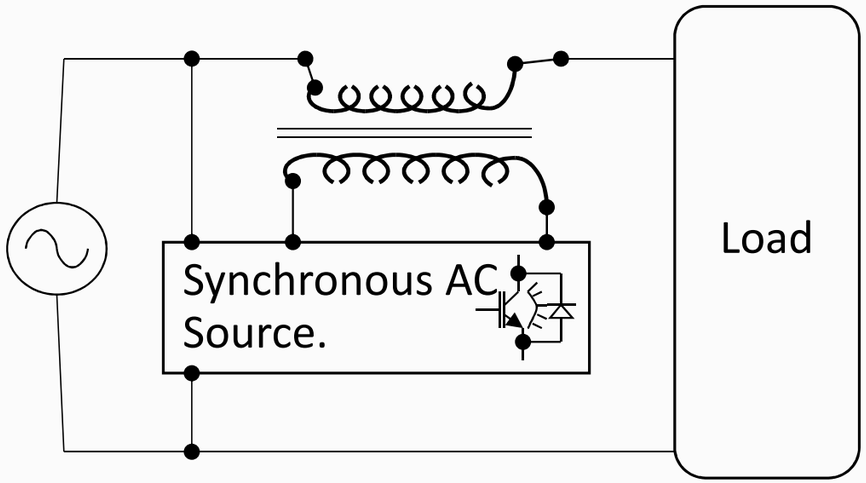
PQ Various methods to Improve:

Voltage Sags & Swells

Series Boost Buck Converter:
(Schematic Block Diagram)



Series Boost Buck Converter Schematic

Merits:

- Output voltage regulation is extremely good and suitable for fast changing load as well as changes in input voltage.
- Output voltage is without harmonics.
- Additional advantage for utilization against other PQ issues like maintaining limits on Harmonics at PCC and some extent the reactive power control.
- Bi-directional control over voltage regulation. i.e. able to effectively control the sags and swells with single equipment with same efficiency.

De-merits:

- High cost of equipment.
- Energy efficiency is not good because it has to handle the entire load current in controlling elements.

Power Quality (PQ) Improvement Systems on LT distribution
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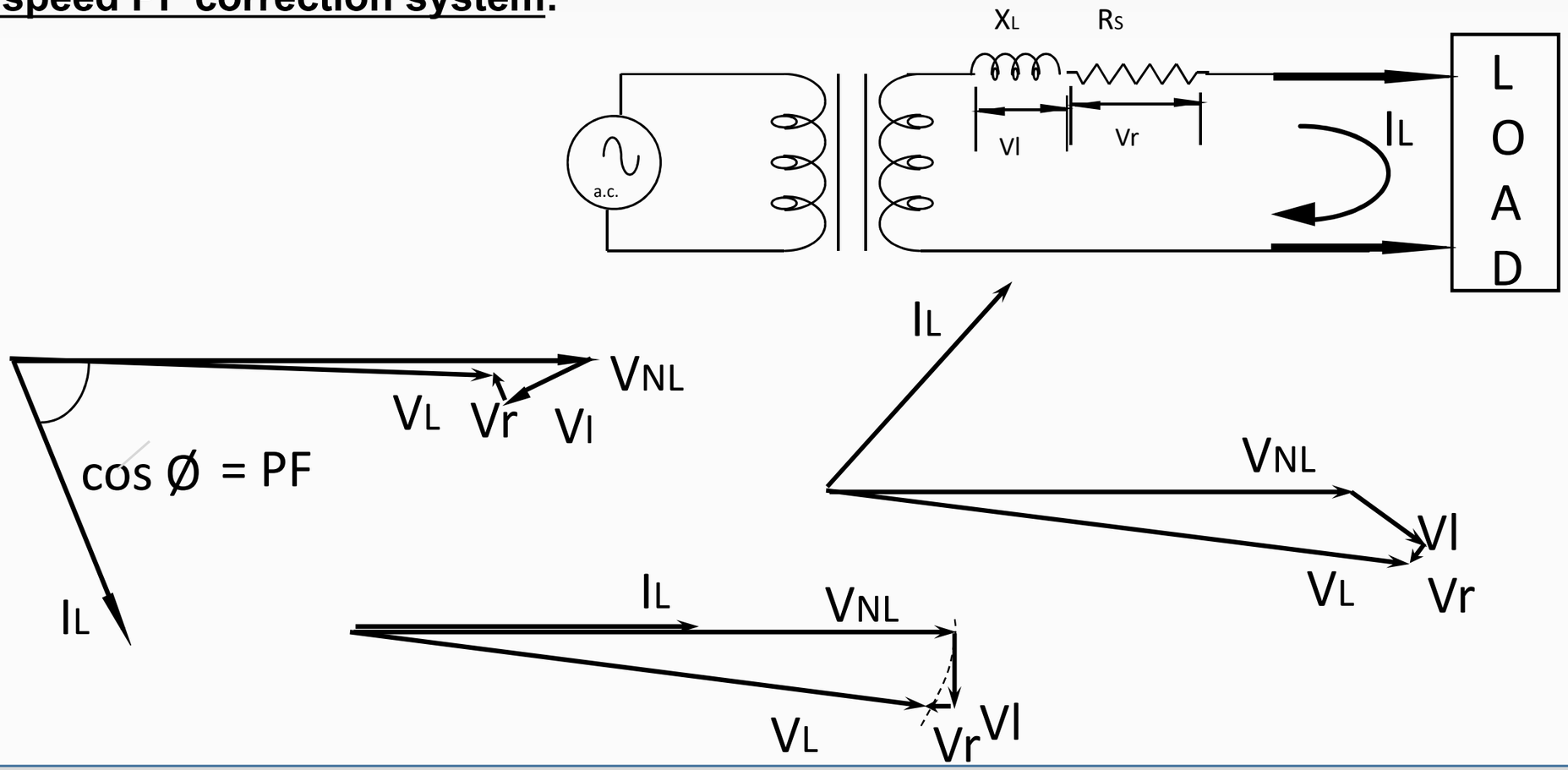
PQ Various methods to Improve:

Voltage Sags & Swells

High speed PF correction system:



PQ Various methods to Improve:

