LARSEN & TOUBRO

REACTIVE POWER MANAGEMENT SOLUTIONS

L&T SWITCHGEAR
SAFE & SURE

Switchgear Factory, Mumbai

Switchgear Factory, Ahmednagar

Switchgear Factory, Vadodara

ABOUT US

Larsen & Toubro is a technology-driven company that infuses engineering with imagination. The Company offers a wide range of advanced solutions in the field of Engineering, Construction, Electrical & Automation, Machinery and Information Technology.

L&T Switchgear, a part of the Electrical & Automation business, is India's largest manufacturer of low voltage switchgear, with the scale, sophistication and range to meet global benchmarks. With over five decades of experience in this field, the Company today enjoys a leadership position in the Indian market with a growing international presence.

It offers a complete range of products including powergear, controlgear, industrial automation, building electricals & automation, reactive power management, energy meters, and protective relays. These products conform to Indian and International Standards.

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Power Capacitors

Reactors

Thyristor Switching Modules

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APFC Controller

MCCBs

Wires

MCBs

Indicating Devices

POWER CAPACITORS

Cylindrical Type

Standard Duty
1-25 kVAr

Heavy Duty
Gas Filled
3-25 kVAr

Box Type

Standard Duty
1-30 kVAr

Heavy Duty
5-50 kVAr

LTXL:
Ultra Heavy Duty
5-100 kVAr
(single unit)

HARMONIC FILTERING

Detuned Harmonic Filter Reactor
5-100 kVAr

CAPACITOR SWITCHING

Thyristor Switched Modules
10, 25 & 50 kVAr

Capacitor Duty Contactors -Type MO C
8.5 – 80 kVAr

POWER FACTOR CONTROLLER

etaCON L series APFC relay
3, 5, 7, 8 and 12-step

PRINCIPLES OF POWER FACTOR CORRECTION

A vast majority of electrical loads in low voltage industrial installations are inductive in nature. Typical examples are motors and transformers, which consume both active and reactive power. The active power is used by the load to meet its real output requirements whereas reactive power is used by the load to meet its magnetic field requirements. The reactive power (inductive) is always 90^{0} lagging with respect to active power as shown in figure1. Figure 2 & 3 show the flow of kW, kVAr and kVA in a network.

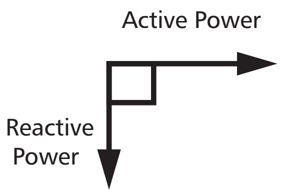


Figure 1:
Phase relationship between Active and Reactive Power

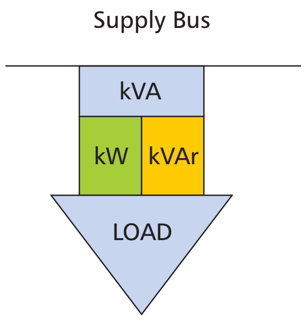


Figure 2:
Network without Capacitor

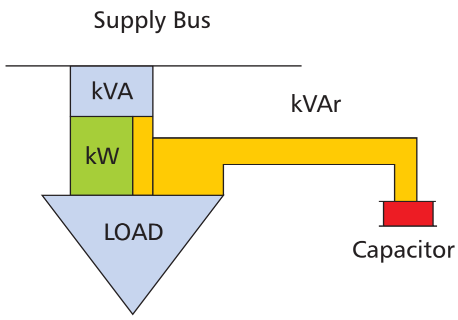


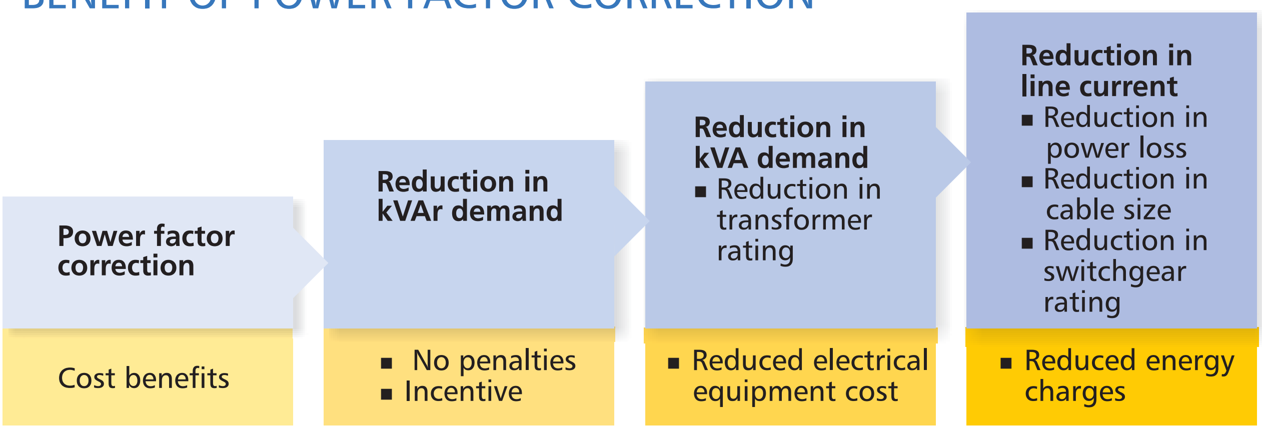
Figure 3:
Network with Capacitor

Flow of active and reactive power always takes place in electrical installations. This means that the supply system has to be capable of supplying both active and reactive power. The supply of reactive power from the system results in reduced installation efficiency due to:

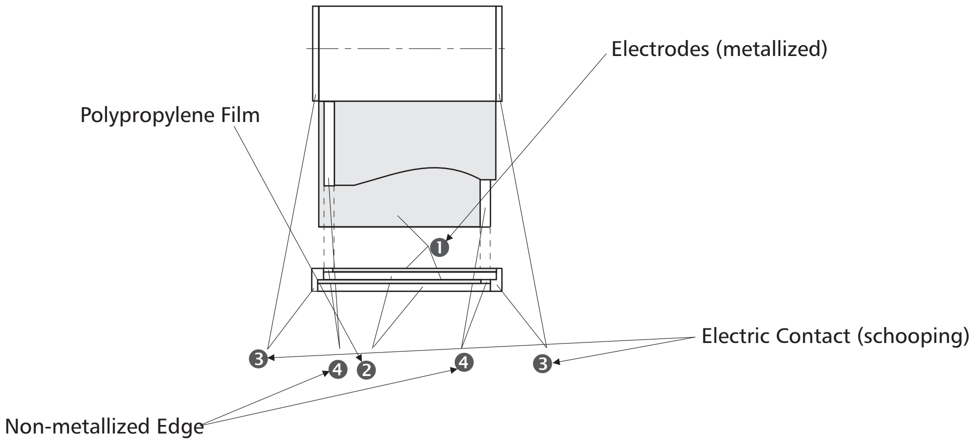
- Increased current flow for a given load
- Higher voltage drops in the system
- Increase in losses of transformers, switchgear and cables
- Higher kVA demand from supply system as given in figure 2
- Higher electricity cost due to levy of penalties / loss of incentives

It is therefore necessary to reduce & manage the flow of reactive power to achieve higher efficiency of the electrical system and reduction in cost of electricity consumed.
The most cost effective method of reducing and managing reactive power is by power factor improvement through Power Capacitors. The concept of reduction in kVA demand from the system is shown in figure 3.

BENEFIT OF POWER FACTOR CORRECTION



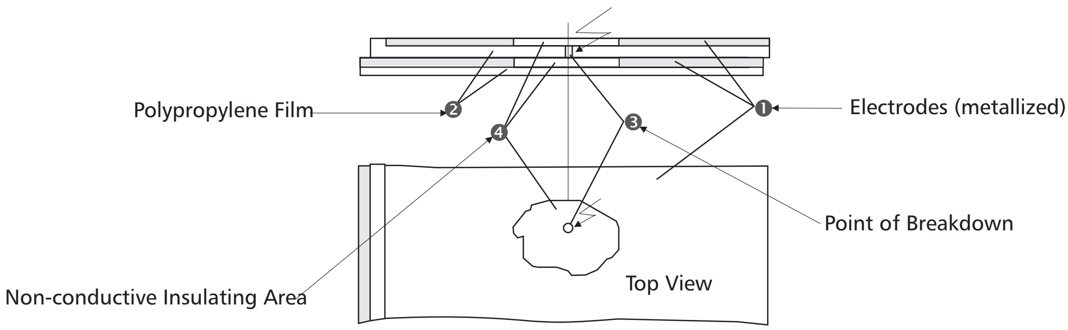
Capacitors are used in many diverse applications, and many different capacitor technologies are available. In low voltage applications, LT cylindrical capacitors which are made in accordance with **metalized polypropylene** technology have proved to be most appropriate and also the most cost effective. Depending on the nominal voltage of the capacitor, the thickness of the polypropylene film will differ.



Design of LT Capacitor

SELF - HEALING

At the end of service life, or due to inadmissible electrical or thermal overload, an insulation breakdown may occur. A breakdown causes a small arc which evaporates the metal layer around the point of breakdown and re-establishes the insulation at the place of perforation. After electric breakdown, the capacitor can still be used. The decrease of Capacitance caused by a self-healing process is less than 100 pF. The self-healing process lasts for a few microseconds only and the energy necessary for healing can be measured only by means of sensitive instruments.



Self - Healing Breakdown

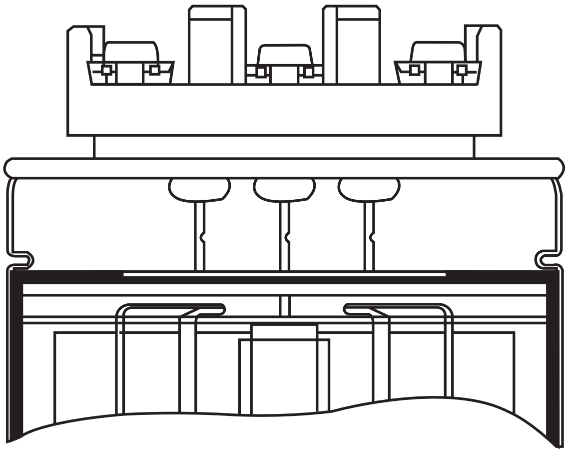
IMPREGNATION

Our LT-type capacitors are impregnated to eliminate environmental influences and to guarantee reliable, long-term operation. Vacuum impregnation eliminates air and moisture, improves "self-healing" and reduces thermal resistance.

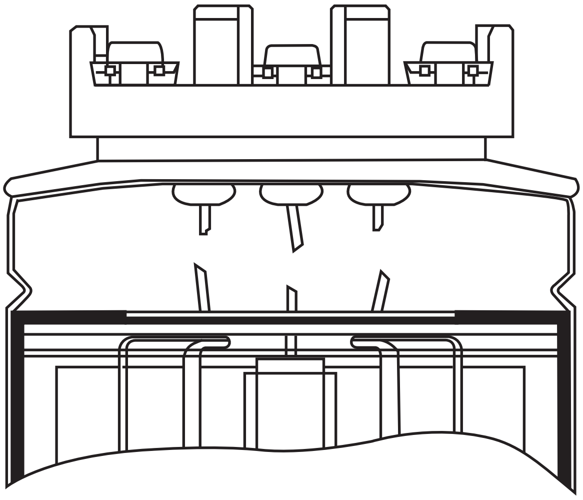
OVER PRESSURE TEAR - OFF FUSE

At the end of service life, due to inadmissible electrical or thermal overload, an over pressure builds up and causes an expansion of the cover. Expansion over a certain limit causes the tear-off of the internal fuses. The active capacitor elements are thus cut-off from the source of supply. The pressure within the casing separates the breaking point so rapidly that no harmful arc can occur.

Operating Condition



Torn - off Condition



BOX TYPE CAPACITORS

Technologically similar to cylindrical capacitors, box type capacitors consist a number of three phase cylindrical capacitor cells. The individual cells are wired together and mounted on a steel frame. The steel frame together with the cells is housed in a common sheet steel casing. The enclosure is powder coated and is designed to protect the capacitor cells from dust and moisture. Ease of mounting is ensured by 4 drillings at the bottom of the container.

This design ensures highest safety by:

- Self healing technology
- Over pressure tear - off fuse
- Robust steel container
- Massive connection studs

CAPACITOR TECHNOLOGY & CONSTRUCTION DETAILS

Capacitors are manufactured in three different types such as Standard duty, Heavy duty and Ultra Heavy duty. The Standard duty capacitors are manufactured using standard thickness of dielectric material with heavy edge metallization. Heavy duty capacitors are manufactured using thicker material and in lower width which increases current handling capacity as well as reduces temperature rise. Ultra Heavy duty capacitors are manufactured using thicker material, in lower width and have greater ability to handle in-rush current.

STANDARD DUTY CAPACITORS

L&T Standard Duty Capacitors are metalized polypropylene capacitors from 1 - 25 kVAr in cylindrical configuration and 1-30 kVAr in box type configuration. These capacitors come with a stacked winding and are impregnated with a biodegradable soft resin. These capacitors are self healing type. The Capacitors come with an over pressure disconnector and finger proof terminals. They can be used to provide effective power factor correction in industrial and semi industrial applications.

For Selection and Application details please refer page no. 46.

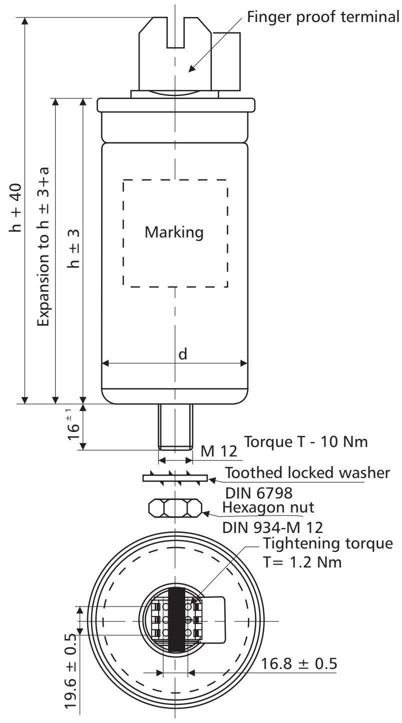
TECHNICAL DETAILS

	Standard Duty	
	Box	Cylindrical
Series	LTBCF (1 to 6 kVAr) and	LTCCF (1 to 6 kVAr) and
	LTBCD (7.5 kVAr and above)	LTCCD (7.5 kVAr and above)
Range	1-30 kVAr	1 - 25 kVAr
Standards	IS 13340-1993, IS 13341-1992, IEC 60831-1+2	IS 13340-1993, IS 13341-1992, IEC 60831-1+2
Rated Frequency	50Hz	50Hz
Rated Voltage	415 / 440 V	415 / 440 V
Over Voltage	+10% (12h/24h), +15% (30m/24h), +20% (5m/24hrs), +30% (1m/24hrs)	+10% (12h/24h), +15% (30m/24h), +20% (5m/24hrs), +30% (1m/24hrs)
Overcurrent	1.5 x In	1.5 x In
Peak Inrush Current	200 x In	200 x In
Operating Losses (Dielectric)	< 0.2 W/kVAr	< 0.2 W/kVAr
Operating Losses (Total)	< 0.45 W/kVAr	< 0.45 W/kVAr
Tolerance on Capacitance	-5 / +10% as per IS	-5 / +10% as per IS
Test Voltage (Terminal-Terminal)	2.15 times rated voltage for 10 sec	2.15 times rated voltage for 10 sec
Test Voltage (Terminal-Casing)	3 kV (AC) for 1 minute	3 kV (AC) for 1 minute
Degree of Protection	IP20, indoor mounting (IP54 optional)	IP20, indoor mounting (optionally with terminal cap for IP54)
Ambient Temperature	-25 / D Max temperature = +55˚C Max mean temperature (24 h) = +45˚C Max mean temperature (1 year) = +35˚C	-25 / D Max temperature = +55˚C Max mean temperature (24 h) = +45˚C Max mean temperature (1 year) = +35˚C
Cooling	Natural or forced air cooling	Natural or forced air cooling
Permissible Relative Humidity	max 95%	max 95%
Maximum Operating Altitude	4000m above sea level	4000m above sea level
Mounting	upright	upright
Safety Features	Overpressure disconnector, Self-healing, Finger-proof terminals	Overpressure disconnector, Self-healing, Finger-proof terminals
Impregnation	Non PCB, biodegradable resin	Non PCB, biodegradable resin
Casing	MS Sheet metal	Aluminum extruded can
Dielectric Composition	Metalized polypropylene	Metalized polypropylene
Terminals	Wire (1 - 6 kVAr)	Wire (1 - 6 kVAr)
	Ceramic Bushing (7.5 kVAr and above)	Finger-proof Clamptite (7.5 kVAr and above)
Discharge Resistors / Time	Discharge Resistors fitted, Standard discharge time 60 seconds, Other discharge times on request	Discharge Resistors fitted, Standard discharge time 60 seconds, Other discharge times on request
Switching Operations (maximum)	5000 switchings per year	5000 switchings per year

STANDARD DUTY CAPACITORS - OVERALL DIMENSIONS

Cylindrical Type

Sr. No.	Voltage	Power rating (kVAr)		Capacitance (uF)	Rated current (A)	Dimensions in (mm)		Cat. Nos.
		50 Hz	60 Hz			H	D	
1	440 V	1	1	16.44	1.31	130	45	LTCCF301B2
2	440 V	2	2	32.88	2.62	130	50	LTCCF302B2
3	440 V	3	4	49.32	3.94	165	50	LTCCF303B2
4	440 V	4	5	65.77	5.25	165	63.5	LTCCF304B2
5	440 V	5	6	82.21	6.56	225	63.5	LTCCF305B2
6	440 V	6	7	98.65	7.87	225	63.5	LTCCF306B2
7	440 V	7.5	9	123.31	9.84	195	75	LTCCD307B2
8	440 V	8.33	10	136.96	10.93	195	75	LTCCD308B2
9	440 V	10	12	164.42	13.12	195	85	LTCCD310B2
10	440 V	12.5	15	205.52	16.40	270	85	LTCCD312B2
11	440 V	15	18	246.62	19.68	270	85	LTCCD315B2
12	440 V	20	24	328.83	26.24	345	85	LTCCD320B2
13	440 V	25	30	411.04	32.80	345	90	LTCCD325B2

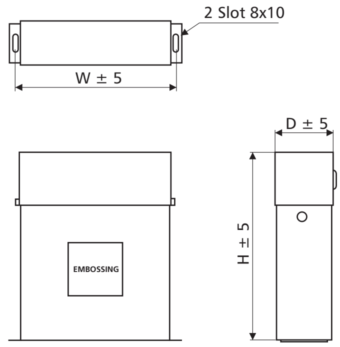


Note :- 1) Seaming adds 4mm. In diameter

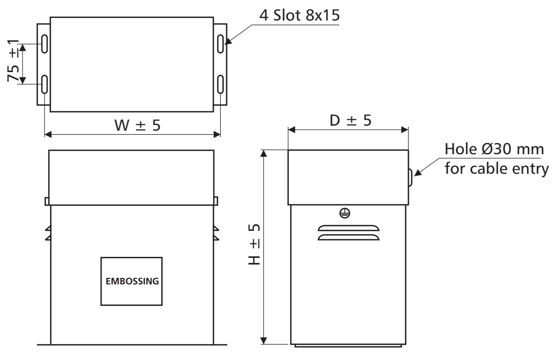
Box Type

Sr. No.	Voltage	Power rating (kVAr)		Capacitance (uF)	Rated current (A)	Dimensions in (mm)			Cat. Nos.
		50 Hz	60 Hz			H	W	D	
1	440 V	1	1	16.44	1.31	125	140	40	LTBCF301B2
2	440 V	2	2	32.88	2.62	125	140	40	LTBCF302B2
3	440 V	3	4	49.32	3.94	145	170	50	LTBCF303B2
4	440 V	4	5	65.77	5.25	145	170	50	LTBCF304B2
5	440 V	5	6	82.21	6.56	175	170	50	LTBCF305B2
6	440 V	6	7	98.65	7.87	175	170	50	LTBCF306B2
7	440 V	7.5	9	123.31	9.84	300	240	80	LTBCD307B2
8	440 V	8.33	10	136.96	10.93	300	240	80	LTBCD308B2
9	440 V	10	12	164.42	13.12	300	240	80	LTBCD310B2
10	440 V	12.5	15	205.52	16.40	300	240	80	LTBCD312B2
11	440 V	15	18	246.62	19.68	300	240	80	LTBCD315B2
12	440 V	20	24	328.83	26.24	300	240	160	LTBCD320B2
13	440 V	25	30	411.04	32.80	300	240	160	LTBCD325B2
14	440 V	30	36	493.25	39.37	300	240	160	LTBCD330B2

7.5 kVAr to 15 kVAr



20 kVAr to 30 kVAr



HEAVY DUTY CAPACITORS

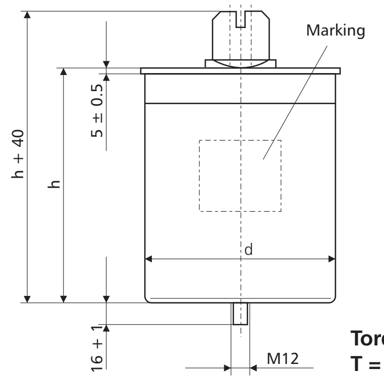
L&T Heavy Duty Capacitors are metalized polypropylene capacitors available from 3-25 kVAr in cylindrical and from 5-50 kVAr in box type construction. These capacitors have an inrush current withstand of 300 In and an overload withstand capacity of 1.8 In. These capacitors have all the features of standard capacitors like over pressure disconnector and self healing.
The cylindrical Capacitors are subjected to an extended period of drying after which the casing is filled with an inert gas to prevent corrosion of the winding elements and inner electrical contacts. Compact design ensures space saving. Heavy Duty capacitors have a long life of 150000 hours.

