Solutions for Power factor Correction at **Medium Voltage**

Energy efficiency technology

CIRCUTOR, SA Headquarters in Viladecavalls.

Leaders by experience

CIRCUTOR has over 40 years experience and 6 production centres in Spain and the Czech Republic working on the design and manufacture of units for improving energy efficiency: Units for measurement and control of electrical energy and supply quality, industrial electrical protection, reactive compensation and harmonic filtering. Providing solutions with over 3,000 products in over 100 countries worldwide.

E *Renewable energies*

m *Measurement and Control*

P *Protection and Control*

Q *Quality & Metering*

R *Power Factor Correction and Harmonic Filtering*

V *Smart Charging of Electric Vehicles*

Two of 6 **CIRCUTOR** production centres.

Medium Voltage reactive compensation begins by developing a project that meets the requirements demanded by our clients. **CIRCUTOR** has extensive experience in developing all types of projects for compensation at MV. Our production centres handle the on-time manufacturing under the most demanding quality standards of projects developed by our technicians in collaboration with our clients. The factories are equipped with the latest technologies and apply the results of the most recent research conducted by **CIRCUTOR's** extensive R+D+i team.

Technical information

Why does the power factor need to be corrected?

Reactive power compensation is essential for the correct technical and economical management of an MV electric system. Its benefits are:

Technical optimisation

- Helping to control voltage throughout the transmission and distribution system
- Discharging power lines and power transformers
- Reducing level of system losses

Economic optimisation

- Reduced billable reactive energy costs (surcharges by country and tariff)
- Reduced hidden economic cost from the Joule effect in transport lines
- Enables a better use ratio (kW/kVA) for installations.

When and where to compensate at MV?

Basically MV must be compensated when working with:

Generation, transport and distribution systems

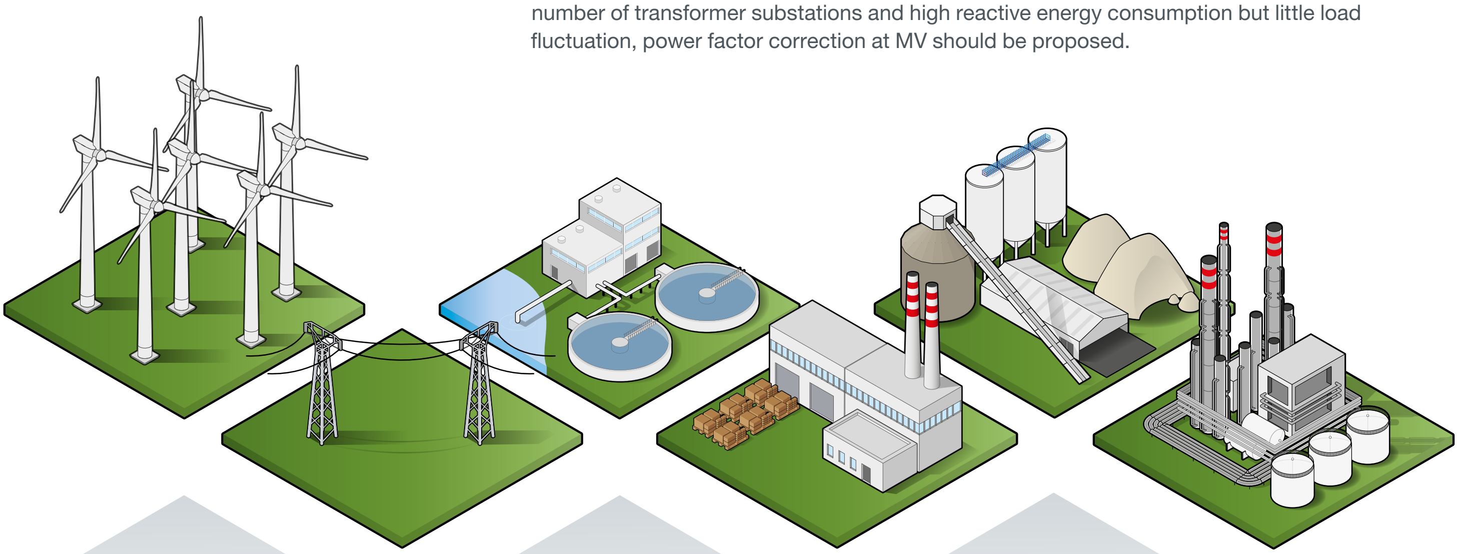
The usual points where power factor correction is carried out are the feeder lines of power generating plants (wind farms, hydroelectric installations, etc.), receiver or distribution substations, and distribution hubs.

Industrial installations with MV distribution and consumption

As a general rule, installations that distribute and consume energy at MV are eligible to be compensated, such as pumping centres desalination plants, paper factories, cement factories, the petrochemical industry, steel mills, etc.

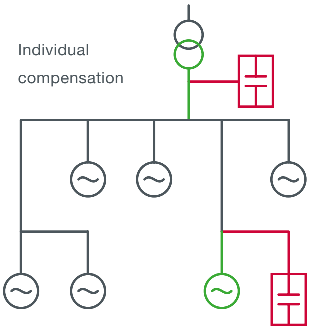
Industrial installations with MV distribution and LV consumption

Normally LV compensation is carried out when dealing with small amounts of power and with a rapid demand fluctuation level in comparison with MV. However, if there is a large number of transformer substations and high reactive energy consumption but little load fluctuation, power factor correction at MV should be proposed.

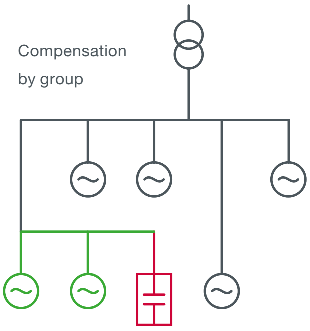


Technical information

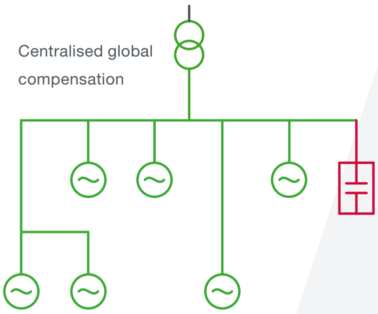
Individual compensation



Compensation by group



Centralised global compensation



How should I compensate?

Reactive compensation may be carried out at any point of an installation. A different strategy must be followed for each method and position to obtain power factor improvement.

Individual compensation
Direct compensation to the machine being compensated is the optimum technical solution for directly reducing reactive consumption in the load. This is commonly used for pumps, motors and transformers.

Compensation by group
Compensation for load groups in installations that have a sectored and extensive distribution. This serves as an ancillary support for a global centralised compensation system for increasing the load capacity of the line supplying the group of compensated loads.

Centralised global compensation
Compensation connected to the installation's main feeder, normally used for reducing electricity billing due to reactive energy surcharges.

Individual compensation of power transformers and asynchronous motors

One of the main applications of MV compensation is the individual compensation of power transformers and asynchronous motors.

Power transformers
Two components must be taken into account when determining the reactive power of a transformer: non-load consumption (magnetising current) and load consumption.

$$Q_T = S_N \cdot \left(\frac{I_0(\%)}{100}\right) + \left(\frac{u_{cc}(\%)}{100}\right) \cdot \left(\frac{S}{S_N}\right)^2 \cdot S_N$$

The fixed part depends on the transformer's magnetising current, which usually accounts for 0.5 to 2% of the transformer's rated power. The variable part depends on the load ratio being consumed (S/S_N) and the short-circuit voltage (V_{cc}%). Actually 5% to 7% compensation of nominal power for industrial-use transformers is recommended and up to 10% for energy distribution line transformers.

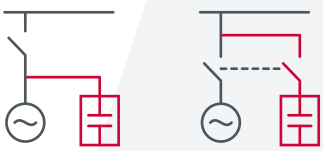
Asynchronous motors
Special care must be taken when opting to directly compensate asynchronous motors, with or without an operation or disconnection element. This aspect is relevant for avoiding the possibility of damaging the motor or the installation from an excitation effect. It is recommended to avoid compensation of over 90% of the motor's idle current in order to prevent autoexcitation of the motor due to capacitor discharge in its direction. The value of the power to be compensated can be estimated as follows:

$$Q_M \leq 0{,}9 \cdot I_0 \cdot U_N \cdot \sqrt{3}$$

$$Q_M \leq 2 \cdot P_N \cdot (1 - \cos\varphi_i)$$

Where Q_M *is the reactive power to be compensated (kvar),* I_0 *the motor's idle current (A),* U_N *the rated voltage (U),* P_N *the nominal power of the motor (kW) and* $\cos\varphi$ *is the initial cosine phi of the motor.*

Preventing the autoexcitation phenomenon.