Voltage Sags & Swells

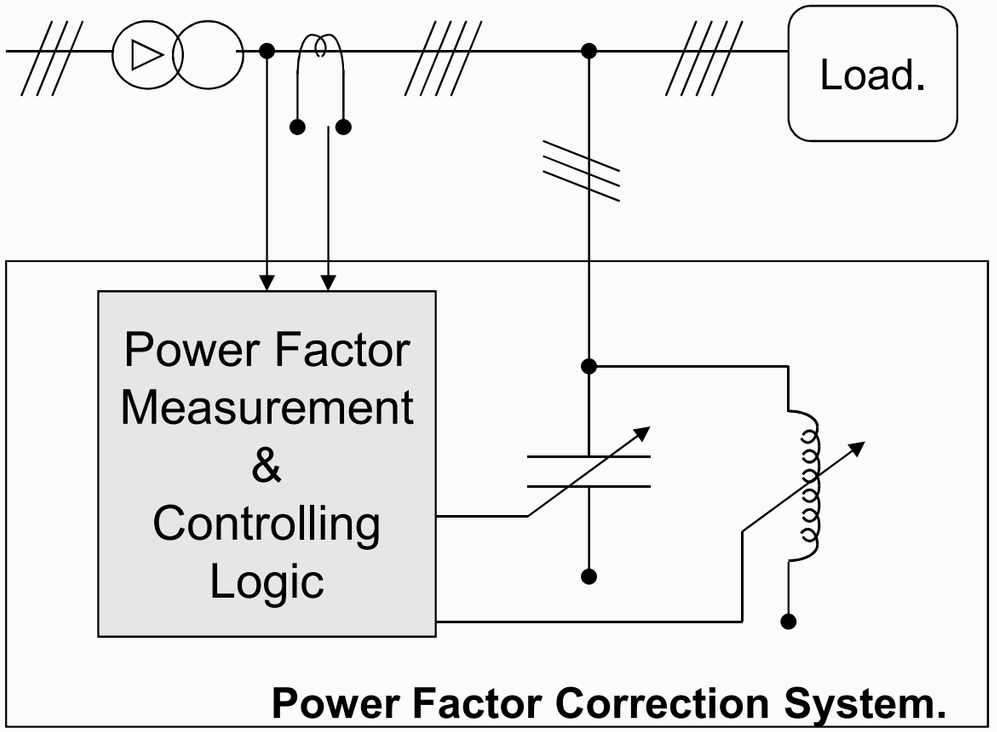
High speed PF correction system:

Merits:

- Voltage regulator is added benefit.
- Speed of compensation is very fast.
- System efficiency is good.
- Almost zero maintenance.

De-merits:

- Cannot compensate for input voltage changes given by utility.
- Such system can give enhancement to harmonics on supply line.



Power Factor Correction System.

2.
Cycle / s Loss:

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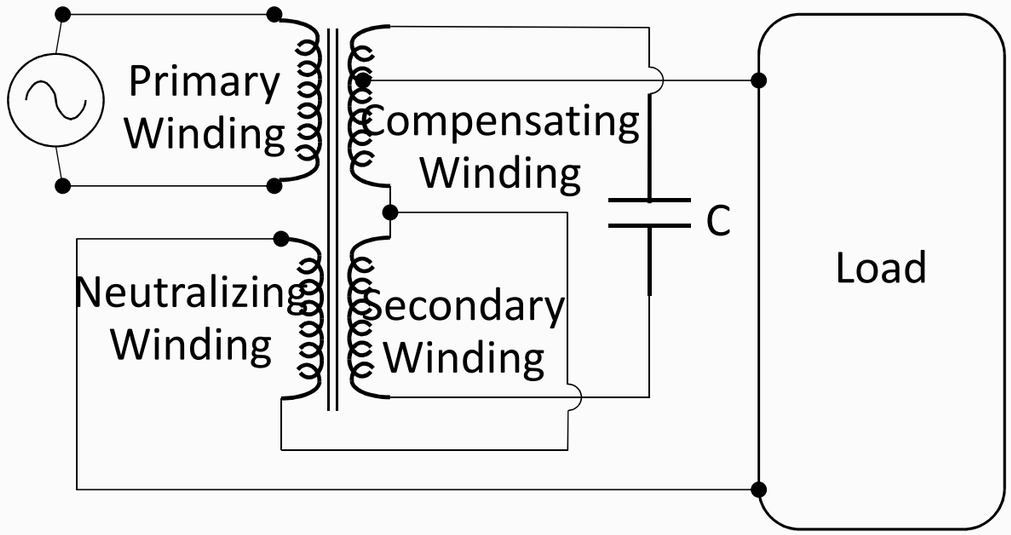
PQ Various methods to Improve:

Cycle /s Loss.

Ferro-Resonant Transformers:

Schematic of Constant Voltage Ferro-Resonant Transformer



Merits:

- Effective against cycle loss with amplitude >30% of the rated voltage value.
- Harmonic values even though present are not very high.
- Extremely good voltage regulation effect even against the continuous voltage sags and swells.
- Robust construction without electromechanical moving part.

De-merits:

- Usage with lower power ratings. Because the transformer needs to be operated at much lower loading condition as compared to design of normal transformer of same rating.
- With higher loading, the voltage suddenly drops near zero.
- Higher design parameters, the cost is comparatively high.

PQ Various methods to Improve:

Cycle /s Loss.

Uninterrupted Power Supply is another effective solution against Cycle/s Loss PQ issue.

UPS is already discussed by us earlier.

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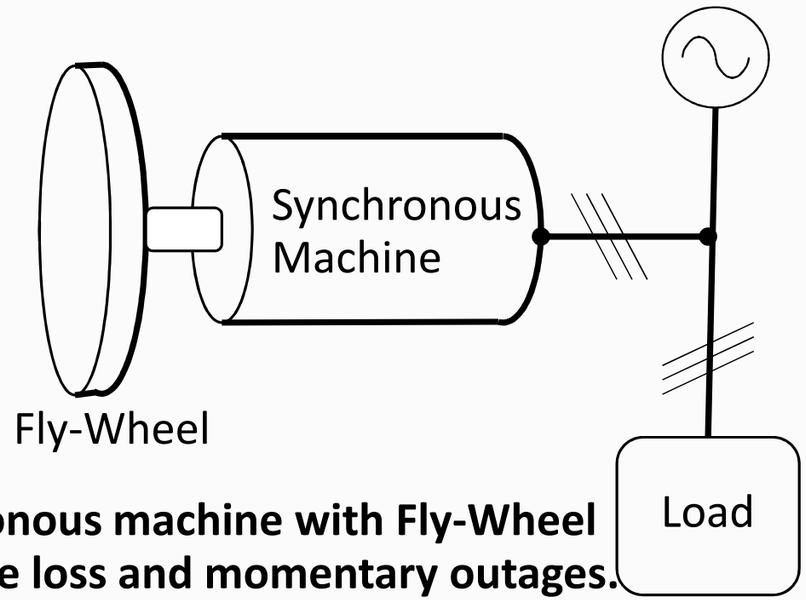
PQ Various methods to Improve:

Cycle /s Loss.

Synchronous M/c with Flywheel:



Synchronous machine with Fly-Wheel For cycle loss and momentary outages.

Merits:

- Effective against the longer duration cycle losses. Well designed system gives the ride through effect up to 30 sec.
- No harmonics generated.
- During normal motoring operation, synchronous machine with over-excitation can compensate for Reactive Power requirements.
- Good reliability against loading conditions.