For Selection and Application details please refer page no. 46.

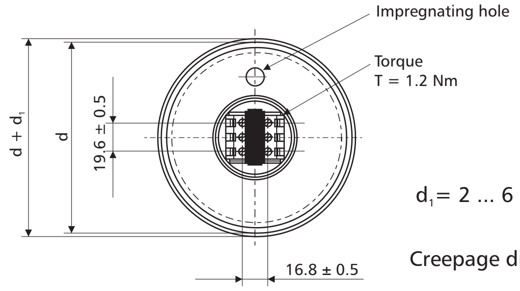
TECHNICAL DETAILS

	Heavy Duty	
	Box	Cylindrical
Series	LTBCH	LTCCN
Range	5-50 kVAr	3-30 kVAr
Standards	IS 13340-1993, IS 13341-1992, IEC 60831-1+2	IS 13340-1993, IS 13341-1992, IEC 60831-1+2
Rated Frequency	50Hz	50Hz
Rated Voltage	415 / 440 / 480 / 525 V	415 / 440 / 480 / 525 / 690 V
Over Voltage	+10% (12h/24h), +15% (30m/24h), +20% (5m/24hrs), +30% (1m/24hrs)	+10% (12h/24h), +15% (30m/24h), +20% (5m/24hrs), +30% (1m/24hrs)
Overcurrent	1.8 x In	1.8 x In
Peak Inrush Current	300 x In	250 x In
Operating Losses (Dielectric)	< 0.2 W/kVAr	< 0.2 W/kVAr
Operating Losses (Total)	< 0.35 W/kVAr	< 0.35 W/kVAr
Tolerance on Capacitance	-5 / +10% as per IS	-5 / +10% as per IS
Test Voltage (Terminal-Terminal)	2.15 times rated voltage for 10 sec	2.15 times rated voltage for 10 sec
Test Voltage (Terminal-Casing)	3 kV (AC) for 1 minute	3 kV (AC) for 1 minute
Degree of Protection	IP20, indoor mounting (IP54 optional)	IP20, indoor mounting (optionally with terminal cap for IP54)
Ambient Temperature	-25 / D Max temperature = +55°C Max mean temperature (24 h) = +45°C Max mean temperature (1 year) = +35°C	-40 / D Max temperature = +55°C Max mean temperature (24 h) = +45°C Max mean temperature (1 year) = +35°C
Cooling	Natural or forced air cooling	Natural or forced air cooling
Permissible Relative Humidity	max 95%	max 95%
Maximum Operating Altitude	4000m above sea level	4000m above sea level
Mounting	upright	upright or horizontal
Safety Features	overpressure disconnector, Self-healing	Dry type (gas filled), Overpressure disconnector, Self-healing
Impregnation	Non PCB, biodegradable resin	Inert gas
Casing	MS Sheet metal	Aluminum extruded can
Dielectric Composition	Metalized polypropylene	Metalized polypropylene
Terminals	Ceramic Bushing	Finger-proof Clamptite
Discharge Resistors / Time	Discharge resistors fitted, Standard discharge time 60 seconds, Other discharge times on request	Discharge resistors fitted, Standard discharge time 60 seconds, Other discharge times on request
Switching Operations (maximum)	8000 switchings per year	8000 switchings per year

Cylindrical Type



Torque
T = 10 Nm

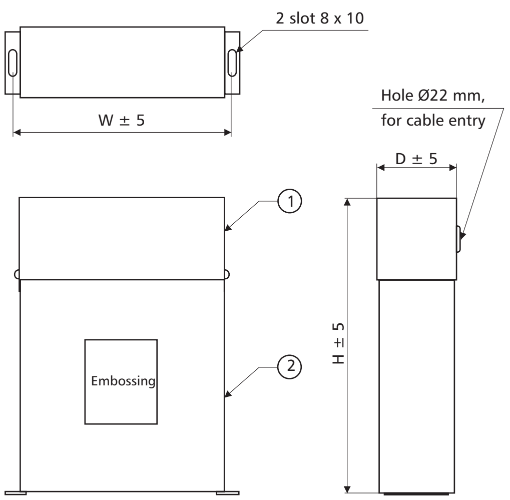


d_1 = 2 ... 6 mm (depending on the capacitor type; for details please refer to the data sheet)
Creepage distance 12.7 mm min. Clearance 9.6 mm min.

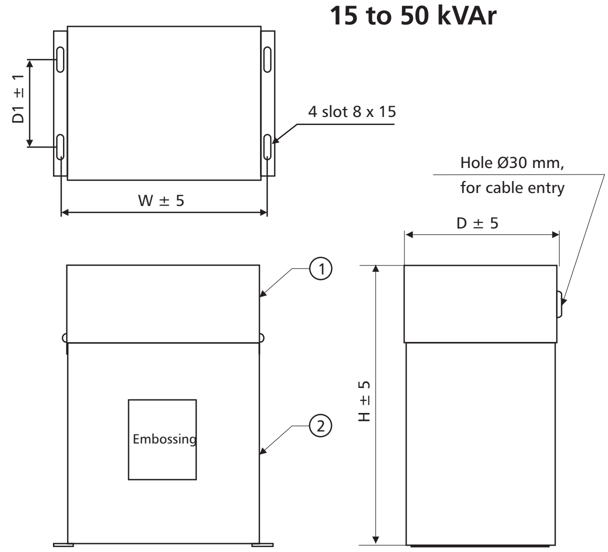
Sr. No.	Voltage	Power rating (kVAr)		Capacitance (uF)	Rated current (A)	Dimensions in (mm)		Cat. Nos.
		50 Hz	60 Hz			H	D	
1	440 V	3	4	49.32	3.94	130	64	LTCCN303B2
2	440 V	4	5	65.77	5.25	190	64	LTCCN304B2
3	440 V	5	6	82.21	6.56	190	64	LTCCN305B2
4	440 V	7.5	9	123.31	9.84	190	64	LTCCN307B2
5	440 V	8.33	10	136.96	10.93	190	64	LTCCN308B2
6	440 V	10	12	164.42	13.12	265	64	LTCCN310B2
7	440 V	12.5	15	205.52	16.40	265	64	LTCCN312B2
8	440 V	15	18	246.62	19.68	190	84.4	LTCCN315B2
9	440 V	20	24	328.83	26.24	265	84.4	LTCCN320B2
10	440 V	25	30	411.04	32.80	265	84.4	LTCCN325B2
11	480 V	5	6	69.08	6.01	190	64	LTCCN305C2
12	480 V	7.5	9	103.62	9.02	190	64	LTCCN307C2
13	480 V	8.33	10	115.08	10.02	190	64	LTCCN308C2
14	480 V	10	12	138.16	12.03	190	84	LTCCN310C2
15	480 V	12.5	15	172.69	15.04	190	84	LTCCN312C2
16	480 V	15	18	207.23	18.04	265	84	LTCCN315C2
17	480 V	20	24	276.31	24.06	265	84	LTCCN320C2
18	480 V	25	30	345.39	30.07	265	84	LTCCN325C2
19	480 V	30	36	414.47	36.09	230	116	LTCCN330C2
20	525 V	5	6	57.74	5.50	190	64	LTCCN305M2
21	525 V	7.5	9	86.61	8.25	190	64	LTCCN307M2
22	525 V	8.33	10	96.20	9.16	190	64	LTCCN308M2
23	525 V	10	12	115.49	11.00	265	65	LTCCN310M2
24	525 V	12.5	15	144.36	13.75	265	65	LTCCN312M2
25	525 V	15	18	173.23	16.50	265	65	LTCCN315M2
26	525 V	20	24	230.97	21.99	265	84	LTCCN320M2
27	525 V	25	30	288.72	27.49	265	84	LTCCN325M2
28	525 V	30	36	346.46	32.99	230	116	LTCCN330M2

Box Type

5 to 12.5 kVAr



15 to 50 kVAr



Sr. No.	Voltage	Power rating (kVAr)		Capacitance (uF)	Rated current (A)	Dimensions in (mm)				Cat. Nos.
		50 Hz	60 Hz			W	D	D1	H	
1	440 V	5	6	82.21	6.56	245	80	-	325	LTBCH305B2
2	440 V	7.5	9	123.31	9.84	245	80	-	325	LTBCH307B2
3	440 V	8.33	10	136.96	10.93	245	80	-	325	LTBCH308B2
4	440 V	10	12	164.42	13.12	245	80	-	325	LTBCH310B2
5	440 V	12.5	15	205.52	16.40	245	80	-	325	LTBCH312B2
6	440 V	15	18	246.62	19.68	240	160	75	325	LTBCH315B2
7	440 V	20	24	328.83	26.24	240	160	75	325	LTBCH320B2
8	440 V	25	30	411.04	32.80	240	160	75	325	LTBCH325B2
9	440 V	30	36	493.25	39.37	240	160	75	325	LTBCH330B2
10	440 V	50	60	822.08	65.61	240	320	150	375	LTBCH350B2
11	480 V	5	6	69.08	6.01	245	80	-	325	LTBCH305C2
12	480 V	7.5	9	103.62	9.02	245	80	-	325	LTBCH307C2
13	480 V	10	12	138.16	12.03	245	80	-	325	LTBCH310C2
14	480 V	12.5	15	172.69	15.04	245	80	-	325	LTBCH312C2
15	480 V	15	18	207.23	18.04	240	160	75	325	LTBCH315C2
16	480 V	20	24	276.31	24.06	240	160	75	325	LTBCH320C2
17	480 V	25	30	345.39	30.07	240	160	75	325	LTBCH325C2
18	480 V	30	36	414.47	36.09	240	160	75	325	LTBCH330C2
19	480 V	50	60	690.78	60.14	240	320	150	375	LTBCH350C2
20	525 V	5	6	57.74	5.50	245	80	-	325	LTBCH305M2
21	525 V	7.5	9	86.61	8.25	245	80	-	325	LTBCH307M2
22	525 V	8.33	10	96.20	9.16	245	80	-	325	LTBCH308M2
23	525 V	10	12	115.49	11.00	245	80	-	325	LTBCH310M2
24	525 V	12.5	15	144.36	13.75	245	80	-	325	LTBCH312M2
25	525 V	15	18	173.23	16.50	240	160	75	325	LTBCH315M2
26	525 V	20	24	230.97	21.99	240	160	75	325	LTBCH320M2
27	525 V	25	30	288.72	27.49	240	160	75	325	LTBCH325M2
28	525 V	30	36	346.46	32.99	240	160	75	325	LTBCH330M2
29	525 V	33.3	40	384.57	36.62	245	160	75	300	LTBCH333M2
30	525 V	50	60	577.43	54.99	240	320	150	375	LTBCH350M2

LTXL: ULTRA HEAVY DUTY CAPACITOR

The LTXL range of capacitors are designed for Ultra heavy duty applications and can withstand heavy load fluctuations, high inrush current and harmonics.

APPLICATIONS

- Applications such as welding, steel rolling, etc., with heavy load fluctuations and high thermal loading
- Systems with high harmonic distortion levels (non linear load >15%)
- Systems with high dv/dt
- Tuned harmonic filter

FEATURES

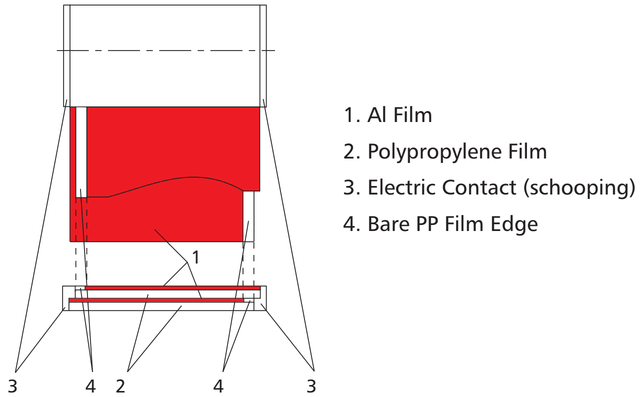
- Long life expectancy (upto 300000 hrs)
- Maximum inrush current withstand capability (upto 500 times I_R)
- Low power loss (0.35 W/kVAr)
- Shock hazard protected terminals
- Internal fuse

The life of a capacitor largely depends upon its operating temperature. LTXL box type capacitors use **advanced APP** technology. By employing thicker aluminum foil, thicker polypropylene film and special impregnates, LTXL box type capacitor is able to operate at lower temperatures and hence achieve a longer life. These capacitors are thus able to withstand stringent operating conditions. The higher surface area and special epoxy based coating also ensures better heat dissipation. The capacitor is designed to operate at ambient temperature up to 70°C.

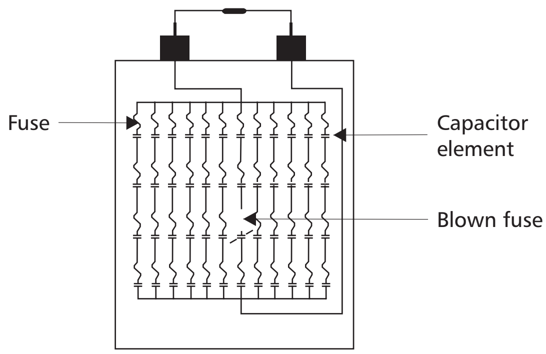
In LTXL box, two polypropylene films and two Al films are grouped together as shown in the figure below. The wave-cut and heavy edge metalized films are then rolled to form a capacitor element. Many such capacitor elements are pressed and stacked together and are internally connected in parallel. Depending upon the rating of the capacitor, the number of stacks differ. These stacks are placed inside a case and are vacuum impregnated with non-PCB, biodegradable impregnates.

Each capacitor element is protected by an internal fuse as shown in the figure below. If there is an internal short circuit in any of the capacitor element, the fuse of that corresponding capacitor elements will blow.

For Selection and Application details please refer page no. 46.



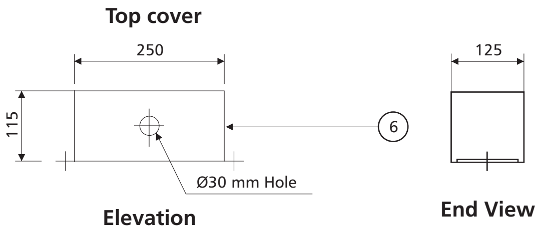
Design of LT Capacitor

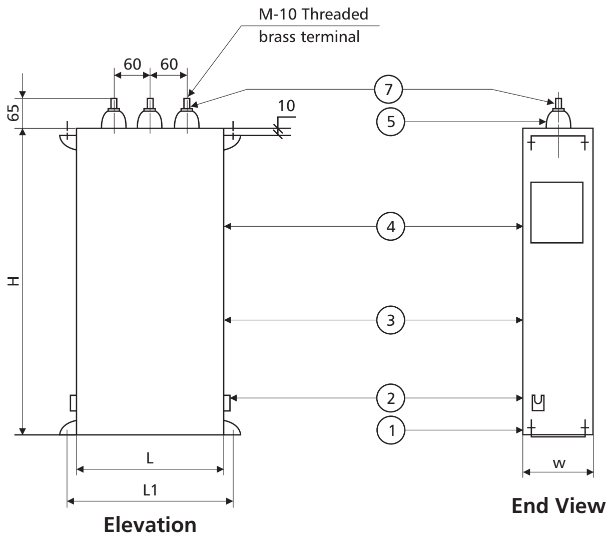


TECHNICAL DETAILS

	LTXL - Ultra Heavy Duty Box
Series	LTBCU
Range	5 - 100 kVAr
Standards	IS 13585-1994, IEC 60931-2002
Rated Frequency	50 Hz
Rated Voltage	415 / 440 / 480 / 525 / 690 / 850 / 1000 V
Over Voltage	+10% (12h/24h), +15% (30m/24h), +20% (5m/24hrs), +30% (1m/24hrs)
Overcurrent	Upto 3 x In
Peak Inrush Current	Upto 500 x In
Operating Losses (Dielectric)	< 0.2 W/kVAr
Operating Losses (Total)	< 0.35 W/kVAr
Tolerance on Capacitance	-5 / +10% as per IS
Test Voltage (Terminal-Terminal)	2.15 times rated voltage for 10 sec
Test Voltage (Terminal-Casing)	3 kV (AC) for 1 minute
Degree of Protection	IP20, indoor mounting (optionally with terminal cap for IP54)
Ambient Temperature	-25 / D (Case temperature 70˚C)
Cooling	Natural or forced air cooling
Permissible Relative Humidity	max 95%
Maximum Operating Altitude	4000m above sea level
Mounting	upright
Safety Features	Internal Fuse
Impregnation	Non PCB Oil, biodegradable oil
Casing	MS Sheet metal
Dielectric Composition	Biaxially oriented polypropylene film with aluminium foil electrode
Terminals	Ceramic Bushing
Discharge Resistors / Time	Discharge Resistors fitted, Standard discharge time 60 seconds, Other discharge times on request
Switching operations (maximum)	20000 switchings per year

Box Type





Sr. No.	Voltage	Power rating (kVAr)		Capacitance (uF)	Rated current (A)	Dimensions in (mm)				Cat. Nos.
		50 Hz	60 Hz			L	L1	W	H	
1	440 V	5	6	82.21	6.56	240	270	115	115	LTBCU305B2
2	440 V	7.5	9	123.31	9.84	240	270	115	150	LTBCU307B2
3	440 V	8.33	10	136.96	10.93	240	270	115	150	LTBCU308B2
4	440 V	10	12	164.42	13.12	240	270	115	175	LTBCU310B2
5	440 V	12.5	15	205.52	16.40	240	270	115	200	LTBCU312B2
6	440 V	15	18	246.62	19.68	240	270	115	225	LTBCU315B2
7	440 V	20	24	328.83	26.24	240	270	115	275	LTBCU320B2
8	440 V	25	30	411.04	32.80	240	270	115	325	LTBCU325B2
9	440 V	30	36	493.25	39.37	240	270	115	375	LTBCU330B2
10	440 V	50	60	822.08	65.61	240	270	115	575	LTBCU350B2
11	440 V	100	120	1645.00	131.22	343	373	118	775	LTBCU300B2
12	480 V	5	6	69.08	6.01	240	270	115	100	LTBCU305C2
13	480 V	7.5	9	103.62	9.02	240	270	115	150	LTBCU307C2
14	480 V	10	12	138.16	12.03	240	270	115	150	LTBCU310C2
15	480 V	12.5	15	172.69	15.04	240	270	115	175	LTBCU312C2
16	480 V	15	18	207.23	18.04	240	270	115	200	LTBCU315C2
17	480 V	20	24	276.31	24.06	240	270	115	250	LTBCU320C2
18	480 V	25	30	345.39	30.07	240	270	115	300	LTBCU325C2
19	480 V	30	36	414.47	36.09	240	270	115	325	LTBCU330C2
20	480 V	50	60	690.78	60.14	240	370	115	500	LTBCU350B2
21	525 V	5	6	57.74	5.50	340	370	115	100	LTBCU305M2
22	525 V	7.5	9	86.61	8.25	340	370	115	115	LTBCU307M2
23	525 V	8.33	10	96.20	9.16	340	370	115	125	LTBCU308M2
24	525 V	10	12	115.49	11.00	340	370	115	125	LTBCU310M2
25	525 V	12.5	15	144.36	13.75	340	370	115	150	LTBCU312M2
26	525 V	15	18	173.23	16.50	340	370	115	175	LTBCU315M2
27	525 V	20	24	230.97	21.99	340	370	115	200	LTBCU320M2
28	525 V	25	30	288.72	27.49	340	370	115	250	LTBCU325M2
29	525 V	30	36	346.46	32.99	340	370	115	275	LTBCU330M2
30	525 V	35	42	404.41	38.49	340	370	115	325	LTBCU335M2
31	525 V	50	60	577.43	54.99	340	370	115	425	LTBCU350M2

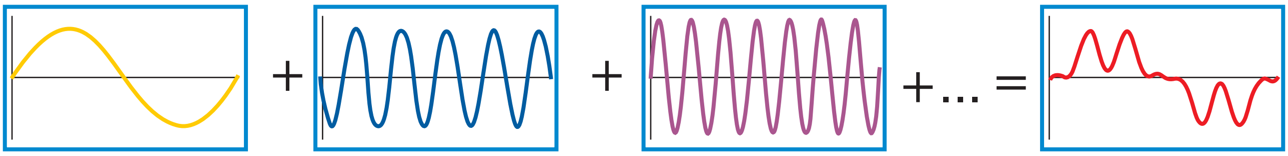

LIFT
HERE

HARMONIC MITIGATION

HARMONICS

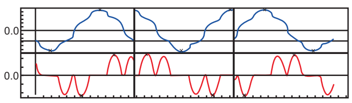
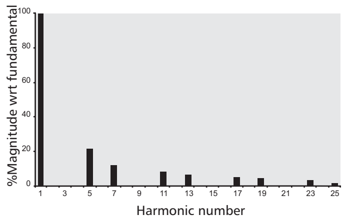
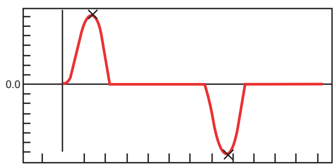
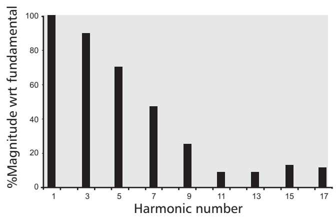
Harmonics is defined as a component of periodic wave (or a signal) whose frequency is integral multiple of the fundamental frequency. Non linear loads such as rectifiers, inverters, variable speed drives, furnaces, etc. create harmonics.

