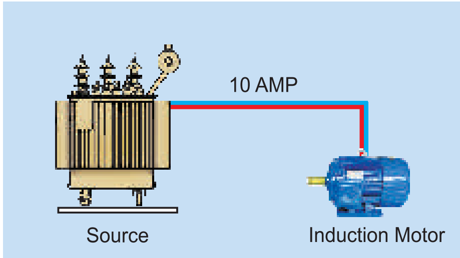
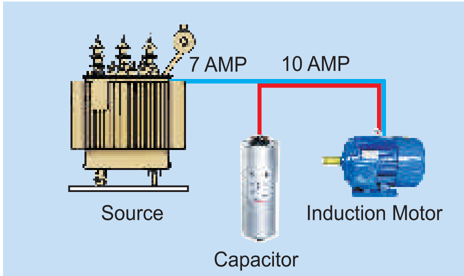
Power Factor Correction - Reactive Power Compensation

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.



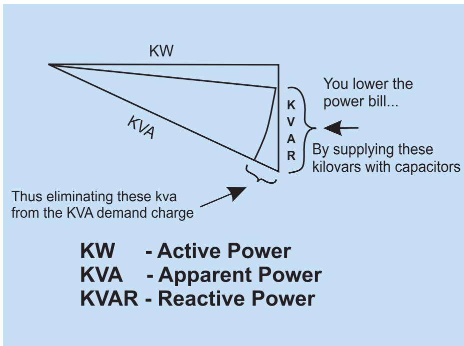


Benefits of Power Factor Correction

- 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?

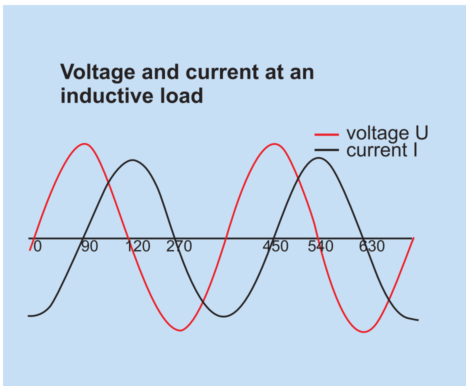
An inductive load requires a magnetic field to operate, and in creating such a magnetic field causes the current to "lag" the voltage (ie, the current is not in phase with the voltage).
Power Factor Correction is the process of compensating for the "lagging" current by applying a "leading" current in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



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

Original P. F. — Multiplication factor (tan Ø1 - tan Ø2) for a target power factor

Cos Ø1	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 Kwh
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

1. Fixed Compensation :

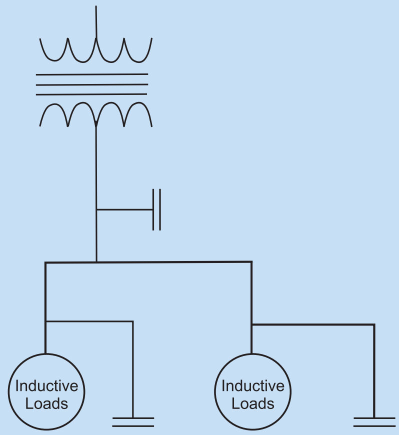
For each individual inductive load corresponding capacitor is allocated. This compensates lagging reactive power immediately at the individual load. Different loads & capacitors can be connected jointly in the system by means of one main switch.

2. Automatic Compensation :

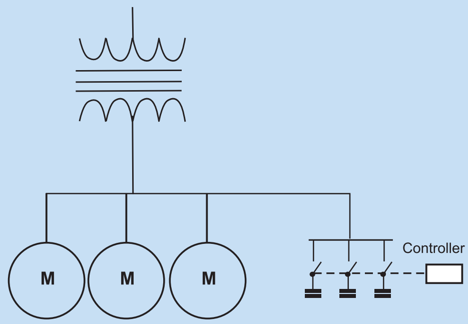
Automatic power factor correction is typical for large electrical systems with fluctuating load where it is common to connect number of capacitors to main power distribution station or substation. The capacitors are controlled by controller which continuously monitors the relative power demand. The relay 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.

