Need of Capacitor

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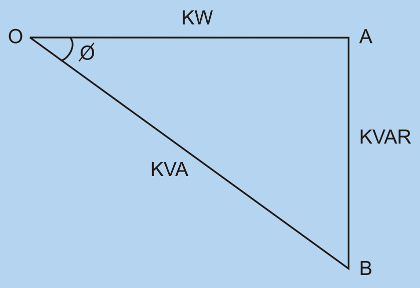
In A.C. electric system inductive loads consume active power and also reactive power. This reactive power is needed to generate magnetic field for inductive loads.

The power factor is the ratio of KW (active power) component to the KVA (apparent power) component.

Power factor will be leading if current is leading the voltage and it is lagging when current is lagging the voltage. The reactive power needs to be generated in electrical system. For that most of electrical utilities penalise for lower power factor with additional charges. A.C. capacitor is the most economical component to supply reactive power which gives following advantages. ...

- Power factor improvement.
- Additional power will be available at secondary of transformer.
- Decrease in cable losses.
- Improved voltage profile.



$$\cos Ø = \frac{\text{Real Power}}{\text{KVA}} = \frac{KW}{KVA}$$

The reactive power necessary to achieve the P.F. is calculated as under

KVAR = KW (tan Ø1 - tan Ø2)

Cos Ø1 - original P.F.

Cos Ø2 - desired P.F.

The multiplying factors to calculate required KVAR are given in following table. -

Original P. F. Cos Ø1	Multiplication factor (tan Ø1 - tan Ø2) for a target power factor Cos Ø2									
	0.70	0.75	0.80	0.85	0.90	0.92	0.94	0.96	0.98	1.00
0.40	1.271	1.409	1.541	1.672	1.807	1.865	1.928	2.000	2.088	2.291
0.45	0.964	1.103	1.235	1.365	1.500	1.559	1.622	1.693	1.781	1.985
0.50	0.712	0.850	0.982	1.112	1.248	1.306	1.369	1.440	1.529	1.732
0.55	0.498	0.637	0.768	0.899	1.034	1.092	1.156	1.227	1.315	1.518
0.60	0.313	0.451	0.583	0.714	**0.849**	0.907	0.970	1.042	1.130	1.333
0.65	0.149	0.287	0.419	0.549	0.685	0.743	0.806	0.877	0.966	1.169
0.70		0.138	0.270	0.400	0.536	0.594	0.657	0.729	0.817	1.020
0.75			0.132	0.262	0.398	0.456	0.519	0.590	0.679	0.882
0.80				0.130	0.266	0.324	0.387	0.458	0.547	0.750
0.85					0.135	0.194	0.257	0.328	0.417	0.620
0.90						0.058	0.421	0.193	0.281	0.484
0.95								0.037	0.126	0.329

Example :

a) Consumption of active energy — Ew = 300 000 Kwh

b) Consumption of reactive energy — EB = 400 000 Kvarh

c) No. of working hours — t = 600 h

Active energy power $P = \frac{300\,000 \text{ Kwh}}{600 \text{ h}} = 500 \text{ KW}$

Calculation of the original power factor Cos Ø1 : =

$$\frac{1}{\sqrt{\left(\frac{EB}{Ew}\right)^2 + 1}} = \frac{1}{\sqrt{\left(\frac{400\,000}{300\,000}\right)^2 + 1}} = 0.6$$

For the improvement of the power factor from 0.6 to 0.9 we read factor 0.849 from table.
Hence required capacitor power is Qc = 500KW X 0.849 ≅ 425 KVAR

L.V. Capacitor Technology

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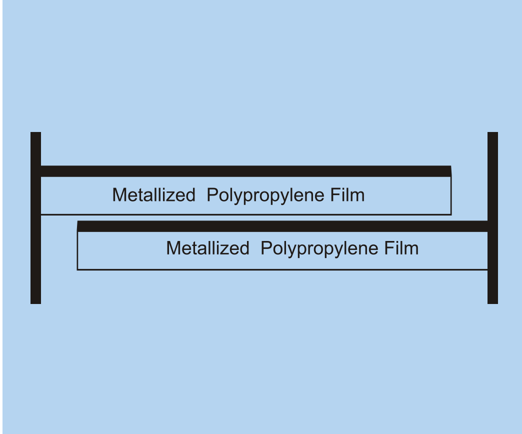
Since last 20 years it is observed that service life of capacitor is hampered due to following causes.

