Thermal design of APFC Panels

The life of the power capacitors and other equipments in APFC panels depend very much on the operating temperature. In panels with detuned harmonic filter reactors and thyristor switches, the chances of elevated temperature are high, as these equipments generate relatively more heat. Hence in order to maximise the life of the capacitors and other important equipments in the APFC panel, the temperature must not be allowed to increase beyond certain limit. This article briefs some guidelines about the thermal design of APFC panels and thereby dissipating the generated heat effectively.

For any panel, the temperature rise can be reduced by the following three ways:

- Operating at lower ambient temperature
- Using devices with lower power loss
- Dissipating the excess heat, so that temperature rise is controlled

There is minimal control over the first two conditions. But the third condition completely depends upon the design of the panel. By offering effective cooling methods, the excess heat generated by the equipments can be dissipated. Selection of the cooling methods can decided based on the internal *temperature rise* inside the panel. The maximum *internal temperature* can be calculated using the following formula:

$$\boldsymbol{Internal\,Temperature\;(T_i) = \frac{P_d}{k\;x\;S} + T_a}$$

Where, P_d = Total power dissipated in the panel (in watts)

k = constant defined by the material used to manufacture the enclosure.

For painted sheet-steel enclosure, $k = 5.5\ W/m^2\ °C$

S = effective surface area of the panel (in m^2)

T_a = Ambient temperature (in °C)

If the *temperature rise* $(T_i – T_a)$ is within the acceptable limits, **natural cooling** would be sufficient; else **forced cooling** method should be employed for dissipating excessive heat.

1. Natural Cooling:

In most of PCCs and MCCs, the temperature rise remains under desirable limits with natural circulation of air (through natural convection and radiation). The air circulation happens through some slots in the enclosure, called the louvers. When temperature rises inside the panel, the pressure of the air increases and the density reduces. Hence the hot air tends to move upwards. The hot air would go out through the louvers provided at the top side of the panel. Fresh cold air would enter the panel through the louvers provided at the bottom. This is represented in *Figure 1*.

Figure 2 represents the common usage of extra louvers in-between the top and bottom louvers. The common misconception behind this is that, extra louver would increase the volume of air flow. Practically, this does not happen because the volume of the panel is fixed. This results in the reduced air flow at the bottom section of the panel, as some air enters through the middle louvers. Hence, the temperature of the lower section of the panel will be higher than the upper section.

It is recommended to follow the panel design as per the Figure 1.

Figure 1

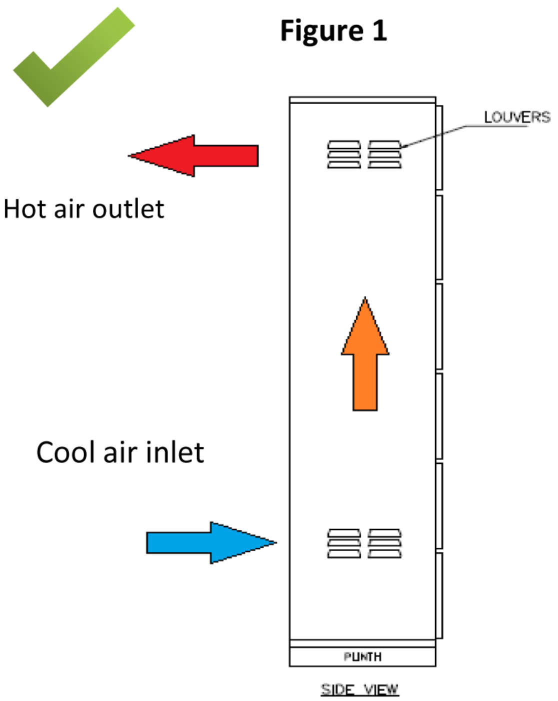
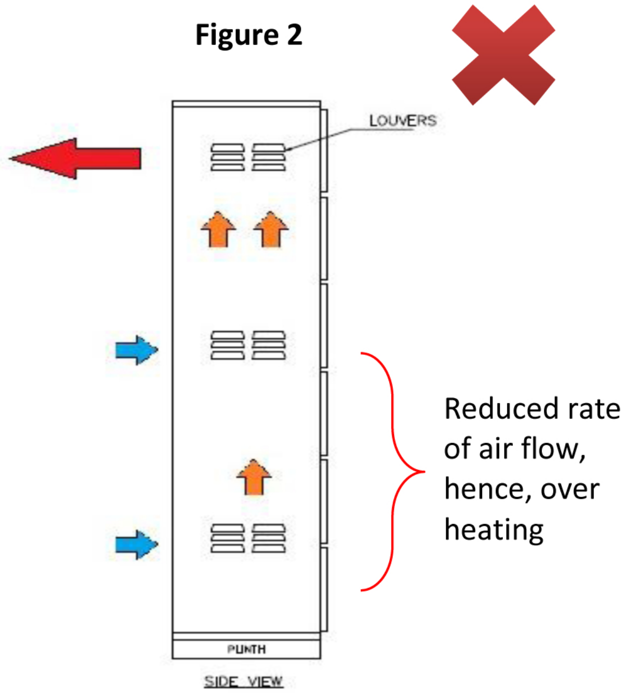