This way makes it difficult to compensate more than one cosine phi greater than 0.95, so individual compensation is carried out by using a disconnection element at the same time as the motor is disconnected in order to avoid the autoexcitation phenomenon.

Technical information

Controlling the voltage level in the lines

One of the critical points during electrical energy distribution is maintaining the voltages at the different points of the distribution lines. This applies to ring networks in the different distribution centres and radial networks at line terminals. There are two methods available for controlling voltage at the MV distribution line terminals, which depend on the configuration of the distribution lines:

— Control at the line origin, generally for lines with a radial configuration.
— Control at the network points in a ring or at the terminal of a MV line in radial configuration.

Voltage control at the line origin
To maintain a nominal voltage level at an unmeshed MV line terminal, distribution companies commonly regulate the voltage at the substation output at above its nominal value. This is done by compensating the reactive energy at its origin in order to compensate for the voltage drop in the line. The MV bus-bar capacitor connection is associated with the voltage increase at its connection point. In accordance with **Standard IEC 60871-1** the following equation can be used for calculating the voltage increase resulting from connecting capacitors to an MV network:

$$\Delta U(\%) = \frac{Q_{bat}}{S_{cc}} \cdot 100$$

$\Delta U(\%)$: Reported percentage voltage drop at U_N
Q_{bat}: Power of the capacitor bank in kvar
S_{dc}: Short-circuit power at the installation point of the capacitors, in kVA

In anticipation of possible load fluctuations, the capacitors that will be connected to the substation output or transformer substation are usually fractioned in steps. The power, type of unit and fractioning level usually depend on the criteria of each distribution company. It should be noted that fractioning the total power in different steps enables voltage levels for different network load states to be improved, thereby avoiding overvoltages that would be produced by over-compensation.

Voltage control at the line termination
The voltage in MV lines with various branches that have a significant length (several km) cannot be regulated at all of the distribution points by placing capacitors at the beginning of the line. In these cases capacitors are usually installed in distribution hubs where voltage regulation is needed. The voltage drop at the end of a line or section can be calculated with the equation:

$$\Delta U(\%) = 100 \cdot \frac{P \cdot L}{U_N^{\,2}} \cdot (R_L + X_L \cdot \tan\varphi)$$

$\Delta U(\%)$: Reported percentage voltage drop at U_N
P: Transported active power
R_L & X_L: resistance and ractive impedance by length (km)
L: length of the line (km)
U_N: Rated voltage of the network

Reduction of losses in MV lines

The reduction of losses in distribution installations and transport is an important factor in the economic assessment of an installation, given that these losses are a hidden economic loss. The Joule effect losses on a line can be summarised as:

$$\Delta P = R_L \cdot \left| \frac{2 \cdot Q_L \cdot Q_{bat} - Q_{bat}^{\,2}}{U_2} \right| \cdot L$$

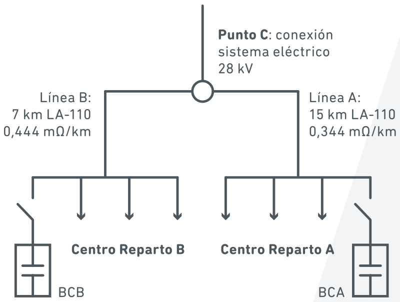
Where R_L is the resistance per unit of length and L is the length.

The decrease in losses as a result of reactive compensation can be calculated as follows:

$$P\,(\mathrm{kW}) = 3 \cdot R_L \cdot I^2 \cdot L$$

With Q_L being the load's reactive power and Q_{bat} the power of the compensation capacitor bank.

Technical information



Distribution lines for the calculation example

Example of a reduction of Joule effect losses in an overhead distribution line system

In this case, the evolution of the level of losses of the line and voltage drops is analysed in a distribution system rated at 20 kV with and without capacitor banks connected.

The effect of the capacitor banks in an MV overhead distribution network in a rural area in which there are two distribution centres A and B, fed by lines A and B with resistances $\mathbf{R}_{IA}$ = 0.344 mΩ/km y R_{IB} = 0.444 mΩ/km.

Status of loads with no capacitor banks connected

At origin, the system's power status is as follows:

Installation data prior to compensation

	Connection point C	Distribution Centre A	Distribution Centre B
Active power (MW)	7.39	2.7	4.39
Reactive power (Mvar)	3.70	1.23	2.13
Apparent power (MVA)	8.26	2.97	4.88
cos phi	0.89	0.91	0.9
Joule losses (kW)		114.5	185
Power factor consumed by the line (kvar)		129	208
Voltage drops (%)		5.2	5.25

As can be seen, the connection conditions at connection point C are not very good, i.e., the apparent power is high and the power factor is low.

Situation with connected capacitor banks

To improve the network conditions, a 1100 kvar capacitor bank at 20 kV is connected to distribution centre A (BCA) and a 2000 kvar capacitor bank at 20 kV is connected to distribution centre B (BCB). The balance of power is modified, as shown in the following table:

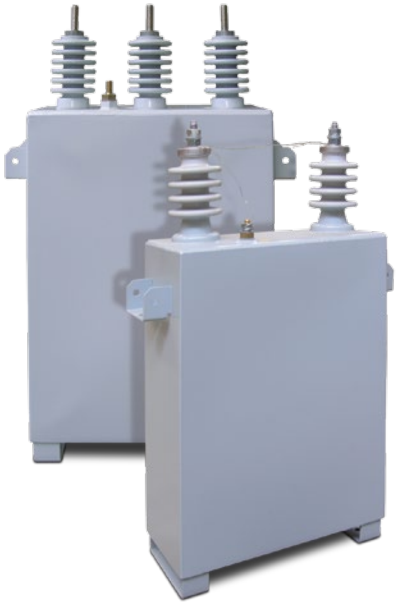
Installation data after compensation

	Connection point C	C. Distribution Centre A with BCA	C. Distribution Centre B with BCB
Active power (MW)	7.33	2.7	4.39
Reactive power (Mvar)	0.54	0.13	0.13
Apparent power (MVA)	7.36	2.7	4.39
cos fi	0.99	0.99	0.99
Joule losses (kW)		94	150
Power factor consumed by the line (kvar)		106	170
Voltage drops (%)		3.9	3.8

In this case it can be seen that at point C the conditions have been substantially optimised, the Joule losses in the lines have been reduced, and the voltage in the distribution centres has increased. Therefore, the operation and performance of the line has been optimised and the voltage level is guaranteed for users.

Capacitors

Full range of MV capacitors



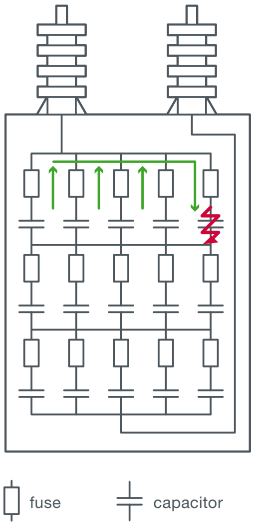
CIRCUTOR's range of MV capacitors comprises a complete series of single and three phase capacitors in full compliance with **International Standard IEC 60871**. The design and production of the capacitors is carried out with the guarantee and reliability of the finest raw materials and sufficient flexibility to provide a personalised solution for each application.

R+D behind the reliability

CIRCUTOR has a department made up of R+D experts who form a highly experienced team that cares for and ensures that the entire design and production process provides the highest guarantee of quality and reliability. Quality management is not only applied internally but also during each step of the supply chain. This means that our specialised suppliers rigorously assess the quality of the materials and their production processes. Before being supplied to the client, all capacitors undergo individual trials in strict compliance with the **International IEC Standard** and all of the data is logged for the resulting documentation and testing certificates.