- Use of low priced material hampers quality, technology working environment resulting in low life of capacitors.
- Non linear inductive loads such as drives, furnaces etc. generate harmonics which leads to increase in voltage and current across capacitor.
- Ambient temperature.



Type of L. V. capacitors

Shreem low voltage capacitors are designed and manufactured with most advanced technology which can sustain 10% to 25% of harmonic generating load (w.r.t. total connected load) and provide complete range of P. F. correction system.

A) MKP capacitors (metallised polypropylene film)

The MKP type capacitor consist of a low-loss Di-electric formed by pure polypropylene film. A thin self healing mixture of zinc and aluminum is metallized directly on one side of the PP-film under vacuum. This technology ensures a long operating life of the capacitor. The capacitor elements, after insertion into the capacitor case, a patented viscous polyurethane resin, mainly containing castor oil, is introduced.

Self-healing dielectric

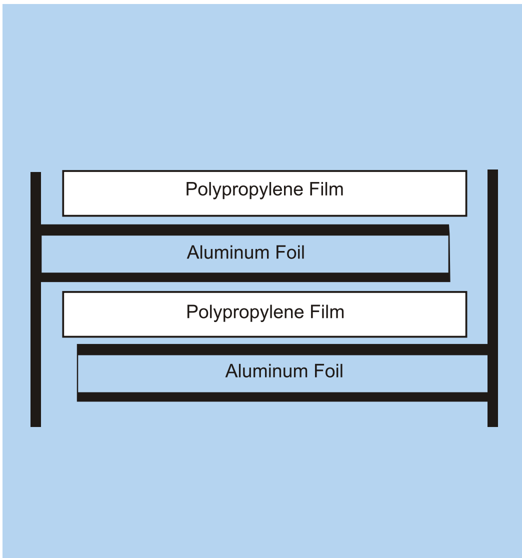
Both dielectric structures described above are “self healing” : In event of a voltage breakdown the metal layers around the breakdown channel are evaporated by the temperature of the electric arc that forms between the electrodes. They are removed within a few microseconds and pushed apart by the over pressure generated in the center of the breakdown spot. An insulation area is formed which is reliably resistive and voltage proof for all operating requirements of the capacitor. The capacitor remains fully functional during and after the breakdown.

Advantages of MKP technology

- Result of the comparably simple construction technology, MKP capacitor can be manufactured using less material and consequently enjoy a competitive price level.
- With a thicker dielectric, capacitors usually have smaller dimensions.
- MKP-type capacitors have a high specific capacitance and a high AC load capacity.

B) APP capacitors
APP (all polypropylene) film type i.e. film + foil

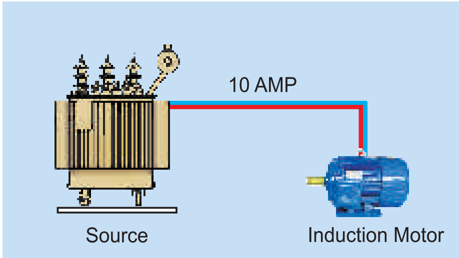
The dielectric of APP-type capacitors takes the form of a low-loss polypropylene film + foil elements completely dried in high vacuum and impregnated in NPCB oil.

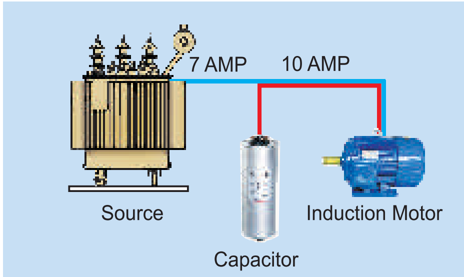


Advantages of the APP technology

- The vacuum drying and impregnation procedure frees the dielectric from any voids and minimize the occurrence of partial discharges. This results in long life expectancy and extremely stable electrical characteristics.
- The zinc contact layer forms a stable contact with the foil and guarantee a very high resistance to impulse charges reducing the self-inductance of the capacitor.
- Very low losses through the application of polypropylene dielectric and aluminum foil.
- Thanks to its low losses and the heat dissipation qualities of the oil impregnant, the capacitor may be operated at high ambient and case temperatures upto 70°C without effecting the life of the capacitor.

