CRT self healing metalized polypropylene film capacitor for power factor correction

INSTALLATION AND MAINTENANCE INSTRUCTION

INDEX

1. INTRODUCTION

The purpose of this document is to give the users the instructions regarding the correct conditions to use CRT capacitors, banks and equipment for power-factor correction applications, in order to prevent damage to persons and/or goods due to improper use.
The energy stored in a capacitor may be lethal. Personal injury or property damage may result from the capacitor disruption and the consequent expulsion of flammable melted material.

Read this first
Before using the capacitors in any application, please read carefully the information contained in this document.

For your safety
Special attention must be taken to make sure the capacitors are correctly used for each applications and that the followings instructions are strictly attended. Disregarding the guide line given in this manual may result in operational failur bursting and fire. In case of doubt contact ICAR tech. Dept.

2. RECOMMENDATION FOR INSTALLATION

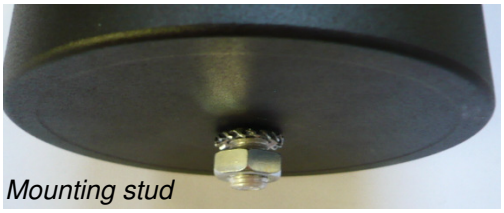
2.1 General requirements

- Safety is defined as the absence of hazard for persons and goods when the apparatus is in service or in storage. This means identify and eliminate any stress, danger and damage which can bring the hazard level to an unacceptable value.
- Maintain good and effective grounding of the capacitor metallic case.
- Handle capacitor units carefully. They may be charged even after disconnection due to faulty discharging devices.
- Foreseen in your application means to isolate any faulty unit or banks.
- CRT capacitors and banks shall not be used for any other purposes than power-factor correction in indoor A.C. systems.

  Note: the use of a capacitor not only for power-factor correction, but also for example as a filter component, shall be specifically agreed with the manufacturer.
- The purpose of the methods and tests defined in the current IEC reference standard for power factor correction capacitors is to verify the design and construction from the point of view of the safety and quality. They shall not be considered as an indication that the capacitor is suitable for service under conditions that are equivalent to the test conditions.
- The user shall be sure that the capacitor's voltage and frequency rating is suitable for the system where it is installed.
- The user shall be sure that CRT capacitors are installed in accordance to the specification defined in this manual and in the catalogue.
- CRT capacitors shall not be exposed to chemical or flora and/or fauna attack.
- CRT capacitors shall be adequately protected against mechanical damage under normal operation or during installation. Any capacitor that for any reason is electrically or mechanically damaged (for example during the transport, storage or mounting), has not to be used and must be immediately removed from the service.

2.2 Fixing and connections

CRT capacitors shall be mounted using the threaded stud on the bottom of the case (suggested torque 10 Nm.). For mounting positions refer to paragraph 4.3.

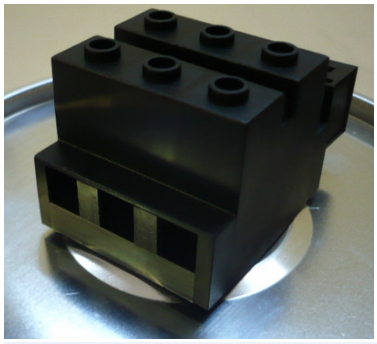

Mounting stud

At the necessary clearance shall be add 15mm to take into account the elongation of the case after the overpressure disconnector release. It is necessary a free space of about 20 mm between one capacitor to the next one in order to improve the cooling (see also paragraph 4.3).

In the CRT catalogue, is specified the recommended cross section of the connecting cables. Two kind of terminals are available: screws or terminal board. The suggested tightening torque is 3 Nm. With screws terminals, two antagonist spanners shall be used.
Prior to start up, check the terminal connections for tightness.

Connection cable must be of flexible type and material should be preferably copper. Do not use solid core cable otherwise the overpressure disconnector will be disabled.