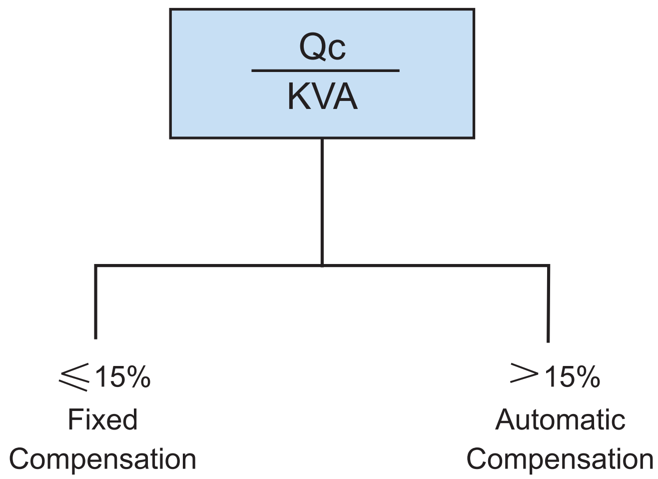


Fixed Compensation



Automatic Compensation

Selection of Compensation



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

L. V. Auto Switched (Contactor) Power factor Correction - Series : LVAS-C

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Features :

- Voltage : 415V/440V/550V/690V
- Frequency : 50 Hz
- Intelligent Power factor controller
- Switching device : Capacitor duty contactor
- Temperature : -5°C to +45°C
- Metal cabinet (Indoor/Outdoor) powder coated
- Incomer : MCCB/ACB
- Equipped with ventilation system

LVAS-C System (with APP) capacitors

Capacitors :

- All polypropylene (APP) film + foil design
- MPP (Metallised polypropylene film) design

Unique Features :

- Semi automatic operation
- Measurement meters with & without data downloading facility (Optional)
- Energy analysis (Optional)

LVAS-C System (with MPP) capacitors

Series	KVAR	Size (With APP Capacitors)			Size (With MPP Capacitors)			Step Configuration
		Width	Depth	Height	Width	Depth	Height	
LVAS-C	150	1350	750	2200	1250	750	2200	25K x 6
LVAS-C	200	1350	750	2200	1250	750	2200	50K x 2 + 25K x 4
LVAS-C	300	2000	750	2200	1250	750	2200	50K x 4 + 25K x 4
LVAS-C	400	2700	750	2200	1300	750	2200	50K x 8
LVAS-C	500	2700	750	2200	1700	750	2200	100K x 2 + 50K x 6
LVAS-C	600	2700	750	2200	1700	750	2200	100K x 4 + 50K x 4
LVAS-C	700	2700	750	2200	2200	750	2200	100K x 6 + 50K x 2
LVAS-C	800	2700	750	2200	2200	750	2200	100K x 8

- Note : Panel size & dimensions with KVAR ratings can be designed as per Customer requirements .

Dynamic Power Factor Correction (Thyristor Switch) System
Series : LVAS-T

LVAS-T System

Thyristor module

Features :

- Voltage : 415V/440V, 3 phase
- Frequency : 50 Hz
- Intelligent Power factor correction
- Switching device : Thyristors (SCR)
- Temperature : -5°C to +45°C
- Metal cabinet (Indoor/Outdoor) powder coated
- Incomer : MCCB/ACB
- Equipped with ventilation system

Capacitors :

- All polypropylene film (APP) film+foil design
- MPP (Metallised polypropylene film) design

Unique Features :

- Zero voltage switching of Thyristors with precise automatic zero search logic
- Smooth, surgeless, transient free switching of capacitors
- Fast & fine correction
- Line chokes for thyristor protection & detuned capacitor usage.

Series	KVAR	Size (With APP Capacitors)			Size (With MPP Capacitors)			Step Configuration
		Width	Depth	Height	Width	Depth	Height	
LVAS-T	150	2500	550	2200	2500	550	2200	25K x 6
LVAS-T	200	2500	550	2200	2500	550	2200	50K x 2 + 25K x 4
LVAS-T	300	3250	550	2200	3250	550	2200	50K x 4 + 25K x 4
LVAS-T	400	3250	550	2200	3250	550	2200	50K x 8
LVAS-T	500	3450	550	2200	3450	550	2200	100K x 2 + 50K x 6
LVAS-T	600	3450	550	2200	3450	550	2200	100K x 4 + 50K x 4
LVAS-T	700	3450	550	2200	3450	550	2200	100K x 6 + 50K x 2
LVAS-T	800	3450	550	2200	3450	550	2200	100K x 8
LVAS-T	900	4200	550	2200	4200	550	2200	100K x 8 + 50K x 2
LVAS-T	1000	4200	550	2200	4200	550	2200	100K x 10