Power Factor is a measure of how efficiently electrical power is consumed.
The ideal Power Factor is unity - or one. Anything less than one, (or 100% efficiency), means that extra power is required to achieve the actual task at hand.
This extra energy is known as Reactive Power, which is necessary to provide a magnetising effect required by motors and other inductive loads to perform their desired characteristic functions.
Power Factor as close to unity is economically possible. The addition of capacitors compensate for the Reactive Power demand of the inductive load and thus reduce the burden on the source of power supply.



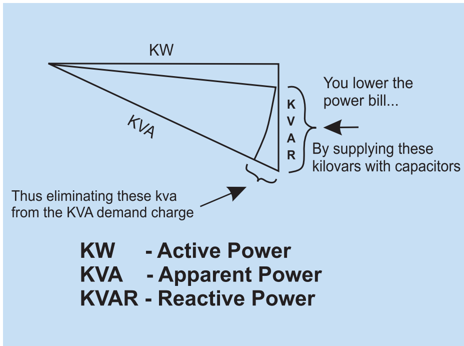


Benefits of Power Factor Correction

- Power Consumption Reduced
- Electrical energy efficiency improved
- Extra kVA availability from the existing supply in other word's release of system capacity.
- Transformer and distribution equipment losses reduced.
- Voltage drop reductions in long cables

How is Power Factor caused?

An inductive load requires a magnetic field to operate, and in creating such a magnetic field causes the current to "lag" the voltage (ie, the current is not in phase with the voltage).
Power Factor Correction is the process of compensating for the "lagging" current by applying a "leading" current in the form of capacitors.
Power Factor is best expressed as ratio of Active Power kW / Apparent Power kVA



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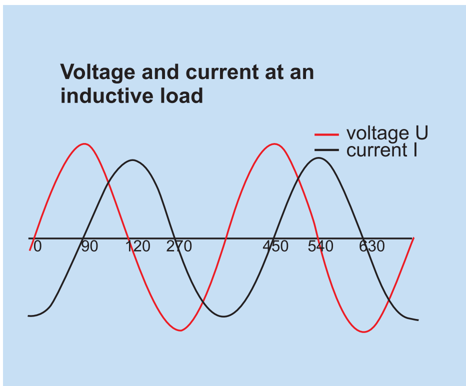

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Types of Compensation

1. Fixed Compensation :

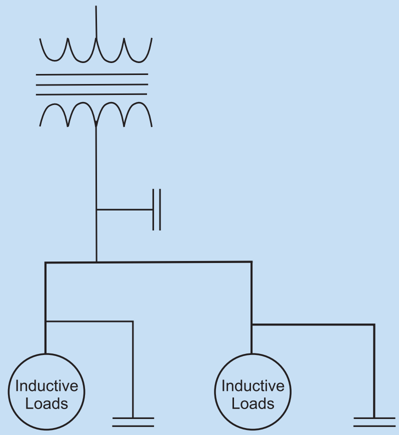
For each individual inductive load corresponding capacitor is allocated. This compensates lagging reactive power immediately at the individual load. Different loads & capacitors can be connected jointly in the system by means of one main switch.

2. Automatic Compensation :

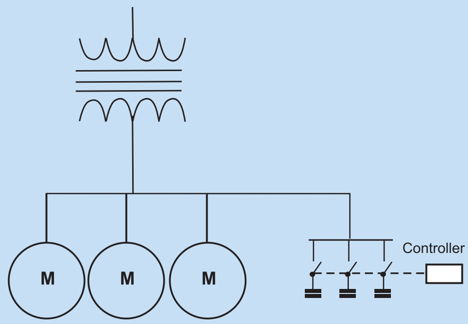
Automatic power factor correction is typical for large electrical systems with fluctuating load where it is common to connect number of capacitors to main power distribution station or substation. The capacitors are controlled by controller which continuously monitors the relative power demand. The relay connects or disconnects the capacitors to compensate for actual reactive power of the total load and reduce overall demand supply.