Measurement of capacity	Prior measurement at a voltage less than 0.15*U_n Measurement between 0.9*U_n and 1.1*U_n Max peak tolerances 7.2 of the Standard (-5% and +15%)
Measurement of loss tangent (tg δ)	Measurement between 0.9*U_n and 1.1*U_n Values established between the manufacturer and purchaser (<0.2 W/kvar)
Voltage between terminals	For 10 s, 2*U_n with AC or 4*U_n with DC.
Alternating voltage between terminals and box	Capacitor insulation level for 10 s
Internal discharge devices	Resistance measurement
Discharges on the internal fuses	Discharge with an exploder without additional impedance after loading it to 1.7*U_n on DC.
Airtightness	

"all capacitors undergo strict individual trials"



Example of a capacitor with an internal fuse

Capacitor protection with an internal fuse

Modern high-voltage capacitors are subject to very high insulation requirements. A capacitor comprises several capacitor units or capacitor elements. Thus, the purpose of suitable internal protection for capacitors is to disconnect a defective unit before dangerous consequences occur, thus reducing any possible secondary effects of the fault.

Standard IEC 60871-4 is applicable to internal fuses that are designed to isolate faulty capacitor elements in order to enable operation of the remaining parts of the capacitor units and the battery to which the unit is connected. These fuses are not a substitute for a switching unit such as a circuit breaker or for external protection of the capacitor bank. In the event of a defect in a basic capacitor element, the sound elements will be discharged in parallel with the faulty element. The discharge will immediately melt the internal fuse of the damaged unit.

This system has a series of advantages which are classified into two groups:

Operational advantages

— Immediate disconnection of the damaged element

— Minimal generation of gases inside the capacitor

— Continuity of service
The elimination of the damaged unit enables the continuity of the connected unit.

— Possibility of planned battery maintenance

— Much simpler maintenance

Design advantages

— Optimisation of battery costs

— Fewer capacitors used per battery

— Reduced battery enclosure size

— Greater capacitor power

Capacitors

Full range of MV capacitors

Table of general technical features for CIRCUTOR Medium Voltage capacitors

Nominal power	**CHV-M**: 25 ... 750 kvar	**CHV-T**: 35 ... 750 kvar
Rated voltage	**CHV-M**: 1 / 24 kV	**CHV-T**: 1 / 12 kV
Frequency	50/60 Hz	
Insulation level	See table of insulation levels	
Maximum overvoltage	See table of overvoltage levels, as per **IEC**	
Overcurrent	$1.3 \cdot I_N$	
Capacity tolerance	-5%…+10%	
Total losses	< 0.15 W / kvar	
Statistical mean lifetime	>130,000 hours (normal conditions)	
Discharge resistors	75 V-10 minutes (optional 50 V-5 minutes)	
Current limits	Maximum 200 x I_N	
Ambient temperature category	-40°C/"C" (optional class D) (table 3)	
Ventilation	Natural	
Protection degree	IP 00	
Humidity	Maximum 95%	
Maximum service altitude	1000 m above sea level (consult other conditions)	
Assembly position	Vertical / Horizontal	
Assembly attachments	Lateral supports and leg anchors	
Container	Stainless steel for internal or external use	
Dielectric	All polypropylene film	
Saturant	PCB free, biodegradable	
Internal safety device	Internal fuses	
External safety device	Pressure switch (optional)	
Terminals	Porcelain	
Terminal tightening torque	10 Nm	
Colour	RAL 7035	

Insulation level (BIL)

These are the insulation levels that must be met in accordance with **Standard IEC 60871-1** and **IEC 60071-1**. These voltage levels depend on the highest voltage level of the unit or on external factors such as altitude or saline environments.

Highest voltage of the unit	Assigned short term voltage	Voltage assigned with ray-type impulse
7.2 kV	20 kV	60 kVpeak
12 kV	28 kV	75 kVpeak
17.5 kV	38 kV	95 kVpeak
24 kV	50 kV	125 kVpeak
36 kV	70 kV	170 kVpeak

Overvoltage levels

Admissible sporadic, non-continuous overvoltage levels in accordance with **Standard IEC 60871-1**.

Voltage	Maximum duration	Observations
U_N	Permanent	Maximum mean value during capacitor energization period
1.1 x U_N	12 hrs per 24 hr period	Network voltage regulation and fluctuation
1.15 x U_N	30 minutes per 24 hr period	Network voltage regulation and fluctuation
1.20 x U_N	5 minutes	

Ambient temperature range

Maximum environmental conditions in which MV capacitors can be used in accordance with **Standard IEC 60871-1**.

Symbol	Maximum	24 hr average	Annual average
A	40 °C	30 °C	20 °C
B	45 °C	35 °C	25 °C
C	50 °C	40 °C	30 °C
D	55 °C	45 °C	35 °C

Capacitors

Full range of MV capacitors

References for CHV-M

Medium voltage single-phase capacitors

Interior use with internal fuses and discharge resistance

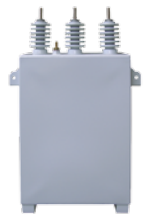
(*) No internal fuses. Other power ratings, please ask

BIL 28/75 kV (50 Hz) - 6.35 kV				
Type	**Code**	**kvar**	**Weight**	**Dimensions (mm)** w x h x d
CHV-M 50/6.35*	**R8B0500006350**	50	17.9 kg	350 x 487 x 160
CHV-M 75/6.35*	**R8B0750006350**	75	21.8 kg	350 x 537 x 160
CHV-M 100/6.35	**R8B1000006350**	100	21.8 kg	350 x 537 x 160
CHV-M 121/6.35	**R8B1210006350**	121	25.2 kg	350 x 587 x 160
CHV-M 133/6.35	**R8B1330006350**	133	25.4 kg	350 x 587 x 160
CHV-M 150/6.35	**R8B1500006350**	150	28.6 kg	350 x 637 x 160
CHV-M 167/6.35	**R8B1670006350**	167	29.1 kg	350 x 637 x 160
CHV-M 200/6.35	**R8B2000006350**	200	33.2 kg	350 x 697 x 160
CHV-M 242/6.35	**R8B2420006350**	242	37.6 kg	350 x 757 x 160
CHV-M 250/6.35	**R8B2500006350**	250	37.8 kg	350 x 757 x 160
CHV-M 300/6.35	**R8B3000006350**	300	45.3 kg	350 x 867 x 160
CHV-M 363/6.35	**R8B3630006350**	363	49.4 kg	350 x 857 x 175
CHV-M 400/6.35	**R8B4000006350**	400	54.5 kg	350 x 927 x 175
CHV-M 484/6.35	**R8B4840006350**	484	62.7 kg	350 x 1027 x 175
CHV-M 500/6.35	**R8B5000006350**	500	65.6 kg	350 x 1067 x 175
CHV-M 600/6.35	**R8B6000006350**	600	79.2 kg	350 x 1247 x 175
CHV-M 750/6.35	**R8B7500006350**	750	90.4 kg	350 x 1217 x 200
BIL 50/125 kV (50 Hz) - 12.7 kV				
CHV-M 50/12.7*	**R8D0500012700**	50	19.7 kg	350 x 615 x 160
CHV-M 75/12.7*	**R8D0750012700**	75	23.4 kg	350 x 665 x 160
CHV-M 100/12.7*	**R8D1000012700**	100	26.8 kg	350 x 715 x 160
CHV-M 121/12.7*	**R8D1210012700**	121	27.3 kg	350 x 715 x 160
CHV-M 133/12.7*	**R8D1330012700**	133	30.5 kg	350 x 765 x 160
CHV-M 150/12.7*	**R8D1500012700**	150	31.2 kg	350 x 765 x 160
CHV-M 167/12.7*	**R8D1670012700**	167	35.1 kg	350 x 825 x 160
CHV-M 200/12.7	**R8D2000012700**	200	39.2 kg	350 x 885 x 160
CHV-M 242/12.7	**R8D2420012700**	242	46.9 kg	350 x 995 x 160
CHV-M 250/12.7	**R8D2500012700**	250	47.0 kg	350 x 995 x 160
CHV-M 300/12.7	**R8D3000012700**	300	48.1 kg	350 x 995 x 160
CHV-M 363/12.7	**R8D3630012700**	363	56.9 kg	350 x 1055 x 175
CHV-M 400/12.7	**R8D4000012700**	400	59.6 kg	350 x 1085 x 175
CHV-M 484/12.7	**R8D4840012700**	484	68.7 kg	350 x 1195 x 175
CHV-M 500/12.7	**R8D5000012700**	500	70.9 kg	350 x 1225 x 175
CHV-M 600/12.7	**R8D6000012700**	600	83.0 kg	350 x 1375 x 175
CHV-M 750/12.7	**R8D7500012700**	750	98.8 kg	350 x 1405 x 200

