ICAR

technology looking ahead

2014

MV POWER CAPACITORS AND BANKS

BIORIPHASO TF

All film dielectric
MV Power Capacitors

QUALITY MADE IN ITALY

Index

Icar: Products and solutions

ICAR is a leading manufacturer of capacitors and power factor correction systems in low and medium voltage; it controls with its own companies all production phases: the polypropylene/paper film, metallization, winding,manufacturing of the finished product.

The ICAR Group has several plants, all located in Europe. The power factor correction range is made entirely in Italy.
For details on the individual families, download the full catalogs on the website, www.icar.com. Here are all equipment and the solutions ICAR proposes.

Custom components for power factor correction

MV Capacitors and banks for power factor correction

Power electronics capacitors

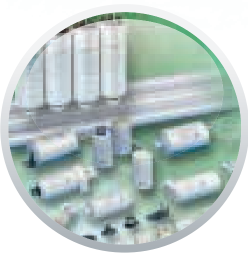
Active Harmonic Filters

LV voltage stabilizers

EMI RFI filters

Motor run capacitors

Capacitors for energy storage and discharge



Lighting capacitors

Isolation and LV/LV special transformers

ICAR Means Capacitors

CSQ

CSQ is a member of IQNet

www.imq.it

CERTIFICATO N.
CERTIFICATE N. 9170.ICAR

SI CERTIFICA CHE IL SISTEMA QUALITA' DI
WE HEREBY CERTIFY THAT THE QUALITY SYSTEM OPERATED BY

ICAR SPA
CORSO MAGENTA 65 - 20123 MILANO (MI)
UNITA' OPERATIVE
OPERATIVE UNITS
VIA ISONZO 10 - 20900 MONZA (MB)
VIA NOSEA 1/3 - 24030 VILLA D'ADDA (BG)
ROMCAP CONDENSATORI SRL
PLOIESTI IND. PARC, 100066, PIRAMIDEI N. 5 - PLOIESTI ROMANIA

E' CONFORME ALLA NORMA
IS IN COMPLIANCE WITH THE STANDARD

ISO 9001:2008

PER LE SEGUENTI ATTIVITA'
FOR THE FOLLOWING ACTIVITIES

Progettazione e costruzione di condensatori, sistemi di rifasamento e filtraggio di armoniche per bassa/media/alta tensione, trasformatori di tensione capacitivi, filtri antidisturbo, apparecchiature speciali, film metallizzato
Design and manufacture of capacitors, equipment for power factor correction and harmonic filter for low/medium/high voltage, transformer coupling capacitors, EMI filters, special equipment, metalized film

Riferirsi al manuale della qualità per l'applicabilità dei requisiti della norma ISO 9001:2008
Refer to quality manual for details of applications to ISO 9001:2008 requirements

IL PRESENTE CERTIFICATO E' SOGGETTO AL RISPETTO DEL REGOLAMENTO PER LA CERTIFICAZIONE DEI SISTEMI DI GESTIONE
THE USE AND THE VALIDITY OF THE CERTIFICATE SHALL SATISFY THE REQUIREMENTS OF THE RULES FOR CERTIFICATION OF MANAGEMENT SYSTEMS

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ACCREDIA

EA: 19

CISQ

ICAR SpA is synonym of capacitor from 1946, conjugated over its multiple applications.
All along ICAR has been believing in the quality of its products and in the strength of the International regulations for the achievements of the high performance standards required for capacitor in industrial applications.
Nowadays ICAR is one of the few companies able to manufacture capacitors starting from the raw material up to the finished product; the entire process is checked in order to obtain a product of high quality level that guarantees its functioning even in the most burdensome plant configurations.

Today ICAR produces different type of capacitors, from the lighting and single phase motor types to the ones for power electronics (electric traction, industrial services) and those of medium voltage. The various characteristics demanded to these products in terms of electric, mechanical and thermal stress, enabled to find technical solutions that have been applying in other fields with interesting results: for instance the optimization of capacitors for special applications enabled to find very strong solutions that have been then applied on power factor correction capacitors.

The production of the dielectric film (polypropylene or special paper), the metallization process, the production of the capacitor and the construction of the power factor correction banks are fully executed within companies of the Group; that guarantees the achievement of the highest quality standard weather of the metalized film or, consequently, the capacitors manufactured.
Furthermore, the know how acquired in almost 50 years of metalized film production, has enabled ICAR to realize absolute innovative products like 3Ut range of capacitors.

Used to deal with International markets ICAR faced the requests of the most strict Certification Bodies and was awarded UNI EN ISO 9001: 2008 Certification.
ICAR periodically takes part to CEI (Italian Ectrotechnical Commission) for the compilation of the product regulations, aimed at setting the objective criterions to evaluate capacitors performances and safety.
It's constantly in the vanguard and able to anticipate the regulations requirements; in order to ensure the accordance with the International regulations and the most strict customers acceptance criterions, products are submitted to tests in the internal laboratories (where it's possible to test capacitors up to 700 μF and voltage up to 80 kV) and in the greatest internationally recognized vanguard laboratories (CESI). Everything is performed for the safety of the customer who entrusted a reliable partner with a pluridecennal experience in capacitors

Medium and High Voltage Solutions

ICAR offers numerous solutions for power-factor correction and filtering of harmonics in Medium and High Voltage:

SINGLE PHASE CAPACITORS

- unit power up to 800kvar
- nominal voltages up to 36kV
- frequency of 50 or 60Hz

THREE-PHASE CAPACITORS

- nominal unit power up to 600kvar
- nominal voltages up to 24kV
- frequency of 50 or 60Hz

SPECIAL CAPACITORS FOR CUSTOMIZED APPLICATIONS, SUCH AS FOR EXAMPLE

- three-phase with neutral brought out
- split-phase capacitor
- for overvoltage protection (typically used in protection of large electrical machines)
- for applications in environments with abnormal characteristics (such as high or very low temperature, salty atmosphere, altitude above 1000 m, etc.)

MV AND HV POWER-FACTOR CORRECTION BANKS

- powers up to 100Mvar
- voltages up to 220kV
- frequency of 50 or 60Hz

TUNED CAPACITOR BANKS

- Tuned on harmonics from the 2nd to the 13th
- power up to 100Mvar
- voltage up to 150kV
- frequency of 50 or 60Hz

MV AND HV SPECIAL FILTERS

Such as high pass, second order filters with double tuning frequency, damping resistor, etc.