Benefits of Automatic Compensation :

- Proper reduction in KVA demand.
- In Auto Compensation at no load condition over compensation does not occur. Over compensation is dangerous as it leads to over voltage in the system, resulting into failure at insulation of terminal equipments.
- Less burden on capacitors & switchgear thus compensation life is more.
- Release of system capacity from same source giving advantage to connect more equipments.

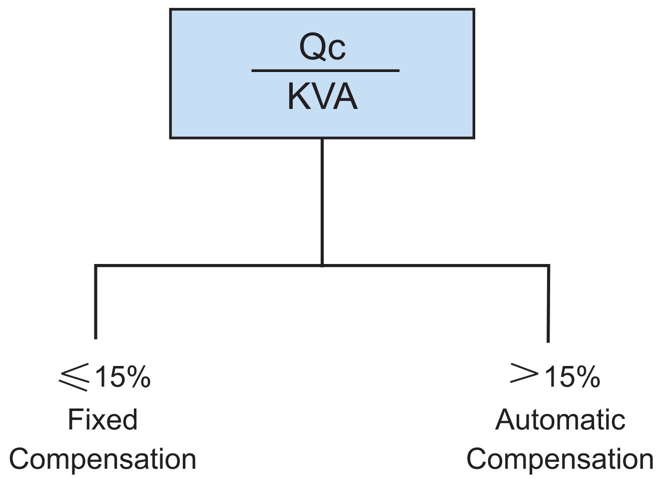


Fixed Compensation



Automatic Compensation

Selection of Compensation



Where Qc - Capacitor bank rating
KVA - Rating of transformer or actual load.

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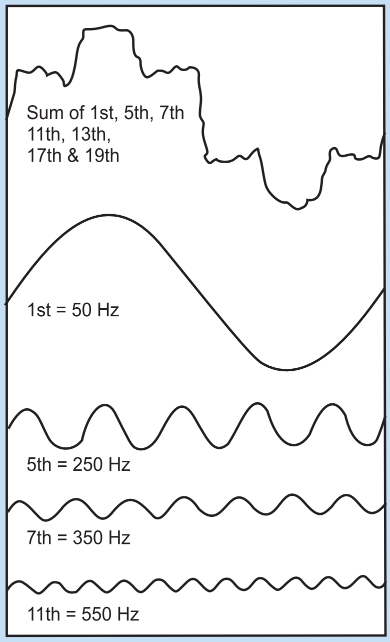
Our engineering is meeting the demand of power quality

Increased power quality problems are caused mainly by the increased use of non-linear loads such as variable speed drives and power electronics gadgets used. These devices are often directly affected by the system anomalies they cause. Earlier the main concern for electricity consumers was having sufficient power available as per their requirements. Now however, consumers are increasingly forced to consider not only the "quantity", but also the "quality" of power used, in order to maintain the correct functioning and reliability of their installed equipment, to achieve techno-economical advantage.

Electricity as supplied by the main generating plants can be considered clean (i.e balanced, sinusoidal, three phase power). Disruption to this supply is only caused by equipment failure or adverse weather conditions. Therefore, any power quality anomalies experienced on the supply network can be attributed to consumers. These anomalies may take the form of voltage surges or sags, spikes, notches and harmonics.

As these power quality problems are created by the consumer's load, these anomalies can also easily travel within the common electricity supply network between premises, in turn disrupting a neighbouring consumers supply. In response to these occurrences, supply authorities have adopted guidelines such as IEEE-519 in order to limit the level of disturbance created by each individual consumer.

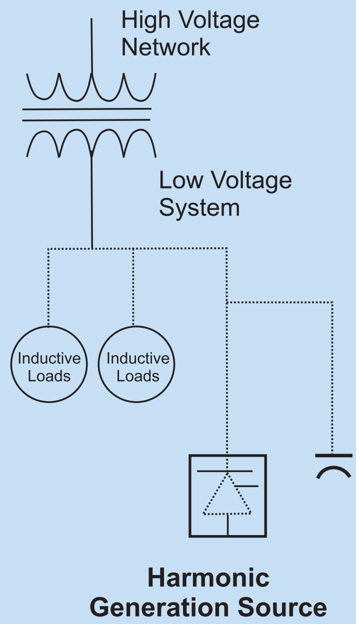


Harmonics

Harmonics are sinusoidal waves that are integral multiples of the fundamental 50 Hz waveform (i.e., 1st harmonic = 50 Hz; 5th harmonic = 250 Hz). All complex waveforms can be resolved into a series of sinusoidal waves of various frequencies, therefore any complex waveform is the sum of a number of odd or even harmonics of lesser or greater value.