Maximum cable cross section and terminal type:



- CRT-E
  Terminals type: terminals board
  - Capacitor diameter ≥ 85 mm : 25mm^2
  - Capacitor diameter = 75 mm : 16 mm^2

- CRT-56V and CRT 66V
  Terminals type: screw terminals
  - Capacitor diameter 55 mm: screws M6
  - Capacitor diameter 65 mm: screws M6

2.3 Switching and protection device

We strongly recommend the capacitor switching by use of specific capacitive contactors with pre-insertion resistors (see paragraph 4.2). The switching and the protection devices shall be dimensioned for the specified capacitive current (at least 1.5 times the rated one), insertion transients and number of operations. No rebound effect and re-striking phenomena shall occur during the capacitor's switching.

2.4 Protection of persons and environment

CRT capacitors are made with polypropylene film and are filled with resin. Even when a fire does not start in the capacitors, it may spread on it depending on its position. Under these circumstances, the capacitor's materials might release fumes and inflammable gases. For these reason, the installation of a capacitor in an ambient without air exchange shall be avoided.
Installation shall be carried out in such a way that the fire and fumes cannot spread outdoor. When hazardous explosive or flammable atmospheres are or might be presents, refer to the relevant IEC standard "Electric installations in environments with explosion or fire hazards".

2.5 Hazards for persons

When CRT capacitors and banks are installed, any live part shall be suitably protected against accidental contact as specified in the relevant IEC standards.
To prevent damage to people and goods due to improper usage and / or capacitor application, the "RECOMMENDATION FOR THE SAFE USE OF STATIC CAPACITORS, BANKS AND EQUIPMENT FOR POWER FACTOR CORRECTION" published by ANIE shall to be strictly respected.
ICAR is not responsible for any kind of possible damage occurred to people and goods originated from the improper installation and application of power factor correction capacitors.

3. PROTECTIONS

CRT capacitors and banks shall always be protected against any possible short-circuits. Fuses and overcurrents protections are especially effective.

3.1 Fuses

The presence of overpressure disconnector in the capacitor shall not be considered as a substitute for external protection fuses or switches, which are always needed and shall be adequately selective.

3.2 Overpressure disconnector

CRT capacitors are equipped with a built in mechanical protection device, activated by internal overpressure, that disconnect the units at the end of the life. If several internal electric breakdowns occur at the end of life or as the result of thermal or electric overload (within IEC 60831 limits) the generation of gas causes the pressure inside the capacitor case to rise. The internal pressure causes a change in the length of the capacitor. Expansion beyond a certain degree will tear of the internal wire disconnecting the capacitor from the line

To ensure full functionality of the overpressure disconnector, respect the following requirements:

- the elastic metal top lid and terminals must not be impaired
- connecting cable must be flexible
- sufficient space for expansion above the connection must be left
- the folded edge of the top lid must not be retain by clamps
- maximum allowed fault current of 10kA must not be exceeded (UL 810 standard)
- stress applied to the capacitor must be within IEC 60831 standard limits.

4. LIMIT CONDITIONS

The influence of each factors here below shall not be considered by itself but concurrent with the other factors.

4.1 Voltage

The rated voltage of a capacitor is the reference voltage at which the capacitor is designed.
A capacitor's safe operation requires the operating voltage not to exceed the rated one. However, under special conditions overvoltages within the limits defined in Appendix 1 are admitted. In any case, it shall be kept in mind that any overloading condition reduces the capacitor's lifetime.
The capacitor's rated voltage shall be selected taking the following considerations into account:

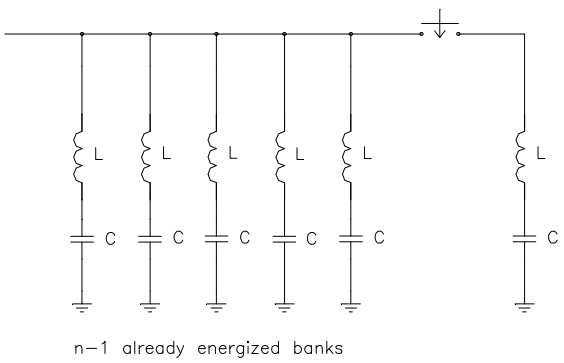
- In some systems, the difference between the operating voltage and rated one may be significant.
- Shunt connected capacitors for power-factor correction application may produce voltage increase where they are installed.
- Further voltage increase may be originated by the presence of harmonics.
- Voltage at the capacitor terminals is likely to be especially high under low load conditions (for example during the night).
- Voltage at the capacitor terminals increases when an inductor is series-connected to the capacitor to limit the harmonics effect.
- When a capacitor is permanently connected to a motor, some overvoltages may occur when the motor is disconnected. The motor revolves by inertia and may operate as a self-excited generator resulting in overvoltages higher than the system's voltage.
- The residual voltage due to self-excitation after the disconnection is especially harmful for induction generators and motors equipped with a no-voltage safety brake (e.g. motors of lifting gear).
- When a capacitor is connected to a delta/star motor start device, it shall be arranged in such a way that no overvoltages occur when the device is operating. Capacitors have to be connected at the end of the operation. The same consideration apply with an electronic start.
- Capacitors that are exposed to overvoltages due to atmospheric discharges shall be properly protected. When overvoltage arresters are used, they shall be located as close as possible to the capacitors.

4.2 Current

The capacitor's rated current is the reference current for which the capacitor has been designed. The current in the capacitor may be higher than the rated one because of the presence of harmonics or higher voltage than the rated one. In no case, the RMS current in the capacitor shall be higher than 1.3 times the current absorbed under rated voltage and frequency, transients excluded. In presence of harmonics, the lifetime expectancy is reduced.

4.2.1 Inrush current limitation

The peak value of the current due to the capacitor insertions shall be limited to a maximum of one hundred times the rated RMS current otherwise this may cause additional stress to contactors as well as to capacitors and reduce their life cycle. This limitation may be obtained by a resistors or an inductors in series to the bank.
We strongly recommend the capacitor switching by use of contactors with pre-insertion resistors (suggested value 1Ω).
If contactors with pre-insertion resistors are not available, there is an easy formula in order to calculate the switching reactor value in case of the insertion of capacitors banks with the same rated power in an ac power system:



$$L = \frac{V_n^2 \cdot 1000}{2 \cdot \pi \cdot F \cdot Q_{Tot}} \cdot \frac{(n-1)^2}{n} \cdot \frac{1}{k^2} \qquad k = \frac{I_s}{\sqrt{2} \cdot I_n}$$

L = inductance to be connected on each phase of the step (μH);
U = phase to phase voltage (V);
F = rated frequency (Hz);
Q = total output of the capacitors bank (kVAr);
n = number of equal steps

Example n°1
200kvar, 400V power factor correction bank with 4 step of 50kvar each.
Considering I_s/I_n=100 and applying the previous formula, we obtain:

$$L = \frac{400^2 \cdot 1000}{2 \cdot \pi \cdot 50 \cdot 200} \cdot \frac{(4-1)^2}{4} \cdot \frac{1}{\left(\frac{100}{\sqrt{2}}\right)^2} = 1.15 \mu H$$

The calculated value represents the minimum value to limit inrush currents

Example n°2:
275kvar, 400V power factor correction bank with 4 step of 25-50-100-100kvar each.
The inductance value for the smallest step considering I_s/I_n=100 is:

$$n = \frac{275}{25} = 11 \qquad L = \frac{400^2 \cdot 1000}{2 \cdot \pi \cdot 50 \cdot 275} \cdot \frac{(11-1)^2}{11} \cdot \frac{1}{\left(\frac{100}{\sqrt{2}}\right)^2} = 3.37 \mu H$$

The inductance value for the 50kvar step is $L = \frac{3.37}{2} = 1.68 \mu H$

The inductance value for the 100kvar step is $L = \frac{3.37}{4} = 0.84 \mu H$

The calculated value represent the minimum value to limit inrush currents.