De-merits:

- Mechanically moving parts creates human safety and maintenance issues.
- During normal motoring mode, considerable power is lost. Thus, system is considered in-efficient for wastage of power.
- Extremely complex design needing trained manpower.

3.

Voltage / Current Surges, Disturbances & Transients :

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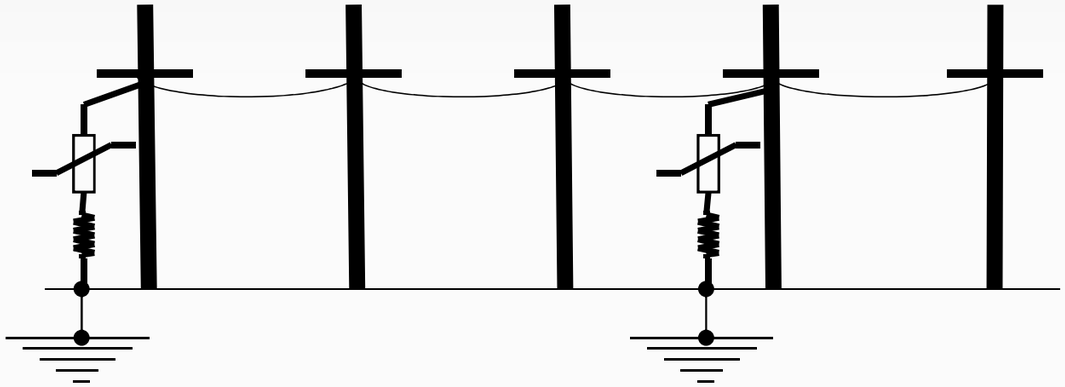
PQ Various methods to Improve:

Voltage / Current Surges, Disturbances & Transients.



Lightning Arresters:

Merits:

- Effective against the high energy lightning strikes.
- New technology design give a good reliability and almost zero maintenance.

De-merits:

- Does not nullify the entire effect of surges.
- Capable of handling the specified levels of Energy. Beyond which is susceptible for damage.
- Cannot be used for other disturbances that are having amplitude equal or lower than supply voltage.
- Usage is limited only on specified voltage HT feeders.

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Benchmarking of PQ and Various methods & merits.

PQ Various methods to Improve:

Voltage / Current Surges, Disturbances & Transients.

Metal Oxide Varistors:

Merits:

- Effective against High voltage transients.
- Can handle high frequency surges effectively.
- Effective against intermittent as well as continuous high voltage transients and disturbances (glitches).

De-merits:

- Limitation on Energy handling capacity.
- Selection of right type of MOV needs elaborate study of requirement. i.e. Voltage surge characteristics and maximum energy value to be handled.
- High energy MOVs are costly.

Power Quality (PQ) Improvement Systems on LT distribution
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PQ Improvement Equipments:
Voltage / Current Surges, Disturbances & Transients:

Capacitor Filters and Low Pass filters like T, L and Pi Filters:

Merits:

- **Strong and Rugged design giving very little maintenance requirements.**
- **Highly economical.**

De-merits:

- **Specific design to match the site conditions.**
- **Any changes in loading conditions on supply lines needs necessary design changes.**
- **Careful approach while designing the filters which otherwise can give rise to the problems like voltage regulation, resonance and harmonic enhancement.**

Power Quality (PQ) Improvement Systems on LT distribution
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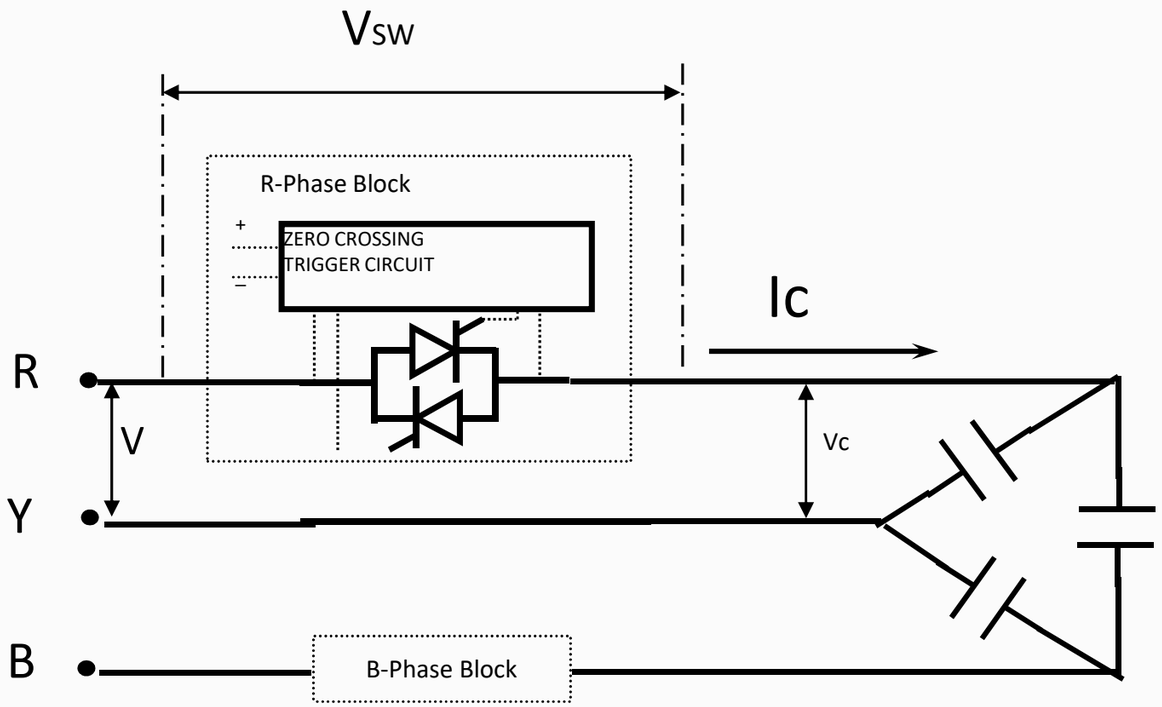
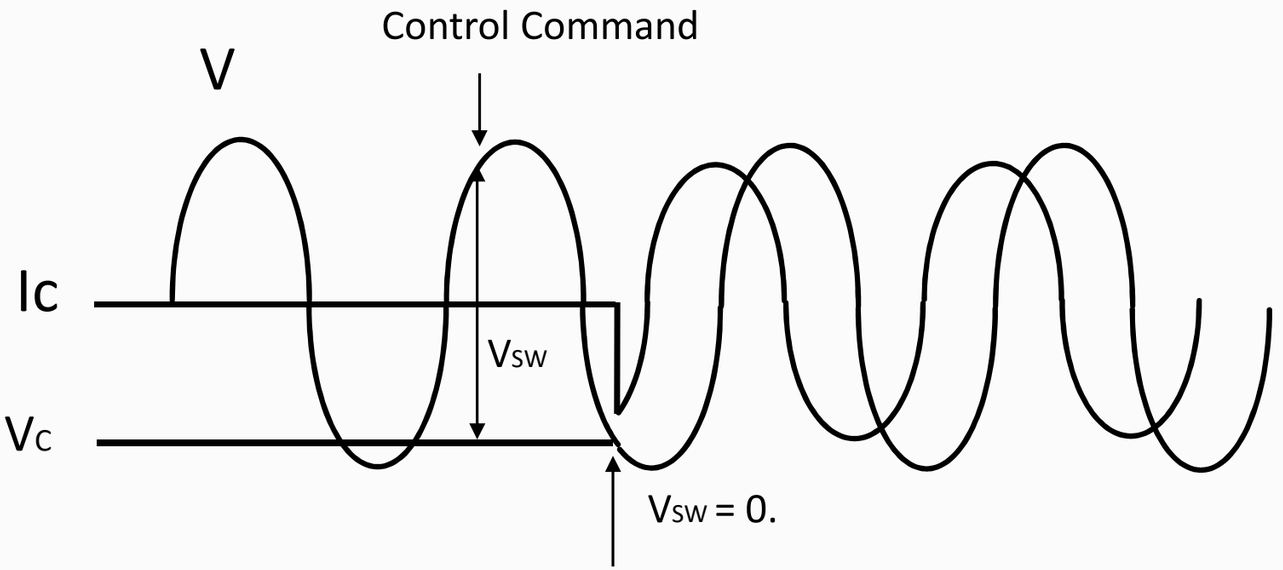
PQ Improvement Equipments:

Voltage / Current Surges, Disturbances & Transients:

Zero Voltage Capacitor Switching and Synchronous Switching of Loads:





PQ Improvement Equipments:

Voltage / Current Surges, Disturbances & Transients:

Zero Voltage Capacitor Switching and Synchronous Switching of Loads:

Merits:

- Zero differential voltage detection switching on of capacitors and SMPS almost eliminates the voltage disturbances on supply system.
- Capacitor switching fast responses can be achieved. – Without waiting for capacitors to be discharged to zero DC voltage before they can be switched ON.
- Well designed system is quite rugged and has reduced maintenance requirements.
- Can be provided with additional protection to the capacitors with the same technology.

De-merits:

- On state conducting watt losses are higher as compared to conventional electromechanical switches.
- Higher costs.

PQ Improvement Equipments:

Voltage / Current Surges, Disturbances & Transients:

Shielding with differential and common mode disturbance filtering like low impedance power conditioning:

Merits:

- Simple design and rugged construction.
- Combined common mode and differential mode filters are available easily for the specific applications.
- Low cost.

De-merits:

- Lower power application usage.
- Not suitable for high energy transients.

4.

Current & Voltage Harmonics and Inter-harmonics :

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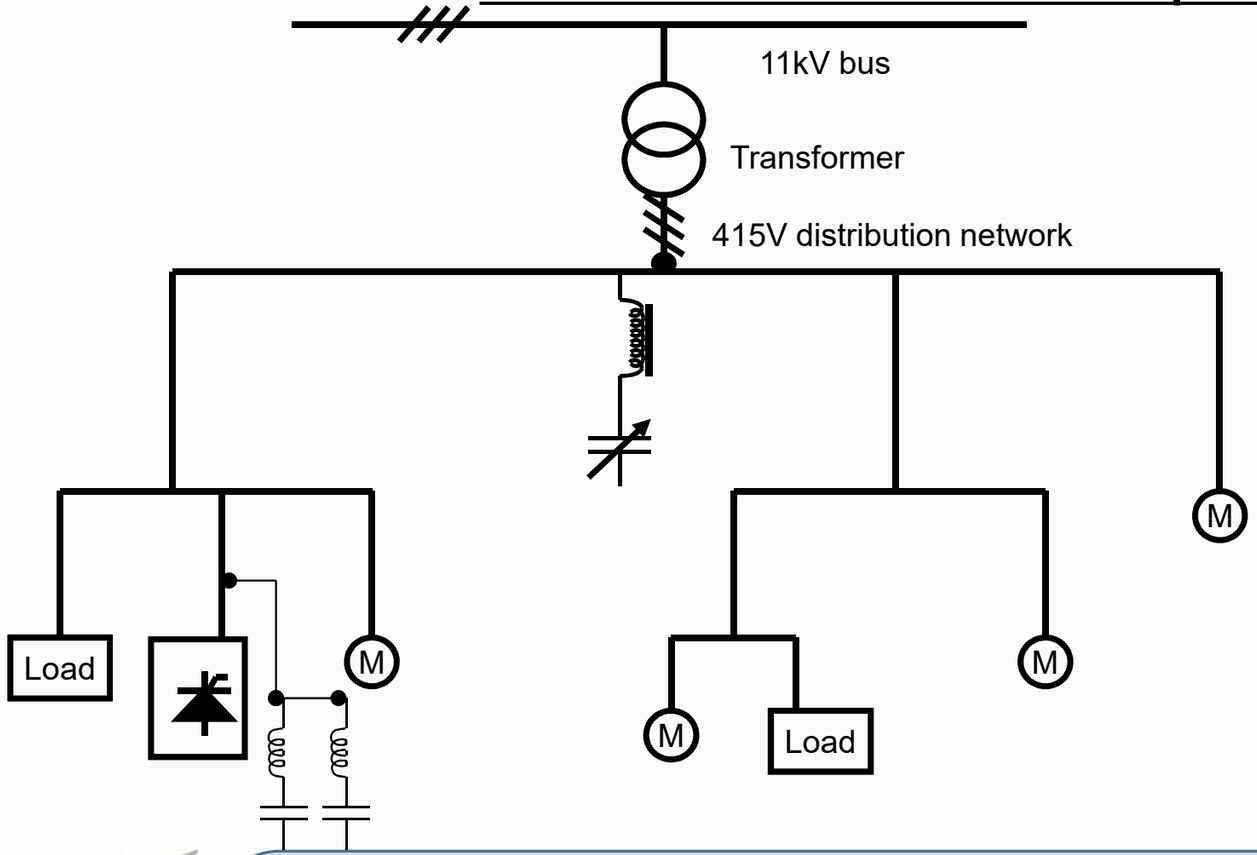
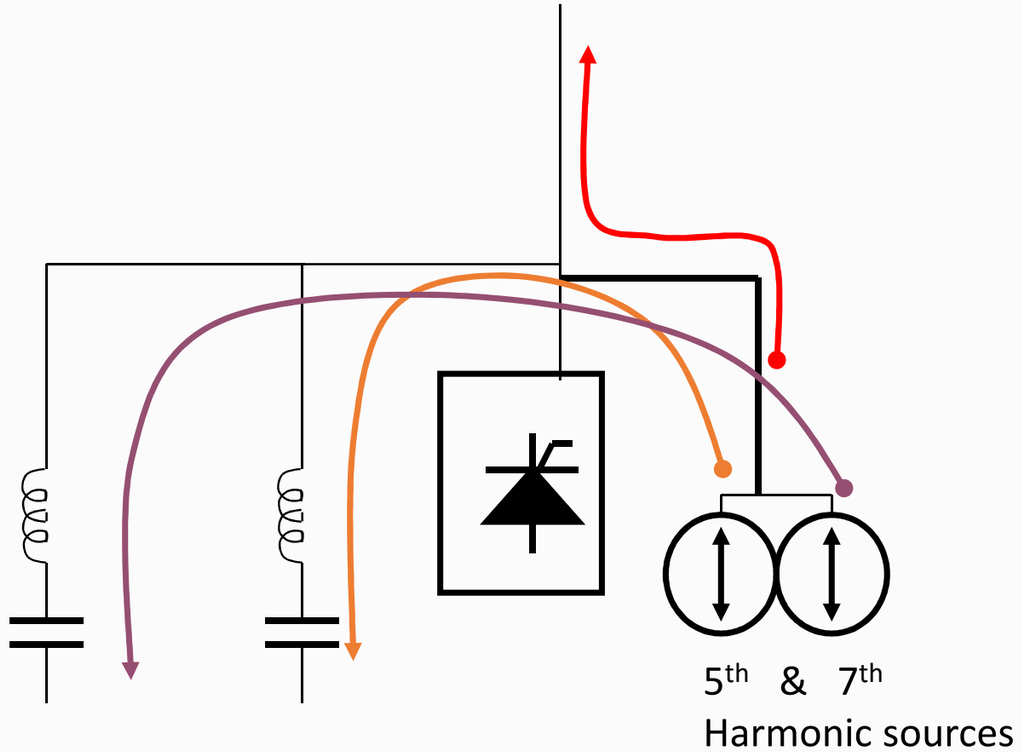
Benchmarking of PQ and Various methods & merits.

PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Tuned Harmonic Passive Component Filters:





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PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Tuned Harmonic Passive Component Filters:

Merits:

- Simplified rugged construction by passive electrical.
- Almost zero maintenance.
- Comparative lower cost if system is with prominent one or two harmonic s.
- Offers additional capacitive reactive power compensation on supply system.

De-merits:

- Site dependent design. Requires complete nodal analysis survey and system impedance calculations for designing.
- Vulnerable to system resonance – specifically with changes in loading.
- Can offer leading PF with low loading conditions thus over-voltage issues.
- With wide band spectrum of harmonic numbers, the cost involvement is high.
- Design is bulky due usage of air core reactors (to avoid saturation effect drift in tuned frequency).

Power Quality (PQ) Improvement Systems on LT distribution
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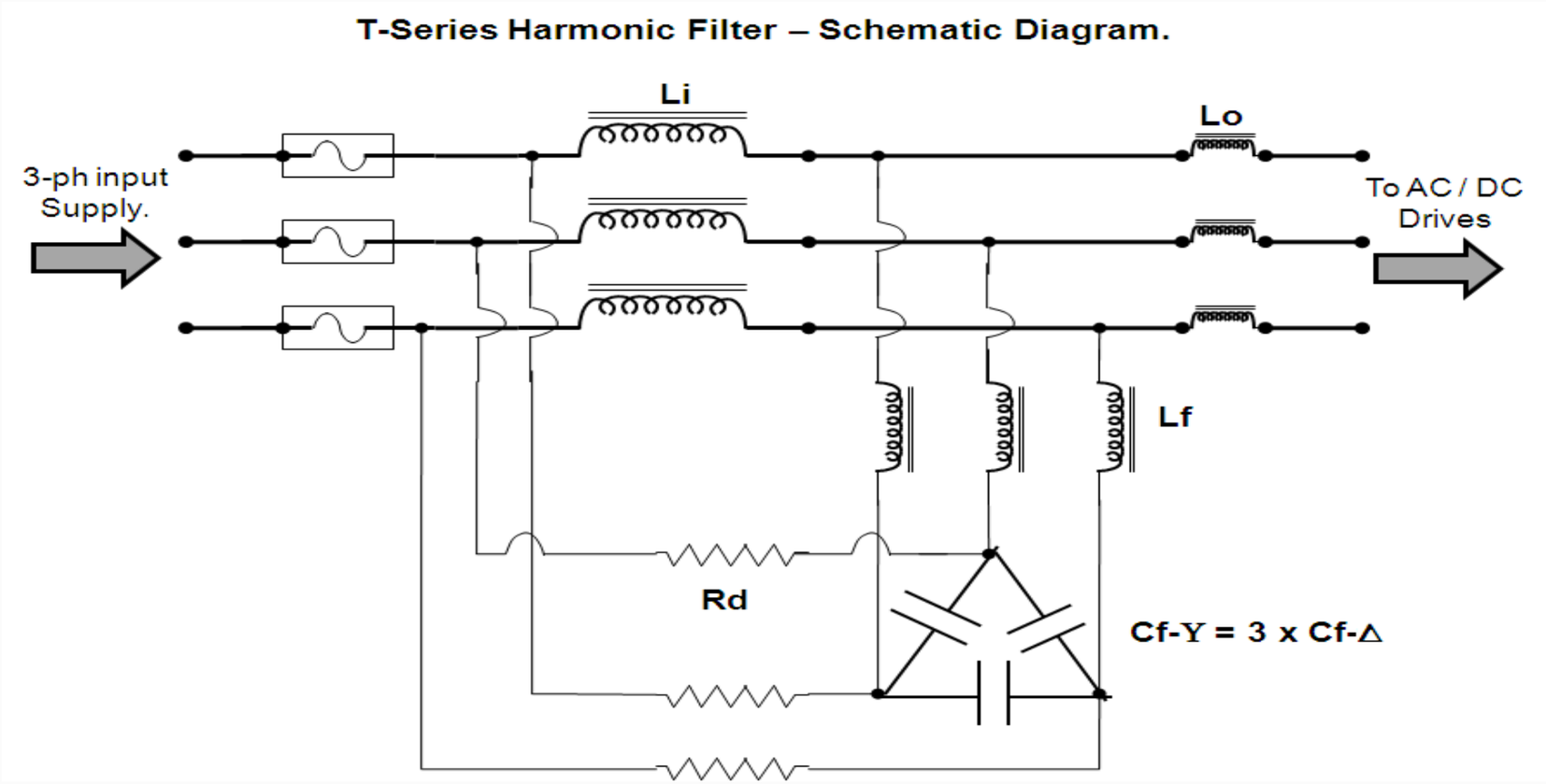
PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Low Pass Filters for 6-pulse converter type Loads (Drives & UPS):



PQ Improvement Equipments:
Current & Voltage Harmonics and Inter-harmonics:

Low Pass Filters for 6-pulse converter type Loads (Drives & UPS):

Merits:

- Extremely effective – gives value for money solution.
- No hassles (normally) of resonance problems.
- Provides some reactive power compensation.
- Rugged construction using passive elements like Inductors, capacitors and resistors.