Any device with non-linear operating characteristics can produce harmonics in the power system. Currently used equipment that can cause harmonics or have experienced harmonic related problems, capacitor reactor or filter bank equipment will be the ultimate solution to safeguard electrical equipments.

Harmonic distortion and related problems in electrical power systems are becoming more and more prevalent & complex in electrical distribution networks.



Problems Created by Harmonics

- Excessive heating and failure of capacitors, lighting ballasts, transformers & motors.
- Nuisance tripping of circuit breaker or blowing of fuses resulting in power supply failure.
- Noise from harmonics leading to erroneous operation of control system premature components failure of sensitive electronic equipments.
- Electronic communications interference
- Blackout & network faults resulting in production loss.

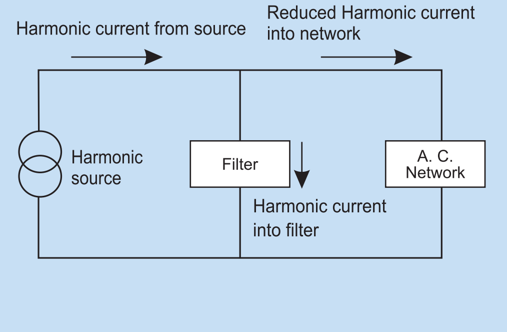
Harmonic Study & Harmonic Filter - The concept

Harmonic Analysis

Industrial customers shall limit the harmonic level to meet the guideline of IEEE-STD 519; This will make the evaluation of power factor/harmonic filters even more essential.

The first step in a harmonic study is to carry out system analysis in the Power System to know following parameters & to determine filter.

- Power System line diagram
- Fault Level
- Transformer rating
- Load details - Motors, drivers etc.
- Harmonic details - THD, Individual harmonic level.
- Energy consumption.



What is Harmonic Filter ?

Suitable series reactor shall be connected in series with capacitor to avoid resonance. A filter may be installed for one load or many loads. Its design requires detail study of the power circuit. Filter sizing depends on the harmonic spectrum & fault level of the load. The types of L.V. filters are indicated below :

1) Detuned Filter :

The idea is to trap the harmonic currents in L/C circuits tuned to the harmonic orders requiring filters . A filter comprises a series of stages each corresponding to harmonic orders. This reactor capacitor combination is designed to have a resonant frequency 131 Hz/189 Hz . In this case 5th, 7th, 11th harmonic currents will be absorbed.

2) Partial Tuned Filter :

In this system reactor/capacitor combination is designed in such a way that system resonance are avoided and approximately 40% of the 5th harmonic current can be absorbed.

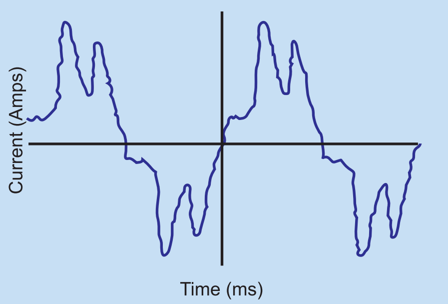
3) Tuned Harmonic Filter :

Tuned filter consists of series reactor & capacitor tuned to the particular given frequency producing zero impedance path to harmonic current. Almost 80 to 90 % of harmonic current can be brought down in the supply network. However it can be installed only across few types of loads.

4) Active Harmonic Filter :

The active harmonic filter concept uses power electronics to introduce current components, which cancel the harmonic components of the non-linear loads. It actively eliminates 100% harmonic distortion & reacts instantly to verifying load conditions. It also balances three phase loads. Today the widespread use of IGBT components and the availability of new DSP components will give bright future for active filters. This type of filter will be launched by us soon.

Current oscillogram before filteration



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