BIL 20/60 kV (50 Hz) - 3.81 kV				
Type	**Code**	**kvar**	**Weight**	**Dimensions (mm)** w x h x d
CHV-M 50/3.81	**R8A0500003810**	50	18.2 kg	350 x 487 x 160
CHV-M 75/3.81	**R8A0750003810**	75	18.5 kg	350 x 487 x 160
CHV-M 100/3.81	**R8A1000003810**	100	21.9 kg	350 x 537 x 160
CHV-M 121/3.81	**R8A1210003810**	121	25.4 kg	350 x 587 x 160
CHV-M 133/3.81	**R8A1330003810**	133	25.5 kg	350 x 587 x 160
CHV-M 150/3.81	**R8A1500003810**	150	29.1 kg	350 x 637 x 160
CHV-M 167/3.81	**R8A1670003810**	167	29.3 kg	350 x 637 x 160
CHV-M 200/3.81	**R8A2000003810**	200	33.5 kg	350 x 697 x 160
CHV-M 242/3.81	**R8A2420003810**	242	38.0 kg	350 x 757 x 160
CHV-M 250/3.81	**R8A2500003810**	250	44.8 kg	350 x 867 x 160
CHV-M 300/3.81	**R8A3000003810**	300	45.8 kg	350 x 867 x 160
CHV-M 363/3.81	**R8A3630003810**	363	52.3 kg	350 x 957 x 160
CHV-M 400/3.81	**R8A4000003810**	400	55.3 kg	350 x 927 x 175
CHV-M 484/3.81	**R8A4840003810**	484	66.1 kg	350 x 1067 x 175
CHV-M 500/3.81	**R8A5000003810**	500	68.3 kg	350 x 1097 x 175
CHV-M 600/3.81	**R8A6000003810**	600	80.2 kg	350 x 1247 x 175
CHV-M 750/3.81	--	--	--	--
BIL 38/95 kV (50 Hz) - 9.53 kV				
CHV-M 50/9.53 *	**R8C0500009530**	50	19.5 kg	350 x 530 x 160
CHV-M 75/9.53 *	**R8C0750009530**	75	20.2 kg	350 x 530 x 160
CHV-M 100/9.53 *	**R8C1000009530**	100	23.6 kg	350 x 580 x 160
CHV-M 121/9.53 *	**R8C1210009530**	121	27.1 kg	350 x 630 x 160
CHV-M 133/9.53 *	**R8C1330009530**	133	30.4 kg	350 x 680 x 160
CHV-M 150/9.53	**R8C1500009530**	150	31.0 kg	350 x 680 x 160
CHV-M 167/9.53	**R8C1670009530**	167	34.9 kg	350 x 740 x 160
CHV-M 200/9.53	**R8C2000009530**	200	35.4 kg	350 x 740 x 160
CHV-M 242/9.53	**R8C2420009530**	242	46.8 kg	350 x 910 x 160
CHV-M 250/9.53	**R8C2500009530**	250	46.9 kg	350 x 910 x 160
CHV-M 300/9.53	**R8C3000009530**	300	48.0 kg	350 x 910 x 160
CHV-M 363/9.53	**R8C3630009530**	363	54.7 kg	350 x 1000 x 160
CHV-M 400/9.53	**R8C4000009530**	400	59.7 kg	350 x 1000 x 175
CHV-M 484/9.53	**R8C4840009530**	484	68.7 kg	350 x 1110 x 175
CHV-M 500/9.53	**R8C5000009530**	500	71.0 kg	350 x 1140 x 175
CHV-M 600/9.53	**R8C6000009530**	600	83.1 kg	350 x 1290 x 175
CHV-M 750/9.53	**R8C7500009530**	750	90.4 kg	350 x 1257 x 200
BIL 70/170 kV (50 Hz) - 19.05 kV				
CHV-M 50/19.05 *	**R8E0500019050**	50	23.3 kg	350 x 644 x 160
CHV-M 75/19.05 *	**R8E0750019050**	75	23.6 kg	350 x 644 x 160
CHV-M 100/19.05 *	**R8E1000019050**	100	27.0 kg	350 x 694 x 160
CHV-M 121/19.05 *	**R8E1210019050**	121	30.5 kg	350 x 744 x 160
CHV-M 133/19.05 *	**R8E1330019050**	133	30.7 kg	350 x 744 x 160
CHV-M 150/19.05 *	**R8E1500019050**	150	35.0 kg	350 x 804 x 160
CHV-M 167/19.05 *	**R8E1670019050**	167	35.3 kg	350 x 804 x 160
CHV-M 200/19.05 *	**R8E2000019050**	200	39.4 kg	350 x 864 x 160
CHV-M 242/19.05*	**R8E2420019050**	242	47.1 kg	350 x 974 x 160
CHV-M 250/19.05	**R8E2500019050**	250	50.8 kg	350 x 964 x 175
CHV-M 300/19.05	**R8E3000019050**	300	56.5 kg	350 x 1034 x 175
CHV-M 363/19.05	**R8E3630019050**	363	57.1 kg	350 x 1034 x 175
CHV-M 400/19.05	**R8E4000019050**	400	64.4 kg	350 x 1134 x 175
CHV-M 484/19.05	**R8E4840019050**	484	70.8 kg	350 x 1204 x 175
CHV-M 500/19.05	**R8E5000019050**	500	73.7 kg	350 x 1244 x 175
CHV-M 600/19.05	**R8E6000019050**	600	84.1 kg	350 x 1264 x 200
CHV-M 750/19.05	**R8E7500019050**	750	104.2 kg	350 x 1454 x 200

Capacitors

Full range of MV capacitors

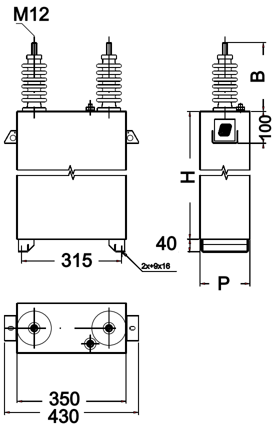


References for CHV-T
Medium voltage three-phase capacitors
Interior use with internal fuses and discharge resistance

