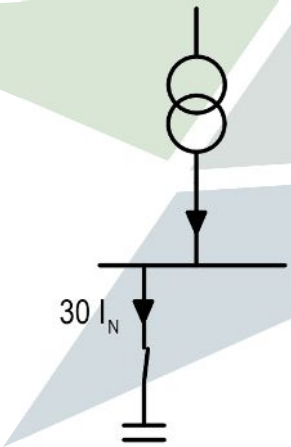
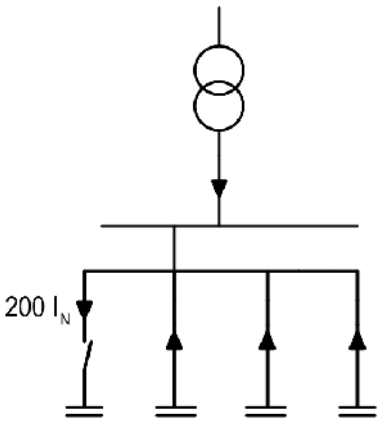
SELECTION OF CONTACTORS



Connection of power capacitors in automatic capacitor banks causes high transitory overcurrents. In the case of individual compensation, the value of the overcurrent connection peak can achieve values of even 30 times the rated current of the capacitor. The great majority of good quality contactors can handle in a safety way this overcurrent level.

Nevertheless, in an automatic capacitor bank the connection overcurrent comes not only from the network but, specially, from capacitors already connected. In this case, peak values of the overcurrent can easily achieve values from 150 up to 200 I_N. These high currents can damage both, contacts of the contactors and capacitors, and the associated voltage oscillations can produce problems in other circuits of the installation.

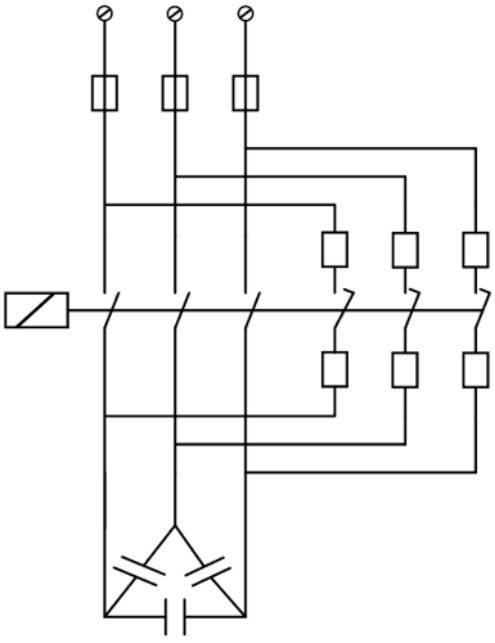


IEC 831 Standard establishes that the peak value of the connection overcurrent has to be lower to 100 I_N. It is then necessary to take steps to reduce the high overcurrents that appear in the switching of the automatic capacitor banks.

Usually, there are used two alternatives: contactors specially designed for the connection of capacitors, or standard contactors including in the circuit inductive elements that reduce the overcurrents.

Special contactors for capacitors

These contactors are characterized for having auxiliary contacts equipped with pre-charge resistors. These contacts are closed before power contacts and connection peak is strongly limited by the effect of the resistors. Immediately after this, power contacts are closed, finishing the resistors action during the normal operation of the capacitor.



Contactor with pre-charge resistors

Use of these contactors is highly recommended because they very notably limit overcurrents. Nowadays the great majority of contactor manufacturers add in their catalogues groups of specific contactors for capacitors.

For information purpose only, following there are indicated some of these groups:

MANUFACTURER / BRAND	CONTACTOR REF.	REMARKS
LIFASA	KML…	
ABB STROMBERG	OK... K11/...	
AGUT (POWER CONTROLS)	CLC ... a	
KLOCKNER MOELLER	DIL ... MK	
SIEMENS	3TK ...	
TELEMECANIQUE	LC1-D ... K	

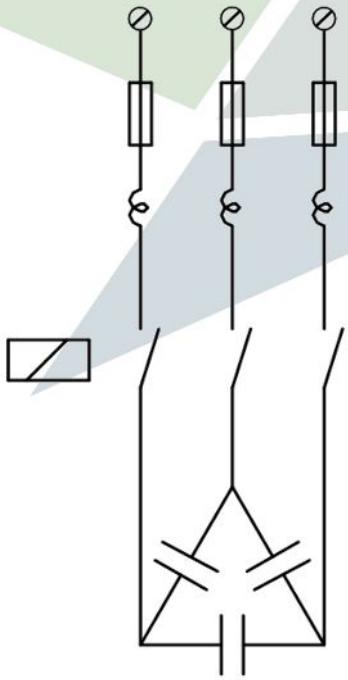
Image: LIFASA contactor with pre-charge block special for capacitor switching

Standard contactors

In the case of using standard contactors it is imperative to reduce the current peak of the connection.