ICAR has over 60 years experience supply of products to industries characterized by complex power factor correction and harmonic filtering situations (steel mills, paper mills, forging, cement factories) around the world (Saudi Arabia, Russia, Hong Kong, China, Greece, France, Argentina, Brazil, etc.). ICAR solutions are proven of effectiveness, robustness and high reliability.

BIORIPHASO/TF MV Power Capacitors

GENERAL FEATURES

Capacitors of the BIORIPHASO/TF type series constitute a complete range for making of solutions for power-factor correction in MV and HV.
They are designed and manufactured using the most modern technologies: ensuring long expected life and high reliability. The BIORIPHASO/TF series is in compliance with applicable standards (IEC 60871, ANSI, IEEE 18, NEMA CP-1, etc.): they are therefore suitable for installation in any environment or conditions described in the above standards.
On request, we can, nevertheless, provide capacitors with special characteristic or tested as specified by the customer.

CLASSIFICATION

The various models are identified by

- series name
- power
- voltage
- typology
  - single-phase: with or without internal fuses, with single or double isolator;
  - three-phase: with delta or star connection with neutral brought out

EXAMPLE

BIORIPHASO/TF 200/12:
single-phase capacitor of 200kvar at 12kV

BIORIPHASO/TF 200/12/E:
as above, but with only one bushing

BIORIPHASO/TF 200/12/T:
three-phase capacitor of 200kvar at 12kV

All capacitors are uniquely identified by the relevant plate as required by the IEC Standard 60871-1:

- Name of manufacturer
- Serial number/year
- Nominal power
- Nominal voltage
- Nominal frequency
- Temperature category
- Insulation level
- Internal discharge device
- Connection symbol
- Name of the impregnating fluid
- Indication of the presence of internal fuses (if included)

CAPACITOR CONSTRUCTION

DIELECTRIC

Dielectric and electrodes constitute the most important parts of the capacitor, which determines the electrical characteristics (capacity, losses) and affects the durability and reliability over the time.

The dielectric of BIORIPHASO/TF capacitors is of the all film type, that is, it is composed of several layers of rough BOPP film (Biaxial Oriented Polypropylene) of very high quality.

ICAR has its own factory of BOPP for capacitors that allows to have complete control of the production chain.

ALUMINIUM ELECTRODES

The electrodes of BIORIPHASO/TF capacitors are made of a thin sheet of purest aluminium to ensure the best performance and greatest reliability.
The winding with the extended foils provides high withstand capacity at current peaks consequent to the transients of the capacitors switching or during the transients relating to network fluctuations. The folded edge ensures a better distribution of the electric field in these regions, providing the capacitors with higher resistance to overvoltage and to prevent the partial discharges.

IMPREGNATION OIL

BIORIPHASO/TF capacitors are vacuum impregnated with dielectric fluid and are sealed without an air head.
The oil impregnates all the individual capacitive elements of which the capacitor is composed, and it fills the entire free volume, ensuring perfect isolation and absence of partial discharges.

Special attention is paid to the various stages of treatment. Drying is carried out with the capacitor placed in a vacuum autoclave at a high temperature.
At the end of the drying process, the interior of the capacitors reaches the molecular vacuum.

BIOIL® is used for the impregnation of BIORIPHASO/TF capacitors: it is a biodegradable, environmentally friendly synthetic oil (free of PCBs and other substances harmful to the environment) and it is non-toxic. The high quality oil, produced by leading chemical companies, is further refined at ICAR through vacuum degasification chemical purification. Rigorous controls of its physical and chemical properties are made prior to impregnation.

BIORIPHASO/TF ● / ● / ●

E if single phase: with one bushing

FI with internal fuses

T three phase

rated voltage, in kV

rated power, in kvar. If Power is shown in two addends, capacitors is split phase type.

DIELECTRIC LOSSES AND TOTAL LOSSES

Dielectric losses in BIORIPHASO/TF are very low, initially below 0.07 W/kvar, reducing in less than 100 hours of work to a value in the range between 0.02 to 0.04W/kvar.
Dielectric losses must be added to those of the discharge resistances built into the capacitors.

BIORIPHASO/TF total losses, dielectric losses + loss of discharge resistance are:

- less than 0.13 W/kvar for models with discharge resistance designed to ensure a residual voltage less than at 75V within 10 minutes (IEC standards)
- less than 0.18 W/kvar for models with discharge resistance designed to ensure a residual voltage less than 50 V within 5 minutes (IEEE standards).

HOUSING

The hermetically sealed housing protects the active part (electrodes and dielectric), ensuring preservation and good function over time.

The housing of BIORIPHASO/TF capacitors is made of AISI 409 stainless steel sheet, very thick, bent and T.I.G. welded. The completely automated process guarantees the highest welding quality and thus the robustness and hermetic sealing of the capacitor.

The elasticity of the larger surfaces of the housing ensures that it follows the thermal expansion of oil due to the variation of room temperatures.
At low temperatures the elasticity of the housing must ensure that there will not be an inner depression that reduces the dielectric strength of the oil and the voltage of partial discharges.
At high temperatures, conversely, the elasticity of the housing must ensure that the internal overpressure be limited. The housing is protected with two layers of synthetic paint suitable for outdoor service and having a high mechanical strength and excellent performance in an environment polluted by industrial fumes and fog.

The blue-gray colour, RAL 7031, allows for efficient transmission heat within the environment.
For applications exposed to high solar radiation, a lighter gray colour, RAL 7035, is used which provides for an increased reflection of solar radiation, limiting internal overheating.

The housing also has two handles for lifting and fixing the capacitor. For specific needs, the positioning of the handles can be changed on request, or additional handles can be included.

BUSHING

The bushing of the BIORIPHASO/TF capacitors are made of the highest quality porcelain, brown in colour; for large lots, it is possible to provide bushing in a light gray colour, upon request.

The porcelain bushings have a high resistance to electrical arcs and to tracking (especially dangerous in highly polluted industrial environments); they are resistant to chemicals, atmospheric agents, heat, fungi and bacteria and are mechanically very robust.

The porcelain bushings are, therefore, a quality choice for BIORIPHASO/TF capacitors.
Before assembling, all the bushings are subjected to strict controls.