De-merits:

- Useful only for six pulse converter type of applications.
- Need to put power consuming resistors to avoid overvoltage issues during lower loading conditions.

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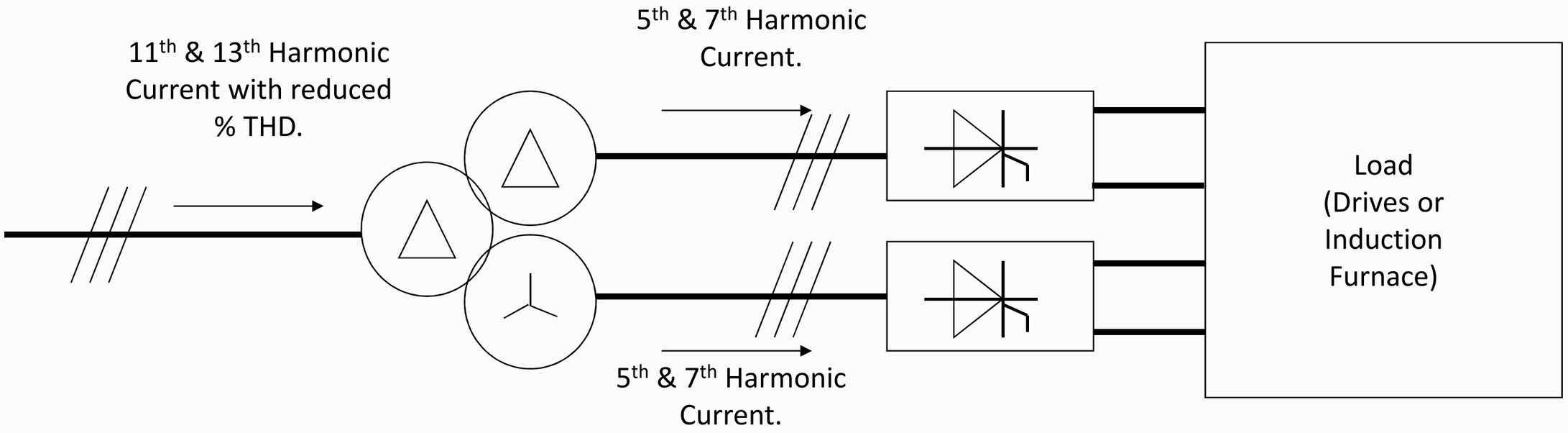
PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Usage of 12 Pulse Converters for Specific High power Applications:



PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Usage of 12 Pulse Converters for Specific High power Applications:

Merits:

- Extremely effective approach for specific applications.
- Transformer impedance itself acts like added filter for 11^{th} and 13^{th} harmonic generated.
- No need of added series reactors or low pass filters that are used for six pulse converters.

De-merits:

- Needs specially designed transformer with higher K-Factor. (Typical K-Factor is 13)
- Some attention may have to be given to 11^{th} and 13^{th} harmonics on primary of the transformer.
- Product design need to use two numbers of six pulse converters and thus can add up the cost.

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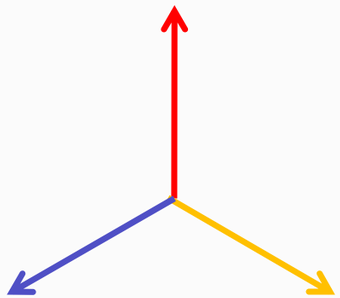
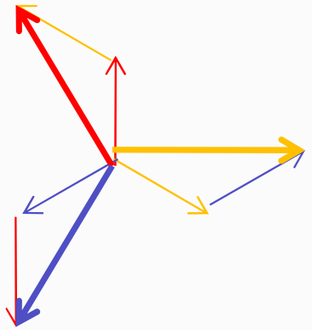
PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

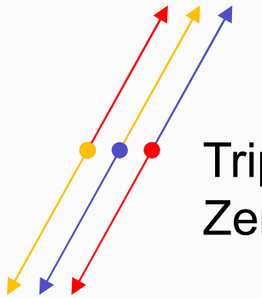
Z-Winding Transformer for Triplen Harmonics:



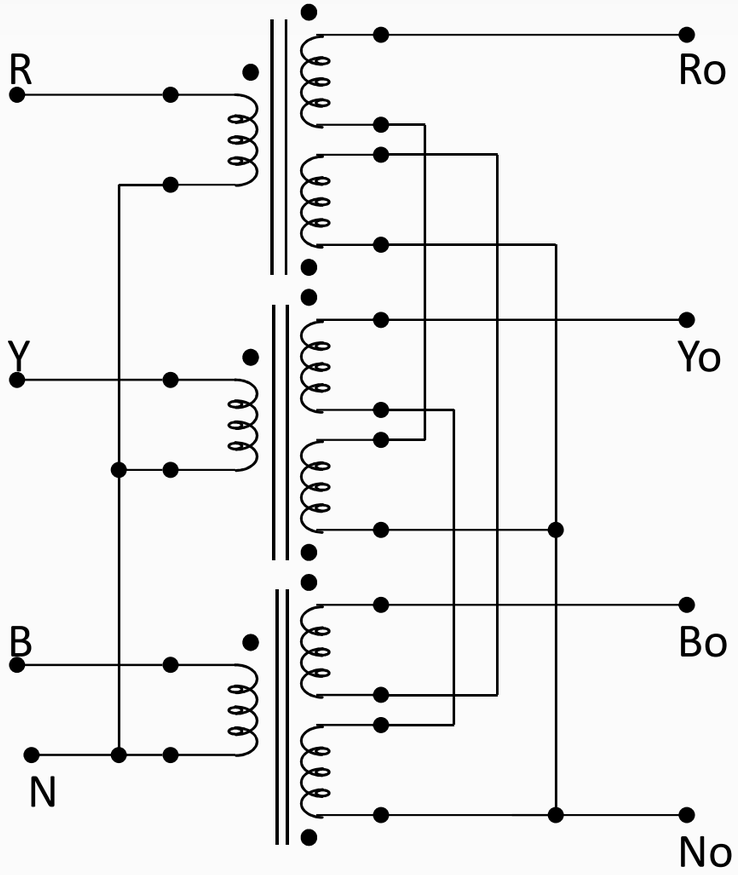
Input Voltage Phasors
(Fundamental freq phasors)



Output Voltage Phasors



Triplen Harmonics
Zero sequence Phasors



PQ for Industrial Benchmarking with various methods to improve.

–Tushar Mogre.

PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Z-Winding Transformer for Triplen Harmonics:

Merits:

- Effective value for money solution against "Triplen Harmonics" on 3-phase supply system.
- Energy efficient solution with transformer efficiency of @ 99%.
- Provides effective solution with Neutral floating issue by galvanic isolation of load with triplen harmonics.
- Rugged construction with little maintenance.

De-merits:

- Effective against only zero sequence component harmonics.

Power Quality (PQ) Improvement Systems on LT distribution
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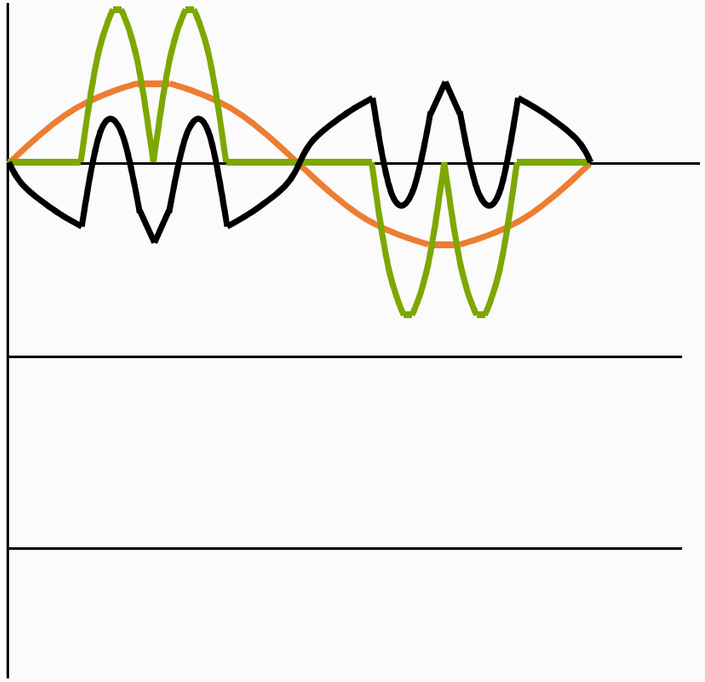
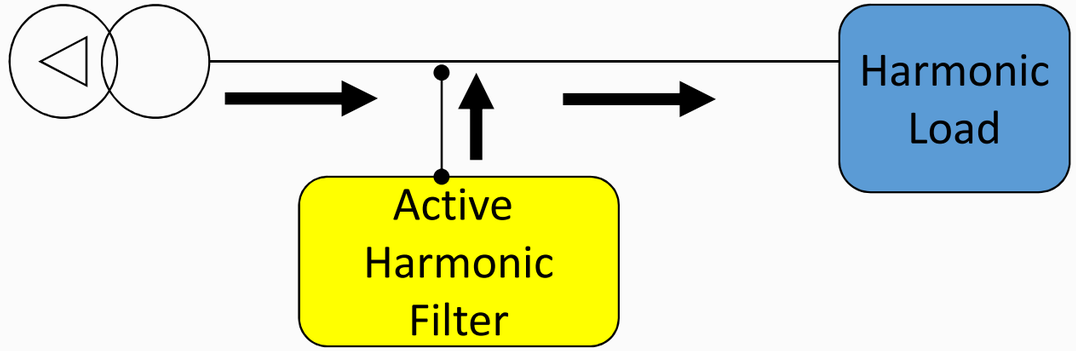
PQ Improvement Equipments:
Current & Voltage Harmonics and Inter-harmonics:

Active Harmonic Filters:



- Sense the Harmonic prone current waveform.
- Analyse the Fundamental part of this waveform.
- Find out the waveform that is a difference
- between the actual waveform and it's fundamental part.
- Make that part of the current to flow through the
- active harmonic filter to give effective vector summation as a purely sinusoidal waveform.



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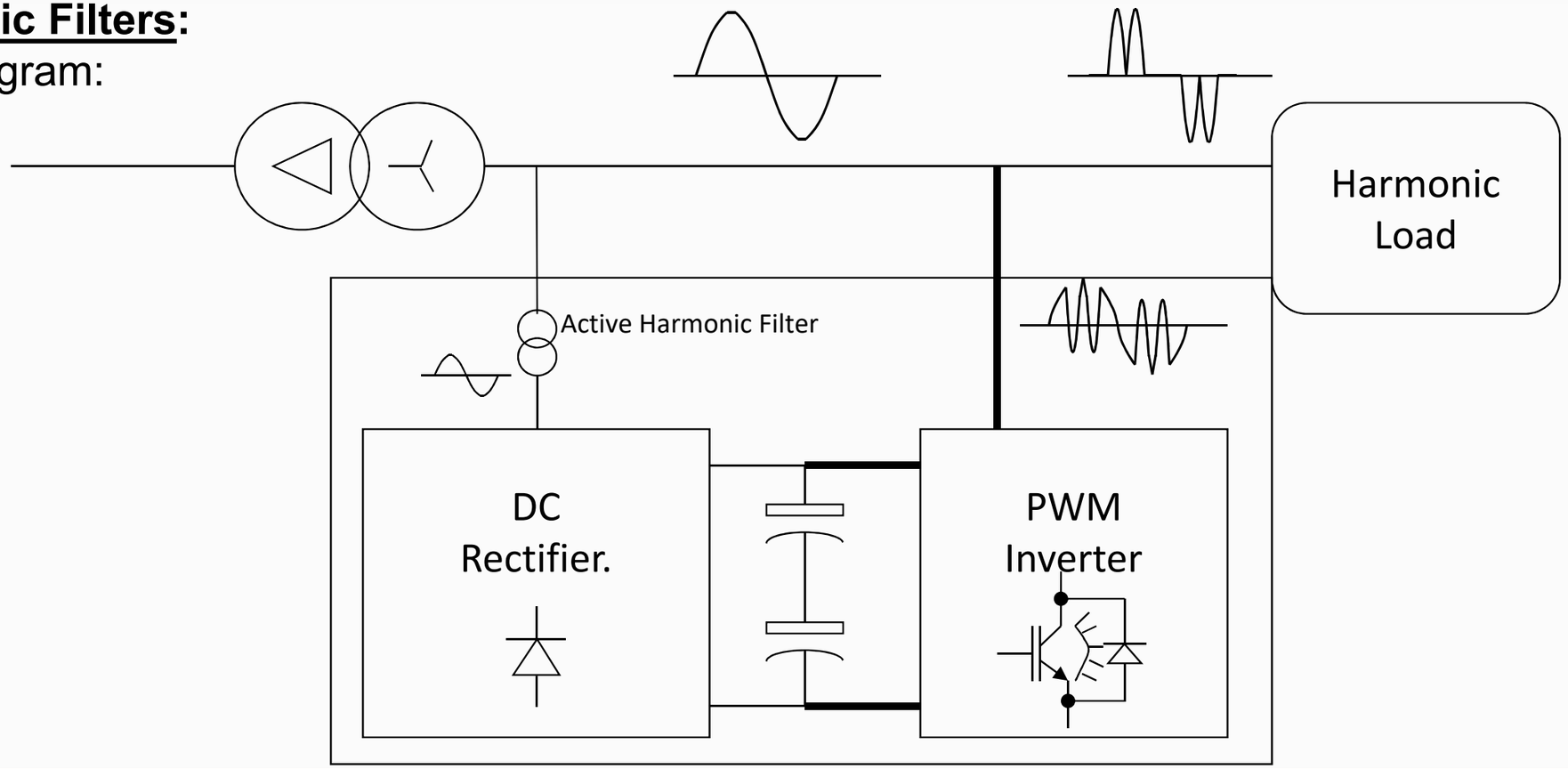
PQ Improvement Equipments:
Current & Voltage Harmonics and Inter-harmonics:

Active Harmonic Filters:

Basic Block Diagram:



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PQ Improvement Equipments:

Current & Voltage Harmonics and Inter-harmonics:

Active Harmonic Filters:

Merits:

- Highly suitable for Loads with wide band spectrum of harmonic numbers.
- Bring down THD% factor to much lower level than any other method available with today's technology. Typically below 5% current THD% factor.
- Added benefit - automatic PF compensation & 3-phase load balancing.
- Resistant to system resonance.
- Real time high speed response . Suitable even for intermittent harmonics.

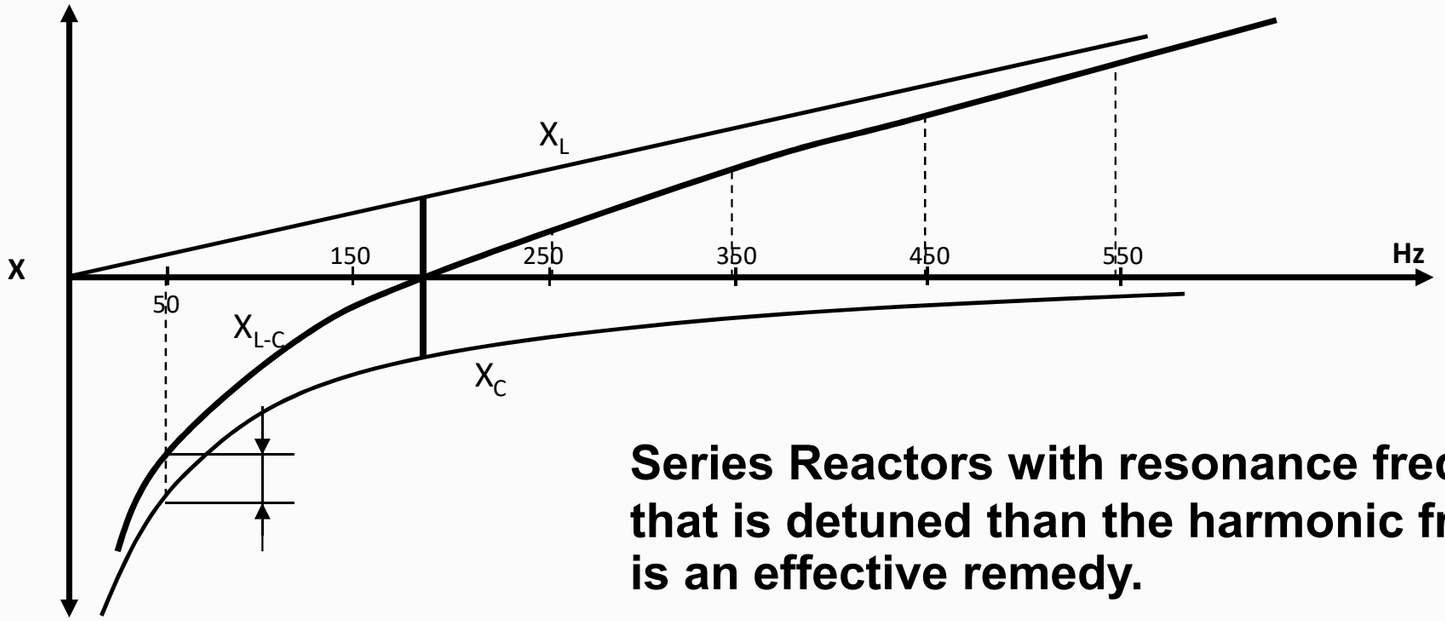
De-merits:

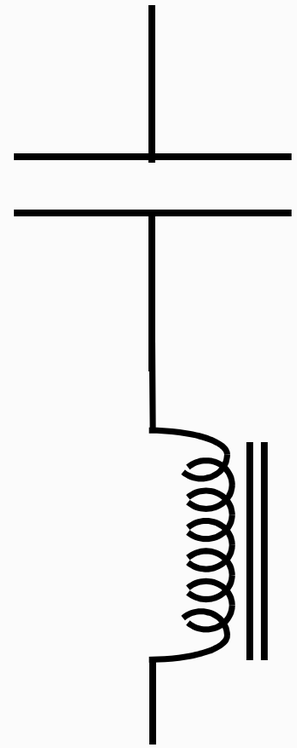
- Efficiency is not as good as other methods. Typically works between 94% to 97% efficiency.
- Extremely high cost – thus sometimes difficult to justify the economic angles.
- Specialized technology. Thus, needs specialist for any maintenance issues.

Power Quality (PQ) Improvement Systems on LT distribution
Benchmarking of PQ and Various methods & merits.

PQ Improvement Equipments:
Current & Voltage Harmonics and Inter-harmonics:

Detuned Reactors with PF Capacitors:





Series Reactors with resonance frequency that is detuned than the harmonic frequency is an effective remedy.

5.

Neutral Shifting and Earth Potential issues :

PQ Improvement Equipments:
Neutral Shifting & Earth Potential Issue:

Normal Approach is to locate the fault and resolve the issue.

Still some other methods used are:

1. **Isolation Transformer usage.**
2. **Dynamic Load Balancing in case of Unbalance observed between phases.**

6.

Power Outage

&

Auto-Reclose Effect :

PQ Improvement Equipments:
Power Outage & Auto-Reclose Effect:

Various Remedies are given based upon the requirements:

- **Usage of Generator Back-up.**
- **Make arrangement with Supply Utility for special emergency feeders supply.**
- **Usage of UPS system or Battery backed Inverters.**
- **For Auto Reclose effect, usage of Synchronous Machines with Fly-wheel (already discussed)**

7.

Power Frequency Variation :

PQ Improvement Equipments:

Power Frequency Variations:

Effect is more prominently seen with the supply system with smaller capacity. Big utility supply companies frequency variation beyond alarming level is rare.

Normally no special care is needed with Utility supply systems.

With local smaller generator driven supply, this is to be taken care at generation end itself.

Thank You