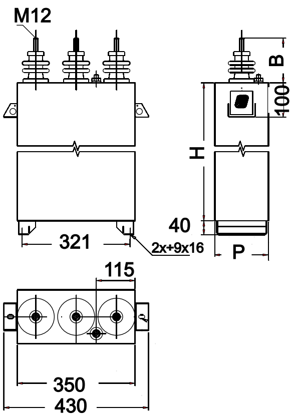
Type	Code	kvar	Weight	Dimensions (mm) w x h d
BIL 20/60 kV (50 Hz) - 3.3 kV				
CHV-T 50/3.3 *	R8K0500003300	50	18.8 kg	350 x 422 x 160
CHV-T 75/3.3 *	R8K0750003300	75	22.4 kg	350 x 472 x 160
CHV-T 100/3.3 *	R8K1000003300	100	22.8 kg	350 x 472 x 160
CHV-T 121/3.3 *	R8K1210003300	121	26.3 kg	350 x 522 x 160
CHV-T 150/3.3 *	R8K1500003300	150	30.0 kg	350 x 572 x 160
CHV-T 200/3.3 *	R8K2000003300	200	34.4 kg	350 x 632 x 160
CHV-T 242/3.3 *	R8K2420003300	242	45.6 kg	350 x 802 x 160
CHV-T 250/3.3 *	R8K2500003300	250	45.7 kg	350 x 802 x 160
CHV-T 300/3.3 *	R8K3000003300	300	46.7 kg	350 x 802 x 160
CHV-T 363/3.3 *	R8K3630003300	363	55.6 kg	350 x 862 x 175
CHV-T 400/3.3	R8K4000003300	400	58.3 kg	350 x 892 x 175
CHV-T 484/3.3	R8K4840003300	484	67.2 kg	350 x 1002 x 175
CHV-T 500/3.3	R8K5000003300	500	69.4 kg	350 x 1032 x 175
CHV-T 600/3.3	R8K6000003300	600	81.2 kg	350 x 1182 x 175
CHV-T 750/3.3	R8K7500003300	750	97.3 kg	350 x 1252 x 200
BIL 20/60 kvar (50 Hz) - 6.6 kV				
CHV-T 50/6.6 *	R8K0500006600	50	19.2 kg	350 x 422 x 160
CHV-T 75/6.6 *	R8K0750006600	75	22.6 kg	350 x 472 x 160
CHV-T 100/6.6 *	R8K1000006600	100	23.0 kg	350 x 472 x 160
CHV-T 121/6.6 *	R8K1210006600	121	26.5 kg	350 x 522 x 160
CHV-T 150/6.6 *	R8K1500006600	150	30.2 kg	350 x 572 x 160
CHV-T 200/6.6	R8K2000006600	200	38.3 kg	350 x 692 x 160
CHV-T 242/6.6	R8K2420006600	242	45.8 kg	350 x 802 x 160
CHV-T 250/6.6	R8K2500006600	250	45.9 kg	350 x 802 x 160
CHV-T 300/6.6	R8K3000006600	300	46.9 kg	350 x 802 x 160
CHV-T 363/6.6	R8K3630006600	363	55.9 kg	350 x 862 x 175
CHV-T 400/6.6	R8K4000006600	400	58.6 kg	350 x 892 x 175
CHV-T 484/6.6	R8K4840006600	484	67.4 kg	350 x 1002 x 175
CHV-T 500/6.6	R8K5000006600	500	69.7 kg	350 x 1032 x 175
CHV-T 600/6.6	R8K6000006600	600	81.2 kg	350 x 1182 x 175
CHV-T 750/6.6	R8K7500006600	750	97.6 kg	350 x 1252 x 200
BIL 28/75 kvar (50 Hz) - 11 kV				
CHV-T 50/11 *	R8L0500011000	50	19.3 kg	350 x 422 x 160
CHV-T 75/11 *	R8L0750011000	75	22.7 kg	350 x 472 x 160
CHV-T 100/11 *	R8L1000011000	100	23.0 kg	350 x 472 x 160
CHV-T 121/11 *	R8L1210011000	121	26.4 kg	350 x 522 x 160
CHV-T 150/11 *	R8L1500011000	150	30.1 kg	350 x 572 x 160
CHV-T 200/11 *	R8L2000011000	200	34.4 kg	350 x 632 x 160
CHV-T 242/11	R8L2420011000	242	45.6 kg	350 x 802 x 160
CHV-T 250/11	R8L2500011000	250	45.7 kg	350 x 802 x 160
CHV-T 300/11	R8L3000011000	300	46.5 kg	350 x 802 x 160
CHV-T 363/11	R8L3630011000	363	53.0 kg	350 x 892 x 175
CHV-T 400/11	R8L4000011000	400	56.1 kg	350 x 862 x 175
CHV-T 484/11	R8L4840011000	484	66.8 kg	350 x 1002 x 175
CHV-T 500/11	R8L5000011000	500	67.0 kg	350 x 1002 x 175
CHV-T 600/11	R8L6000011000	600	80.7 kg	350 x 1182 x 175
CHV-T 750/11	R8L7500011000	750	92.1 kg	350 x 1192 x 200

(*) No internal fuses
Other power ratings, please consult

Dimensions
CHV-M



Dimensions
CHV-T



Capacitors

Full range of MV capacitors

Capacitor selection

When selecting MV power capacitors it is important to know the conditions under which the capacitors are going to operate, basically: assigned voltage, insulation level, working temperature and special conditions.

Assigned voltage

It is best to ensure that the assigned or rated voltage of the capacitors is not lower than the maximum working voltage where they are going to be installed. There could be considerable differences between the operating and the assigned network voltage, and so the necessary voltage variation margins must be taken into account. For safety reasons, values between 5% and 10% of voltage margin over the declared value are used. This will affect the selection of the capacitor power in order to maintain the required power at the declared working voltage. *(See Example 1)*

Example 1

Three-phase MV capacitor selection

We need 300 kvar at 6 kV, and so we will choose a capacitor at 6.6 kV (U_s+10%), for which we would need a capacitor of 363 kvar at 6.6 kV.

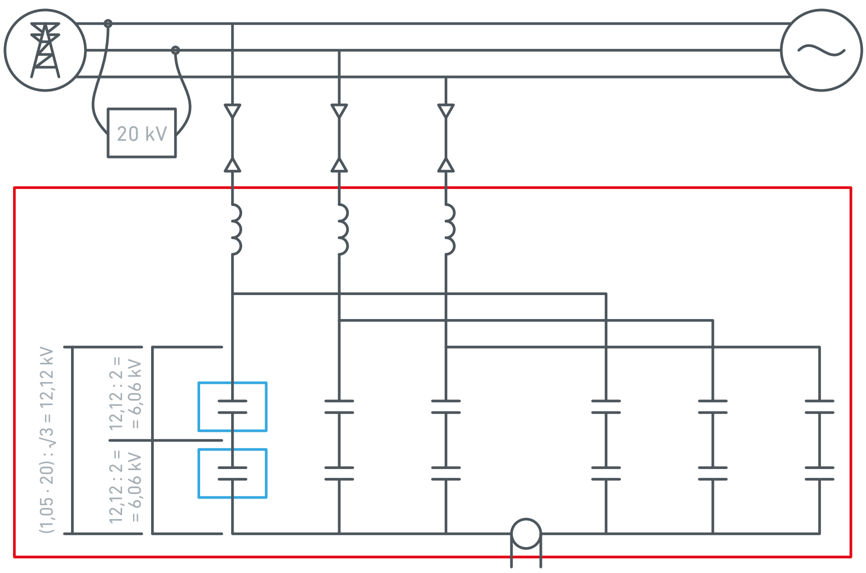
$$Q_N = Q_S \cdot \left(\frac{U_N}{U_S}\right)^2$$

$$Q_{6,6kV} = 300 \cdot \left(\frac{6,6}{6}\right)^2 =$$

$$= 300 \cdot 1,21 = 363 \text{ kvar}$$

Insulation level

The insulation level must be selected in accordance with the network where it is going to be connected. *(See Example 2)*



Example 2

Insulation for a 36 kV battery

The capacitor insulation level will depend on the design specifications and must be in accordance with **Standard IEC 60871-1**. Even though the capacitors are 6 kV, their insulation level will be 24 kV.

A — **BIL battery** 24/50/125 kV

B — **BIL capacitors** 24/50/125 kV

Working temperature

It is important to take into account the highest temperature of the capacitor given that this influences its useful life, both for low temperatures, because the dielectric may undergo partial discharges, and environmental temperatures that exceed established design temperatures. It is best to use a suitable temperature class and if this is not possible, the cooling conditions of the capacitors should either be improved or a higher rated voltage should be used.

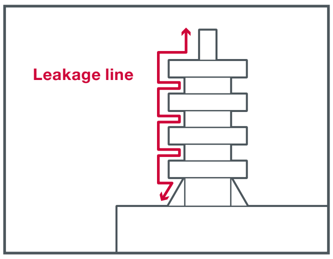
Special conditions

Conditions such as pollution, saline or corrosive environments, or altitudes over 1000 m above sea level may affect the choice of capacitor . Pollution or saline environments mainly affect the leakage line of the capacitors (creepage), thus requiring a larger leakage line. In the case of altitude, the insulation level must be adjusted according to the altitude where the capacitors are going to be installed. *(See Example 3)*

Example 3

Pollution levels

No.	Level	mm/kV
1	Low	16
2	Medium	20
3	High	25
4	Very high	31



RMV type reactors

Choke reactor for MV capacitor banks

The connection of capacitor banks has very high associated currents and voltage transients. **Standard IEC 60871-1** defines the maximum value that can be supported by a capacitor bank as the peak connection value. This peak value must be less than 100 times the nominal current of the capacitor bank or step that is being operated.