The bushings of standardized models are suitable for installation in places with moderate fog or industrial fumes. For exceptionally polluted (salty or desert-like environments), special bushings are provided with creepage distance of up to 31 mm/kV.

The BIORIPHASO/TF capacitors are supplied with 1 or 2 bushing; the three-phase version are with 3 bushings or 4 (in the latter case, the internal connection of the capacitor is star with neutral brought out).

DISCHARGE RESISTANCE

When the capacitors are disconnected from the network, they remain charged, and the stored energy would be fatal in case of accidental contact, so the power-factor correction capacitors have an incorporated discharge resistor which ensures capacitor discharge in a fixed time.

In accordance with IEC standards, the incorporated discharge resistor in BIORIFASO/TF series ensures a reduction of the residual voltage to 75V in less than 10 minutes.

On request, in accordance with IEEE standards, discharge resistance at 50V in less than 5 minutes can be provided.

Important Safety Notice
Notwithstanding the presence of the discharge resistor, it is mandatory to short circuit and earthing terminals of the capacitors before any possible contact or handling.
Capacitors shall be also stored with short circuited terminals.

ROUTINE TESTS, TYPE TEST AND SPECIAL TEST

ICAR subjects all BIORIPHASO/TF capacitors to all routine tests required by IEC standards 60871 and it issues relevant certificates.
The HV laboratory of ICAR is equipped to perform all routine tests, type tests and the special tests as foreseen for by IEC 60871.

- **Routine tests:**

Capacitance measurement (IEC 60871-1, art. 7)
Measurement of the tangent of the loss angle (tanδ) of test capacitor (IEC 60871-1, art. 8)
Voltage test between terminals (IEC 60871-1, art. 9)
AC voltage test between terminals and container (IEC 60871-1, art. 10)
Test of internal discharge device (IEC 60871-1, art. 11)
Sealing test (IEC 60871-1, art. 12)
Discharge test on internal fuses (IEC 60871-4, art 5.1.1)

- **Type Test**

Thermal stability test (IEC 60871-1, art. 13)
Measurement of the tangent of the loss angle (tanδ) of the capacitor at elevated temperature (IEC 60871-1, art. 14)
AC voltage test between terminals and container (IEC 60871-1, art. 15)
Lightning impulse voltage test between terminals and container (IEC 60871-1, art. 16)
Short circuit discharge test (IEC 60871-1, art. 17)
Disconnecting test on internal fuses (IEC 60871-4, art. 5.3)

- **Special tests**

Ageing test (IEC 60871-2, art. 2.1.4)
Overvoltage cycling test (IEC 60871-2, art. 2.1.3).

BIORIPHASO/TF
Single Phase

ICAR makes two types of single phase capacitors:

- without internal fuses
- with internal fuses.

MV capacitors are internally made by connecting in series a number of parallel element groups (see picture 1).
In the capacitors with internal fuses, there is a fuse in series to each element which melts and isolates the same in case of dielectric perforation: so capacitors can keep on service with a small output reduction (see picture 1).

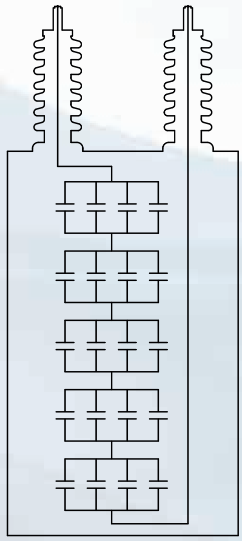
In case of capacitors without internal fuses the element perforation short circuits the entire series group at which it belongs, and the capacitors keep on service with an inner fault.
The choice of capacitors types depends on bank designer choice and on its power and rated voltage.

BIORIPHASO/TF SINGLE PHASE WITHOUT INTERNAL FUSES
Small capacitors banks (up to 600 kvar) are made with single phase capacitors without internal fuses, they are connected in delta and protected by means of HRC limiting current fuses.
Capacitors banks of higher power (from 600kvar to 1500kvar) are made up of at least six single phase capacitors or three split-phase, without internal fuses, with capacitor bank connected in insulated double star and unbalance protection.

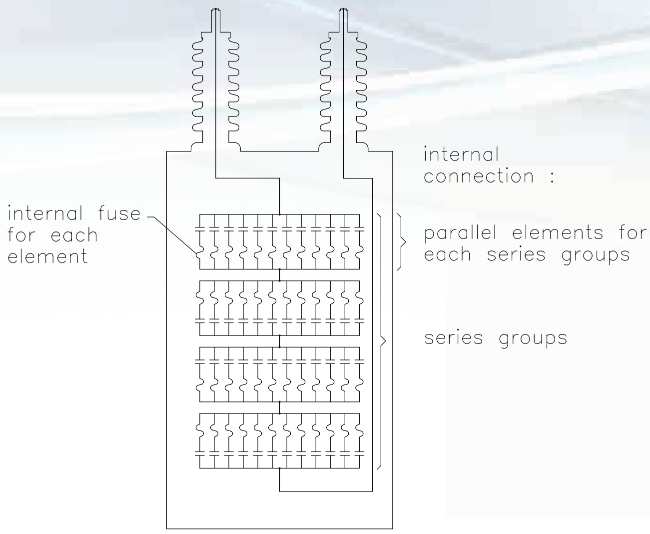
In case of capacitors without internal fuses, higher power capacitor banks use one single external expulsion fuse for each capacitor; this fuse, which is specific for power capacitors, is very easy and effective, and it allows an immediate evidence of faulty capacitor.

In these type of banks the number of capacitors is chosen so to allow the bank to keep on service even in the case one capacitor has been insulated by its fuse melting.
An unbalance protection, which works out a lower priority protection, will provide the capacitor bank disconnection after a certain number of capacitors are out of order.
Capacitors without internal fuses, which have smaller losses than those with internal fuses, are designed to lower dielectric withstand and are so much more robust and reliable.

Single phase without internal fuses capacitors are made in units of power ranging from 50 to 500 kvar, and with rated voltage from 1.5 kV to 25 kV.