As duration and resistance of the contacts of the contactors varies according to the model and the contactor manufacturer, procedure to be followed is the one preceding:

- First of all calculate the current value of the connection (formulas in Annex 1)
- Verify through the information of the contactor manufacturer if the contactor to be used can stand that said current. In the contrary case there has to be calculated by means of the same formulas, which inductance has to be added in series with the capacitor, so that the current gets reduced to an admissible value for the contactor.
- After this, Annex 2 gives a method for the constructive calculation of the needed coil.



Contactor with limiting inductances

Calculations previously stated are slow and bothersome to put into practice, for what in general it is enough to follow this practical rule: to incorporate to the circuit an inductance in between 3 and 4 µH per phase, in series with each capacitor. This inductance value can easily be obtained by winding 4 or 5 spires from the same feeding conductor of the capacitor, with a diameter of 120 - 140 mm.

Remark: In any case, it is imperative to ensure that at the time of connecting the capacitor, this one is duly discharged (see **TS 03-011I** Fast discharge resistors).

ANNEX 1: CALCULATION OF THE SWITCHING CURRENTS OF POWER CAPACITORS

Switching of single capacitor:

In the case of switching a single capacitor, peak value of the connecting current can be approximately calculated, through the following expression:

$$I_S = I_N \sqrt{\frac{2S_k}{Q}}$$

Where:

I_S = Peak value of the transitory switching current (A)
I_N = R.m.s. value of the rated current of the capacitor (A)
S_k = Short-circuit power at the point where the capacitor is connected (MVA)
Q = Rated power of the capacitor (Mvar)

Switching of one capacitor in parallel with others already energized:

In this case peak value can be calculated through the following expressions:

$$I_S = \frac{U\sqrt{2}}{\sqrt{X_C X_L}} \qquad \text{Where} \qquad X_C = 3U^2 \left(\frac{1}{Q_1} + \frac{1}{Q_2}\right) * 10^{-6}$$

And the frequency of the connecting current:

$$f_S = f_N \sqrt{\frac{X_C}{Q X_L}}$$

Where:

I_S = Peak value of the transitory switching current (A)
U = R.m.s. value of the voltage (neutral-phase) (V)
X_C = Series capacitive reactance per phase (Ω)
X_L = Series inductive reactance per phase between capacitors (Ω)
Q_1 = Power of the capacitor to be connected (Mvar)
Q_2 = the sum of the capacitors already connected (Mvar)
f_N = Rated frequency of the network (Hz)
f_S = Frequency of the transitory switching current (Hz)

ANNEX 2: INDUCTANCE OF A CYLINDRICAL COIL OF SINGLE LAYER

Value of the inductance obtained through a cylindrical winding of a single layer can be calculated through:

$$L = \beta * 2aN^2$$

Where:

L = Value of the inductance of the coil (µH)
a = Radius of the coil (m)
N = Number of spires
B = Coefficient

The corrective coefficient β depends on the relation diameter/length (2a/l) of the coil and it is tabulated:

2a/l	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6
β	0,1812	0,3355	0,4964	0,5804	0,6795	0,7664	0,8449	0,9152

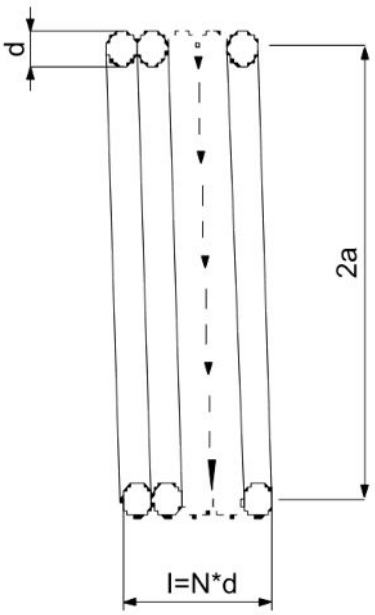
2a/l	1,8	2,0	2,2	2,4	2,6	2,8	3,0	4,0
β	0,9789	1,0373	1,0910	1,1407	1,1870	1,2302	1,2708	1,4426

Example: Calculation of the inductance obtained while winding over a 130 mm diameter, 5 spires of a 50 mm^2 cable.

Departing data are:
N = 5
2a = 0,13 m
D = 9,3 mm (50 mm^2 cable diameter)

Coefficient β is calculated:

$$\frac{2a}{l} = \frac{0,13}{5 * 0,0093} = 2,8$$ We get $$\beta = 1,2302$$



And the inductance value will be:

$$L = \beta * 2aN^2 = 1,2302 * 0,13 * 5^2 = \mathbf{3,9\mu H}$$