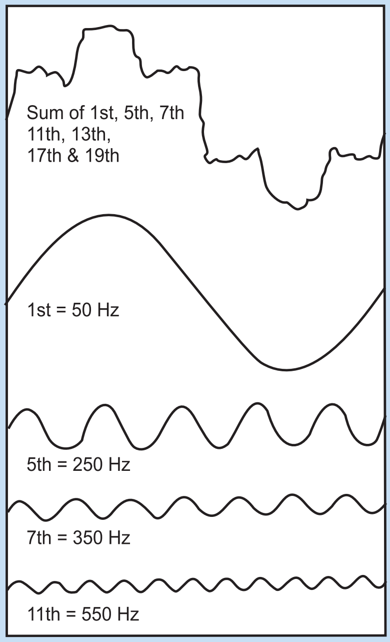
- Note : Panel size & dimensions with KVAR rating can be designed as per customer requirements.

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.

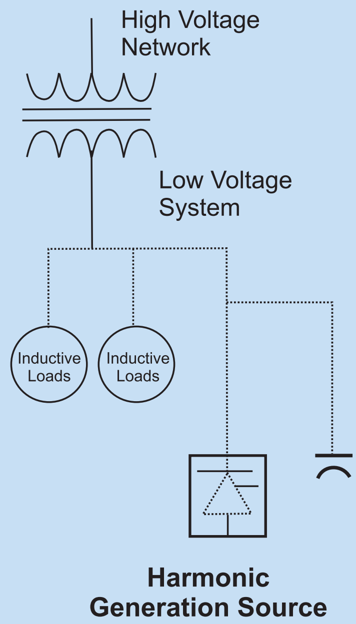


Harmonics

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.

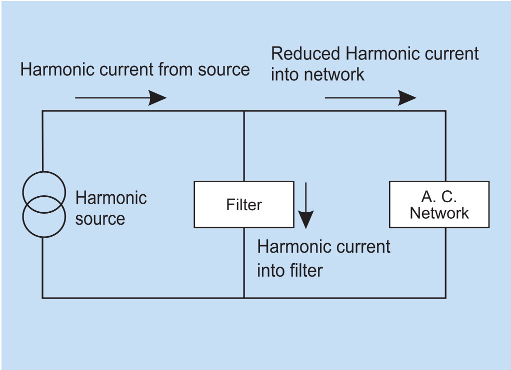
Harmonic Study & Harmonic Filter - The concept

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 :

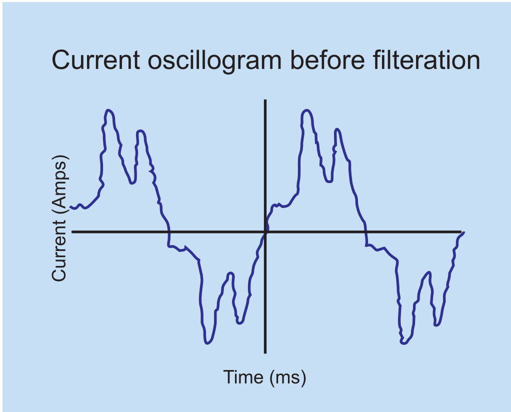
In this system reactor/capacitor combination is designed in such a way that system resonance are avoided and approximately 40% of the 5th harmonic current can be absorbed.

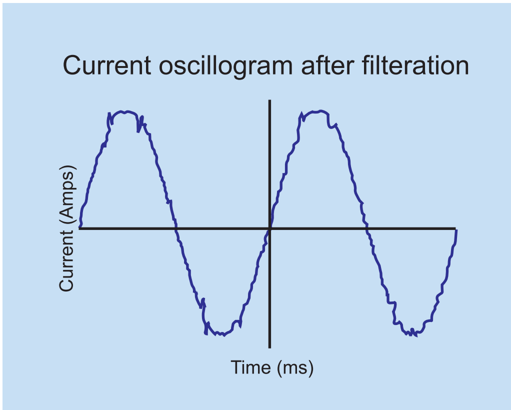
3) Tuned Harmonic Filter :

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.