Picture 1

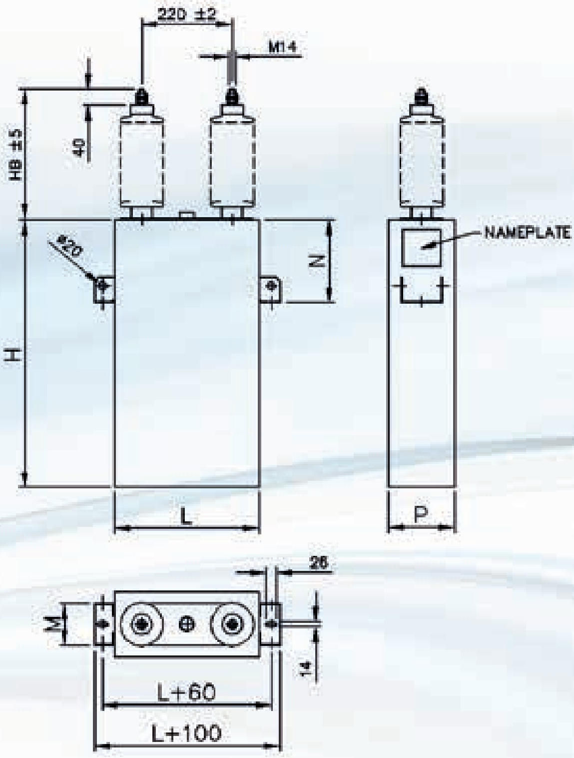


Picture 2

Power (kvar)	Voltage (kV)	Dimensions (mm) L	P	H	Bushing	N	M	Weight kg
50		350	**140**	180		170	**100**	14
100	**4.16/√3 - 4.16 6.6/√3 -6.6**	350	**140**	270		100	**100**	21
150	**10/√3**	350	**175**	310	**up to 75 kV BIL 180**	140	**100**	29
200	**10.5/√3**	350	**175**	380		140	**100**	34
250	**11/√3 15/√3**	350	**190**	420	**up to 125 kV BIL 318**	200	**165**	39
300	**20/√3 22/√3**	350	**190**	490		200	**165**	47
400	**30/√3 33/√3**	350	**190**	620		200	**165**	57
500		350	**190**	760		200	**165**	71

OPERATING CONDITIONS

- Temperature class -40/B
- Use: indoor/outdoor
- Altitude a.s.l.: 1000 m
- Frequency: 50/60 Hz

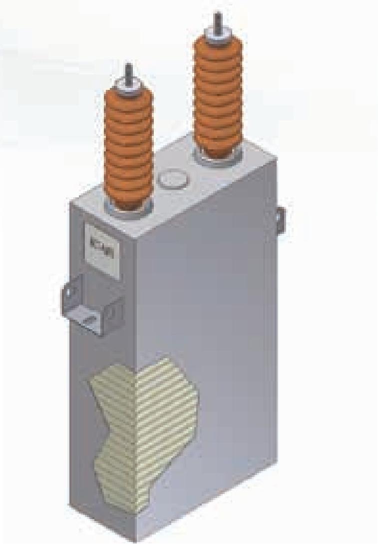


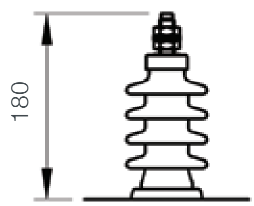
INSULATING VOLTAGES

Highest system Voltage (kV)	Short time withstand voltage (kV)	Lighting impulse voltage test (kV)
3.6	**10**	40
7.2	**20**	60
12	**28**	75
17.5	**38**	95
24	**50**	125

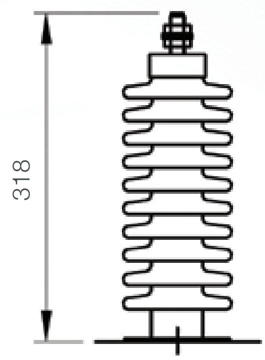
BUSHINGS

- Voltage levels: 12/28/75 kV
- Creepage distance > 255 mm
- Voltage levels: 24/50/125 kV
- Creepage distance > 600 mm
- Other voltages and powers available upon request





BIL 75 kV



BIL 125 kV

BIORIPHASO/TF SINGLE PHASE WITH INTERNAL FUSES

As mentioned earlier in these capacitors each capacitive element inside the capacitor has an internal fuse in series (see picture 2). In the event that an element has a fault, the fuse intervenes to exclude the damaged element, without removing the parallel elements from service.
The break of the fuse is very fast (tens of milliseconds) due to energy stored in parallel elements.
Doing so other protection can't operate and capacitor can stay in service with a small capacitance reduction.

The high reliability of these solutions allows to design capacitors with an higher dielectric stress and so units of reduced volume and higher reactive power per volume unity.

ICAR available capacitor range which can be equipped with internal fuses is shown in Table 2 (blue zone).
It is clear that small power capacitors and those of high voltage are excluded.
The reason of this choice are strictly related to the criterion of good design of these type of capacitors and they are briefly described below.

A well made design of internally fused capacitors requires indeed that each series group stored energy, while the sinusoidal voltage reaches its peak value, is sufficient to assure an immediate fusion of the fuses in the even of one element fault.
With a lower stored energy the fusion time would be uncertain, it would indeed happen for the capacitor current and within a time equal to several cycles of the fundamental frequency.

Each element disconnection due to its fuse melting, causes a voltage increase across the other elements of the same series group.
This voltage increase is in reverse proportion to the number of group elements.
A good internally fused capacitor design requires that the number of parallel elements is chosen to limit such rise: it is necessary at least 10 elements to ensure the voltage rise is less than 10%.
Usually the series group parallel elements are not less than 14-16.

Series group stored energy limitations and minimum number of parallel elements, along with the limitations voltage per element, lead to make not convenient to make internally fused capacitors of small power and high voltage or big power and low voltage.