The inrush current that appears at the connection mainly comes from the network and other capacitor banks connected in parallel. The inductance value is a variable that depends on the installation's conditions and mainly on the following parameters:

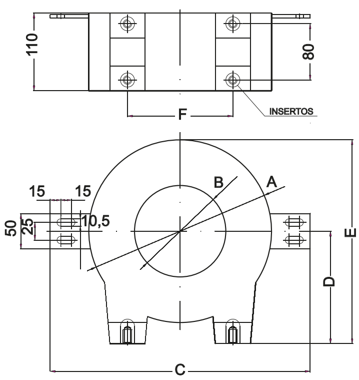
— Short-circuit power of the installation
— Existence of more capacitor banks

Table of technical features of choke reactors for MV capacitor banks

Electrical features	Short-duration nominal current	43 I_n / 1 s
	Dynamic current	2.5 It
	Insulation level	Up to 12 kV (28/75)
Environmental conditions	Operating temperature	Category B
	Mean temperature	40 °C
Build features	Type	Encapsulated in resin. Air core.
	Fittings	M12 / M16, depending on the type
	Dimensions (mm)	depending on the type
	Weight	depending on the type (see above table)
	Colour	colour RAL 8016
Standard	IEC 60289	

*** For higher insulation levels the reactors must be mounted on insulators.**

Dimensions



Model	AØ	BØ	C	D	E	F
RMV-260	260	130	370	160	290	150
RMV-330	330	150	470	190	355	210

References for RMV

RMV-260				
Type	**Code**	**I (A)**	**L (µH)**	**Weight (kg)**
RMV - 260 - 50 - 350	**R80628**	50	350	13
RMV - 260 - 60 - 250	**R80637**	60	250	14
RMV - 260 - 100 - 100	**R80664**	100	100	16
RMV - 260 - 125 - 50	**R80672**	125	50	14
RMV - 260 - 175 - 30	**R80691**	175	30	14
RMV-330				
RMV - 330 - 60 - 450	**R80739**	60	450	20
RMV - 330 - 75 - 350	**R80748**	75	350	21
RMV - 330 - 90 - 250	**R80757**	90	250	26
RMV - 330 - 125 - 100	**R80774**	125	100	22
RMV - 330 - 200 - 50	**R807A2**	200	50	22
RMV - 330 - 250 - 30	**R807B1**	250	30	23

*** Please consult other reactors.**

RMV type reactors

Choke reactor for MV capacitor banks

The following two situations may arise:

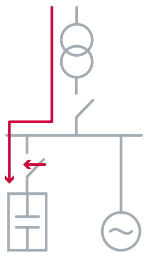
Insulated battery

A battery comprising a single step without capacitor banks connected in parallel. This situation does not normally require choke reactors because the inherent impedance of the network limits the current to below 100 times the battery current.

Example

2500 kvar battery at 6.6 kV connected to a network with a short-circuit power of 350 MVa. The battery has a nominal current of 218.95 A and the peak current will be 4486.32 A, which means it is 20.49 times the nominal current and therefore within the limits established by the Standard.

Insulated capacitor bank (without more capacitor banks)



Inrush current

$$I_c = \sqrt{2} \cdot I_n \cdot \sqrt{\frac{S_{cc}}{Q}}$$

Required inductance

For limiting the current in battery 100 I_n

$$L \geq \frac{U^2}{\omega} \cdot \left[\frac{200}{Q} - \frac{10^6}{S_{cc}} \right]$$

Required inductance

For limiting below the shut off power

$$L \geq \frac{10^6}{\omega} \cdot \left[\frac{2Q}{3I_a^2} - \frac{U^2}{S_{cc}} \right]$$

Capacitor banks in parallel

Capacitor banks comprising two or more steps, or that are connected in parallel at the same voltage level as other capacitor banks. This is a more critical situation because normally there can be peak values that are greater than 100 times the nominal current. Therefore, the use of **RMV** choke reactors is essential.

Example

5000 kvar capacitor bank at 6.6 kV comprising 1 step of 1000 kvar and 2 of 2000 kvar, 50 Hz frequency and 6 kV working voltage. With no choke reactor and considering an inductor appropriate for a one-metre long conductor (0.5 µH/m), the following results are obtained:

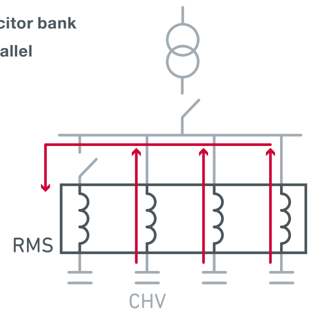
	Step 1 (1000 kvar)	Step 2 (2000 kvar)	Step 3 (2000 kvar)
$C_{step\ protection}$	73.07 µF	146.15 µF	146.15 µF
C_{eq}	292.3 µF	219.22 µF	219.22 µF
L	0.5 µH	0.5 µH	0.5 µH
L_T	0.25 µH	0.25 µH	0.25 µH
I_N	87.48 A	174.95 A	174.95 A
I_P	43251 A	52972 A	52972 A
I_P/I_N	494.41	302.78	302.78

The ratio I_P/I_N is shown to exceed the allowed limit, and so choke reactors must be incorporated. Using 100 µH reactors for the first step and 50 µH for the rest yields:

	Step 1 (1000 kvar)	Step 2 (2000 kvar)	Step 3 (2000 kvar)
$C_{step\ protection}$	73.07 µF	146.15 µF	146.15 µF
C_{eq}	292.3 µF	219.22 µF	219.22 µF
L	100 µH	50 µH	50 µH
L_T	0.25 µH	0.25 µH	0.25 µH
I_N	87.48 A	174.95 A	174.95 A
I_P	3350 A	5025 A	5025 A
I_P/I_N	38.29	28.79	28.79

Confirmed, the ratio I_P/I_N meets the inrush current limit that is 100 times less than I_N.

Capacitor bank in parallel



Expressions for simplifying the calculation

$$I_c = U \cdot \sqrt{\frac{2}{3} \cdot \frac{C_1 \cdot C_{eq}}{C_1 + C_{eq}} \cdot \frac{1}{L_1 + L_{eq}}}$$

$$L_{eq} = \frac{1}{\frac{1}{L_2} + .. + \frac{1}{L_n}}$$

$$C_{eq} = C_2 + C_3 + .. + C_n$$

I_c - Inrush current
S_{cc} - Short-circuit power in kVA
Q - Capacitor bank power in kVA
U - Network voltage in kV
I_a - Circuit-breaker breaking capacity
C_1 - Capacity of the last connected capacitor bank
C_{eq} - Capacity equivalent to the capacitor bank
C_t - Capacity of all the capacitor banks in parallel
L_1 - Choke inductance of the last connected capacitor bank
L_t - Inductance equivalent to the connected capacitor banks

Reactors

Reactors for MV capacitor banks

A wide range of both single and three phase reactors for manufacturing tuned harmonic filters, which can be manufactured for different voltages from 1 kV up to 36 kV, and any tuning frequency: 5.67%, 6%, 7%, 14%, etc.

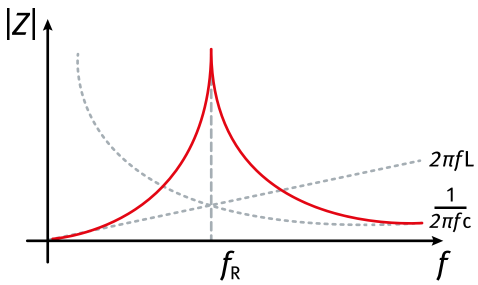
The reactors are made from low-loss plate metal and a copper coil or aluminium band, depending on the model. Once assembled they are impregnated using a sophisticated vacuum system that guarantees minimum loss, greater mechanical consistency, increased insulation and low noise emissions.

Capacitor bank resonance

Capacitor banks are units that do not intrinsically generate harmonics, although they can be affected by the injection of harmonic currents from non-linear loads, which together can produce a parallel resonance between the capacitor bank and the installation's power transformer, resulting in a maximum impedance at a frequency called resonance.
A resonance frequency occurs in industrial installations when the impedance values of the transformer coincide (X_T) with the capacitor's (X_C):

$$f_R = f \cdot \sqrt{\frac{X_C}{X_T}} = f \cdot \sqrt{\frac{S_{CC}}{Q}}$$

Where S_{DC} is the short-circuit power of the transformer in kVA, and Q the capacitor bank's power in kvar.