These currents consist of a fundamental frequency component rated at 50 Hz, plus a series of overlapping currents, with frequencies that are multiples of the fundamental frequency. The result is deformation of the current (and, as a consequence, voltage) that has a series of associated secondary effects.



Fundamental Wave 50 Hz	Harmonic wave of 5^{th} order 250 Hz	Harmonic wave of 7^{th} order 350 Hz	Distorted wave

TYPES OF HARMONIC LOADS

Type of load	Wave shape	Harmonic spectrum THD I
• 6 Pulse and 12 Pulse drive* (VFD & UPS) • Three-phase / Single-phase rectifiers • Arc / Induction furnace		
• Discharge lamps / CFL • Single-phase converters • Computer, IT loads • SMPs • TVs		

* Harmonics are inversely proportional to (n±1) for an n-Pulse drive

ILL EFFECTS OF HARMONICS

Type of equipment	Effect of Harmonics
Rotating machines	Increased losses, over heating due to skin effect as higher frequency current flows on cable periphery increasing cable resistance, pulsating torque due to negative phase sequence harmonics
Transformer, switch-gear, power cables	Over-heating, increased power consumption
Protective relays	Mal-operation, nuisance tripping
Power electronics	Mal-operation, failure
Power capacitors	High currents & failure due to overload

The above malfunctions are not always felt immediately after the system is installed, but the effects may be felt in the long term and are difficult to distinguish from the natural ageing of equipment. Hence it is high time to have some basic knowledge about harmonics and find solutions for the same.

- **Reduction in operating expenses**
  Harmonic mitigation contributes to reduced power losses in transformers, cables, switchgear. Harmonic mitigation helps in reducing the energy losses
- **Reduction in capital expenditure**
  Harmonic mitigation reduces the r.m.s. value of the current and it eliminates the need to oversize transformers and hence switchgear, cables and busbars
- **Improved business performance**
  Harmonics are responsible for increased line currents, resulting in additional power losses and increased temperature in transformers, cables, motors, capacitors. The consequence may be the unwanted tripping of circuit breakers or protection relays. This might cause significant financial losses linked to a process interruption

IEEE 519-1992 GUIDELINES ON HARMONIC LIMITS

The following are the guidelines on limits for current and voltage harmonics at point of common coupling (PCC) set by IEEE

Table 1: Maximum Harmonic Current Distortion in % I_L

Individual Harmonic Order (Odd Harmonics)						
I_{sc} / I_L	**<11**	**11⩽h<17**	**17 ⩽h<23**	**23 ⩽h< 35**	**35⩽h**	**TDD**
<20	4.0%	2.0%	1.5%	0.6%	0.3%	5.0%
20 - 50	7.0%	3.5%	2.5%	1.0%	0.5%	8.0%
50 - 100	10.0%	4.5%	4.0%	1.5%	0.7%	12.0%
100 - 1000	12.0 %	5.5%	5.0%	2.0%	1.0%	15.0 %
>1000	15.0%	7.0%	6.0%	2.5%	1.4%	20.0%

where
I_{sc} = maximum short-circuit current at PCC [Can be calculated as MVA/(%Z x V)].
I_L = maximum demand load current (fundamental frequency component) at PCC.

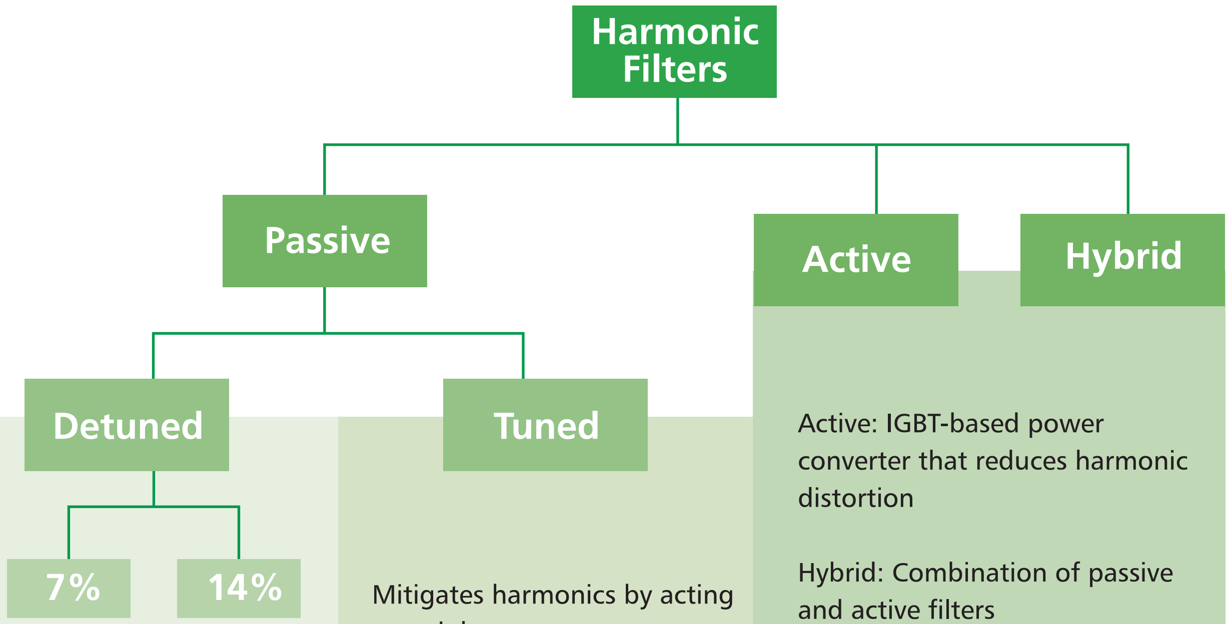
A system's impedance limits the short circuit current for that system. Systems with higher I_{SC}/ I_L have smaller impedances and thus they contribute less in the overall voltage distortion of the power system to which they are connected. Thus, the TDD limits become less stringent for systems with higher I_{SC}/ I_L values.

Table 2: Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion	V_{THD}
⩽69 kV	3.0%	5.0%
69 kV < V ⩽160 kV	1.5%	2.5%
> 160 kV	1.0%	1.5%

For any electrical system, which is expected to be harmonics rich, it is recommended to study the harmonics level, analyze and then a proper solution should be employed.

The different solutions employed are as follows:



Detuned

Series LC combination helps in avoiding harmonic resonance and amplification

Merits:
- ✓ Simple and economical

Demerits:
- × Marginal reduction of %THD
- × High V_{THD} will affect the performance

Tuned

Mitigates harmonics by acting as a sink

Merits:
- ✓ Reduces %THD

Demerits:
- × Tuning efficiency is susceptible to system frequency & load variations leading to overheating & failure of filter
- × Extensive harmonic audit is mandatory before installation

Active / Hybrid

Active: IGBT-based power converter that reduces harmonic distortion

Hybrid: Combination of passive and active filters

Merits:
- ✓ Reduces THD within IEEE limits
- ✓ Dynamic correction of THD is possible
- ✓ Improves Distortion PF
- ✓ Load balancing and Displacement PF improvement possible
- ✓ Modular – Can be expanded along with the load

DETUNED FILTERS

Detuned Filters are a combination of series inductors and power factor correction capacitors that are meant to:

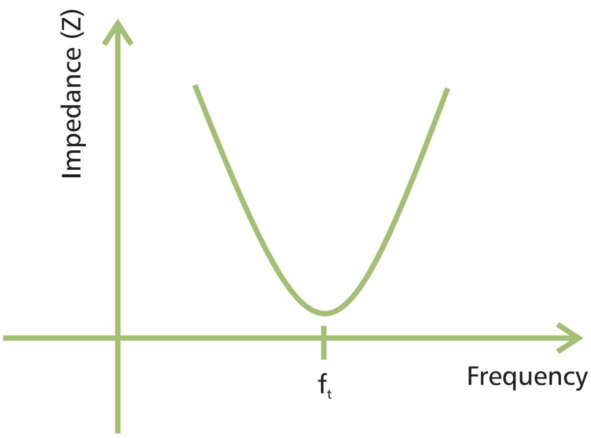
1. Prevent resonance
2. Prevent harmonic amplification
3. Protect power factor correction capacitors from overload

Every series LC combination behaves capacitive below its tuning frequency [$f_t = 1 / (2\pi\sqrt{(LC)})$] and inductive above. The inductive element of the detuned filter is selected such that the tuning frequency of the filter is significantly lower than the lowest order harmonic frequency present in the system. The filter is thus 'detuned'. The ratio of inductive reactance (X_l) and capacitive reactance (X_c) is defined as the tuning factor.
Eg : A tuning factor of 7% implies $X_l / X_C = 0.07$.

The tuning frequency using tuning factor can be calculated as

$$f_t = \frac{f_s}{\sqrt{p/100}}$$

Where,
f_s = Supply Frequency = 50 Hz
For tuning factor of 7%, f_t = 189 Hz.

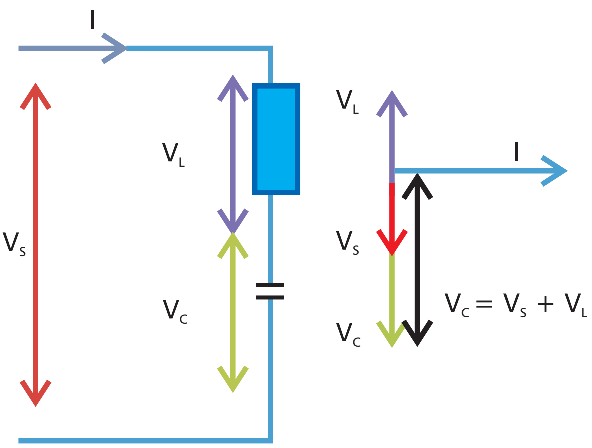


As can be seen from the above graph, for all frequencies above the tuning frequency (f_t), the combination will provide increasing impedance. The combination will not provide a low impedance path for harmonics that the capacitor did earlier, thus preventing harmonic amplification. Further as the tuning frequency of the combination is lower than the lowest order harmonic in the system, there is no question of resonance. At 50 Hz the combination behaves capacitive and power factor correction is achieved

The voltage that appears across the terminals of a capacitor increases the moment you connect an inductor in series with it. This can be illustrated by the below phasor:

V_s : System Voltage; V_c : Voltage across the capacitor; V_L : Voltage across the inductor; I : current.

As can be seen $V_c > V_s$ by an amount V_L. Thus if reactors are to be added to an existing APFC panel, the capacitors will have to be replaced with those capable of withstanding higher voltages. More over, the output of the capacitors will have to compensate for the reactive power that will be consumed by the reactor.



Secondly reactors are a major source of heat. The existing panel may not have sufficient space or cooling arrangement to handle the heat generated by the newly installed reactors. For these reasons, it is not advisable to add detuned reactors to existing APFC panels.

Hence, it is difficult to solve harmonics related problems, once the power factor correcting capacitors are installed. It is thus important to incorporate harmonic mitigation techniques in the system design stage itself.

SELECTION OF CAPACITOR - REACTOR COMBINATION FOR DETUNED HARMONICS FILTERS

Typically a detuned filter has a series connected capacitor and reactor. The capacitor terminal voltage varies with respect to the tuning factor (%p) of the reactor. Tuning factor (%p) is the ratio of inductive impedance to the capacitive impedance (X_L / X_C). Common tuning factors of detuned filters are 7% and 14%.

The voltage that appears across the terminals of a capacitor increases the moment an inductor is connected in series.

The actual amount of voltage increase can be calculated using the following formula:

$$V_c = \frac{V_s}{(1 - \frac{\%p}{100})}$$

- For example, the capacitor terminal voltage with 7% detuned reactor shall be calculated using the above formula:

$$Vc = \frac{440}{(1 - \frac{7}{100})} \qquad Vc = 473\ V$$

Hence the rated voltage of the capacitor should be selected as 480 V when used along with 7% reactor. Sometimes, the voltage variations, as per the electricity board voltage limits, may cause the supply voltage to exceed 480 V. Also, due to harmonics, both peak and rms voltage may go beyond 480 V. In such cases, a 525 V capacitor should be used along with 7% detuned reactor. Selection for both 480 V and 525 V capacitor with 7% reactor is given in the table.

- When 14% reactor is used along with the capacitor, the capacitor terminal voltage,

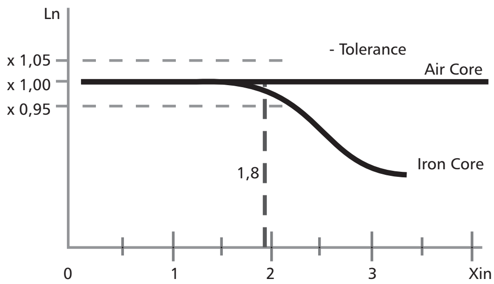
$$Vc = \frac{440}{(1 - \frac{14}{100})} \qquad Vc = 512\ V$$

Here the capacitor should be rated for 525 V when used along with 14% reactor.

Capacitor voltage and kVAr selection for both 7% and 14% reactors are given below:

Effective kVAr output	With 7% detuned reactor			With 14% detuned reactor	
	Reactor (440 V)	Capacitor (480 V)**	Capacitor (525 V)**	Reactor (440 V)	Capacitors (525 V)**
5 kVAr	5 kVAr	7.5 kVAr 480 V	7.5 kVAr 525 V	5 kVAr	7.5 kVAr 525 V
10 kVAr	10 kVAr	12.5 kVAr 480 V	12.5kVAr 525 V	10 kVAr	12.5 kVAr 525 V
12.5 kVAr	12.5 kVAr	15 kVAr 480 V	15 kVAr 525 V	12.5 kVAr	15 kVAr 525 V
15 kVAr	15 kVAr	20 kVAr 480 V	20 kVAr 525 V	15 kVAr	20 kVAr 525 V
20 kVAr	20 kVAr	25 kVAr 480 V	25 kVAr 525 V	20 kVAr	25 kVAr 525 V
25 kVAr	25 kVAr	30 kVAr 480 V	33.3 kVAr 525 V	25 kVAr	30 kVAr 525 V
50 kVAr	50 kVAr	2 nos of 30 kVAr 480 V	2 nos of 33.3 kVAr 525 V	50 kVAr	2 nos of 30 kVAr 525 V
75 kVAr	75 kVAr	3 nos of 30 kVAr 480 V	3 nos of 33.3 kVAr 525 V	75 kVAr	3 nos of 30 kVAr 525 V
100 kVAr	100 kVAr	4 nos of 30 kVAr 480 V	4 nos of 33.3 kVAr 525 V	100 kVAr	4 nos of 30 kVAr 525 V

** Capacitor kVAr selection is done considering the tuning frequency (189 Hz with 7% and 133 Hz with 14%), reactor current and standard capacitor ratings available.



Relation between inductance (L_n) and inductor current (I_n)

LINEARITY OF REACTORS

An industry whose load includes a high proportion of non-linear load (harmonic generating loads), with poor power factor, requires capacitor with de-tuned filter. This would perform the function of power factor improvement while preventing harmonic amplification.

Normally, the inductance of the series reactor (of de-tuned filter) connected is chosen such that the tuning frequency of the de-tuned filter is 10% below the lowest harmonic frequency with considerable current/voltage amplitude. Therefore, resonance will not happen in the system and reactor offers high impedance for higher frequency harmonics.

Normally, 7% detuned reactors are designed considering typical industrial loads such as drives that have the following harmonic voltages: V_3= 0.5% V_n, V_5= 6% $V_n V_7$= 5% V_n and so on. However, if the individual harmonic voltages increase, the following phenomenon happens:

- The magnitude of net current (through LC) increases
- If the current increases beyond certain limit, the reactor will be driven into its saturation region
- Once the reactor saturates, inductance value (L, in henry) of the reactor starts decreasing (as L = NF/I)
- Therefore, the resonant frequency (Fr) of the LC will rise [as Resonant frequency $=\pi 1/(2\sqrt{LC})$]
- As the resonant frequency rises, the capacitor-reactor combination will offer lower impedance to the fifth harmonic component and the current through the combination will increase further
- Thus the resonant frequency of the reactor capacitor combination will increase continuously resulting in a thermal runaway
- The new resonant frequency may match the fifth harmonic frequency and can results in resonance

Normally, reactors are designed with predefined linearity. A reactor having a higher linearity will not saturate for higher harmonic currents and will prevent the system from a thermal run away as described above.

REACTORS - HARMONIC FILTERS

The increasing use of modern power electronic apparatus (drives, uninterruptible power supplies, etc) produces nonlinear current and thus influences and loads the network with harmonics (line pollution).

The capacitance of the power capacitor forms a resonant circuit in conjunction with the feeding transformer. Experience shows that the self-resonant frequency of this circuit is typically between 250 and 500 Hz, i.e. in the region of the 5th and 7th harmonics. Such a resonance can lead to the following undesirable effects:

- Overloading of capacitors
- Overloading of transformers and transmission equipment
- Interference with metering and control systems, computers and electrical gear
- Resonance elevation, i.e. amplification of harmonics
- Voltage distortion

These resonance phenomena can be avoided by connecting capacitors in series with filter reactors in the PFC system. These so called "detuned" PFC systems are scaled in a way that the self-resonant frequency is below the lowest line harmonic and the detuned PFC system is purely inductive as seen by harmonics above this frequency. For the base line frequency (50 or 60 Hz usually), the detuned system on the other hand acts purely capacitive, thus correcting the reactive power.

FEATURES:

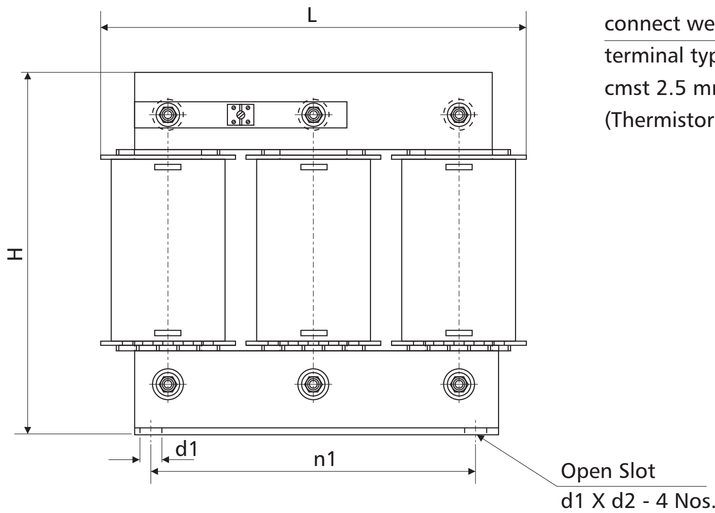
- Copper and Aluminium wound reactors
- Very low operating losses - 3 to 5 W / kVAr
- High linearity - 1.8 times the rated current
- Low noise
- Auto-thermal cutoff**

Reactor tuning factor	Tuning frequency	Application (harmoic orders)	Typical loads
7%	189 Hz	5th harmonic (250 Hz) and above	6 pulse drives (AC / DC), 3 phase UPS, frequency converters
14%	133 Hz	3rd harmonic (150 Hz) and above	Single phase UPS, CFL lamps, SMPS, dimmers

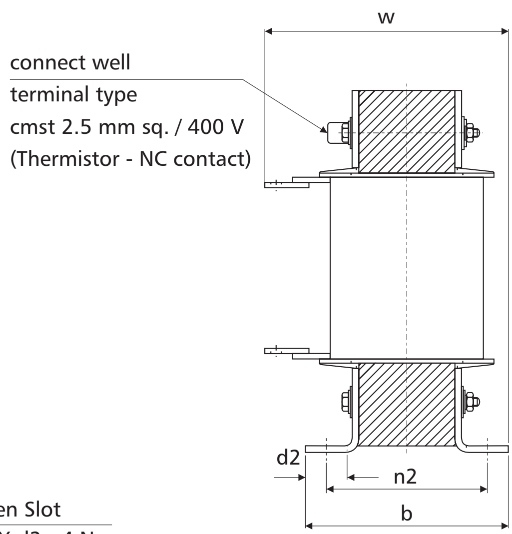
TECHNICAL DETAILS

Standards	IEC 60289, IS 5553
Rated Voltage (V)	440 V
Rated Frequency (F)	50 Hz
Max Permissible Operating Voltage	1.05 Un Continuously, 1.1 Un for 8 hours
Max Permissible Operating Current (Linearity)	1.8 In Continuously
Duty Cycle	100%
Class of Protection	I
Ambient Temperature	40°C
Winding	Cu / Al
Insulation Class	Class H
Protection	Thermal Switch**
De-Tuning	5.67%, 7% & 14%
Harmonics Limit	V_3 = 0.5% V_R (duty cycle = 100%) V_5 = 6.0% V_R (duty cycle = 100%) V_7 = 5.0% V_R (duty cycle = 100%) V_{11} = 3.5% V_R (duty cycle = 100%) V_{13} = 3.0% V_R (duty cycle = 100%)
Effective Current	$I_{rms} = \sqrt{(I_1^2 + I_3^2 + I_5^2 + ...)}$
Fundamental Current	$I_1 = 1.06 \times I_R$

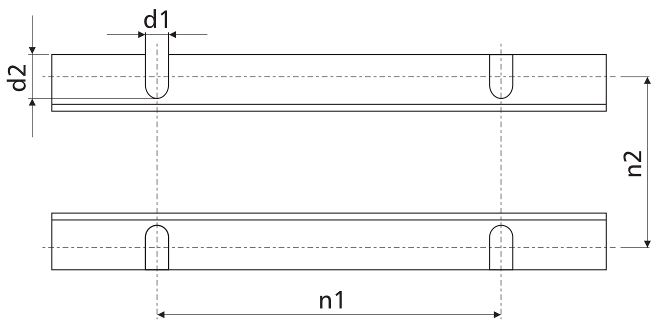
** in NC, to be connected in series with contactor coil. When temperature exceeds 100° C, NC opens and disconnects the reactor from the circuit.