Power	Voltage								
V / Q	1.9 kV	2.4 kV	3.8 kV	4 kV	5.7 kV	6.1 kV	6.6 kV	8.66 kV	11.5 kV
100-150 kvar									
150-200 kvar									
200-250 kvar									
250-300 kvar									
300-350 kvar									
350-400 kvar									
400-450 kvar									
450-500 kvar									
500-550 kvar									
550-600 kvar									

Table 2

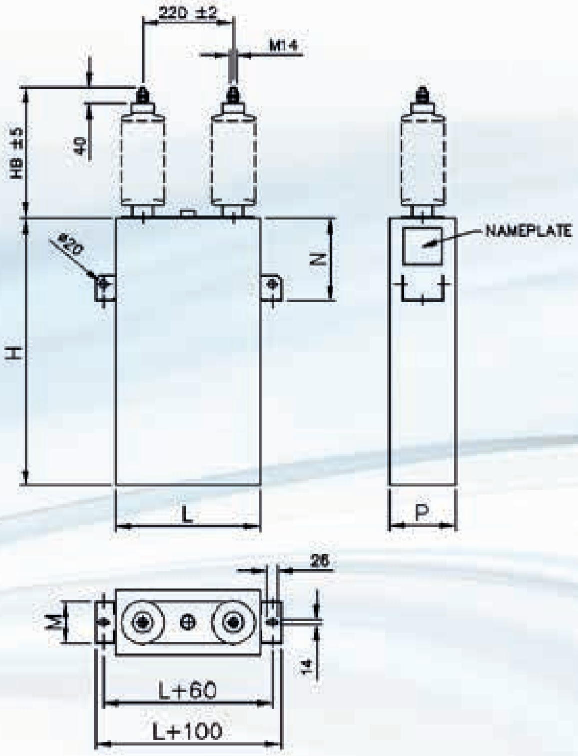
Power (kvar)	Voltage (kV)	Dimensions (mm)						Weight
		L	P	H	HB Bushing	N	M	Kg
400		350	**175**	720	**up to 75 kV BIL 180**	200	**100**	60
500	**4.16/√3 - 4.16 6.6/√3 -6.6**	350	**190**	810		200	**165**	73
600	**10/√3 10.5/√3 11/√3**	350	**190**	930	**up to 125 kV BIL 318**	200	**165**	83
700	**15/√3 20/√3**	350	**190**	1070		300	**165**	94
800		350	**205**	1100		300	**165**	106

OPERATING CONDITIONS

- Temperature class -40/B
- Use: indoor/outdoor
- Altitude a.s.l.: 1000 m
- Frequency: 50/60 Hz

INSULATING VOLTAGES

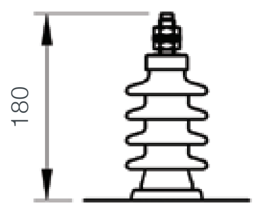
Highest system Voltage (kV)	Short time withstand voltage (kV)	Lighting impulse voltage test (kV)
3.6	**10**	40
7.2	**20**	60
12	**28**	75
17.5	**38**	95
24	**50**	125



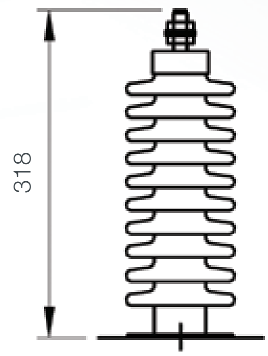
BUSHINGS

- Voltage levels: 12/28/75 kV
- Creepage distance > 255 mm
- Voltage levels: 24/50/125 kV
- Creepage distance > 600 mm

Other voltages and powers available upon request



BIL 75 kV



BIL 125 kV

Bioriphaso/TF Three-Phase

The three-phase capacitors are a simple and cheap solution to create groups of three-phase power factor up to 500 kvar. They are normally used for power factor correction of motors or no load MV/LV transformers. Inside the three-phase capacitors are composed of three single phase units connected in delta or star or star with neutral brought out.

The three-phase capacitors for voltages up to 12 kV are usually delta connected and protected with current-limiting type fuses (HRC fuses with a high switching capacity). It's important to use this type of fuses to prevent the explosion of the capacitor that in case of short circuit will absorb the phase to phase short-circuit system current. Capacitors with internal star connection or with neutral brought out are provided on request.

Power (kvar)	Voltage (kV)	Dimensions (mm)						Weight Kg
		L	P	H	HB Bushing	N	M	
100	**2,4**	450	**130**	250	**up to 60 kV BIL indoor 135**	230	**100**	21
200	**4.16 6.3**	450	**130**	390		300	**100**	33
300	**6.6 7.2**	450	**185**	390	**up to 75 kV BIL indoor outdoor 180**	300	**165**	45
400	**10 10.5**	450	**185**	500		340	**165**	56
500	**11 12**	450	**185**	610		340	**165**	69

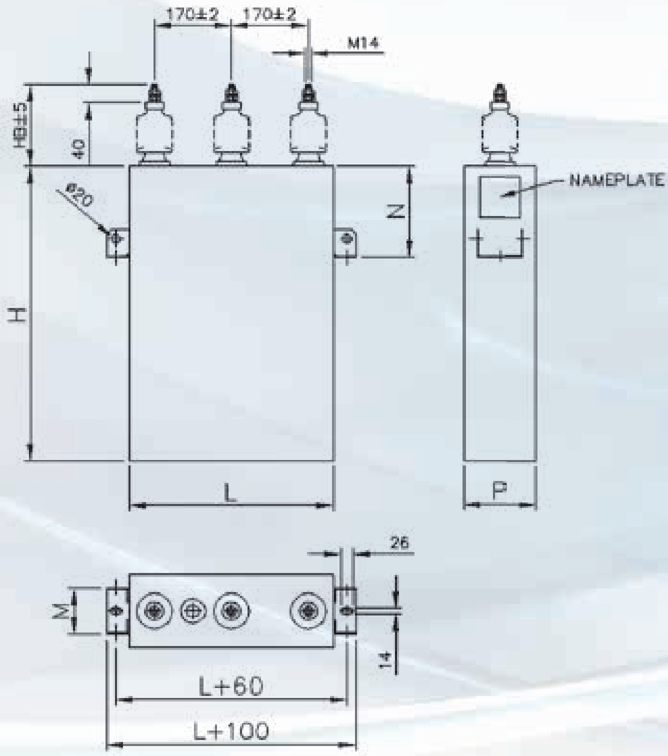
OPERATING CONDITIONS

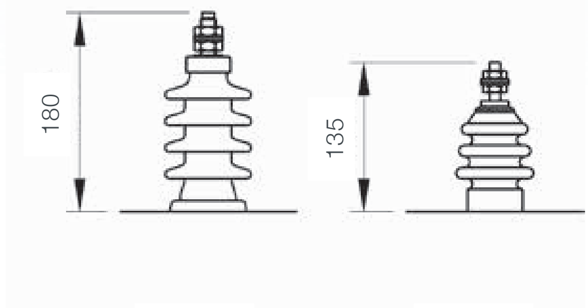
- Temperature class -40/B
- Use: indoor/outdoor
- Altitude a.s.l.: 1000 m
- Frequency: 50/60 Hz

BUSHINGS

- indoor
- Voltage levels: 7.2/20/60 kV
- Creepage distance > 135 mm
- indoor/outdoor
- Voltage levels: 12/28/75 kV
- Creepage distance > 255 mm

Other voltages and powers available upon request





outdoor
BIL 75 kV

indoor
BIL 60 kV

Capacitor Banks

ICAR proposes Medium Voltage capacitor banks by assembling BIORIPHASO/TF capacitors along with other components in order to make integrated and completed solutions.
Capacitor banks can be suitable for indoor or outdoor use, with damping reactors, tuned or detuned reactors for harmonic blocking or absorption.
The most adopted scheme is double insulated star with unbalance protection between the two stars; which allows to spot a single capacitor fault.