This increase in impedance does not remain static at a single frequency but will shift depending on the resonance conditions at each moment. If the power Q of the capacitor bank decreases, the resonance frequency of the installation increases and, inversely, if the power Q of the capacitor bank increases, the installation's resonance frequency decreases, becoming more dangerous as it approaches the frequencies where considerable current values are injected, resulting in:

— Voltage wave quality deterioration (THD*U*% increase)
— Reduced useful life of the capacitors or their destruction
— Capacitors bank or installation protections trip.

The solution involves using capacitor banks with a detuned filter to avoid the risk of resonance with harmonic currents present in the installation with frequencies that exceed the design of the filter itself.

Operating elements

Elements for operation or protection for MV capacitor banks

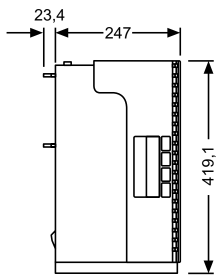
Contactors

The **LVC** contactor is a vacuum contactor prepared for controlling inductive and capacitive loads. It is specifically designed for industrial applications that require a large number of operations, specifically, the loads associated with motors and capacitors.

The **LVC** vacuum contactor is the ideal unit for capacitor bank operations between 3.3 and 6.6 kV to avoid restrikes and overvoltages.

Its general features are as follows:
— Vacuum extinction means
— Perfect control of the electric arc during capacitor operations
— Long useful life
— Strong overall insulation formed by three independent vacuum poles mounted on an insulating structure
— Compact dimensions
— Light unit with highly optimised weight
— Easy maintenance

Dimensions



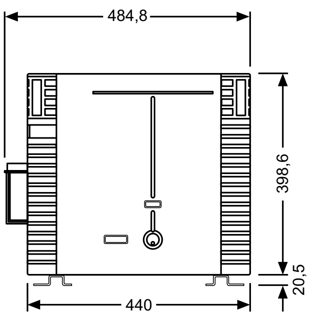


Table of technical features for MV contactors

Electrical features	Nominal current	400 A
	Rated voltage	7.2 kV
	Frequency	50/60 Hz
	Insulation level	20...60 kV
	Cut-off means	Vacuum
	Rated short circuit breaking current	4 kA
	Short-circuit current	6.3 kA/1s
	Excitation method	Continuous
	Voltage control	220 Vac.
	Auxiliary contacts	3 NO + 3 NC
Build features	Connection	Fixed
	Dimensions	350 x 392 x 179 mm
	Weight	22 kg
Standard	IEC 60470	

References

Type	*I* maximum	Type	*U* auxiliary	Code
6.6 kV ac.	**3 x 400 A**	LVC-6Z44ED	220 Vac.	R80911
6.6 kVac.	**3 x 400 A**	LVC-6Z44ED	110 Vdc.	R809110010000

Circuit breakers

Use of circuit breakers with vacuum cut-off technology for capacitor bank operation and/or protection, with insulation levels up to 36 kV.

Compact circuit breakers that meet international standard **IEC 62271-100** and with a cut-off power of up to 40 kA*, adaptable to the specific requirements of each capacitor bank. Easy maintenance and high performance capacitor banks.

* Please consult for specific models.

Capacitor banks

CIRKAP. Easy to choose complete product

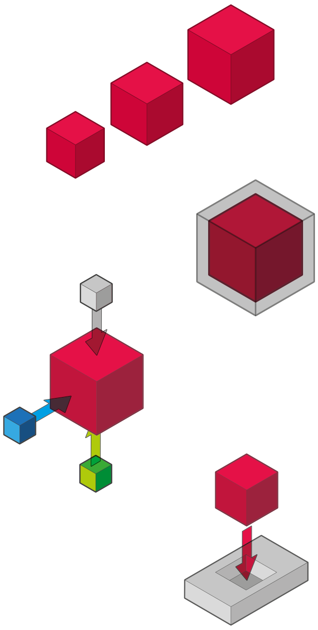
Our MV capacitor banks are designed, manufactured and adapted to the specific needs of each client. A high quality intelligent design brings advantages to your project from the start.

Our experience guarantees benefits to all involved:

Engineering firms
These firms ensure that the proposed solution meets the specifications and adapts to the demands of the installation.

Installers
Easy to install and handle modular units that save time and money.

End user
High performance and easily maintained units that benefit from the advantages (technical and economical) that the power factor correction at MV provides.



The Perfect Solution

The **CIRKAP** series provides constant benefits such as flexibility, safety, reliability and easy installation and maintenance throughout the life of the capacitor banks.

Flexibility
Compact and robust modular design. Optimised to the client's operations and requirements. Easily accessible from any point.

Safety
Complete safety provided by the metal enclosure with panels that shape the capacitor banks, preventing access to the active parts. Secure access to the control panel.

Reliability
CIRCAP capacitor banks combine over 40 years of **CIRCUTOR's** experience and know-how manufacturing MV batteries using components from leading brands. We apply strict quality controls throughout the entire production process. Our production process is certified under international standard **ISO 9001** and subject to strict control processes.

Easy installation and maintenance
CIRKAP capacitor banks, with all internal elements mounted, wired and pre-assembled, are easy to install, which facilitates handling and connecting. Simple maintenance, with all of the parts being easily accessible.

Capacitor banks

Application examples

Water treatment plant

Multistep automatic capacitor bank with detuned filter model **CMSR** of 2250 kvar at 6,6 kV, 50 Hz, composition 5x650 kvar, tuned at 189 Hz (p:7%), outdoor, IP44. Details of a step with APR fuses, vacuum contactor, filter reactor and three-phase capacitor.

Paper industry

Multistep automatic capacitor bank with detuned filter model **CMSR** of 6750 kvar at 22 kV, 50 Hz, composition 750+4x1500, tuned at 189 Hz (p:7%), a¡outdoor, IP54. Details of control board, with voltage indicator, step ON/OFF, manual/automatic selector per bach step, three-phase power factor regulator and overcurrent, short-circuit and unbalance protection per step.

Petrochemical industry

Multistep automatic capacitor bank model **CMSC** of 8790 kvar at 20 kV, 50 Hz, composition 2930+5860 kvar, indoor, IP23. Details of panels and entrance door around the enclosure which allows properly maintenance of the equipment.

Road infrastructure

Automatic capacitor bank with detuned filter model **CMAR** of 100 kvar at 3,3 kV, 50 Hz, composition 1x100 kvar, tuned at 189 Hz (p:7%), indoor, IP23. Details of enclosure adapted to be located in tunnel and corporate colour required by the client.

Capacitor banks

Protection elements

The MV capacitor bank protection elements are comprised of high cut-off power (APR) fuses and/or indirect protection relays.

Fuses

APR fuses are frequently used for protecting small and medium power MV capacitor banks.

This protection system has the following advantages:
— Limits the electrodynamic forces in the battery's bus-bars
— Decreases the thermal effects of short-circuit currents.
— Relatively low cost.

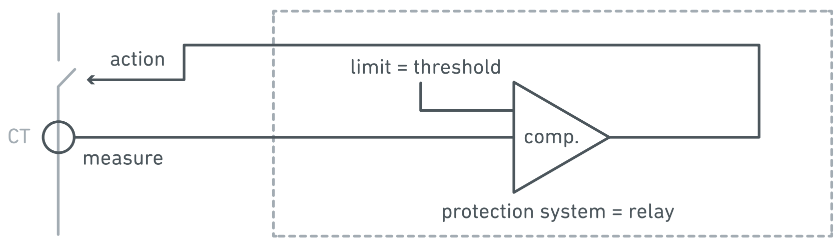
Their main drawback, however, is zero overload protection

Fuse selection
In order to bear the maximum tolerance and harmonics and to reduce the temperature increase in fuses, manufacturers recommend using at least 1.8 to 2 times the nominal current of the step or battery. The transient voltage increase of the connection cannot be overlooked, which means that for safety purposes the following voltage level should be used: in 7.2 kV networks use 12 kV, in 12 kV use 24 kV, and in 24 kV use 36 kV. It is also important to ensure that the fuse admits the peak connection current and must remain below the current curve for about 20-100 ms.