Elevation

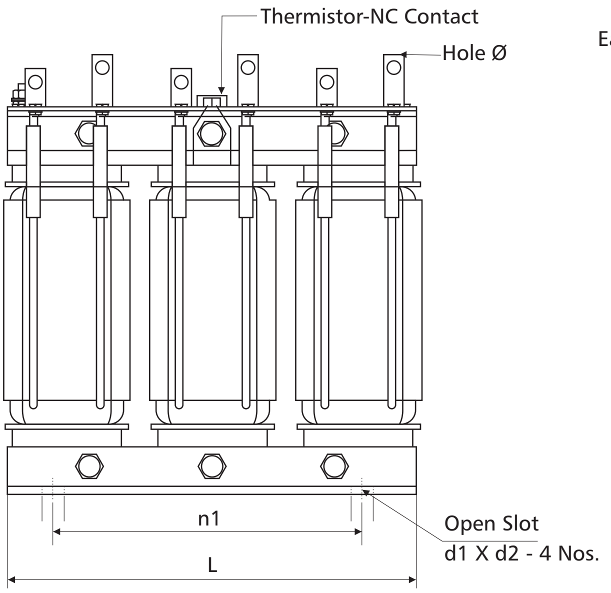


R. H. Side View

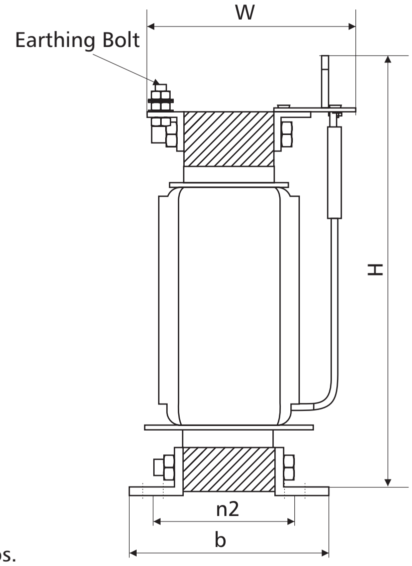


Mounting Plan

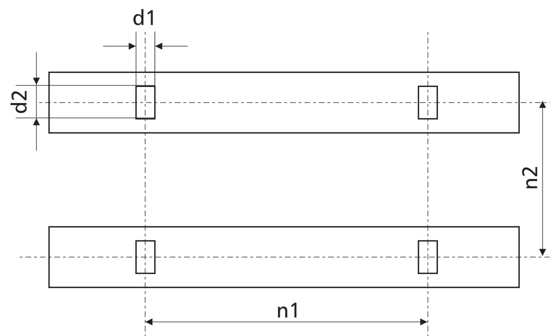
kVAr	Cat. No.	Rated Current	I rms	Inductance	Terminal Hole	L	W	H	n1	n2	b	d1	d2
					All Dimensions in mm								
5	LTFR0705B2	6.6A	7.5A	9.280 mH	6Ø	175	96±5	157	100	55±3	73	10.5	18
10	LTFR0710B2	13.12A	14.9A	4.641 mH	6Ø	178	125±5	161	100	75±3	93	10.5	20
12.5	LTFR0712B2	16.5A	18.7A	3.71 mH	6Ø	178	125±5	161	100	75±3	93	10.5	20
15	LTFR0715B2	19.8A	22.35A	3.1 mH	8Ø	225	150±5	230	150	73±3	93	10.6	21.5
20	LTFR0720B2	26.4A	29.8A	2.328 mH	8Ø	226	152±5	205	150	96±3	109	10.8	22
25	LTFR0725B2	32.8A	37.2A	1.86 mH	8Ø	226	152±5	205	150	96±3	109	10.8	22
30	LTFR0730B2	39.6A	44.7A	1.552 mH	8Ø	226	152±5	205	150	96±3	109	10.8	22
35	LTFR0735B2	46.2A	52.15A	1.33 mH	8Ø	226	152±5	205	150	96±3	109	10.6	22
50	LTFR0750B2	65.61A	74.45A	0.93 mH	8Ø	260	207±5	240	150	167±3	185	10.6	55
75	LTFR0775B2	99A	112.2A	0.62 mH	20 x 3	300	182±5	270	150	132±3	152	10.8	38
100	LTFR0700B2	131.2A	148.9A	0.464 mH	25 x 3	330	180±5	270	150	132±3	155	10.8	15.5



Elevation



R. H. Side View



Mounting Plan

kVAr	Cat. No.	Rated Current	I rms	Inductance	Terminal Hole	L	H	W	n1	n2	b	d1	d2
					All Dimensions in mm								
5	LTAL0705B2	6.6 A	9 A	9.28 mH	6ø	215	185	130 ± 3	203	80 ± 3	100 ± 3	8	12
10	LTAL0710B2	13.2 A	18 A	4.64 mH	6ø	215	185	155 ± 3	203	92 ± 3	110 ± 3	8	12
12.5	LTAL0712B2	16.5 A	21 A	3.97 mH	6ø	215	185	170 ± 3	203	105 ± 3	123 ± 3	8	12
15	LTAL0715B2	19.8 A	26 A	3.21 mH	6ø	215	185	196 ± 3	203	130 ± 3	150 ± 3	8	12
20	LTAL0720B2	26.4 A	35 A	2.32 mH	6ø	250	225	170 ± 3	150	110 ± 3	140 ± 3	12	20
25	LTAL0725B2	33 A	43 A	1.85 mH	6ø	270	265	165 ± 3	150	110 ± 3	140 ± 3	12	20
50	LTAL0750B2	66 A	86 A	0.92 mH	10ø	270	375	210 ± 5	150	110 ± 5	140 ± 5	12	20
75	LTAL0775B2	99 A	129 A	0.62 mH	10ø	270	385	210 ± 5	150	110 ± 5	140 ± 5	12	20
100	LTAL0700B2	132 A	172 A	0.46 mH	10ø	370	305	205 ± 5	180	145 ± 5	185 ± 5	12	20

CAPACITOR SWITCHING IN APFC PANEL

The switching of capacitor banks is a special and challenging task in Automatic Power Factor Correction (APFC) panels. The selection of appropriate switching device for such application is based on two criteria:

- Ability to carry rated capacitor current continuously
- Ability to withstand the peak-inrush current of capacitor

It is simple to calculate the capacitor rated current and select the switching device to be able to carry rated capacitor current (2.5 to 3 times the capacitor rated current to take care of overload, harmonics, supply voltage variation and capacitor value tolerance). However, it is little difficult to select the switching device which is able to withstand the peak-inrush current. This is because the peak inrush current for capacitor switching application depends upon various factors such as:

- The inductance of the network (including cables, switchgears and transformer)
- The transformer power rating and % impedance
- Method used for power factor correction
  - Fixed capacitor bank
  - Multi-stage capacitor bank with steps of equal ratings
  - Multi-stage capacitor bank with steps of unequal ratings
- In multi-stage capacitor bank, the nos. and rating of steps already switched on

In most of the installations, the multi-stage capacitor banks are used with steps of unequal ratings. The bigger steps of higher kVAr ratings being switched on initially and smaller steps are switched on periodically, for achieving the targeted power factor. In such cases, the value of inrush-current peak will be far higher and hence the smaller capacitors will be heavily stressed.
Capacitor switching can be done by various ways like:

POWER CONTACTOR:

- Normal power contactors will simply allow the inrush current to flow through it. Because of this, contactors and capacitors are heavily stressed. So the contactor selection should be such that it withstands the heavy inrush current. Hence, power contactors should be heavily de-rated
- This inrush current will also stress the power capacitors and may result in premature failure
- Power contactors should be used along with inrush current limiting resistors, for reducing the magnitude of inrush current. But this will increase the cost & size of the APFC panel and extra power losses

CAPACITOR DUTY CONTACTOR:

- Capacitor duty contactors can be used to limit the inrush current to less than 10*IN
- Capacitor duty contactors have pre-contacts/auxiliary contacts with current limiting resistors (of 4 Ω). At the moment of switching, the pre-contacts (with resistors) closes first. This will reduce the inrush current to less than 10*IN. After a few milliseconds, main contacts will be closed and the pre-contacts will open and go out of the circuit
- Capacitor duty contactors are employed where the frequency of switching is less i.e., the load fluctuation is not very often. The capacitor requires atleast 60 seconds to discharge to a nominal value (50 V). So capacitor duty contactors cannot be used when load fluctuation is heavy

THYRISTOR SWITCHING MODULE (TSM):

- TSM is a static switching device that is used specially for switching capacitors (dynamic power factor correction), wherever the load fluctuation is heavy (like welding, steel rolling, etc.)
- Rapid switching (5 ms to 20 ms) is possible with TSM along with Quick Discharge Resistor (QDR)
- There will be no inrush current while using TSM (zero voltage switching and zero current switching). So frequent switching will not affect the life of capacitors and no need to use extra current limiting reactors
- TSM has thermal cutoff, which will switch off when temperature exceeds beyond certain limit. It will automatically switch on when optimum temperature is attained

In industrial application, capacitors are mainly used for power factor correction. Capacitor Duty Contactors are used to switch power capacitors depending upon the amount of reactive power compensation required.

Capacitor Duty Contactors are required because conventional contactors when used for capacitor switching are unable to meet the operational requirements. At the time of switching, a capacitor effectively appears as a short-circuit.

The magnitude of capacitor inrush or charging current will depend upon value of AC voltage level along with impedance of feeder cables and supply transformers.

When switching individual capacitor bank, charging current can reach a peak value of upto 30 times the rated capacitor current and in case of multistage capacitors it can reach upto 180 times the rated capacitor current. The resultant high inrush current peak caused due to capacitor switching depends upon the following factors:

- Network Inductance
- Transformer MVA and short-circuit impedance
- Type of power factor correction; fixed or automatic
- Harmonic content in the system

This large current can flow through the contactor since initial inrush current is taken from both main supply and capacitor already connected. Conventional power contactors will simply allow the inrush current to flow through them. As a result, both contactors and capacitors will be heavily stressed. This will in turn greatly reduce the life of conventional power contactors and capacitors. Sometimes it may also result in welding of main contacts of conventional power contactors. It is therefore, essential to limit the current peak by inserting series damping resistors provided in specific Capacitor Duty Contactors.

Hence, special purpose Capacitor Duty Contactors are used to meet capacitor switching application requirements and they are designed to withstand:

1. Permanent current that can reach 1.5 times the nominal current of capacitor bank
2. Short but high peak current on pole closing

Contactors are fitted with block of three early make auxiliary contacts in series with six damping resistors (2 per phase) to limit peak current to a value within contactor making capacity.

After successful damping of high inrush current, when the main contacts close, the auxiliary contacts are automatically disconnected from the circuit by De-Latching mechanism.

BENEFITS OF USING CAPACITOR DUTY CONTACTORS:

- Since switching of capacitor banks involves high transient inrush currents, the size of the contactor required to switch these high currents becomes higher. Hence, current limiting inductors are used in series to attenuate this inrush current.

  This increases the system cost and panel space.
  A typical case below illustrates the magnitude of transient inrush current for switching of a capacitor bank.
  For a 12.5 kVAr Capacitor bank:

  Rated current of 12.5 kVAr 415 V Capacitor = 18 A
  Peak Inrush current without Damping Resistors = 1200 A

- Capacitor Duty Contactors are designed to limit this high transient inrush current by introducing damping resistors with early make auxiliary contacts. The current limiting due to damping resistors protects the APFC system from harmful effects of the capacitor charging inrush current.

  Peak Inrush current with Damping Resistors = 260 A
  It is observed that peak inrush current with damping resistors is one fifth of that without damping resistors.

  As the contactor is now required to switch the rated capacitor current, the size of the contactor required is smaller. Thus the system cost and panel space are significantly lower when Capacitor Duty Contactors are used.

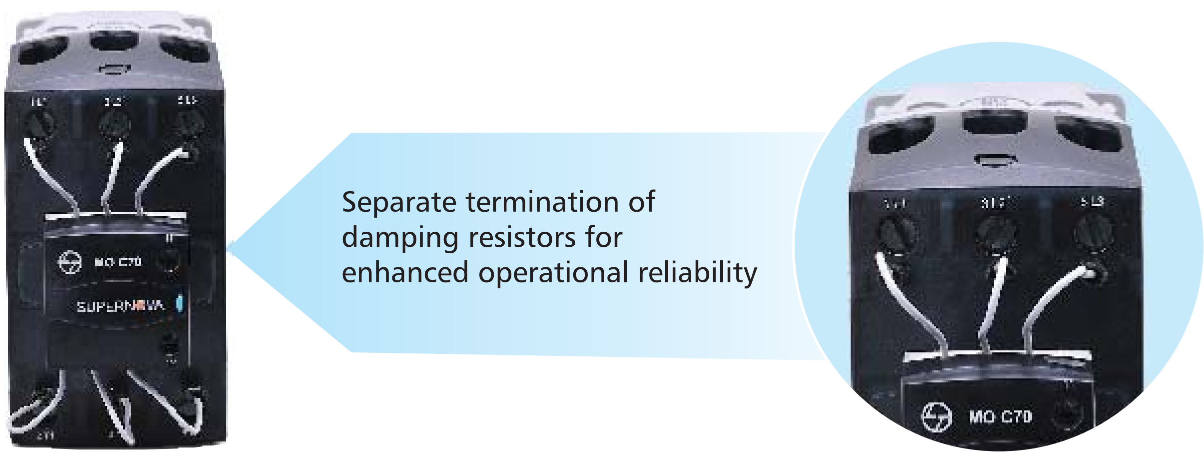
MO C CAPACITOR DUTY CONTACTORS:

MO C Capacitor Duty Contactors are designed for switching 3 phase, single or multi-step capacitor bank.

- In conventional capacitor switching contactors, early make auxiliary contacts used for insertion of damping resistors used to remain in the circuit continuously. During current breaking these auxiliary contacts would also carry and break the currents due to higher arc resistance in the main pole during arcing. This current breaking by auxiliary contacts at higher transient recovery voltage causes unreliable product performance and premature product failures
- MO C range of capacitor switching contactors have patented mechanism which disconnects the early make auxiliary contacts after the main contacts are closed. This completely eliminates the possibility of auxiliary contacts carrying and breaking the currents during breaking operation. This enhances the product switching performance and improves the product life

FEATURES AND BENEFITS OF MO C CAPACITOR DUTY CONTACTORS

Feature	Customer Benefits
De-latching auxiliary contacts	Improved switching performance
	Reduced losses in auxiliary
Dual contact gap for auxiliary contacts	Higher electrical life
Encapsulated resistor assembly	Enhanced product safety
	No flash over between phases
Separate termination of damping resistors	Ease of wiring
	Enhanced operational reliability
Wide and chatter-free operating band	Improved switching performance
	Higher electrical life
	Higher product reliability
Boxclamp termination in 33.5 kVAr and above	Lugless termination for faster and easier termination



TECHNICAL SPECIFICATION



Type Designation				MO C8.5	MO C12.5	MO C15
Catalogue No.		Built in Aux Contacts	1NO	CS96320	CS96321	CS90019
			1NC	CS96337	CS96338	CS90020
Conformance to Standards						
Rated Operational Current (AC - 6b) 3 phase delta connected capacitor bank at 415 V , 50 Hz		I_e	A	12	18	21
Short circuit protection						
kVAr Rating	230 V AC		kVAr	5.0	7.5	8.5
	415 V AC		kVAr	8.5	12.5	15
Max. Operational Voltage		U_e	V	415	415	415
Rated Insulation Voltage		U_i	V	690	690	690
Rated Impulse withstand Voltage		U_{imp}	kV	8	8	8
Degree of Protection						
Overall Dimensions	Height	H	mm	83.5	83.5	83.5
	Width	W	mm	45	45	45
	Depth	D	mm	133.5	133.5	133.5
	Mounting Dimensions		mm	35 x 60 - 65 - 70	35 x 60 - 65 - 70	35 x 60 - 65 - 70
No. of built in Aux. Contacts				1 NO / 1 NC	1 NO / 1 NC	1 NO / 1 NC
Main Terminal Capacity	Solid Conductor		mm^2	2 x 10	2 x 10	2 x 10
	Stranded Conductor		mm^2	2 x 10	2 x 10	2 x 10
	Finely Stranded Conductor		mm^2	2 x 6	2 x 6	2 x 6
Coil Operating Band	Pick - Up	% Uc	V	75 - 110	75 - 110	75 - 110
	Drop - Off	% Uc	V	35 - 65	35 - 65	35 - 65
Coil Consumption	Pick - Up		VA	77	77	77
	Hold - On		VA	9	9	9
			W	2.8	2.8	2.8
Life (Operating Cycles)		Mechanical	Million	10	10	10
		Electrical	Million	0.2	0.2	0.2
Max. Operating Frequency		Operations / Hr		240	240	240
Operating Sequence	Making			Early Make / Main	Early Make / Main	Early Make / Main
	Breaking			Main Contacts Break	Main Contacts Break	Main Contacts Break

* Accessories & Spares same as that of MO Contactors * Add 4 digit suffix as per required coil voltage

MO C20	MO C25	MO C33.5	MO C50	MO C70	MO C80
CS90021	CS96322	CS96323	CS96324	CS96325	CS96326
CS90022	CS96339	CS96340	CS9A6341	CS96342	CS96343
EN 60947-4-1 IEC 60947-4-1 IS/IEC 60947-4-1					
28	35	50	70	95	110
gG type fuses rated at 1.5 - 2 I_e					
11	14.5	20	30	40	45
20	25	33.5	50	70	80
415	415	415	415	415	415
690	690	1000	1000	1000	1000
8	8	8	8	8	8
	IP 20				
83.5	83.5	123.5	123.5	135	135
45	45	55	55	70	70
133.5	133.5	163.0	163.0	175.0	175.0
35 x 60 - 65 - 70	35 x 60 - 65 - 70	45 x 100 - 105	45 x 100 - 105	60 x 115 - 120	60 x 115 - 120
1 NO / 1 NC	1 NO / 1 NC	1 NO / 1 NC	1 NO / 1 NC	1 NO / 1 NC	1 NO / 1 NC
2 x 10	2 x 10	-	-	-	-
2 x 10	2 x 10	2 x 35	2 x 35	2 x 70	2 x 70
2 x 6	2 x 6	2 x 25	2 x 25	2 x 50	2 x 50
75 - 110	75 - 110	75 - 110	75 - 110	75 - 110	75 - 110
35 - 65	35 - 65	35 - 65	35 - 65	35 - 65	35 - 65
77	77	144	144	240	240
9	9	15	15	25	25
2.8	2.8	5	5	6.5	6.5
10	10	10	10	10	10
0.2	0.2	0.2	0.2	0.2	0.2
240	240	240	240	240	240
Early Make / Main	Early Make / Main	Early Make / Main	Early Make / Main	Early Make / Main	Early Make / Main
Main Contacts Break	Main Contacts Break	Main Contacts Break	Main Contacts Break	Main Contacts Break	Main Contacts Break

ORDERING INFORMATION - CONTACTORS

Product Designation	kVAr Rating @ 415V 50 Hz	In Built Aux contacts	Cat. No.*
MO C8.5	8.5	1 NO	CS96320
MO C8.5	8.5	1 NC	CS96337
MO C12.5	12.5	1 NO	CS96321
MO C12.5	12.5	1 NC	CS96338
MO C15	15	1 NO	CS90019
MO C15	15	1 NC	CS90020
MO C20	20	1 NO	CS90021
MO C20	20	1 NC	CS90022
MO C25	25	1 NO	CS96322
MO C25	25	1 NC	CS96339
MO C33.5	33.3	1 NO	CS96323
MO C33.5	33.5	1 NC	CS96340
MO C50	50	1 NO	CS96324
MO C50	50	1 NC	CS96341
MO C70	70	1 NO	CS96325
MO C70	70	1 NC	CS96342
MO C80	80	1 NO	CS96326
MO C80	80	1 NC	CS96343

* Add four digit suffix as per coil voltage.
Note: For MO C70 and MO C80 kindly contact the nearest branch office.