L.V. Auto Switched Harmonic Filter
Series : LVAS-F

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LVAS-F Harmonic Filter System

Features

- Rated Voltage : 415/ 440 / 525 / 690 V, 50 Hz
- Intelligent Power factor controller
- 2mm CRCA sheet metal cabinet with epoxy powder coating
- Forced ventilation for proper heat dissipation
- Heavy duty contactors for filter steps switching
- Step Protection - HRC fuse/MCCB

Capacitors :

- All PP, 3 Phase capacitors, 440/480 V
- MPP - Suitable for 525 V capacitors

Harmonic Filter Reactor :

- Tuned frequency - 134 Hz, 141 Hz, 189 Hz
- Iron core, cu-wound, dry type
- Linearity 1.8 x In

In-house Testing :

All the Harmonic Filters are subjected to following tests.

- Insulation test 3 KV
- Test of each filter step with contactor at rated voltage
- Power factor relay operations
- Visual inspection

Series	KVAR	Size (With APP Capacitors)			Size (With MPP Capacitors)			Step Configuration
		Width	Depth	Height	Width	Depth	Height	
LVAS-F	150	1350	750	2200	1350	750	2200	25K x 6
LVAS-F	200	1350	750	2200	1350	750	2200	50K x 2 + 25K x 4
LVAS-F	300	2200	750	2200	1350	750	2200	50k x 4 + 25K x 4
LVAS-F	400	2200	750	2200	2200	750	2200	50K x 8
LVAS-F	500	2700	750	2200	2400	750	2200	100K x 2 + 50K x 6
LVAS-F	600	2700	750	2200	2400	750	2200	100K x 4 + 50K x 4
LVAS-F	700	2700	750	2200	2400	750	2200	100K x 6 + 50K x 2
LVAS-F	800	2700	750	2200	2400	750	2200	100K x 8

Common Problems Associated with Poor Power Quality

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Power Quality Condition	Problem & Effects	Typical Causes	Remedical Equipment
Harmonic Current Distortion (General)	1. Transformer & network overload 2. Nuisance tripping 3. Premature failure of unprotected PFC 4. System resonance 5. Monitor Display wobble	1. Non linear loads 2. Variable speed drives 3. Electronic lighting 4. Control/ ballasts	1. Passive filter 2. Phase shift or *zig-zag* transformer 3. Active filter 4. K-rated transformers
Triplen harmonic current distortion	1. Neutral cables overheating 2. Transformer burn out 3. High neutral to ground voltage	1. Non-linear loads 2. Switch mode power supplies 3. Variable speed drives	1. Transformers delta/ star 2. Phase shift or zig - zag transformer 3. Passive/ Active filter 4. K-rated transformers
Harmonic Voltage distortion	1. Random equipment reset/ crash 2. Clock and synchronising 3. Problems due to multiple zero crossing	1. High non-linear current 2. Variable speed drives 3. System resonance 4. High system impedance	1. Active filter 2. Passive filter 3. K-rated transformers
Poor Power Factor	1. Excessive power usage 2. High kVA demand 3. Increased network losses	1. Inductive loads 2. Motors 3. Fluorescent lighting	1. Passive/ Automatic/ Static 2. Capacitor Banks 3. Active Power Factor Correction
Network anomalies Transients surges & sags Flicker over-voltage under - voltage	1. Random equipment failure 2. Computer data loss/ error 3. Power supply failure 4. Circuit breaker tripping 5. Equipment reset/ error 6. Motor torque reduction 7. Motor overheating burn-out 8. Lighting problems flicker 9. Transformer noise 10. Monitor display wobble	1. Tap changing 2. Load switching 3. Load variations 4. System overload 5. Motor starting 6. Electrostatic discharge 7. Lightning 8. Arc furnaces	1. Surge arrestors 2. Isolation transformers 3. In-line filter reactors 4. Electronic Voltage stabiliser 5. Uninterruptible Power Suppliers (UPS) 6. K-rated transformers 7. Voltage stabilisers 8. Static VAr controllers
Supply Interruptions Power failure	1. Black out 2. Data loss 3. Network faults 4. Production line down time	1. Fault clearing 2. Load shedding 3. Lightning interrupters 4. Supply system failure	1. Uninterruptible Power Supply 2. Back up generator/ CHP 3. Rotary UPS