4.2.2 Overcurrent

In order to evaluate the presence of overcurrents in a capacitor, the following items shall be considered:

- in an electric system, harmonics* result from the operation of electric loads with non linear voltage-current characteristics. Main non linear loads are power electronic equipment (converters, drives), welding machines, arc furnaces, uninterruptible power supply (UPS) and transformers / reactors with saturated cores

- the increase in the line voltage is exalted by the capacitors presence. The transformer core saturation may generate voltage and harmonic currents that seriously may damage cables and transformers. For this reason, the capacitors shall not be left inserted when power-factor correction is not needed.

- when harmonics are present, one of them may be amplified by a resonance between the capacitors and the supply lines. The originated overcurrents can be harmful for the capacitors and for the entire system. Installation of capacitors shall have to be performed in such a way that any dangerous phenomena due to harmonics is avoided. In these situations, suitable inductors shall be series connected to prevent the resonance. As the voltage will consequently increases, the capacitors may be not more suitable for the application.

The cables cross section connecting the capacitors and banks, shall be sizing for at least 1.5 times the rated current. In no case, the heating generated by the cables shall significantly overheats the capacitor terminals.

* Harmonics are voltages and currents with frequency that differ from a 50Hz or 60Hz power supply frequency.

4.3 Temperature

The operating temperature is the main stress factors for polypropylene capacitors strongly influencing their useful life expectancy. So it must be considered as the major parameter for the safe operation of power-factor correction capacitors.
Therefore, the capacitors units or bank shall be installed in such a way that:

- adequate convective and radiating dissipation of the generated heating is assured.
- when installed inside a cabinet they should be placed on the bottom in order to ensure the lowest stress temperature possible.
- avoid vicinity to objects that radiate heat such as filter or detuning reactors, furnaces or direct sun light.
- if reactors are used in the application note that they operate at a much higher temperature than that of a capacitor. Distance between reactors and capacitors must be long enough to avoid that reactor heat conducted via the connection cable to the capacitor or that radiated heat from the reactors to the capacitor causes overheating.
- the capacitors banks, shall be ventilated in a way that depending on the capacitor's climatic category, the cooling air temperature shall never exceed the limits indicated in Appendix 2. If these limits are not satisfied, forced cooling with adequate air temperature becomes indispensable.
- for cooling reason CRT capacitors with rated reactive power higher than 30 kvar shall be mounted only in the vertical position. Otherwise, if not possible, thermal test shall be performed in order to verify if the temperatures are within ICAR design limit.
  CRT capacitor with rated reactive power lower than 30kvar may be mounted in the vertical or horizontal position. Maximum hot spot temperature should be anyway within ICAR design limit.

To check the capacitor's thermal conditions in service, the air temperature shall be measured at steady state at the hottest spot between two capacitors. When only one capacitor is installed, the cooling air temperature shall be measured at 2/3 of its height above the base and at 0.1m distance towards outside.

4.4 Mechanical stresses

Capacitors shall not be subjected to excessive mechanical stress:

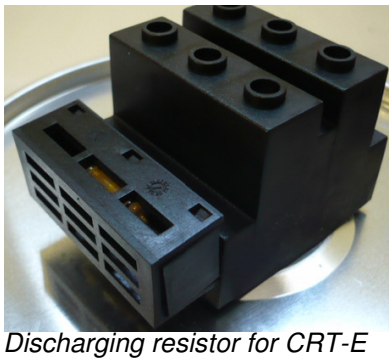
- during the cables connections, the terminals shall not be tightened to a greater torque than specified.
- during the cable connection avoid pronounced bending of cables or cable lugs or the use of other forms of mechanical forces on the terminals.
- care is required in the electrical and geometrical sizing of the connections to prevent mechanical stress due to temperature changes.

Excessive mechanical stress could compromise the overpressure disconnector functionality.