ORDERING INFORMATION - ACCESSORIES & SPARES

Add on Blocks

Mounting Position	Contacts	Cat. No.
First Left	1 NO + 1 NC	CS94580OOOO
First Right	1 NO + 1 NC	CS94581OOOO
Second Left	1 NO + 1 NC	CS94582OOOO
Second Right	1 NO + 1 NC	CS94583OOOO

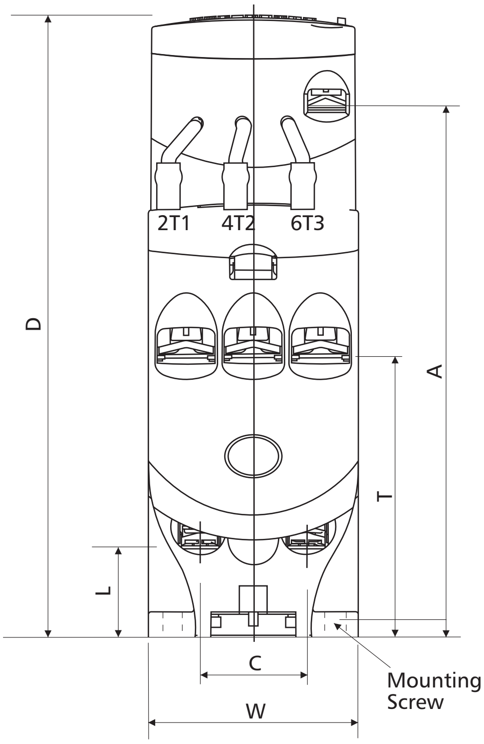
Spare Coils

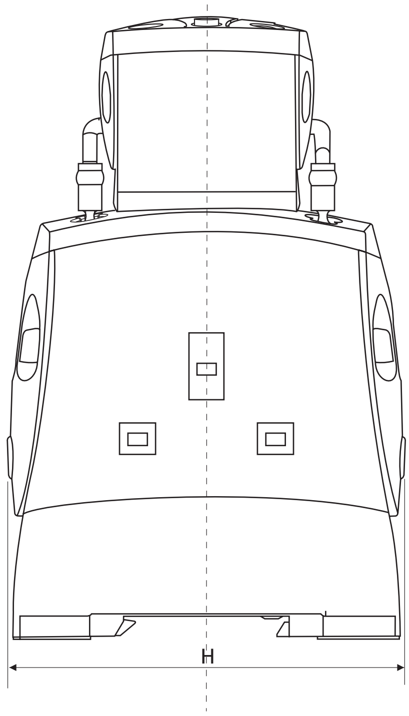
For Contactor	Cat. No.
MO C8.5 - MO C25	CS96317
MO C33.5 - 50	CS96318
MO C70 - 80	CS96319

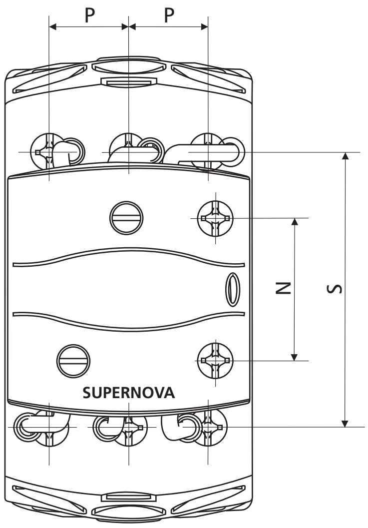
* Add four digit suffix as per coil voltage

ORDERING SUFFIX FOR COIL VOLTAGES

Std Coil Voltage at 50 Hz	24	42	110	220	240	360	415	525
Ordering Suffix	GOOO	HOOO	AOOO	KOOO	BOOO	COOO	DOOO	MOOO







Label	MO C8.5 - 25	MO C33.5 - 50	MO C70 - 80
W	45	55	70
D	133.5	163	175
H	83.5	123.5	135
N	26	26	26
T	60	68	68
C	22.8	27	35
L	19.6	29.5	30
S	50	82	93
P	14.4	18	23
A	113	142	154

All dimensions are in mm.

THYRISTOR SWITCHING MODULES

In some modern industries, due to special processes with rapidly fluctuating loads, the demand for reactive power also fluctuates rapidly. Usage of mechanical switch (contactors) has the following negative impacts:

- Average unity power factor cannot be maintained due to delay in capacitor switching
- Reduction in the life of capacitors, contactors and other equipments
- Power quality issues due to current and voltage transients

The solution is dynamic power factor correction system.

With the thyristor module we provide the main component - "The Electronic Switch"- for dynamic power factor correction. The LT-TSM series offers fast electronically controlled, self-observing thyristor switches for capacitive loads up to 50 kVAr, that are capable to switch PFC capacitors within a few milliseconds nearly without a limitation to the number of switchings during the capacitor lifetime. These switching modules are easy to install, have a fast reaction time of 5 msec and come with built-in indications of operations, faults and activation. These thyristor modules are very compact and operate at lower power losses.

FEATURES:

- High peak inverse voltage (2.2 kV) ensures long operational life
- Automatic thermal cut-off
- Monitoring of voltage, phase sequence, faults; display of status via LED
- Faster response time (5 ms)
- No system perturbation caused by switching operations (no transients)
- No auxiliary supply needed
- Maintenance free
- No noise during switching
- Compact design ready for connection and easy installation

APPLICATION:

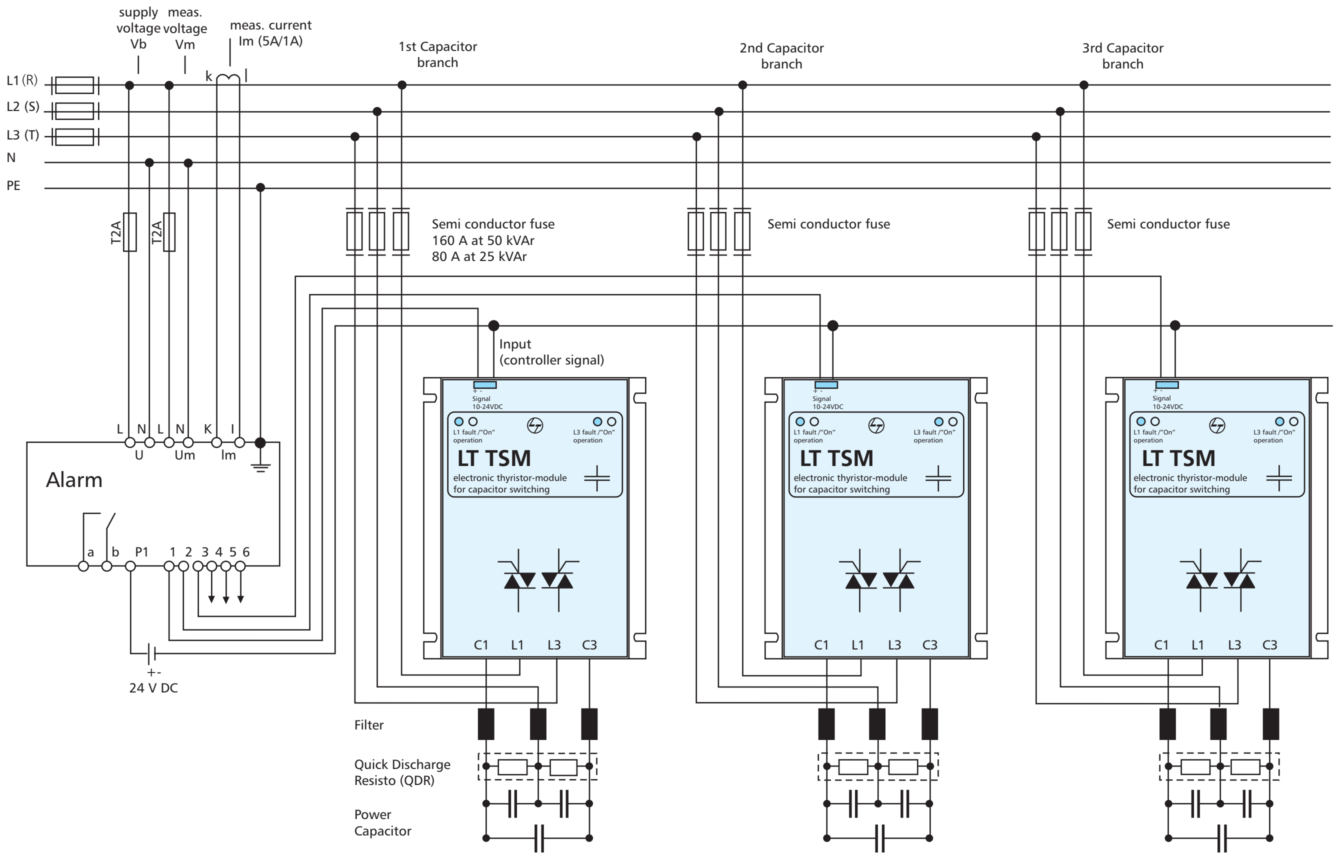
Industries and applications with high load fluctuations, where the demand for reactive power is also very dynamic:

- Welding
- Elevators and cranes
- Presses

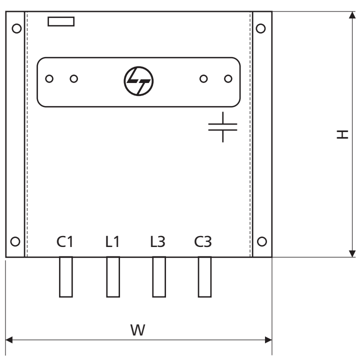
TECHNICAL DETAILS

	LT TSM 10	LT TSM 25	LT TSM 50
Rated Voltage (V)	440 V		
Frequency (Hz)	50 / 60		
Rating (kVAr)	10	25	50
Losses Power Losses (W)	35	75	150
LED Display Per Phase	2	2	2
Ambient Temperature (°C)	-10 to 55		
Signal Voltage Required	24 Vdc (20 mA)		
Reaction Time (msec)	5		
Peak Inverse Voltage (PIV)	2.2 kV		
Re-switching Time	60 ms		
Indication / Display	2 LEDs per phase. **Green:** Operating voltage activated, thyristor module standby **Flashing Red:** Under voltage / Over-temperature **Permanent Red:** No capacitor connected / Input phase not connected **Yellow:** Module ON and operating		
Termination	Connection from bottom; Cable lug: 25 sq. mm. D: 8 mm		
Protection	Semiconductor fuse (High speed fuse) is mandatory for short circuit protection.		
	10 kVAr : 32 A	25 kVAr : 80 A	50 kVAr : 160 A
Capacitor Discharge resistor	Quick discharge resistors (Default capacitor discharge resistors shall be interchanged with QDR)		
Mounting Position	Vertical, minimum 100 mm space clearance around the module		
Operating Temperature	-10°C to 55°C		

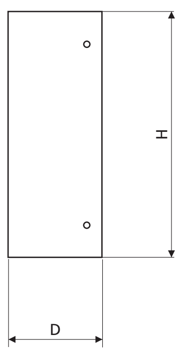
NETWORK OF THYRISTOR SWITCHING MODULES



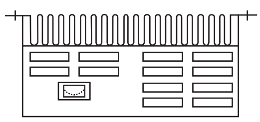
THYRISTOR SWITCHING MODULES - DIMENSIONS



Front View



Side View



Top View

Rating (kVAr)	Max. RMS Current (A)	Dimensions in (mm)			Cat. Nos.
		W	D	H	
10	20	153	75	153	LTTSM10B2
25	50	156	171	200	LTTSM25B2
50	100	156	171	200	LTTSM50B2

TROUBLE-FREE POWER FACTOR CORRECTION:

The *etaCON* L series digital Power Factor Controllers are microprocessor-based controllers which automatically correct power factor, with the help of contactors by switching capacitor banks. The series comes in 3, 5, 7, 8 and 12-step versions.

The *etaCON* controller offers power factor correction without any need for manual intervention. It decides the optimum configuration of capacitor banks to achieve desired power factor by taking into consideration the kVAr of each step, the number of operations, total usage time, re-connection time of each step, etc. The intelligent adjustment interface helps in achieving balanced capacitor usage ensuring longer life for switchgear and capacitors. Besides, manual switching of capacitors is also possible directly through the controller.

Automatic Programming

With automatic programming at start-up, there is no need for manual feeding of parameter values. In this mode, the controller automatically senses the kVAr rating of each step and configures the controller, ready to be placed in service.

By pressing just two buttons simultaneously, the automatic controller set-up can be activated.

Feature	Description
3 Digit 7 Segment LED display	Display of V, A, ΔkVAr, Average Weekly PF, Capacitor Overload & Panel Temperature
4 Key Membrane keypad	Selecting & configuring parameters
Internal temperature sensor	Temperature Sensing for control of fan and alarm
Programmable relay O/Ps	Programmable for normal contact / alarm / fan control

COMPACT RELAY

Compact relay of 96 x 96 x 71 mm for 3, 5 and 7 stage for space economy.

AUTOMATIC RECOGNITION OF CURRENT FLOW DIRECTION

The *etaCON* detects the CT reversal and automatically corrects the same. This saves the effort put into the detection/correction of CT polarity at site.

DISPLAY OF AVERAGE WEEKLY POWER FACTOR

Average value of power factor of last seven days is displayed and updated every day for assessment of APFC panel performance.

INTELLIGENT SWITCHING SENSITIVITY

Hunting of capacitors is avoided by faster switching of step in case of higher kVAr demand and more delay in case of smaller demand

KEYPAD LOCK

The keypad lock function eliminates unauthorized modification of operating parameters.

PROVISION OF ALARMS

Alarms for Under / Over compensation, Low/ High current, Low / High voltage, Capacitor overload due to harmonic voltage, Over temperature, No-voltage release.

PROTECTION OF CAPACITOR

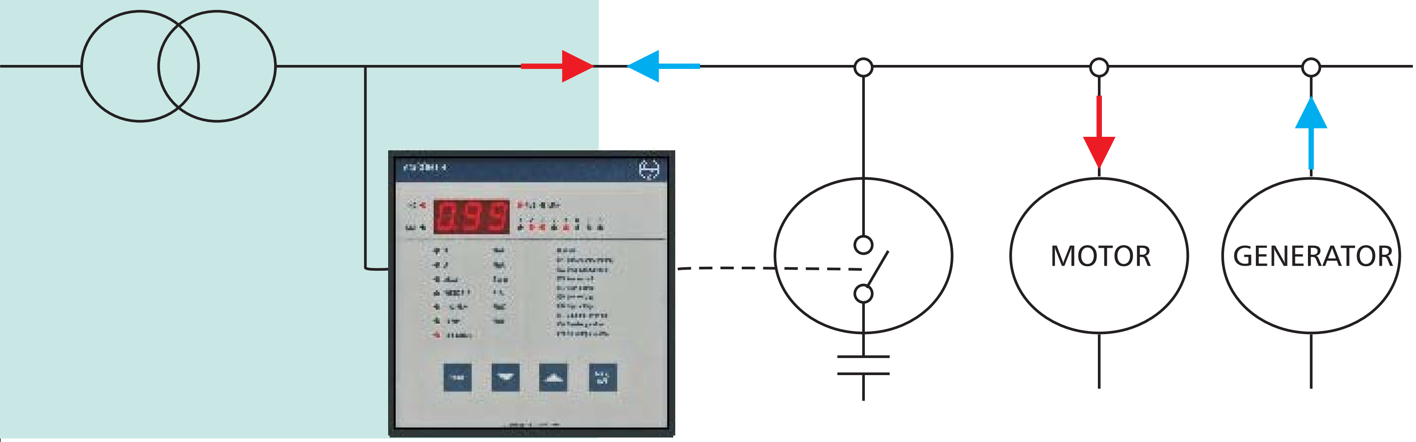
Capacitors are protected from overload due to harmonics, over-voltage and over-temperature. If threshold value is exceeded, alarm is triggered and steps are disconnected either immediately or after some delay depending upon the different settings

PROTECTION OF PANEL FROM OVER-HEATING

An inbuilt temperature sensor monitors temperature variation of the panel. Alarm is triggered in case of over-heating. Fan start & stop temperature can be set to operate cooling fans.

4-QUADRANT OPERATION

Two independent cos set points, one for import and the other for export, can be set. This ensures smooth 4-quadrant operation.



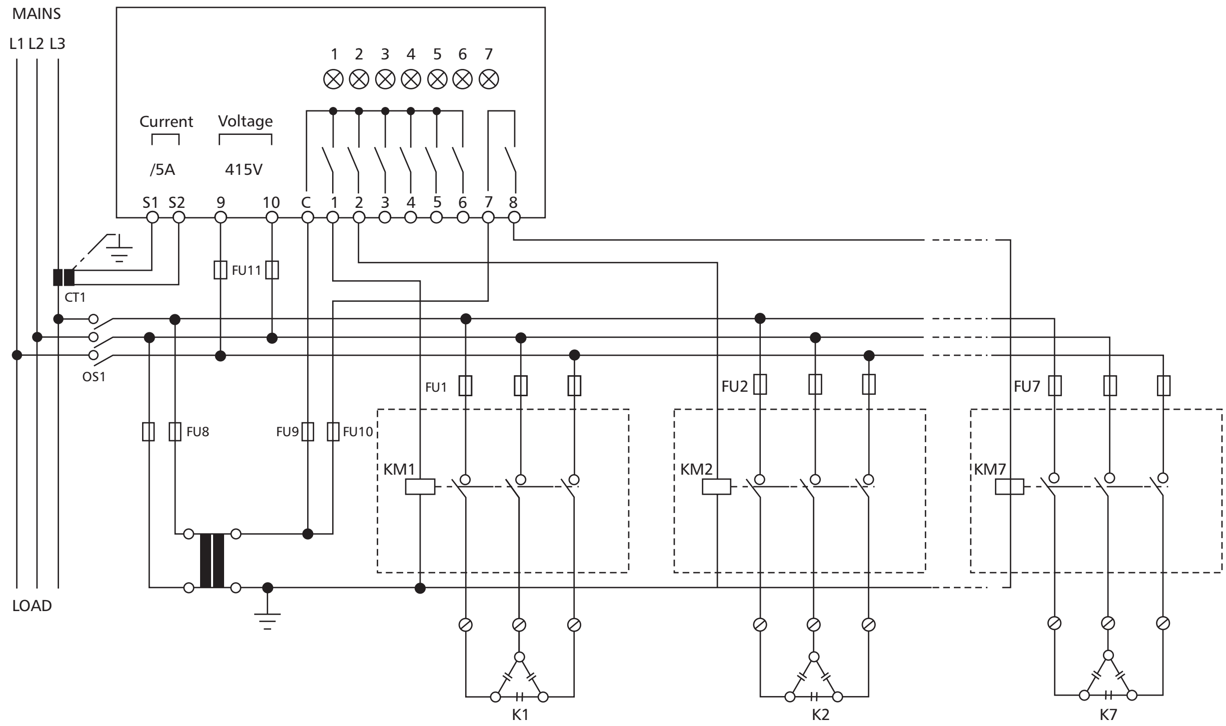
Auxillary Supply	etaCON L3	etaCON L5	etaCON L7	etaCON L8	etaCON L12
Rated Voltage Ue	415 - 440 VAC				
Operating Limit	-15% to +10% Ue				
Rated Frequency	50 or 60 Hz± 1%				
Maximum Consumption	6.2 VA			5 VA	
Maximum Dissipation	2.7 W			3 W	
Maximum Power Dissipation by Output Contacts	0.5 W with 5 A				
Immunity Time for Micro Breakings	≤ 30 ms				
No-Voltage Release	≥ 8 ms				
Current Input					
Rated Current Ie	5 A				
Operating Limit	0.125 - 6 A				
Constant Overload	+ 20%				
Type of Measurement	True RMS				
Short-time withstand Current	10 Ie for 1 sec				
Dynamic Limit	20 Ie for 10 ms				
Burden on CT	0.65 VA				
Control Range					
Power Factor Setting	0.8 ind - 0.8 cap				
Reconnection Time of the Same Step	5 - 240 secs				
Sensitivity	5 - 600 s/step				
Relay Outputs	*etaCON L3*	*etaCON L5*	*etaCON L7*	*etaCON L8*	*etaCON L12*
Number of Outputs*	3	5	7	8	12
Type of Output	3NO	4 + 1 NO	6 + 1 NO	7NO + 1C/O	11NO + 1C/O
Maximum Current at Contact Common	12 A				
Rated Current Ith	5 A				
Rated Capacity of NO Contact	1.5 A 250 VAC (AC15) - 1.5 A 400 VAC (AC15)				
Rated Capacity of NC Contact	1.5 A 250 VAC (AC15) - 0.75 A 400 VAC (AC15)				
Electric Life at 0.33A, 250 VAC and AC11 load conditions	5000000 ops				
Electric Life at 2A, 250 VAC and AC11 load conditions	400000 ops				
Electric Life at 2A, 400 VAC and AC11 load conditions	200000 ops				

Ambient Conditions					
Operating Temperature	-20 to +60℃				
Storage Temperature	-30 to +80℃				
Relative Humidity	<90%				
Overvoltage Category	3				
Maximum Pollution Degree	3**				
Connections					
Type of Terminal	Removable / Plug-in				
Conductor Cross Section (min-max)	0.2 - 2.5 sq mm (24 - 12 AWG)				
Tightening Torque	0,5 Nm (4.5 l bin)				
UL Rating - Conductor Cross Section (min -max)	18-12 AWG				
Housing					
Mounting	Flush mount				
Material	Thermoplast NORYL SE1 GN F2			Thermoplast LEXAN 3412R	
Degree of Protection	IP54			IP41	
Weight	420 g	440 g	460 g	740 g	770 g
Compliance					
IEC/EN 61010-1, IEC/EN 61000-6-2, ENV 50204, CISPR 11/EN55011, IEC/EN 61000-3-3, IEC/EN 60068-2-61, IEC/EN 60068-2-27, IEC/EN 60068-2-6, UL 508, CSA C22.2n°14					
Certifications					
Use 60℃/75℃ CU conductor and wire size range 18-12 AWG, stranded or solid					
Other Features					
Measurement	Instantaneous PF, V, I, & DkVAr, Capacitor overload Panel temperature, Average weekly PF				
Metering / Logging	Average weekly PF, Maximum values of voltage, Current, Overload & temperature				
Alarms	Under / Over compensation, Low/ High current, Low / High voltage, Capacitor overload due to harmonic voltage, Over temperature, No-voltage release				