The bank, depending on type of capacitor, could be also equipped with the following protection means:

- Expulsion or HRC fuses
- Capacitor inner fuses

DAMPING REACTORS

Transient overcurrents of high amplitude and high frequency may occur when capacitors are switched on and especially when a step of a capacitor bank is switched in parallel with other steps which are already energized.

The peak value of the inrush current should be limited to a maximum of 100 times the r.m.s. value (see IEC 60871-1).

For MV or HV capacitor banks when the natural values of the inductance of the network, in the case of a single bank, or inductance between the batteries in the case of multiple batteries in parallel, is not sufficient to limit the inrush current, damping reactors are installed in series with the capacitor banks that aim to limit this current.

The reactors are installed directly on the capacitor bank and remain in service throughout the operating time of capacitor banks.

The damping reactors are made of an air core, dry insulation and winding copper or aluminum.
The design of the damping reactor must consider both, the maximum continuous current as well as the inrush current and its frequency.

An accurate assessment of the switching on transient is necessary for the correct sizing of the reactor and its internal insulation (insulation between turns).

Because the damping reactors are air core, during the installation of the capacitor bank the isolation distances and the magnetic distances from metal and from closed turns must be respected.

HARMONIC DETUNED AND TUNED FILTERS

DETUNED CAPACITOR BANKS

In case of capacitor banks to be installed inside harmonic current polluted networks, which are generated by no linear loads such as frequency converters, drivers a specific study of the network impedance should be done at the point of capacitor bank connection.
The switching of a capacitor bank can indeed trip resonance phenomenon which amplifies harmonic currents and generates overloads and higher distortions.

In the simpler case of a shunted capacitor bank, which is in parallel to harmonic current generating loads, the parallel resonance frequency between the capacitor bank capacitance and the line inductance could be close to the several harmonic current frequency and so to magnify them and to over charge both the distribution transformer and the capacitor bank itself, further than lead to a very high distortion of the voltage waveform that could compromise the proper working of all other electrical devices which are wired to the same distribution system.

Whenever harmonic generating loads are a small part of the whole and harmonic absorption filters are not required, detuned capacitor banks are used; they are made up of pure capacitor banks which are in series to properly sized reactors to generate low pass filter having a detuning frequency which is below the lower existing harmonic current frequency.
This way the bank behaves as a pure capacitor below such frequency and as a pure reactor above such frequency.

The resonance parallel frequency is so shifted below all no-linear loads generated harmonic current frequencies and any amplification phenomenon is avoided.
While the detuned capacitor bank will be working at a frequency above the blocking, it will turn to be as big impedance and the load generated harmonic currents will partially flow either on the mains or inside the capacitor banks, depending on the specific frequency.
For capacitor bank power lower than 1-2 MVAR capacitor bank absorbed harmonic currents are small, the higher the capacitor bank reactive power the bigger the capacitor bank absorbed harmonic currents is; for big banks the absorbed fifth harmonic current by a 4,1 times the fundamental detuned bank might reach as much as 40-50% of the no linear load absorbed currents, which turns the detuned filter a low efficiency absorption filter.

In MV networks the most common detuning frequency is 4,1 times the 50Hz or 60Hz fundamental frequency (XL%=6%), or seldom 3.8 (XL%=7%) or 2.8 (XL%=13%).

As far as small capacitor banks are concerned, iron multiair gaps linearized core reactors are recommended.
On the contrary for higher power capacitor banks air core reactors are more adequate.
At capacitor bank design a higher actual voltage level shall be considered, this is for the series reactors voltage increased effect and for the absorbed harmonic current contribution (see IEC 60871-1 appendix B).

TUNED FILTERS

As far as harmonic generating loads are prevailing among the others, typically in plants such as steel mills, arc furnaces, it is likely that substantial current and voltage harmonic pollution levels are flowing through the network, and so it turns to be required to adopt harmonic absorption filters to reduce such distortions and to compensate for the most relevant harmonics.

MV harmonic absorption filters are of passive type, and they are made by capacitor banks which are wired in series to properly design reactor to create absorption targeted harmonic resonance circuits.

Below the tuning frequency the filter capacitor bank behaves as capacitor and it cater for power factor correction as well. At the tuning frequency the capacitive reactance and the inductive reactance are mutually compensated and the cap bank impedance is made by the resistive part only, so it becomes a low impendence path for the harmonic current to be erased.

Above the tuning frequency the inductive reactance will prevail and the filter will be an inductance.

Tuned harmonic filters shall always be tuned to the lower harmonic current present, in other words, if the aim is to reduce or erase a determined harmonic current, lower frequency harmonics shall be compensated as well, otherwise they would be amplified by the parallel resonance between network impendence and filters of higher order.

For example if in a plant 5, 7, 11, 13 harmonic currents are found, even if the 11th would be the most relevant, it wouldn’t be enough to install 11th harmonic filter, but 5th and 7th harmonic filter shall be there as well.

In special cases also attenuating filters and high pass filters are used.

MV tuned filter reactors are generally air core and the most disadvantageous and heavy harmonic conditions load shall be considered at their design stage.

At capacitor bank design a higher actual voltage level shall be considered, this is for the series reactors voltage increased effect and for the absorbed harmonic current contribution (see IEC 60871-1 appendix B).

UNBALANCE PROTECTION

Capacitor banks are usually protected by means of unbalance protection which ensures the phase balance.

The most common protection scheme foresee an insulated double star capacitor bank connection, where the two start points are connected via an unbalance protection CT which supplies secondary current to an homopolar over current relay.

