INTERNAL HEATING OF CAPACITOR BANKS

A very important matter to consider when working in the design of a capacitor bank for the automatic compensation of the power factor is the one of its internal heating.

This heating, provoked by the losses of the components that are placed inside, produces an increase of the temperature that should be lower to the maximum working temperatures of the equipment and capacitors. This point is especially important in the case of power capacitors because their work at temperatures higher than the maximum expected produce a premature ageing of the dielectric.

An estimation of the heating of the equipment to be built can be easily done by taking the following steps:

- Calculation of losses
- Determination of the cooling surface
- Calculation of the temperature rise

1st CALCULATION OF LOSSES

Internal dissipation of the capacitor bank is the sum of the individual losses of each of its components:

Fuses

I_N (A)	Losses for each type of fuse			
	DO	NH 00	NH 0	NH 1
25	2,5 W	1,7 W		
35	3,0 W	2,4 W	2,4 W	
50	3,5 W	3,6 W	3,6 W	
63	4,0 W	4,6 W	4,6 W	4,6 W
100		7,5 W	7,5 W	7,5 W
125		9,5 W	9,5 W	10,0 W
160		10,7 W	12,0 W	12,7 W
200				16,4 W
250				21,5 W

Losses of the link fuses and their bases are usually indicated in the catalogue of manufacturer.

Most usual values for several types and sizes of fuses are indicated in the table.

Contactors

Dissipated power due to contactors is composed of the power consumed by the coil besides the one dissipated in the contacts. These values can be found in the technical information from the contactor manufacturer.

Guiding values of the total power dissipation of several contactors for different capacitor powers are indicated in the table.

Contactor for capacitors	Losses coil	Losses per pole	Total power
20 kvar 400 V	4,5 W	7,0 W	25,5 W
30 kvar 400 V	4,5 W	7,0 W	25,5 W
40 kvar 400 V	4,5 W	10,5 W	36,0 W
50 kvar 400 V	4,5 W	10,5 W	36,0 W
60 kvar 400 V	4,5 W	14,0 W	56,5 W
75kvar 400 V	4,5 W	14,0 W	56,5 W

Cables

Section (mm^2)	Resistance (Ω/km)
4	4,95
6	3,3
10	1,91
16	1,21
25	0,78
35	0,554
50	0,386
70	0,272
95	0,206
120	0,161

Internal cables of the capacitor bank are an important source of heating inside the equipment.

To evaluate its contribution there must be determined: total length of the cables, current circulating through the cable. Next, following formula has to be applied:

$$P(W) = R * I^2$$

Where:

R = Resistance of the conductor in ohm
I = Current in the conductor (A)
P = Total dissipated power (W)

R resistance is calculated by multiplying total length of the conductors by the value given in the enclosed table.

Power capacitors

Power capacitor losses can be considered in regard to 0.5 W per each kvar.

Other equipments

If the bank is incorporating other equipments (main general switch, reactors, transformers, etc.) their losses must be taken into account.

2nd Cooling surface

It is calculated the surface of the cabinet which contributes to the refrigeration (by radiation and convection). In normal conditions this surface will be the sum of the lateral panels, the rear panel, the door and the ceiling.

3rd Calculation of temperature rise

Increase average of the temperature in the interior of a closed cabinet is calculated through the formula:

$$\Delta T = P_T \div (h * A)$$

Where,

ΔT = Increase of temperature in the interior of the cabinet
H = Coefficient of transmission (convection and radiation)
Approximately 5.8 W/m2 K for metallic cabinets
5.2 W/m2 K for insulating cabinets
A = Cooling surface in m2
P_T = Total power of losses in W

Calculation example: Capacitor bank 300 kvar 400 V
Composition 6 x 50 kvar 400 V
Fuses NH00 125 A
Power cables 50 mm2, total length 18 m
Dimensions of metallic cabinet 2000 x 1000 x 400 mm

1st Calculation of losses

Fuses:	6 x 3 x 9.5 W	171 W
Contactors:	6 x 36 W	216 W
Cables:	18 x 0.000386 x 72.22	36 W
Capacitors:	6 x 50 x 0.5	150 W
	Total losses	**573 W**

2nd Cooling surface

Lateral panels	2 x 1 x 0.4	0.8 m2
Rear part and door	2 x 2 x 1	4.0 m2
Ceiling	1 x 0.4	0.4 m2
	Total surface	**5.2 m2**

3rd Calculation of temperature increase

$$\Delta T = P_T \div (h * A) = 573 \div (5{,}8 * 5{,}2) = 19$$

Average increase of temperature in the interior of the cabinet will be then 19ºC. If room temperature is 30ºC, temperature inside of the cabinet will be 49ºC, lower than the maximum 50ºC recommended by the IEC 831 Standard for power capacitors.

If outside temperature is expected to be higher, following solutions can be used:

- **Enlarge the size of the cabinet in order to have a bigger refrigeration surface**

- **Use a cabinet having lower and upper openings, so to easier refrigeration by natural convection:** for instance, a capacitor bank with similar characteristics, **N450** type, equipped with ventilation openings on the lateral and frontal panels, shows a temperature increase of only 15 ºC.

- **Use a ventilator to improve even more the refrigeration by convection:**

In this case the additional decrease of temperature depends on the air flow of the ventilator used and it has to be calculated according to the instructions of the ventilator manufacturer.

Here following it is exposed a simplified system of calculation in which the flow can be calculated by the formula:

Where,

V = Necessary air flow (m3/h)

P_D = Extra power to be dissipated by the ventilator (equal to the difference between total power of losses PT and the power evacuated by the own cabinet ΔT (h • A), that is : $P_D = P_T - \Delta T\,(h \bullet A)$

ΔT = Increase of temperature desired in the interior of the cabinet

Calculation example: In the same capacitor bank of the previous example, we wish to reduce the increase of temperature from 19 to 10ºC (ΔT = 10)

Extra power to be dissipated by the ventilator will be then:

$$P_D = 573 - 10 * (5{,}8 * 5{,}2) = 271{,}4W$$

And the necessary air flow:

$$V = 3{,}1 * 271{,}4 \div 10 = 84m^3/h$$

Remark: It is convenient to choose a ventilator having approximately a 5% more of air flow than the one calculated, so to have a security margin and foresee the possible reduction of the air flow in case of working with dirty filters.