$1{,}8I_N < I_{fuse} < 2I_N$ $\quad$ $I_{fuse\_t<10ms} > I_{peak}$ $\quad$ U_{fuse} = higher BIL

Protection relay

The protection systems that give the order to the switch to actuate are called protection relays. For them to function, an external power supply and signal input for the measurement sensors are required in accordance with the required protection.



Basic diagram of an electric protection chain

The level of protection that a relay can provide is indicated by an international ANSI protection code. The relevant protection levels for MV capacitor banks are:

50 — **Instant overcurrent relay. *Short-circuit***

51 — **Timed current relay. *Overcurrent***

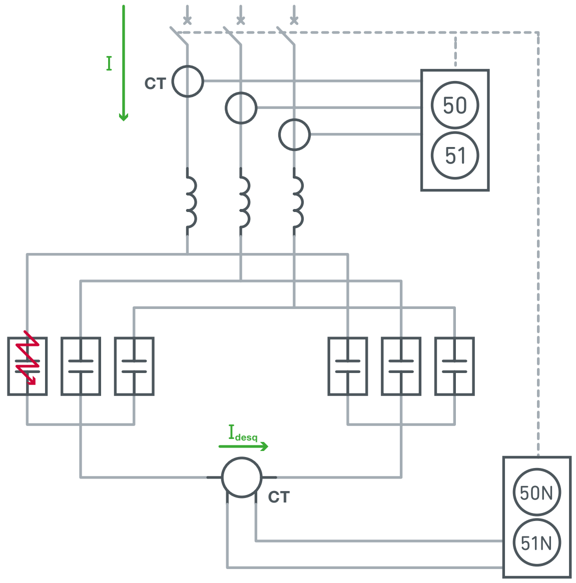
50N, 51N — **Timed, instant neutral current relay. *Double star imbalance***

27 — **Minimum voltage relay**

59 — **Maximum voltage relay**

Capacitor banks

Protection elements



Example of protection against overload imbalance and short-circuits of the battery/steps

Unbalance protection (double star)

When an element suffers a fault, the capacity of the group where this element is installed decreases. This capacity variation results in an impedance increase for this group and at the same time a variation in the voltage distribution in the capacitor. The group of elements where the anomaly occurs suffers an overvoltage.

The unbalance protection parameters in the double star are:

— The voltage in a capacitor cannot exceed 110% of its rated voltage.

— If the number of faulty elements in a unit is so high that there is a danger of provoking a chain reaction of faults, the battery must be disconnected even if the voltage has not exceeded 110% of its rated value in any of the capacitors in the bank. Normally, the battery should be disconnected when the voltage in the working elements exceeds 140% of its nominal value.

Generally, the second parameter is the one that determines the battery's trip current level. Unbalance protection is based on the current measurement that is detected between equipotential points, such as the two neutrals of the double stars. If the impedance varies in one of the branches, it will give rise to an unbalance that provokes the circulation of a current between the neutrals of the two stars. To operate correctly the transformer must be at least of accuracy class 1.

General battery protection

Use of a main circuit breaker is recommended for general protection, either installed inside the unit itself or in the installation upstream of the battery.

Overload and short-circuit protection are required as a minimum. The following protection regulations are recommended:

— **Short-circuit protection** at 4-6 I_n with a 0.1 second delay.

— **Overload**. Inverse reaction time curve ≈ 4 seconds at 1.3 I_n (depending on the neutral scheme of the installation).

Step protection

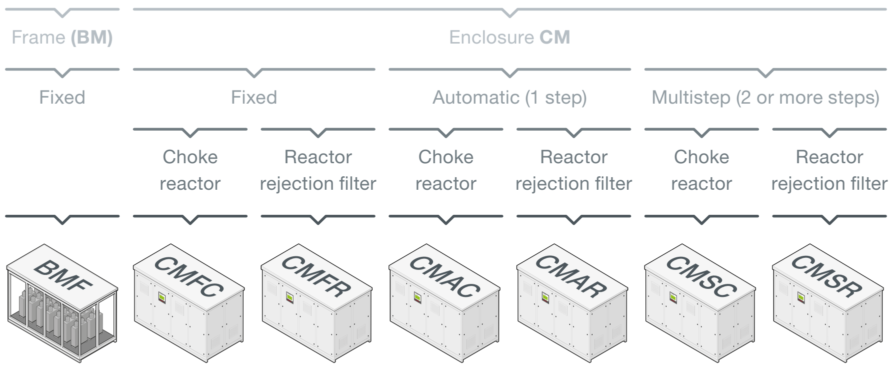
Each step has its own protection controlled by a set of high breaking capacity fuses that incorporate a micro-fuse to ensure step disconnection during a fault and which is wired to the operating panel to monitor the problem.

Capacitor banks

CIRKAP. Easy to choose complete products

Capacitor bank selection

CIRKAP capacitor banks are divided in two main groups: Capacitor banks in a **CM** enclosure and capacitor banks in open **BM** frames.



References for CIRKAP BM

Code

B M X X X X X X X X X X X

Fixed (step 1)	F
Without choke reactor	-
With choke reactor	C
Number of steps (1)	*No.*
Rated voltage (3 figures) 3.3 kV	033
Rated voltage (3 figures) 4.2 kV	042
Rated voltage (3 figures) 5.5 kV	055
Rated voltage (3 figures) 6.0 kV	060
Rated voltage (3 figures) 6.3 kV	063
Rated voltage (3 figures) 6.6 kV	066
Rated voltage (3 figures) 11 kV	110
Rated voltage (3 figures) 13.2 kV	132
Rated voltage (3 figures) 15 kV	150
Rated voltage (3 figures) 16.5 kV	165
Rated voltage (3 figures) 22 kV	220
Rated voltage (3 figures) 33 kV	330
Nominal capacitor bank power in kvar (5 figures)	*No.*

References for CIRKAP CM

Code

C M X X X X X X X X X X X

Fixed (step 1)	F
Automatic (1 step)	A
Multistep	S
Without choke reactor	-
With choke reactor	C
With detuned filter	R
Number of steps (1...9)	*No.*
Rated voltage (3 figures) 3.3 kV	033
Rated voltage (3 figures) 4.2 kV	042
Rated voltage (3 figures) 5.5 kV	055
Rated voltage (3 figures) 6.0 kV	060
Rated voltage (3 figures) 6.3 kV	063
Rated voltage (3 figures) 6.6 kV	066
Rated voltage (3 figures) 11 kV	110
Rated voltage (3 figures) 13.2 kV	132
Rated voltage (3 figures) 15 kV	150
Rated voltage (3 figures) 16.5 kV	165
Rated voltage (3 figures) 22 kV	220
Rated voltage (3 figures) 33 kV	330
Nominal capacitor bank power in kvar (5 figures)	*No.*

Capacitor banks

Additional components

Pressure switch
It enables the step/capacitor bank to be disconnected based on pressure arising from a serious defect inside the capacitor, thereby preventing it from further damages. It enables the power circuit to be disconnected and signals the fault when the pressure reaches the maximum value.

Voltage presence indicator
A unit that lights up permanently when the power circuit is fed in order to provide greater safety during operations made on the unit.

Smoke detector
Smoke detectors are devices that warn of the possibility of internal combustion in the capacitor bank and send a signal to activate an alarm (in the unit or at the discretion of the user), disconnecting the bank if required.

Electric circuit with opening delay for doors
For units that are ordered with ports in the power modules, Circutor offers the option of including a solenoid electrical interlock system in order to prevent access to the bank's interior if the necessary time has not elapsed.

Vacuum off-load and/or earthing switch
The off-load and/or earthing switch enables the unit to be visually disconnected and isolated at the capacitor bank input.

Ventilation
In batteries installed in environmental conditions where natural convention cooling is insufficient, an auxiliary thermostat-controlled forced air system is essential for evacuating the internal heat of the battery.

Anti-condensation heating resistors
These are used to avoid condensation due to temperature gradients during the day, saline environmental conditions, high relative humidity and low temperatures. Heating resistors controlled by thermostat and/or hygrometer.

Solutions for Power Factor Correction at **Medium Voltage**

Additional information: **comunicacion@circutor.com**

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Code: C2R823 -02