5. OTHER SAFETY CONDITIONS

5.1 Discharging device

Each capacitor shall be equipped with a device that discharges the unit within 3 minutes from the initial peak voltage of $\sqrt{2} \cdot U_N$ to 75 V. No switches, fuses or other breakers shall be inserted between the capacitor and the discharging device. The user is in any case obliged to short-circuit and earthed the terminals before handling a capacitor.
In an automatic power factor correction bank, the user shall verify that the discharging device is appropriate with the re-connection time of the bank. The switching of a capacitor bank in parallel with energized capacitors produce extremely high inrush current and voltage transient. For this reason, it is extremely important to wait for the unit discharge before a new switching.


Discharging resistor for CRT-E

- CRT-E : discharge resistor are mounted on the terminal board
- CRT-56V and CRT 66V : discharge resistor are mounted inside the capacitor case

5.2 Residual voltage

When the capacitor is energized, the residual voltage shall not exceed 10% of the rated one. The user shall verify the capacitors are automatically switched on / off in accordance with this requirement.

5.3 Ground connection

To maintain the case at fixed potential and allows in case of discharge, the conduction of the fault current towards the case, the capacitor is equipped with a ground terminal for fixing (M12 stud on the bottom of the case) capable to withstand the fault current limited by fuses. Connect the bottom stud to the ground by cable, or by any other conductive frame which is connected to the ground. If grounding is done via the metal frame the capacitor is mounted to, any layer of varnish or lacquer beneath the washer and nut must be removed

5.4 Altitude

The maximum permissible altitude is 2000 m above sea level. In case of doubt, please contact ICAR technical department.

5.5 **Special environmental conditions**

The CRT capacitors are not suitable for installation in ambient where the following conditions occur:

- Relative humidity higher than 95%. Condensation is not permitted;
- Altitude higher than 2000m above sea level;
- Rapid mould growth;
- Corrosive/saline atmosphere, especially where chloride gas, sulfide gas, acid, alkali, salt or the like are present (factory by the sea, chemical and tannery factories …);
- High dust concentration (paper and textile factory…);
- Presence of explosive or high flammable materials (power factor correction banks installed in a mine, silo..);
- Atmospheric pollution. Capacitors are not suitable for outdoor use;
- Vibration. Capacitors are not suitable for railways application and can not be mounted on board of mobile equipment.

7. MAINTENANCE

Before any operation, disconnect the capacitor or the bank, wait 5 minutes, short-circuit and earth the terminals. Do not touch any capacitor terminals if not short circuited and earthed in advance.

Periodical checks and inspections are required to ensure reliable operations: disregarding the following basic maintenance rules may result in severe operation, bursting and fire.

- Two weeks after installation
  - check the tightness of the connection and terminals. This operation is always required before the start up.
- Once a month
  - clean the bushings and terminal boards to avoid short circuit due to dust or contaminants.
  - check the tightness of the connection and terminals;
  - perform a visual inspection in order to check mechanical deformation
  - check ambient temperature of the cabinet where the capacitors are installed. An increase of temperature could be an indication of reduced efficiency of the cooling systems due to dust and other contaminants.
- Once a 6 months
  - check the surface temperature of energized capacitors. In case of excessive temperature is recommended to replace the capacitor. This could be due to an increase of loss angle which is an indication of reached end of life.
  - Perform a current measurement, by means of a true effective rms meter or an harmonic analyser, and compare with nominal current. In case of current above nominal value check your application-systems for modification.
  - In case of an increase of harmonics due to an increased use of non linear load, the installation of detuning reactors must be considered.
  - Check the functionality of discharge resistors: switching off the capacitors and measuring the voltage between terminals. Within 3 min the voltage must be less than 75V.

A more thorough maintenance schedule has to be established according to the specific operating conditions. For instance, in a polluted environment cleaning may be more frequently necessary.

6. STORAGE AND HANDLING

- Move packed capacitors with care, especially when using a fork lift truck.
- Do not strain the insulators or the terminal board. The capacitors shall be stored indoors packed.
- Do not store capacitor in corrosive atmosphere: presence of chloride and sulphide gas, acid, alkali, salt or equivalent substances.
- Storage condition to be respected:
  - maximum relative humidity: 95%.
  - condensation : not permitted.
  - maximum storage temperature: 65°C.

