How to Protect Capacitor Banks?

Introduction

Capacitor banks are used to **compensate for reactive energy** absorbed by electrical system loads, and sometimes to make up filters to reduce harmonic voltage.

Their role is to **improve the quality** of the electrical system. They may be connected in star, delta and double star arrangements, depending on the level of voltage and the system load.

A capacitor comes in the form of a case with insulating terminals on top. It comprises individual capacitances which have limited maximum permissible voltages (e.g. **2250 V**) and are series-mounted in groups to obtain the required voltage withstand and parallel-mounted to obtained the desired power rating.

**There are two types of capacitors:**

1. Those with no internal protection,
2. Those with internal protection: a fuse is combined with each individual capacitance.

Types of faults

The main faults which are liable to affect capacitor banks are:

1. Overload,
2. Short-circuit,
3. Frame fault,
4. Capacitor component short-circuit

1. Overload

An overload is due to temporary or continuous overcurrent:

Continuous overcurrent linked to:

- Raising of the power supply voltage,
- The flow of harmonic current due to the presence of non-linear loads such as static converters (rectifiers, variable speed drives), arc furnaces, etc.,

Temporary overcurrent linked to the energizing of a capacitor bank step. Overloads result in overheating which has an adverse effect on dielectric withstand and leads to premature capacitor aging.

2. Short Circuit

A short-circuit is an internal or external fault between live conductors, phase-to-phase or phase-to-neutral depending on whether the capacitors are delta or star-connected.

The appearance of gas in the gas-tight chamber of the capacitor creates overpressure which may lead to the opening of the case and leakage of the dielectric.

3. Frame fault

A frame fault is an internal fault between a live capacitor component and the frame created by the metal chamber.

Similar to internal short-circuits, the appearance of gas in the gas-tight chamber of the capacitor creates overpressure which may lead to the opening of the case and leakage of the dielectric.

4. Capacitor component short-circuit

A capacitor component short-circuit is due to the flashover of an individual capacitance.

With no internal protection: The parallel-wired individual capacitances are shunted by the faulty unit:

- The capacitor impedance is modified
- The applied voltage is distributed to one less group in the series
Each group is submitted to greater stress, which may result in further, cascading flashovers, up to a full short-circuit.

_With internal protection:_ the melting of the related internal fuse eliminates the faulty individual capacitance: the capacitor remains fault-free, its impedance is modified accordingly.

### Protection devices

_Capacitors should not be energized unless they have been discharged._ Re-energizing must be time-delayed in order to avoid transient overvoltage. A 10-minute time delay allows sufficient natural discharging.

Fast discharging reactors may be used to reduce discharging time.

#### Overloads

Overcurrent of long duration due to the _raising of the power supply voltage_ may be avoided by overvoltage protection that monitors the electrical system voltage. This type of protection may be assigned to the capacitor itself, but it is generally a type of overall electrical system protection.

Given that the capacitor can generally accommodate a voltage of _110% of its rated voltage_ for 12 hours a day, this type of protection is not always necessary.

_Overcurrent of long duration due to the flow of harmonic current is detected by an overload protection of one the following types:_

- Thermal overload
- Time-delayed overcurrent

provided it takes harmonic frequencies into account.

The amplitude of overcurrent of short duration due to the energizing of capacitor bank steps is limited by series-mounting impulse reactors with each step.

#### Short circuits

Short-circuits are detected by a _time-delayed overcurrent protection device_. Current and time delay settings make it possible to operate with the maximum permissible load current and to close and switch steps.

#### Frame faults

Protection depends on the _grounding system_. If the neutral is grounded, a time-delayed earth fault protection device is used.

_Capacitor component short-circuits:_ Detection is based on the change in impedance created by the short-circuiting of the component for capacitors with no internal protection by the elimination of the faulty individual capacitance for capacitors with internal fuses.

When the capacitor bank is _double star-connected_, the unbalance created by the change in impedance in one of the stars causes current to flow in the connection between the netural points. This unbalance is detected by a _sensitive overcurrent protection device._
Examples of capacitor bank protection

Double star connected capacitor bank for reactive power compensation

Double star connected capacitor bank for reactive power compensation

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Setting information

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<td>Overload</td>
<td><strong>Overvoltage setting:</strong> ≤110% Vn</td>
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<td></td>
<td><strong>Thermal overload:</strong> setting ≤1.3 In or overcurrent</td>
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<td>setting ≤1.3 In direct time</td>
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<td>or IDMT time delay 10 sec</td>
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<td>Short-circuit</td>
<td><strong>Overcurrent direct time setting:</strong></td>
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<td>approximately 10 In time delay approximately 0.1 sec</td>
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### Frame fault

_Earth fault direct time setting:_
- ≤20% maximum earth fault current
- and ≥10% CT rating if supplied by 3 CTs
- time delay approximately 0.1 sec

### Capacitor component short circuit

_Overcurrent direct time setting:_
- < 1 ampere
- time delay approximately 1 sec

**Resource:** Protection Guide – Schneider Electric