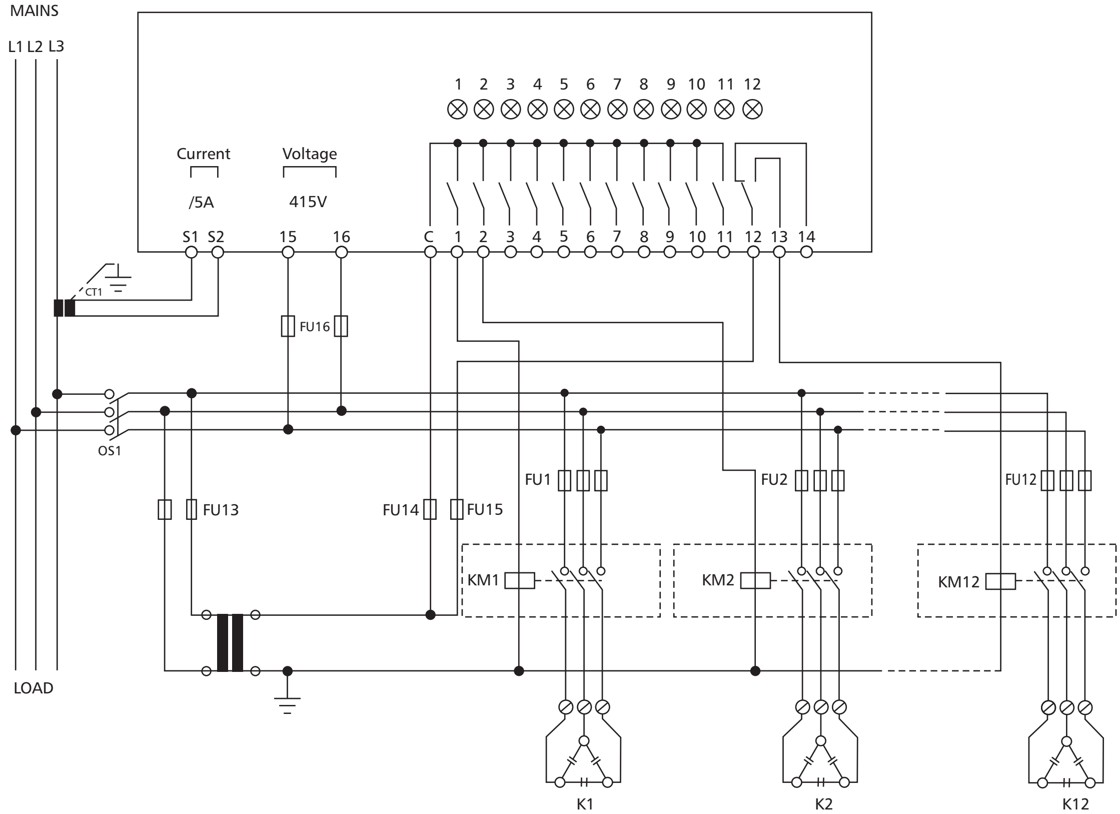
* 1 output contact is Galvanically isolated

** Pollution degree 2 when outputs used with 400 VAC load

etaCON L3 / L5 / L7

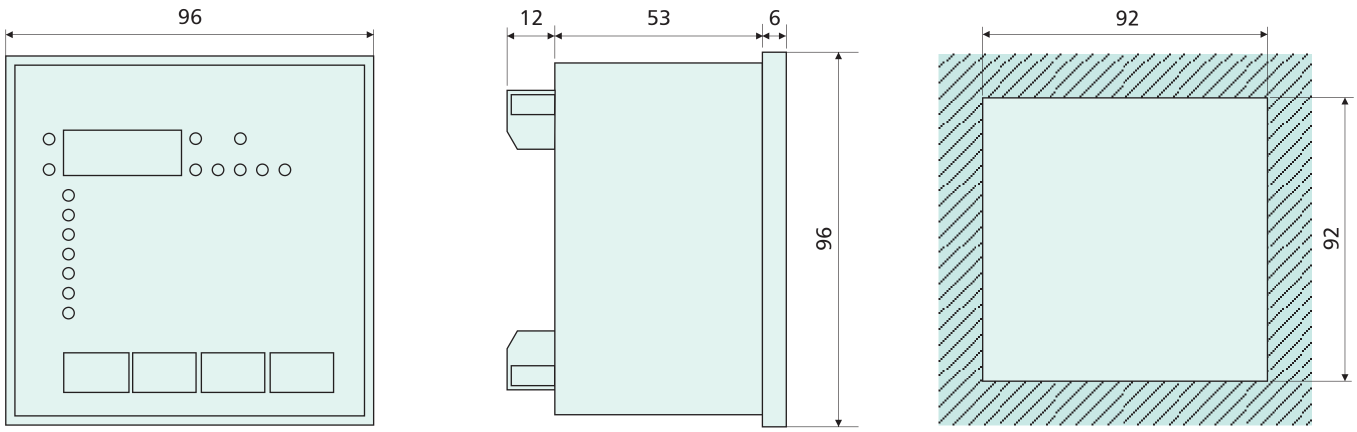


etaCON L8 / L12

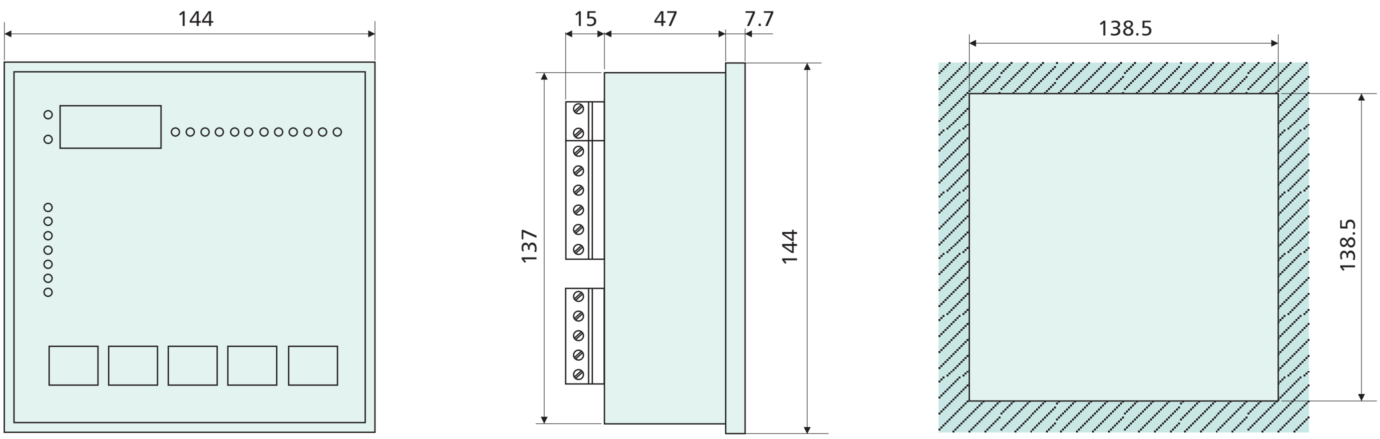


OVERALL DIMENSIONS

etaCON L3 / *etaCON* L5 / *etaCON* L7



etaCON L8 / *etaCON* L12



Dimensions in mm

Product		Steps	CT / Voltage Input	Dimensions (mm)			Panel Dimensions (mm)		Cat. Nos.
				L	H	D	L	H	
etaCON L3	3 stage APFC relay	3	5 A / 415 V	96	96	71	92	92	ERPML03D500
etaCON L5	5 stage APFC relay	4+1*	5 A / 415 V	96	96	71	92	92	ERPML05D500
etaCON L7	7 stage APFC relay	6+1*	5 A / 415 V	96	96	71	92	92	ERPML07D500
etaCON L8	8 stage APFC relay	7+1*	5 A / 415 V	144	144	69.7	138.5	138.5	ERPML08D500
etaCON L12	12 stage APFC relay	11+1*	5 A / 415 V	144	144	69.7	138.5	138.5	ERPML12D500

* Last contact is programmable for normal contact / alarm / fan control

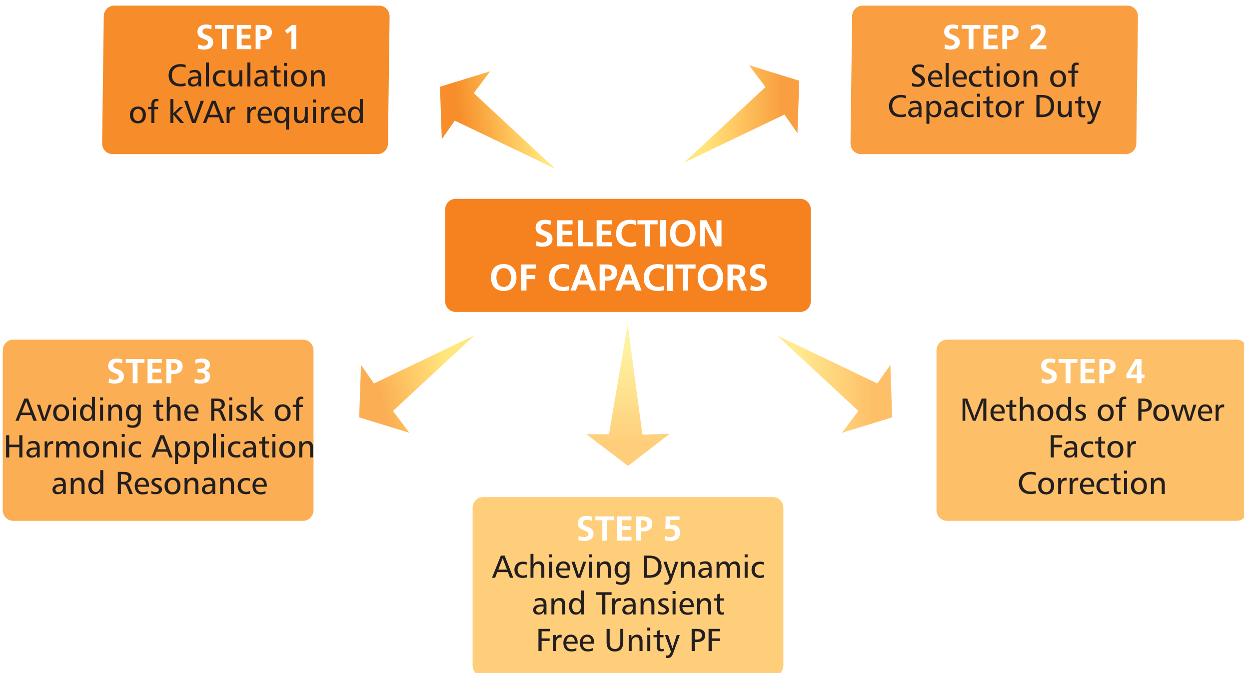
SELECTION OF CAPACITOR - 5 STEP APPROACH

Power Factor Correction Capacitors have been used for many years as the most cost effective solution for PF improvement. Modern electrical networks are continuously evolving into more complex installations due to the increasing usage of non-linear loads, sophisticated control & automation, UPS systems, energy efficiency improvement devices etc.

This evolution is also accompanied by increased dependency on captive power generation as well as growing concerns about incoming supply power quality.

In this background, it is necessary to involve also the Power Factor Correction solution to a higher level so as to ensure sustainable achievement of high PF & acceptable harmonic distortion levels.
The selection of the correct type of PFC Capacitors & Filter reactors thus needs better understanding of the various issues involved.

This publication outlines a "5 Step" technology based approach, simplified for easier understanding to enable the correct selection of PFC Capacitors & Filter Reactors.



STEP 1: Calculation of kVAr Required for Industries & Distribution Networks

In electrical installations, the operating load kW and its average power factor (PF) can be ascertained from the electricity bill. Alternatively, it can also be easily evaluated by the formula:
Average PF = kW/kVA
Operating load kW = kVA Demand x Average PF

The Average PF is considered as the initial PF and the final PF can be suitably assumed as target PF. In such cases required capacitor kVAr can be calculated as given below table.

Example: To calculate the required kVAr compensation for a 500 kW installation to improve the PF from 0.75 to 0.96

kVAr = kW x multiplying factor from table = 500 x 0.590 = 295 kVAr

Note: Table is based on the following formula:

$$\textbf{kVAr required} = \textbf{kW} (\tan\text{Ø}_1 - \tan\text{Ø}_2)$$

where
$\text{Ø}_1 = \cos^{-1}(PF_1)$ and $\text{Ø}_2 = \cos^{-1}(PF_2)$.

Target PF / Initial PF	0.9	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
0.4	1.807	1.836	1.865	1.896	1.928	1.963	2.000	2.041	2.088	2.149
0.42	1.676	1.705	1.735	1.766	1.798	1.832	1.869	1.910	1.958	2.018
0.44	1.557	1.585	1.615	1.646	1.678	1.712	1.749	1.790	1.838	1.898
0.46	1.446	1.475	1.504	1.535	1.567	1.602	1.639	1.680	1.727	1.788
0.48	1.343	1.372	1.402	1.432	1.465	1.499	1.536	1.577	1.625	1.685
0.5	1.248	1.276	1.306	1.337	1.369	1.403	1.440	1.481	1.529	1.590
0.52	1.158	1.187	1.217	1.247	1.280	1.314	1.351	1.392	1.440	1.500
0.54	1.074	1.103	1.133	1.163	1.196	1.230	1.267	1.308	1.356	1.416
0.56	0.995	1.024	1.053	1.084	1.116	1.151	1.188	1.229	1.276	1.337
0.58	0.920	0.949	0.979	1.009	1.042	1.076	1.113	1.154	1.201	1.262
0.6	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191
0.62	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.015	1.062	1.123
0.64	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058
0.66	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996
0.68	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936
0.7	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878
0.72	0.480	0.508	0.538	0.569	0.061	0.635	0.672	0.713	0.761	0.821
0.74	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766
0.75	0.38	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739
0.76	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713
0.78	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.699	0.660
0.8	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608
0.82	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556
0.84	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503
0.85	0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477
0.86	0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451
0.87	0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424
0.88	0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397
0.89	0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370
0.9		0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342
0.91		0.030	0.060	0.093	0.127	0.164	0.205	0.253	0.313	0.313
0.92				0.031	0.063	0.097	0.134	0.175	0.223	0.284
0.93					0.032	0.067	0.104	0.145	0.192	0.253
0.94						0.034	0.071	0.112	0.160	0.220
0.95							0.037	0.078	0.126	0.186

STEP 2: Selection of Capacitor Duty

Selecting the type of Capacitor is the first decision to be made. Power Factor Correction Capacitors can be classified as follows:

- Standard Duty
- Heavy Duty
- LTXL: Ultra Heavy Duty

The criteria for this classification is based on the following:

- Operating life
- Permissible over voltage & over current coupled with the time duration
- Number of switching operations per year
- Peak inrush current withstand capability
- Operating ambient temperature

Duty	Over Current	Permissible Over Voltage @ rated Voltage 440V	Peak Inrush Currents	Ambient Temperature	Maximum switching operations / year
Standard Duty	1.5 x In	1.1 Un (12h/24h)	200 x In	-25°C to 55°C	5000
Heavy Duty	1.8 x In	1.1 Un (12h/24h)	300 x In	-25°C to 55°C	8000
LTXL: Ultra Heavy Duty	3 x In	1.1 Un (12h/24h)	500 x In	-25°C to 70°C	20000

It is strongly recommended that the above table be followed as a guideline for selecting the appropriate capacitor for a given application. While choosing the type of duty it is also very important to identify the % age non-linear load in the system. The method of calculating the % age non-linear load is shown below:

Calculation of Non - linear load:

Example:
Installed transformer rating = 1000 kVA

Non - linear loads = 100 kVA
% non - linear loads = (non - linear loads / transformer rating) x 100
= (100 / 1000) x 100
= 10%

Examples of non - linear load
UPS, Arc / induction furnace, Rectifiers, AC / DC Drives, Computer, CFL lamps, CNC machines, etc.

% Age Non - linear Load	Type of Duty
≤10%	Standard Duty
Upto 15%	Heavy Duty
Upto 25%	Ultra Heavy Duty
Above 25% to 30%	Use Capacitor + Reactor (detuned filters)
Above 30%	Hybrid filters (Active filter + detuned filters)*

*For solutions contact L&T

In addition to the above, a simplified way of using capacitor duty based on type of industry is given in the following table**:

Standard Duty	Heavy Duty	Ultra heavy Duty
Steady uniform inductive loads like	**Variable inductive loads, THD < 5%**	**Variable and fluctuating inductive loads, THD < 8%**
Agricultural pump sets	Commercial buildings with CFL lamps, SMPS, UPS, etc	Steel Rolling mills
Commercial establishments	Garment industries	Cement Industries
Small scale Industries etc.,	Fabrications shops	Textiles
	Welding shops	Heavy chemical industries
	Machine &Tool shops	Pharmaceutical industries
	Steel wire drawings	Sugar plants
	Bakeries	Automobile plants
	Flour mills	Paper industries
	Coffee curing works	Food processing plants
	Oil mills	Granites & Stone polishing units
	Steel melting	IT industries
	Glass industries	Wind mills
		Heavy welding equipments
		Power Frequency induction furnaces

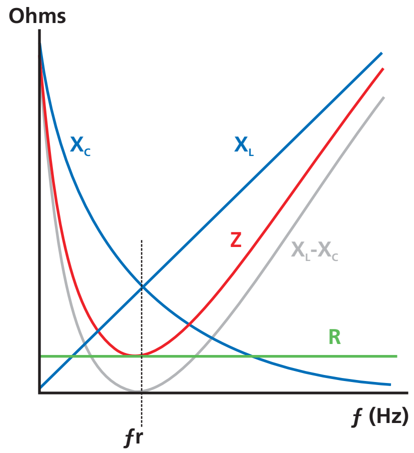
** The above table is for illustration; actual selection of capacitors & reactors shall be carried out based on THD or % non-linear load.

STEP 3: Avoiding the Risk of Harmonic Application and Resonance

To make a choice between the use of Capacitors or Capacitors + Filter reactors.
In a system with inductive (X_L) and capacitive (X_C) impedances, resonance can happen at one particular frequency (resonant frequency, F_R).

Resonant frequency, $$F_R = \frac{1}{(2\pi\sqrt{LC})}$$

At this point X_L will be equal to X_C and the net impedance will be very low. Hence, at resonance point, the magnitude of the current (with frequency F_R) will be very high and only inherent resistance in the network would limit the current. Typically, the resonance will create major problem in harmonics rich industry. The resonant frequency may match with any of the harmonic frequency and create very high harmonic amplification, which will create maximum damage to the electrical equipments.



In a practical network, X_L is contributed by the transformers & line inductances and X_C is contributed by the PF capacitors. Hence for any industry with power factor correction capacitors installed, there is a possibility of resonance, due to one of the reasons:

- Parallel resonance within a given electrical system, involving internally generated harmonics and resonance between local capacitors and the predominantly inductive supply (transformers)
- Series resonance between external harmonics (in the supply system) and capacitors within electrical system
- Interactive resonance between different harmonics filters within a given electrical network.

Addition of detuned reactors (in series to capacitors) forcefully shifts the resonant frequency to a safer level.

For example, combination of capacitor and 7% detuned filter reactor has the resonant frequency of 189 Hz, which will avoid resonance with 5^{th} harmonic and above.

STEP 4: Methods of Power Factor Correction

To estimate whether fixed compensation or automatic compensation is to be used. In order to achieve high power factor i.e., close to unity PF, the following guideline may be adopted to make a decision.If the total kVAr required by the installation is less than 15% of the rating of the incoming supply transformers, then the use of fixed capacitors may be adopted at various points in the installation.

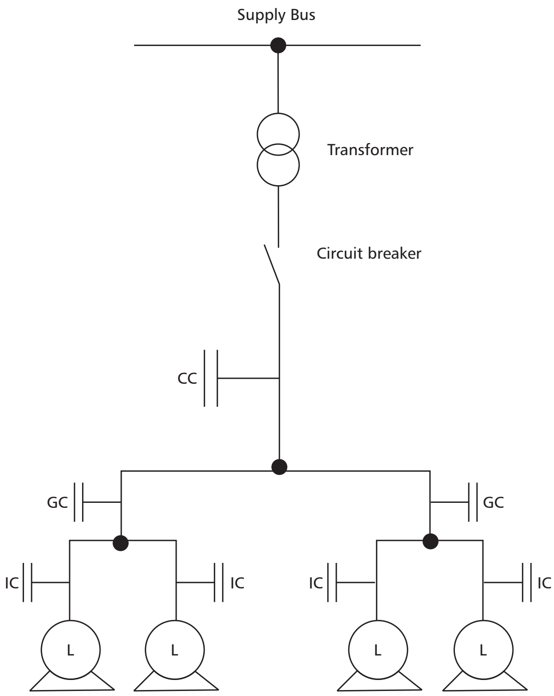
If the kVAr required by the installation is more than 15% of the rating of the incoming supply transformers, then automatic power factor correction solution needs to be adopted.

APFC panels with suitable kVAr outputs may be distributed and connected across various points within the installation.

Note: As in the case of selection of capacitors De-tuned filter APFC panels must be selected if non-linear loads exceed as per previous table.

Methods of Power Factor Compensation:

	Individual Compensation	Group Compensation	Central Compensation
Control	Manual / Semi-automatic	Manual / Semi-automatic	Automatic
Elimination of penalties due to low PF	Yes	Yes	Yes
Achievement of Unity PF	No	No	Yes
Optimization of the kVA demand of the installation to the installed load in kW	Yes	Yes	Yes
Reduction of transformer loading	Yes	Yes	Yes
Reduction of transformer losses	Yes	Yes	Yes
Reduction of circuit breaker rating	Yes	Yes	Yes
Reduction of switchgear ratings and cable sizes down the line	Yes	Partial reduction	No
Reduction in I^2R losses	Yes	Partial reduction	No
Chance of leading PF	No	Yes	No
Advantages	Simple and inexpensive for few number of motors	Relatively better management of loads	Best suited for industries with large and variable loads
Disadvantages	Managing becomes difficult if the number of motors are more	Difficult to manage, if there is load variation in the group	Relatively expensive



L : Inductive load
IC : Individual Compensation
GC : Group Compensation
CC : Central Compensation

STEP 5: To Achieve Dynamic and Transient Free Unity PF

To decide whether transient free PF correction is required. This is due to the fact that conventional switching techniques of capacitors involving electro-mechanical contactors will give rise to transient phenomena. This transient phenomena can interact with impedances present in the installation to create "Surges". This occurrence of surges can cause serious damage to sensitive electronics and automation resulting in either their malfunction or permanent damage. The transient phenomenon is a sudden rise in voltage or current at the point of switching.