In normal working conditions star points are balanced and no current flows into the CT. As soon as one capacitor is faulty, its star becomes unbalanced and an unbalance current flows into the CT.

In fact CT connection between the two star points, ensure their equipontential status, hence if any of the two stars is unbalanced a homopolar current is generates and it closes the loop through the CT.

OPEN RACK BANKS

They are made of capacitors which are mounted on hot deep galvanized steel rack; they are usually complete of aluminum connecting banks, unbalance protection CT, stacking insulators, damping resistors and expulsion fuses. ICAR designs, manufactures and delivers complete open rack banks suitable for network voltage from 1 kV to 220 kV and power up to 100 Mvar.

Metal Enclosed Capacitor Banks

ICAR proposes metal enclosed capacitors banks in many different versions (fixed or automatic, with damping, blocking and absorbtion reactors).

FIX CAPACITOR BANKS (WITH OR WITHOUT MAIN BREAKER)

The fix banks are mainly adopted for the compensation of steady loads or for fixed portions of the plant required reactive power.

Typical example of the first case is compensation of large MV motors, which are used for large pumping stations, cement or chemical plants.
In this case the bank is placed close to the motor and it is wired downstream its main Circuit Breaker, so it is switched on and off along with its motor (for this connecting scheme see Technical Remarks within this catalogue).

In the second case the capacitor bank is directly connect to the distribution system bus bars.
Typical scheme of these capacitor banks is as follows:

Incoming Compartment can be equipped with options:

- Bus bars only and earthing switch (for the safety earthing of the cap bank and so to make inspection and maintenance
- inside the cell).
- no load line disconnector, earth switch;
- line disconnector or fixed CB;
- withdrawable CB;

Capacitor Step Compartment:

- Capacitors and Unbalance CT;
- Damping reactors, Capacitors and Unbalance CT;
- Blocking reactors, Capacitors and Unbalance CT;

For small power banks more essential solution may be provided, such as a single compartment with Incoming busbars, HRC current liming fuses, three phase delta connection capacitors, earthing switch.
Fixed enclosed capacitor banks are available as standard for power up to 5 MVAR and voltage up to 12 kV, both for indoor and outdoor use.

AUTOMATIC CAPACITOR BANKS

These types of MV banks are normally divided in two or three steps of regulation of the total reactive bank power and they are operated automatically by a power factor correction controller.
Each single step is switched by MV vacuum contactors.

Typical scheme of these capacitor banks is as follows:
Incoming Compartment can be equipped with options:

- bus bars only;
- no load line disconnector;
- line disconnector or fixed circuit breaker;
- withdrawable circuit breaker;

Capacitor step compartment:

- MV vacuum contactor with HRC current limiting fuses;
- Damping or blocking reactors;
- Fast discharge resistors;
- Capacitors;
- Unbalance protection CT;
- Each step earthing switch.

In order to reduce dimensions of these banks, withdrawable vacuum contactor solutions are also available.
These contactor metal clad cells are placed in the upper part of the compartment.
This solution perfectly segregates the capacitor bank compartment while the contactor is withdrawn, and it is so possible to make step maintenance while the others are live.
As option, each capacitor bank step can be equipped with a harmonic overload protection, which is made up of a high current three phase relay integrated inside a multifunction protection relay, along with unbalance protection function.
Automatic capacitor banks are available as standard for power up to 5 MVAR and voltage up to 12 kV, both for indoor and outdoor use, and steps from 500kvar to 2000 kvar.

Technical Remarks

VOLTAGE

Nominal voltage of a capacitor is the value of the alternating voltage for which the capacitor has been designed and that test voltage are referred. The proper and safe use of power capacitors impose that working voltage does not overcome nominal voltage.
In special and particular conditions, capacitor units shall be suitable for operation at voltage levels according to table below (long lasting voltage levels, extract of IEC 60871-1).

TYPE	Voltage Factor x Un	Max duration	Remarks
Rated frequ.	**1**	Continue	Highest average value during any period of capacitor energization
Rated frequ.	**1.1**	12 h every 24 h	System voltage regulation and fluctuations
Rated frequ.	**1.15**	30 min every 24 h	System voltage regulation and fluctuations
Rated frequ.	**1.2**	5 min	Voltage rise at light load
Rated frequ.	**1.3**	1 min	

In any case capacitors and other power factor correction devices while they are working in overload leads to a reduction of their expected life. Nominal voltage choice is then influenced by the following facts:

- On some networks working voltage could be very different
- from nominal voltage
- Power factor correction equipment in parallel could cause an
- increase of the voltage at the connection point
- The voltage increases with the presence of harmonics on the
- network and/or cosδ of in advance (leading).
- Voltage at capacitor terminals is likely to be especially high
- Under low-load conditions.

When a capacitor is permanently connected to a motor, difficulties may arise after disconnecting the motor from the supply.
The motor, while still rotating, may act as a generator by self-excitation and may give cause to voltages considerably in excess of the system voltage. This, however, can usually be prevented by ensuring that the capacitor current is less than the no-load magnetizing current of the motor; a value of about 90 % is suggested. As a precaution, live parts of a motor to which a capacitor is permanently connected should not be handled before the motor stops.

WORKING TEMPERATURE

Working temperature of capacitor is a fundamental parameter for safe operation. As a consequence it is very important that heat generated is dissipated correctly and that the ventilation is such that the heat losses in the capacitors do not exceed the ambient temperature limits. The capacitor temperature must not exceed the temperature limits hereinafter tabled. Ambient air temperature categories (60871-1) The lower ambient air temperature at which the capacitor may be operated should be chosen from the five preferred values +5 -5 -25 -40 -50 °C.

AMBIENT TEMPERATURE °C

Symbol	Max value	Highest mean over any period of 24 h	1 year
A	**40**	30	20
B	**45**	35	25
C	**50**	40	30
D	**55**	45	35

Safety and Storage Instructions

CAPACITOR DISPOSAL

The capacitor and its impregnant oil should be disposed of in a manner consistent with the laws in force in the country where they are installed.
Loss of the impregnant in the environment should be avoided or minimized. Consult the Material Safety Data Sheet for further information.

SAFETY INSTRUCTIONS

Power must be switched off before doing any work on capacitors or equipments and accidental access has to be prevented.
To be certain that the capacitors have been disconnected from the power source, it is necessary to make a visual check for an open-contact disconnect.