7. MOST COMMON MISAPPLICATION FORMS

In general, the main errors people makes in the capacitor use are the followings:

- Current, voltage and frequency above the specification;
- Presence of harmonics;
- Working or storage temperature beyond the specified limits;
- Not suitable switching devices (contactors without pre-insertion resistors);
- Unusual service conditions as mechanical shock and vibrations, corrosive or abrasive conductive parts in cooling air, oil or water vapour or corrosive substances, explosive gas or dust, radioactivity, excessive and fast variations of ambient conditions;
- Service areas higher than 2000m above the sea level;
- No correct maintenance of the bank.

In case of doubt in choice or in performances of the capacitors, ICAR technical service must be contacted.

9. ADDITIONAL REQUIREMENTS FOR POWER-FACTOR CORRECTION EQUIPMENTS

9.1 Definition

A power-factor correction equipment is mainly composed by:

- one or more capacitors which can be automatically or manually switched via suitable controls (contactors, switches, breakers etc.);
- Controllers;
- Protection, measurement and control devices;
- Wiring.

The purpose of this paragraph is to define the requirements to prevent improper use of capacitors in the installations.
All was been stated above mainly regards capacitors and banks. For power factor correction equipment the following consideration have to be further considered.

9.2 General requirements

Observe safety distances, operating criteria, inspection and maintenance instructions.
Unless allowed by the degree of protection, the apparatus shall not be exposed to rain and solar radiation and shall not be placed in an ambient where the humidity may produce condensation.
If the equipment is fitted with forced cooling, check its effectiveness once a month and clean the filters if any.

9.3 Compatibility

Suitable precautions should be taken to prevent dangerous interference with adjacent equipment.

9.4 Automatic installations

Capacitors mounted in an automatic-power factor correction bank are submitted to frequent and severe voltage and current surges at insertion. These transients damages the capacitors. Use contactors with pre-insertion resistance and without any further information select the components with a rated current of at least 1.5 times the capacitor rated current.
Once a month inspect the contactor switches: the use of worn switches is hazardous.

9.5 Consequential damage

Equipment shall be provided with disconnecting devices which switched off the capacitors or the bank when particular electrical or environmental parameters exceed the threshold values (mostly harmonics, current and temperature). In these situations, the equipment may remain disconnected for a long time waiting for the re-connection. This means consequential damages due to the uncorrected power factor correction control. Any users that systematically exceed manufacturer's thresholds limits with consequent disconnection, shall consult the manufacturer and take all the necessary precautions (e.g. remote signal, acoustic alarms, warning lights, etc.). The arbitrarily change of the protection limits is forbidden.

APPENDIX 1: MAXIMUM PERMISSIBLE VOLTAGE

Type	*Voltage factor x U_N (r.m.s.)*	*Maximum duration*	*Observation*
Power frequency	*1.00*	*Continuous*	*Highest average value during any period of capacitor energization. For energization periods less than 24 h exception apply*
Power frequency	*1.10*	*8 h in every 24 h*	*System voltage regulation and fluctuations*
Power frequency	*1.15*	*30 min in every 24 h*	*System voltage regulation and fluctuations*
Power frequency	*1.20*	*5 min*	*Voltage rise at light load*
Power frequency	*1.30*	*1 min*	

It is assumed that the overvoltages given in the table and having a value higher than 1.15 U_N occur 200 times in the life of the capacitor.

APPENDIX 2: COOLING – AIR TEMPERATURE LIMITS

Symbol	*Ambient air temperature (°C)*		
	Max	*Highest average in all period of*	
		24 h	*1 year*
A	*40*	*30*	*20*
B	*45*	*35*	*25*
C	*50*	*40*	*30*
D	*55*	*45*	*35*

Note. *The temperature values according to this table can de found in the meteorological temperature tables covering the installation site.*

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