In this background, it is important to ensure that all the capacitors installed are switched in a transient free manner so as to ensure reliable performance of the installation.

In such a situation, it is necessary to specify the use of Thyristor switches for transient free switching of Capacitors.

Note: Thyristor switching can also be used for dynamic compensation which is needed if the fluctuation of loads is very high; such as lifts, welding load is very high; fast presses etc.

MOTOR POWER FACTOR COMPENSATION

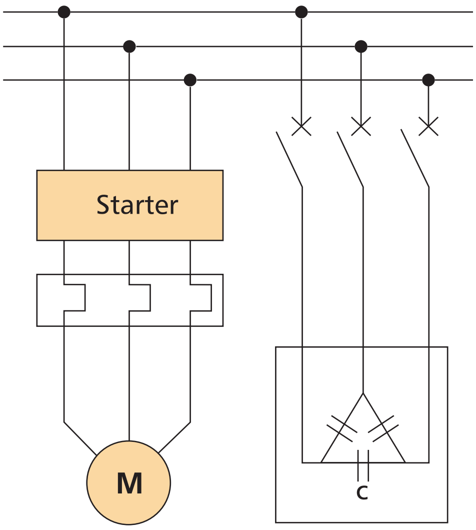
In agricultural pump-sets and some small scale industries with a few large motor loads, the power factor correction can be done by connecting shunt capacitors directly to the motors. This is the simple and ideal method of reactive power compensation.

The below given chart can be referred as a ready reckoner, where kVAr can be selected for various motor ratings (in HP) and motor rpm:

Motor (hp)	3000 rpm	1500 rpm	1000 rpm	750 rpm	500 rpm
2.5	1	1	1.5	2	2.5
5	2	2	2.5	3.5	4
7.5	2.5	3	3.5	4.5	5.5
10	3	4	4.5	5.5	6.5
15	4	5	6	7.5	9
20	5	6	7	9	12
25	6	7	9	10.5	14.5
30	7	8	10	12	17
40	9	10	13	15	21
50	11	12.5	16	18	25
60	13	14.5	18	20	28
70	15	16.5	20	22	31
80	17	19	22	24	34
90	19	21	24	26	37
100	21	23	26	28	40
110	23	25	28	30	43
120	25	27	30	32	46
130	27	29	32	34	49
140	29	31	34	36	52
145	30	32	35	37	54
150	31	33	36	38	55
155	32	34	37	39	56
160	33	35	38	40	57
165	34	36	39	41	59
170	35	37	40	42	60
175	36	38	41	43	61
180	37	39	42	44	62
185	38	40	43	45	63
190	38	40	43	45	65
200	40	42	45	47	67
250	45	50	55	60	70

Even though this is the effective method of power factor compensation, there is a limitation in sizing of the capacitors. That is, the maximum kVAr should be decided such that, the rated capacitor current is less than 90% of the motor's no-load current. If this condition is not met, self-excitation may occur, in which the motor acts as a generator.

This happens when a motor has enough inertia to keep rotating even after disconnected from the power system and the capacitor is large enough to supply the reactive power needs of the motor.
Self-excitation would result in high voltage available at the terminals of the motor and this can damage the contactor and the capacitor.



Specifically for motor with star-delta starter, it is recommended to connect the capacitor before the starter. If capacitors are directly connected to the terminals of the motor, the life of the capacitor drops drastically because of the voltage spikes that happen during every star to delta transition.
So it will be safer to connect the capacitor before the star-delta starter, through a separate contactor. Other important points to be noted are

- The operating power factor varies with respect to the percentage loading of the motors. Hence with the varying load, the fixed capacitors would not be able to maintain the unity power factor
- After switching off the capacitor, it is very important to maintain a minimum time delay of 30 to 60 seconds, for switching ON the capacitor again. Else, there are more chances of contactor damage because of charged capacitor
- If the motor is operated with any drives/converters, it is recommended to detune the capacitors by adding series reactors
- It is recommended to use capacitor duty contactors for minimizing the inrush current and hence to maximize the life of contactors and the capacitors

etaSYS - STANDARD AUTOMATIC POWER FACTOR CORRECTION PANELS

Modern power networks cater to a wide variety of electrical and power electronics loads, which create a varying power demand on the supply system. In case of such varying loads, the power factor also varies as a function of the load requirements.

It therefore becomes practically difficult to maintain consistent power factor by the use of fixed compensation i.e. fixed capacitors which shall need to be manually switched to suit the variations of the load. This will lead to situations where the installation can have a low power factor leading to higher demand charges and levy of power factor penalties.

In addition to not being able to achieve the desired power factor it is also possible that the use of fixed compensation can also result in leading power factor under certain load conditions. This is also unhealthy for the installation as it can result in over voltages, saturation of transformers, mal-operation of diesel generating sets, penalties by electricity supply authorities etc.

Consequently the use of fixed compensation has limitations in this context. It is therefore necessary to automatically vary, without manual intervention, the compensation to suit the load requirements. This is achieved by using on Automatic Power Factor Correction (APFC) system which can ensure consistently high power factor without any manual intervention. In addition, the occurrence of leading power factor will be prevented.

APFC Panels are fully automatic in operation and can be used to achieve:

- Consistently high power factor under fluctuating load conditions
- Elimination of low power factor penalty levied by electrical supply authorities
- Reduced kVA demand charges
- Lower energy consumption in the installation by reducing losses
- Preventive leading power factor in an installation

BASIC OPERATION:

- To continuously sense and monitor the load condition by the use of external CT (whose output is fed to the control relay)
- To automatically switch ON and OFF relevant capacitor steps on to ensure consistent power factor
- To ensure easy user interface for enabling reliable system operations
- To protect against any electrical faults in a manner that will ensure safe isolation of the power factor correction equipment

SALIENT FEATURES AND ADVANTAGES:

- Pre-selected optimal number of steps and step sizes, for better step resolution and hunt free capacitors switching
- Ideal switchgear selection for reliable short circuit protection, without nuisance tripping
- Right capacitor-reactor combination selection to prevent harmonic amplification and resonance
- Option of capacitor duty contactor or thyristor switch for transient free switching
- Panels with better electrical, mechanical and thermal design for longer life of capacitors and other components
- Panels are with advanced microcontroller based APFC relay that offers reliable switching operation with four quadrant sensing

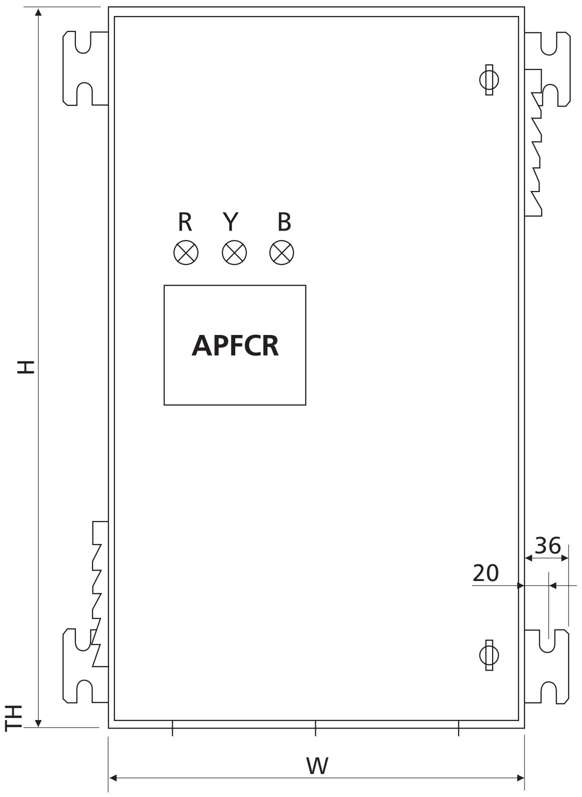
etaSYS Standard APFC Panel Range

Product	Description	kVAr ratings	Capacitors	Main Incomer	Branch Protection	Switching	Harmonic Filter
etaSYS - MH1	Contactor switched standard APFC Panels	35 to 500 kVAr	Heavy Duty Gas filled Capacitors	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	MCCB	MO C Capacitor duty contactor	-
etaSYS - MH2	Contactor switched standard APFC Panels with harmonic filters	100 to 500 kVAr	Heavy Duty Gas filled Capacitors	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	MCCB	MO C Capacitor duty contactor	7% copper reactor
etaSYS - FH1	Contactor switched standard APFC Panels	35 to 500 kVAr	Heavy Duty Gas filled Capacitors	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	HRC Fuse	MO C Capacitor duty contactor	-
etaSYS - FH2	Contactor switched standard APFC Panels with harmonic filters	100 to 500 kVAr	Heavy Duty Gas filled Capacitors	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	HRC Fuse	MO C Capacitor duty contactor	7% copper reactor
etaSYS - FH3(RTPFC)	Thyristor switched standard APFC Panels with harmonic filters	100 to 500 kVAr	Heavy Duty Gas filled Capacitors	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	Semiconductor Fuse	Thyristor switching modules	7% copper reactor
etaSYS - MU1	Contactor switched standard APFC Panels	100 to 500 kVAr	LTXL - Ultra Heavy Duty capacitor	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	MCCB	MO C Capacitor duty contactor	-
etaSYS - MU2	Contactor switched standard APFC Panels with harmonic filters	100 to 500 kVAr	LTXL - Ultra Heavy Duty capacitor	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	MCCB	MO C Capacitor duty contactor	7% copper reactor
etaSYS - FU1	Contactor switched standard APFC Panels	35 to 500 kVAr	LTXL - Ultra Heavy Duty capacitor	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	HRC Fuse	MO C Capacitor duty contactor	-
etaSYS - FU2	Contactor switched standard APFC Panels with harmonic filters	100 to 500 kVAr	LTXL - Ultra Heavy Duty capacitor	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	HRC Fuse	MO C Capacitor duty contactor	7% copper reactor
etaSYS - FU3(RTPFC)	Thyristor switched standard APFC Panels with harmonic filters	100 to 500 kVAr	LTXL - Ultra Heavy Duty capacitor	MCCB - upto 350 kVAr; ACB - 400 to 500 kVAr	Semiconductor Fuse	Thyristor switching modules	7% copper reactor

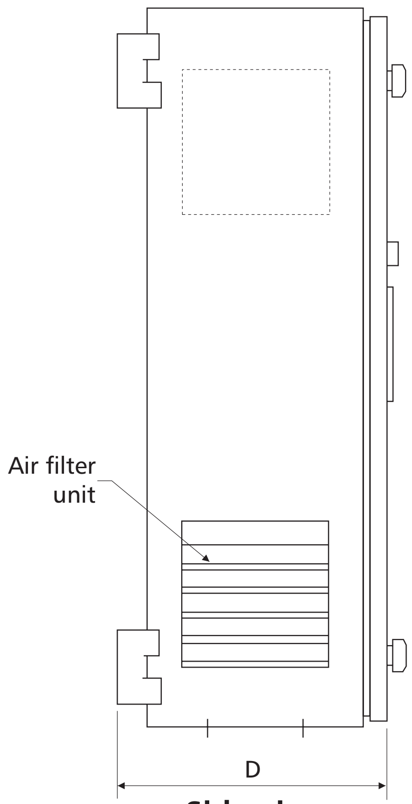
etaSYS Basic Design Specifications

Power Range	35 kVAr to 500 kVAr
Rated System Voltage	440 V / 415 V / 400 V / 380 V
Rated Frequency	50 Hz
Short Circuit Rating	> 36 kA
Altitude	1000 m
Duty	Continuous
Ambient Temperature	-5°C to 45°C
Power Supply	Three phase, four line
Relay Current Input Signal	– / 5A, from CT on line
Enclosures	The load bearing structure is made of 2 mm sheet steel
	The front door and partition are made of 1.6 mm sheet steel
	The internal components are accessible on opening the front door
	Ingress protection - IP42
Installation	Indoor, wall mounted (upto 100 kVAr), floor mounted (100 kVAr and above) in a well-ventilated, non-dusty environment, cable entry from bottom
Incomer	3 Pole MCCBs upto 630 A, 3 Pole ACBs above 630 A
Capacitors	1. Heavy duty cylindrical gas filled capacitors.
	2. LTXL Ultra Heavy Duty Capacitors (see below table for step ratings).
Reactors	1. Without Reactors
	2. With 7% Dutuned Reactors
Switching	1. 3 Pole MO C Capacitor duty contactors of adequate ratings for respective steps.
	2. Thyristor Switching Modules of suitable ratings.
Branch Protection	1. MCCBs for providing short circuit protection and isolation.
	2. HRC Fuses of adequate ratings.
	3. High speed fuse / semiconductor fuse for thyristor switched APFC panels.

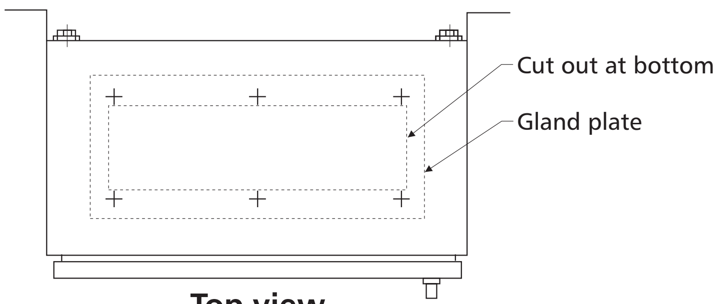
APFC PANEL - OVERALL DIMENSIONS



Front view



Side view



Top view

Notes:

- Wall mounted : upto 100 kVAr
- Floor mounted : above 100 kVAr
- Recommended front access : 1000 mm
- Recommended side clearance : 1000 mm
- Paint shade : RAL 7032 Powder coated
- Tolerance on dimensions : ±10 mm
- Cable entry : bottom

etaSYS - MH1 Standard APFC with a combination of Heavy Duty Capacitors & MCCB

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPMH0351B2	35	2 x 12.5 + 2 x 5	4	Contactor	MPPH	-	DU MCCB	dsine MCCB	1100 x 600 x 400
LTAPMH0501B2	50	2 x 12.5 + 2 x 10 + 1 x 5	5	Contactor	MPPH	-	DU MCCB	dsine MCCB	1100 x 600 x 400
LTAPMH0751B2	75	2 x 25 + 2 x 10 + 1 x 5	5	Contactor	MPPH	-	DU MCCB	dsine MCCB	1200 x 800 x 400
LTAPMH1001B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	MPPH	-	DU MCCB	dsine MCCB	1500 x 1000 x 600
LTAPMH1251B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	MPPH	-	DU MCCB	dsine MCCB	1500 x 1000 x 600
LTAPMH1501B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	1800 x 1000 x 600
LTAPMH1751B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	1800 x 1000 x 600
LTAPMH2001B2	200	2 x 12.5 + 25 + 3 x 50	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	1800 x 1000 x 600
LTAPMH2251B2	225	2 x 12.5 + 4 x 50	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	1800 x 1000 x 600
LTAPMH2501B2	250	2 x 25 + 4 x 50	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	1800 x 1000 x 600
LTAPMH2751B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	2100 x 1200 x 600
LTAPMH3001B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	MPPH	-	DU MCCB	dsine MCCB	2100 x 1200 x 600
LTAPMH3501B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	MPPH	-	DU MCCB	dsine MCCB	2100 x 1200 x 600
LTAPMH4001B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	MPPH	-	DU MCCB	ACB	2000 x 1600 x 800
LTAPMH4501B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	MPPH	-	DU MCCB	ACB	2000 x 1600 x 800
LTAPMH5001B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	MPPH	-	DU MCCB	ACB	2000 x 1600 x 800

etaSYS - MH2 Standard APFC with a combination of Heavy Duty Capacitors, MCCB & 7% Detuned Reactor

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPMH1002B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	MPPH	7%	DU MCCB	dsine MCCB	1600 x 1000 x 800
LTAPMH1252B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	MPPH	7%	DU MCCB	dsine MCCB	1600 x 1000 x 800
LTAPMH1502B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMH1752B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMH2002B2	200	2 x 12.5 + 1 x 25 + 3 x 50	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMH2252B2	225	2 x 12.5 + 4 x 50	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMH2502B2	250	2 x 25 + 4 x 50	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMH2752B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1200 x 800
LTAPMH3002B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1200 x 800
LTAPMH3502B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	MPPH	7%	DU MCCB	dsine MCCB	2100 x 1400 x 800
LTAPMH4002B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	MPPH	7%	DU MCCB	ACB	2000 x 1600 x 1200
LTAPMH4502B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	MPPH	7%	DU MCCB	ACB	2000 x 1600 x 1200
LTAPMH5002B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	MPPH	7%	DU MCCB	ACB	2000 x 1600 x 1200

etaSYS - FH1 Standard APFC with a combination of Heavy Duty Capacitors & HRC Fuse

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPFH0351B2	35	2 x 12.5 + 2 x 5	4	Contactor	MPPH	-	HRCF	dsine MCCB	1100 x 600 x 400
LTAPFH0501B2	50	2 x 12.5 + 2 x 10 + 1 x 5	5	Contactor	MPPH	-	HRCF	dsine MCCB	1100 x 600 x 400
LTAPFH0751B2	75	2 x 25 + 2 x 10 + 1 x 5	5	Contactor	MPPH	-	HRCF	dsine MCCB	1200 x 800x 400
LTAPFH1001B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	MPPH	-	HRCF	dsine MCCB	1500 x 1000 x 500
LTAPFH1251B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	MPPH	-	HRCF	dsine MCCB	1500 x 1000 x 500
LTAPFH1501B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	MPPH	-	HRCF	dsine MCCB	1800 x 1000 x 600
LTAPFH1751B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	MPPH	-	HRCF	dsine MCCB	1800 x 1000 x 600
LTAPFH2001B2	200	2 x 12.5 + 25 + 3 x 50	6	Contactor	MPPH	-	HRCF	dsine MCCB	1800 x 1000 x 600
LTAPFH2251B2	225	2 x 12.5 + 4 x 50	6	Contactor	MPPH	-	HRCF	dsine MCCB	1800 x 1000 x 600
LTAPFH2501B2	250	2 x 25 + 4 x 50	6	Contactor	MPPH	-	HRCF	dsine MCCB	1800 x 1000 x 600
LTAPFH2751B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	MPPH	-	HRCF	dsine MCCB	2100 x 1200 x 600
LTAPFH3001B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	MPPH	-	HRCF	dsine MCCB	2100 x 1200 x 600
LTAPFH3501B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	MPPH	-	HRCF	dsine MCCB	2100 x 1200 x 600
LTAPFH4001B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	MPPH	-	HRCF	dsine MCCB	2000 x 1600 x 800
LTAPFH4501B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	MPPH	-	HRCF	dsine MCCB	2000 x 1600 x 800
LTAPFH5001B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	MPPH	-	HRCF	dsine MCCB	2000 x 1600 x 800

etaSYS - FH2 Standard APFC with a combination of Heavy Duty Capacitors, HRC Fuse & 7% Detuned Reactor

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPFH1002B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	MPPH	7%	HRCF	dsine MCCB	1600 x 1000x 800
LTAPFH1252B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	MPPH	7%	HRCF	dsine MCCB	1600 x 1000 x 800
LTAPFH1502B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFH1752B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFH2002B2	200	2 x 12.5 + 1 x 25 + 3 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFH2252B2	225	2 x 12.5 + 4 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFH2502B2	250	2 x 25 + 4 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFH2752B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1200 x 800
LTAPFH3002B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1200 x 800
LTAPFH3502B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1400 x 800
LTAPFH4002B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFH4502B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFH5002B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2000 x 1600 x 1200

etaSYS - FH3 Standard APFC with a combination of Heavy Duty Capacitors, Thyritor Switching & 7% Detuned Reactor

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPFH1003B2	100	50 + 25 + 15 + 5 + 5	5	Thyristor	MPPH	7%	HSF	dsine MCCB	1800 x 1000 x 800
LTAPFH1253B2	125	2 x 12.5 + 2 x 25 + 50	5	Thyristor	MPPH	7%	HSF	dsine MCCB	1800 x 1000 x 800
LTAPFH1503B2	150	2 x 12.5 + 3 x 25 + 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFH1753B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFH2003B2	200	2 x 12.5 + 1 x 25 + 3 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFH2253B2	225	2 x 12.5 + 4 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFH2503B2	250	2 x 25 + 4 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFH2753B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2200 x 1200 x 800
LTAPFH3003B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2200 x 1200 x 800
LTAPFH3503B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1600 x 800
LTAPFH4003B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2000 x 1600 x 1200
LTAPFH4503B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2000 x 1600 x 1200
LTAPFH5003B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2000 x 1600 x 1200

etaSYS - MU1 Standard APFC with a combination of LTXL Capacitors & MCCB

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPMU1001B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	LTXL	-	DU MCCB	dsine MCCB	1500 x 1000 x 700
LTAPMU1251B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	LTXL	-	DU MCCB	dsine MCCB	1500 x 1000 x 700
LTAPMU1501B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	1800 x 1000 x 700
LTAPMU1751B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	1800 x 1000 x 700
LTAPMU2001B2	200	2 x 12.5 + 25 + 3 x 50	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	1800 x 1000 x 700
LTAPMU2251B2	225	2 x 12.5 + 4 x 50	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	1800 x 1000 x 700
LTAPMU2501B2	250	2 x 25 + 4 x 50	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	1800 x 1000 x 700
LTAPMU2751B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	2100 x 1200 x 700
LTAPMU3001B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	LTXL	-	DU MCCB	dsine MCCB	2100 x 1200 x 700
LTAPMU3501B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	LTXL	-	DU MCCB	dsine MCCB	2100 x 1200 x 700
LTAPMU4001B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	LTXL	-	DU MCCB	dsine MCCB	2000 x 1600 x 1200
LTAPMU4501B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	LTXL	-	DU MCCB	dsine MCCB	2000 x 1600 x 1200
LTAPMU5001B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	LTXL	-	DU MCCB	dsine MCCB	2000 x 1600 x 1200

etaSYS - MU1 Standard APFC with a combination of LTXL Capacitors, MCCB & 7% Detuned Reactor