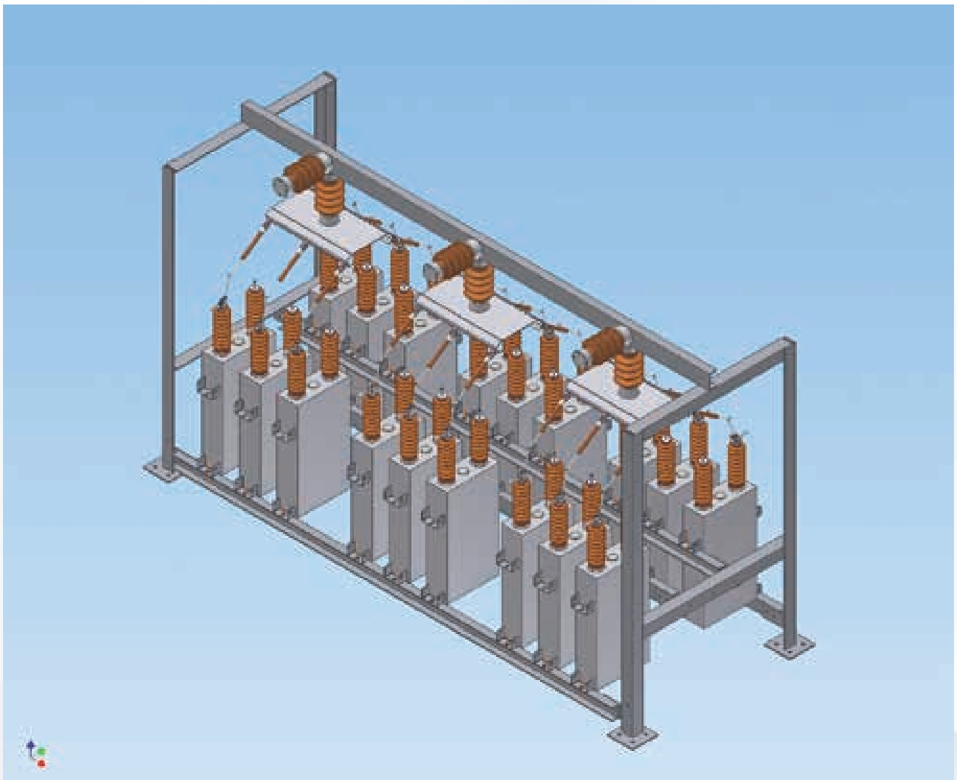
After being disconnected, the capacitors or equipment should then be shorted and grounded.
The capacitors have built-in discharge resistors which are designed to reduce the voltage, after the power is switched off, to 75 Vdc or less in 10 minutes.
After the indicated time, the capacitors or equipment should be shorted and grounded by utilizing and insulated grounding stick or equivalent and then the capacitor terminals should be connected together and to the case and grounded before handling.

Remove the shorting connection only just before the unit is reconnected in the circuit.
A failed capacitor should be handled very carefully.
It should be shorted with suitable insulated shorting sticks to discharge any residual charge.

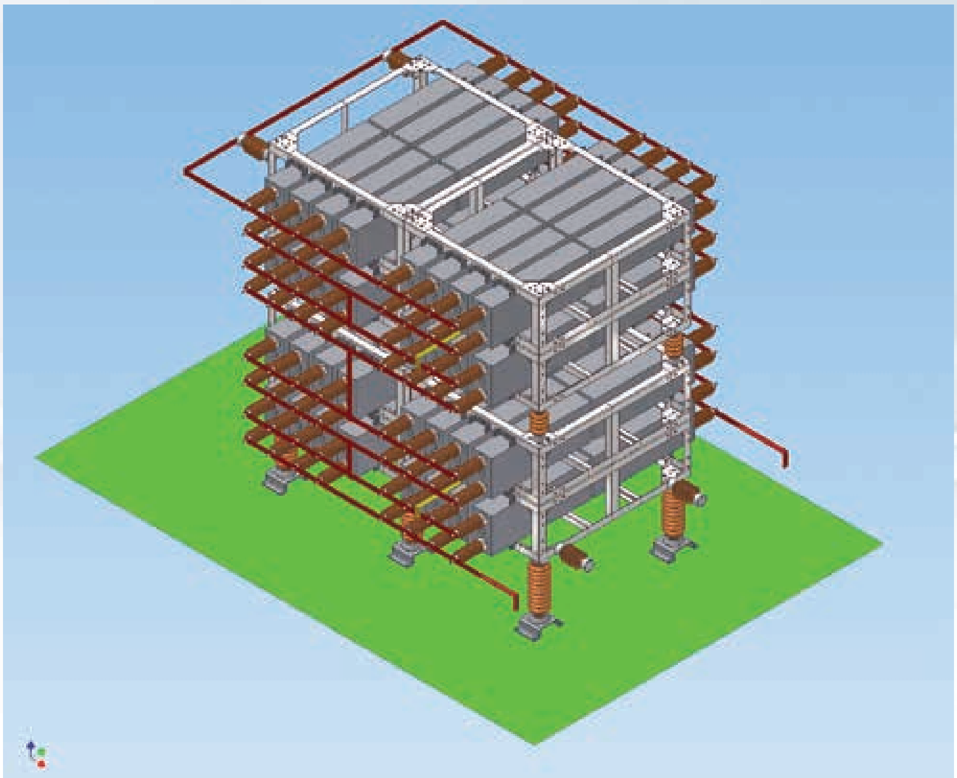
Particular attention has to be paid to the internal pressure from gassing, which is reduced if the capacitor is permitted to cool before handling. In handling capacitors which have liquid leaking out, avoid contact with the skin and prevent entry into sensitive areas such as the eyes.
Close-fitting protecting gogglesshould be worn when handling units which are leaking or might suddenly squirt impregnant while being handled.
Contact with the skin is taken care of by simply washing off thoroughly with soap and water as soon as possible.
The eyes can be quite irritated by the impragnant and so they should be flushed with large amounts of water as soon as possible and the examined by a physician.

STORAGE

Power must be switched off before doing any work on Capacitors can be stored at temperatures between –40°C and +75°C and they are not affected by humidity variation.
Take care of the terminals by protecting them against accidental impacts which might damage them.
Shelter the capacitors from dust and aggressive or polluting substances.



Icar Technical department is ready to support customers in design the most apropriéted capacitor bank and harmonic filters for their needs.



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