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPMU1002B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU1252B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU1502B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU1752B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU2002B2	200	2 x 12.5 + 1 x 25 + 3 x 50	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU2252B2	225	2 x 12.5 + 4 x 50	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU2502B2	250	2 x 25 + 4 x 50	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1000 x 800
LTAPMU2752B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1200 x 1200
LTAPMU3002B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1200 x 1200
LTAPMU3502B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2100 x 1400 x 1200
LTAPMU4002B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2000 x 1800 x 1200
LTAPMU4502B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2000 x 1800 x 1200
LTAPMU5002B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	LTXL	7%	DU MCCB	dsine MCCB	2000 x 1800 x 1200

etaSYS - FU1 Standard APFC with a combination of LTXL Capacitors & HRC Fuse

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPFU1001B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	LTXL	-	HRCF	dsine MCCB	1500 x 1000 x 700
LTAPFU1251B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	LTXL	-	HRCF	dsine MCCB	1500 x 1000 x 700
LTAPFU1501B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	LTXL	-	HRCF	dsine MCCB	1800 x 1000 x 700
LTAPFU1751B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	LTXL	-	HRCF	dsine MCCB	1800 x 1000 x 700
LTAPFU2001B2	200	2 x 12.5 + 25 + 3 x 50	6	Contactor	LTXL	-	HRCF	dsine MCCB	1800 x 1000 x 700
LTAPFU2251B2	225	2 x 12.5 + 4 x 50	6	Contactor	LTXL	-	HRCF	dsine MCCB	1800 x 1000 x 700
LTAPFU2501B2	250	2 x 25 + 4 x 50	6	Contactor	LTXL	-	HRCF	dsine MCCB	1800 x 1000 x 700
LTAPFU2751B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	LTXL	-	HRCF	dsine MCCB	2100 x 1200 x 700
LTAPFU3001B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	LTXL	-	HRCF	dsine MCCB	2100 x 1200 x 700
LTAPFU3501B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	LTXL	-	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFU4001B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	LTXL	-	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFU4501B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	LTXL	-	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFU5001B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	LTXL	-	HRCF	dsine MCCB	2000 x 1600 x 1200

etaSYS - FU1 Standard APFC with a combination of LTXL Capacitors, HRC Fuse & 7% Detuned Reactor

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPFU1002B2	100	50 + 25 + 15 + 5 + 5	5	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU1252B2	125	2 x 12.5 + 2 x 25 + 50	5	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU1502B2	150	2 x 12.5 + 3 x 25 + 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU1752B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU2002B2	200	2 x 12.5 + 1 x 25 + 3 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU2252B2	225	2 x 12.5 + 4 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU2502B2	250	2 x 25 + 4 x 50	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1000 x 800
LTAPFU2752B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1200 x 1200
LTAPFU3002B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1200 x 1200
LTAPFU3502B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2100 x 1400 x 1200
LTAPFU4002B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFU4502B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2000 x 1600 x 1200
LTAPFU5002B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Contactor	MPPH	7%	HRCF	dsine MCCB	2000 x 1600 x 1200

etaSYS - FU3 Standard APFC with a combination of LTXL Capacitors, Thyritor Switching & 7% Detuned Reactor

Cat. Nos.	Panel Rating (kVAr)	Step size (kVAr)	Steps	Switching Device	Type of Capacitor	Reactor	Branch Protection	Main Incommer	Dimension (mm) (H x W x D)
LTAPFU1003B2	100	50 + 25 + 15 + 5 + 5	5	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU1253B2	125	2 x 12.5 + 2 x 25 + 50	5	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU1503B2	150	2 x 12.5 + 3 x 25 + 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU1753B2	175	2 x 12.5 + 2 x 25 + 2 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU2003B2	200	2 x 12.5 +1 x 25 + 3 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU2253B2	225	2 x 12.5 + 4 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU2503B2	250	2 x 25 + 4 x 50	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1000 x 800
LTAPFU2753B2	275	1 x 100 + 3 x 50 + 2 x 12.5	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2200 x 1200 x 1200
LTAPFU3003B2	300	1 x 100 + 3 x 50 + 2 x 25	6	Thyristor	MPPH	7%	HSF	dsine MCCB	2200 x 1200 x 1200
LTAPFU3503B2	350	1 x 100 + 3 x 50 + 4 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2100 x 1600 x 1200
LTAPFU4003B2	400	2 x 100 + 2 x 50 + 4 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2000 x 1800 x 1200
LTAPFU4503B2	450	2 x 100 + 4 x 50 + 2 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2000 x 1800 x 1200
LTAPFU5003B2	500	3 x 100 + 3 x 50 + 2 x 25	8	Thyristor	MPPH	7%	HSF	dsine MCCB	2000 x 1800 x 1200

The life of the power capacitors and other equipments in APFC panels depend very much on the operating temperature. In panels with detuned harmonic filter reactors and thyristor switches, the chances of elevated temperature are high, as these equipments generate relatively more heat.

Hence in order to maximise the life of the capacitors and other important equipments in the APFC panel, the temperature must not be allowed to increase beyond certain limit. This article briefs some guidelines about the thermal design of APFC panels and thereby dissipating the generated heat effectively.

For any panel, the temperature rise can be reduced by the following three ways:
- Operating at lower ambient temperature
- Using devices with lower power loss
- Dissipating the excess heat, so that temperature rise is controlled

There is minimal control over the first two conditions. But the third condition completely depends upon the design of the panel. By offering effective cooling methods, the excess heat generated by the equipments can be dissipated.

Selection of the cooling methods can decided based on the internal temperature rise inside the panel. The maximum internal temperature can be calculated using the following formula:

$$\textbf{Internal Temperature } (T_i) = \frac{P_d}{k \times S} + T_a$$

Where, P_d = Total power dissipated in the panel (in watts)
k = constant defined by the material used to manufacture the enclosure
For painted sheet-steel enclosure, k = 5.5 W/m^2 °C
S = effective surface area of the panel (in m^2)
T_a = Ambient temperature (in °C)

If the temperature rise (T_i – T_a) is within the acceptable limits, natural cooling would be sufficient; else forced cooling method should be employed for dissipating excessive heat.

1. NATURAL COOLING:

In most of PCCs and MCCs, the temperature rise remains under desirable limits with natural circulation of air (through natural convection and radiation). The air circulation happens through some slots in the enclosure, called the louvers. When temperature rises inside the panel, the pressure of the air increases and the density reduces.

Hence the hot air tends to move upwards. The hot air would go out through the louvers provided at the top side of the panel. Fresh cold air would enter the panel through the louvers provided at the bottom. This is represented in **Figure 1.**

Figure 2 represents the common usage of extra louvers in-between the top and bottom louvers. The common misconception behind this is that, extra louver would increase the volume of air flow. Practically, this does not happen because the volume of the panel is fixed.

This results in the reduced air flow at the bottom section of the panel, as some air enters through the middle louvers. Hence, the temperature of the lower section of the panel will be higher than the upper section.

It is recommended to follow the panel design as per the Figure 1.

Figure 1

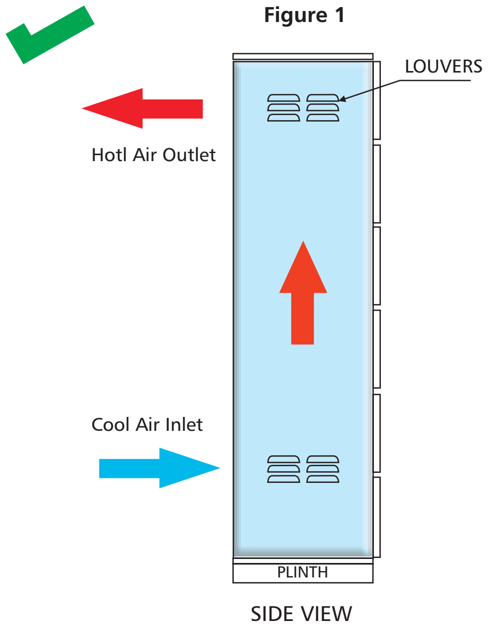
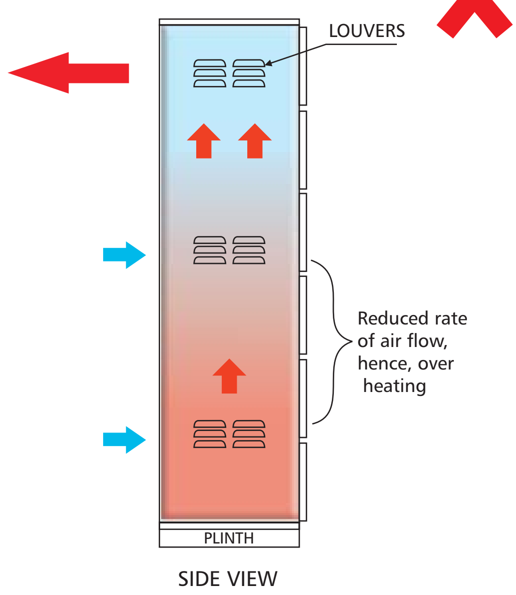


Figure 2



2. FORCED COOLING:

In most of the APFC panels and in some MCC and PCC panels, the above method would not offer sufficient cooling. In order to maintain the desired temperature levels (ambient temperature + allowed temperature rise), forced cooling methods (using fans at the top) should be employed, which would increase the rate of air flow.

In **Figure 3** the cold air enters through the bottom louvers, flows through all the equipments and they are forced out of the panel through fans. Hence, temperature rise in the panel is kept under check and there are no hot spots/sections.

In **Figure 4** provision of additional louvers, actually disturbs the uniformity of the flow. Major chunk of cold air would enter through the top louver and result in "short cycling". So the bottom section of the panel would see higher temperature rise.

Figure 3

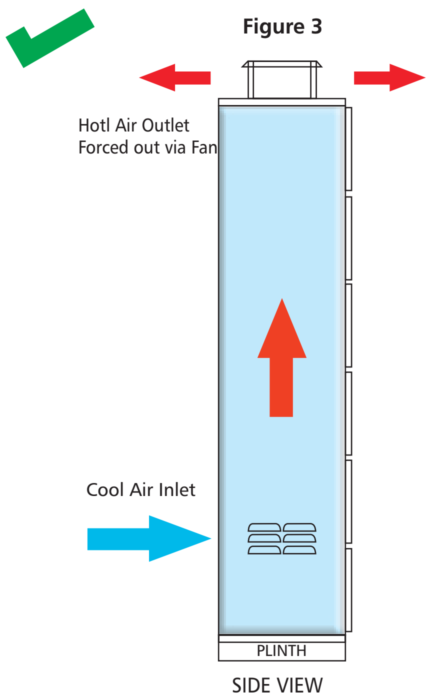
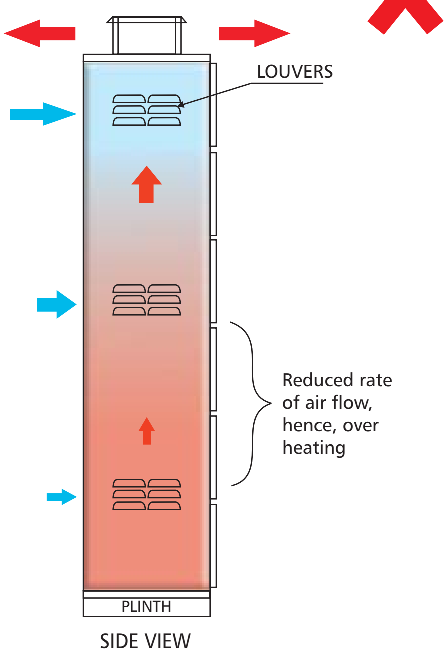


Figure 4



2.1 Fan Selection for forced cooling:

Fan selection is based on the rate of air flow, which is measured in m^3/h or Cubic Feet per Minute (CFM), where 1 CFM = 1.7 x 1 m^3/h. Following is the formula to calculate air flow rate:

$$Q = C_x \frac{P_d - [k \times S (T_d - T_a)]}{(T_d - T_a)}$$

Where,

Q = Air flow rate (in m^3/h)

C = Coefficient related to the altitude above the sea level

Altitude (in meters)	C
0 to 100	3.1
101 to 250	3.2
251 to 500	3.3
501 to 750	3.4
751 to 1000	3.5

P_d = total power loss (watts) inside the panel, by summing up the power loss of individual devices like capacitors, reactors, thyristor switches, contactors, bus bars, joints and so on.

k = constant defined by the material used to manufacture the enclosure.

For painted sheet-steel enclosure, k = 5.5 W/m^2 °C

S = Open surface area of the panel (in sq. m) can be calculated using one of the below formulas:

Position of the enclosure		Formula for calculating S (in sq. m) as per IEC 890
	accessible on all sides	S = 1.8 x H x (W + D) + 1.4 x W x D
	placed against a wall	S = 1.4 x W x (H + D) + 1.8 x D x H
	end of a row of enclosures	S = 1.4 x D x (H + W) + 1.8 x W x H
	end of a row of enclosures with back against the wall	S = 1.4 x H x (W + D) + 1.4 x W x D
	intermediate in a row of enclosures	S = 1.8 x W x H + 1.4 x W x D + D x H
	intermediate in a row of enclosures with the back against the wall	S = 1.4 x W x (H + D) + D x H
	intermediate in a row of enclosures back against the wall with top part covered	S = 1.4 x W x H + 0.7 x W x D + D x H

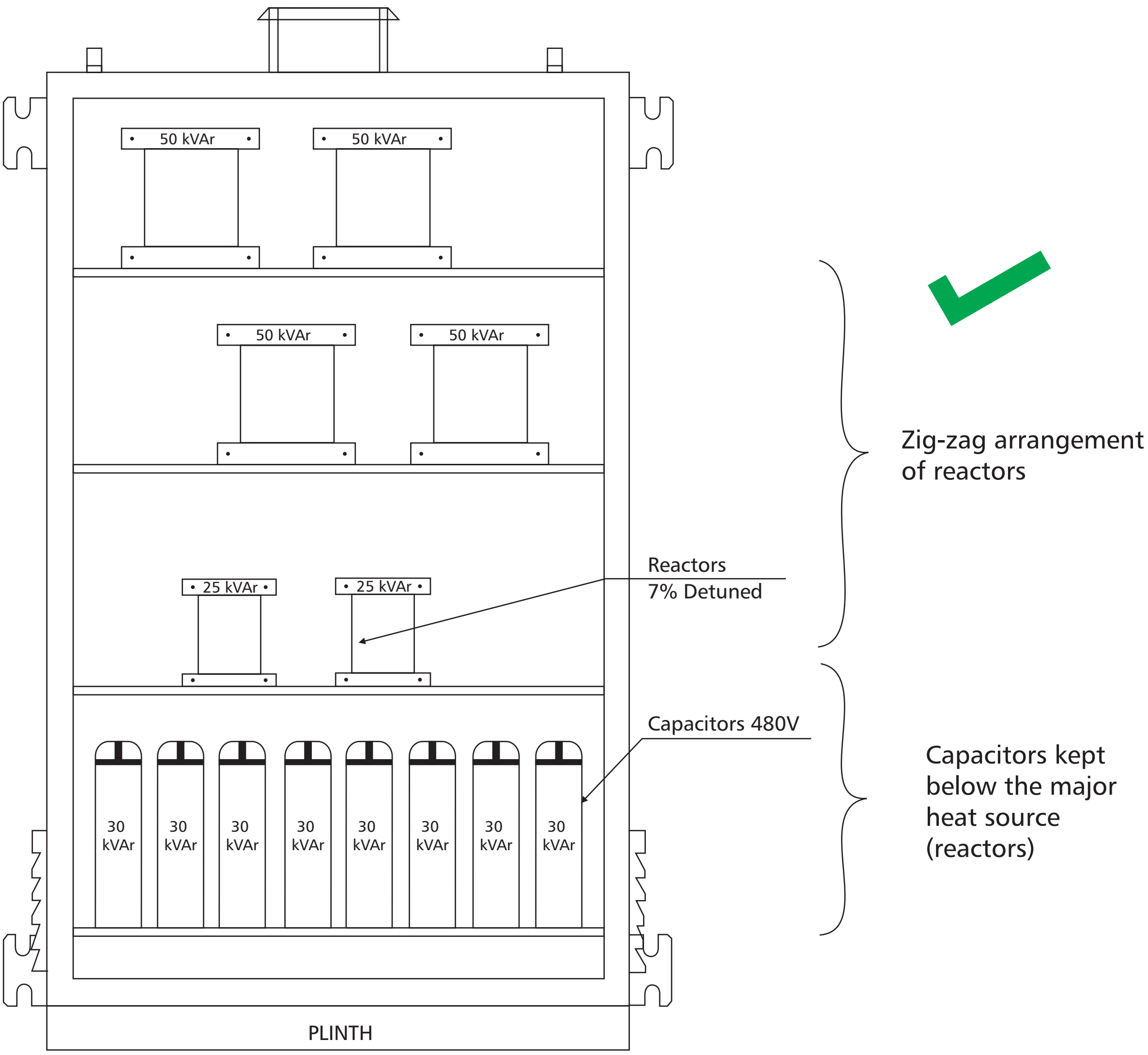
Td = Desired Maximum temperature inside the enclosure

Ta = Ambient temperature

This is a simple method of thermal management and fan selection, which is suitable for majority of the panels. At the same time, some other aspects like position of mounting various equipments in the APFC panel should be taken care.

Some of them are as follows:

- Capacitors should be kept below the reactors, which are the major heat sources. This is because the elevated temperature would reduce the life of the capacitors
- The reactors should be mounted in the zigzag position (as shown in the below figure), in order to ensure better heat flow. If the reactors are kept one above other, the bottom most reactors would heat up the other reactors that are mounted above them
- Thyristor switching modules should be mounted vertically (position of heat sink should be parallel to the air flow direction) and in zigzag positions
- It is recommended to use copper reactors, which have lower power loss than aluminium reactors



Hence, in APFC panels, a proper thermal design would pave way for maximising the life of important equipments like capacitors, thyristor switches, reactors and other switchgear.

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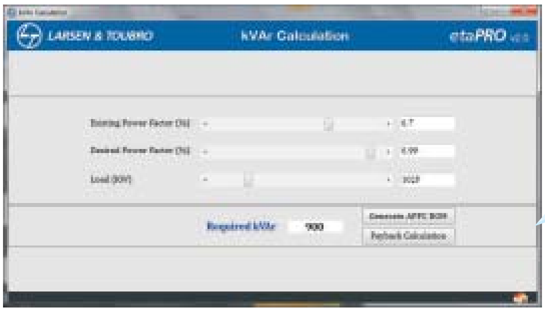
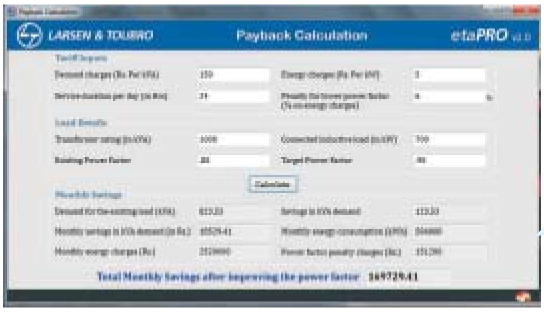


- **KVAR CALCULATION**
  Easy calculation of capacitor kVAr rating if initial power factor and final power factor are known

- **DETUNED HARMONIC FILTER SELECTION**
  Selection of right capacitor-reactor combination (detuned harmonic filter) and the catalogue numbers



- **PAYBACK CALCULATION**
  Monthly payback calculation, after improving the power factor to the desired level

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  generation of bill of materials, covering capacitor selection, switchgear selection, switching device selection. - The output gives the catalogue numbers and MRP of all the items in the panel, that can be exported to excel format.
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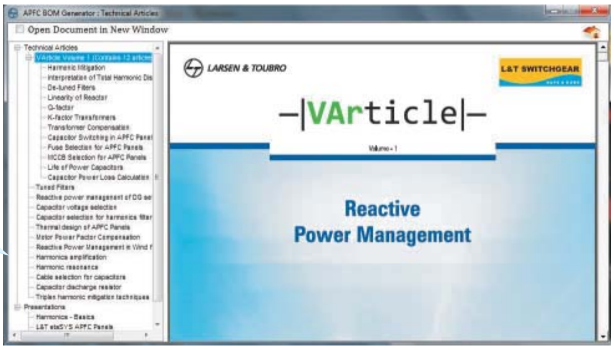

BENEFITS:

End customers and panel builders will be benefitted by the following ways:

- Easy selection of capacitors and reactors
- Error free switchgear ratings selection
- Time saving while preparing APFC quotations
- Optimum step size selection
- Automatic selection of capacitor-reactor combinations
- BoM can be exported to Microsoft Excel format

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Larsen & Toubro Limited
Switchgear Training Centre
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Kolkata: 700071
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E-mail: STC-KOLKATA@LNTEBG.COM

Electrical Standard Products (ESP) Branch Offices:

REGISTERED OFFICE AND HEAD OFFICE
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