Figure 2



2. Forced Cooling:

In most of the APFC panels and in some MCC and PCC panels, the above method would not offer sufficient cooling. In order to maintain the desired temperature levels (ambient temperature + allowed temperature rise), forced cooling methods (using fans at the top) should be employed, which would increase the rate of air flow. In *figure 3*, the cold air enters through the bottom louvers, flows through all the equipments and they are forced out of the panel through fans. Hence, temperature rise in the panel is kept under check and there are no hot spots/sections.

In *figure 4*, provision of additional louvers, actually disturbs the uniformity of the flow. Major chunk of cold air would enter through the top louver and result in “short cycling”. So the bottom section of the panel would see higher temperature rise.

Figure 3

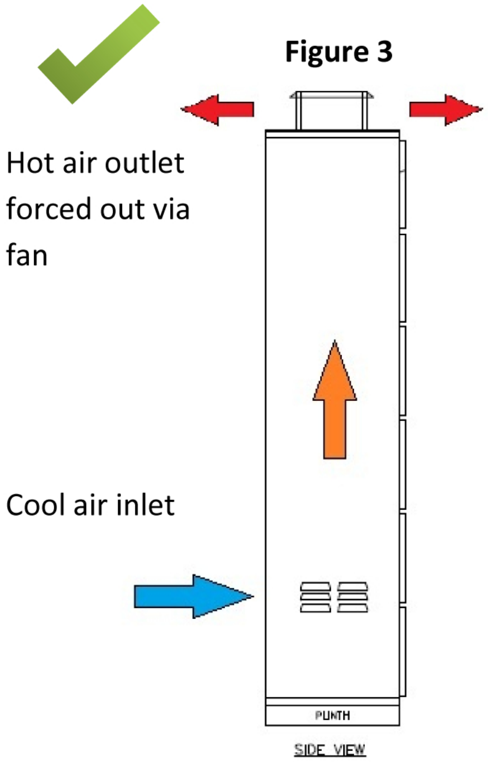
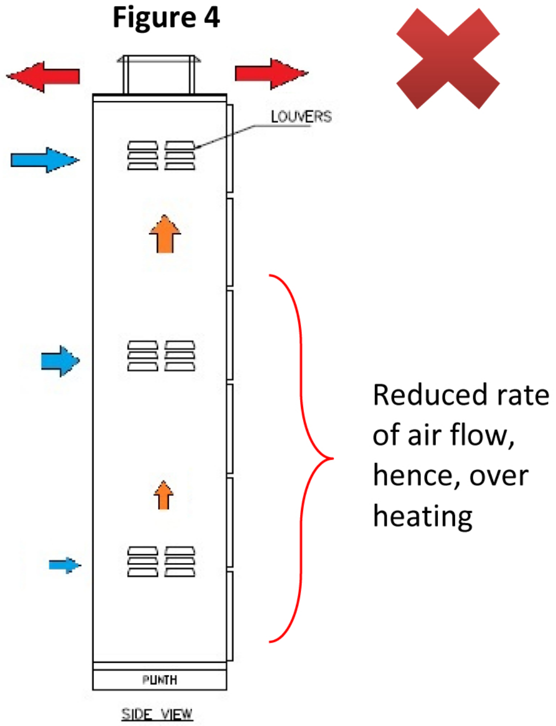


Figure 4



2.1 Fan Selection for forced cooling:

Fan selection is based on the rate of volume of air flow, which is measured in m^3/h or Cubic Feet per Minute (CFM), where **1 CFM = 1.7 x 1 m^3/h**. Following is the formula to calculate air flow rate:

$$Q = C\,x\,\frac{P_d - [k\,x\,S\,(T_d - T_a)]}{(T_d - T_a)}$$

Where,

Q = Air flow rate (in m^3/h)

C = Coefficient related to the altitude above the sea level

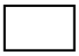
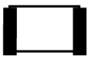
Altitude (in meters)	C
0 to 100	3.1
101 to 250	3.2
251 to 500	3.3
501 to 750	3.4
751 to 1000	3.5

P_d = total power loss (watts) inside the panel, by summing up the power loss of individual devices like capacitors, reactors, thyristor switches, contactors, bus bars, joints and so on.

k = constant defined by the material used to manufacture the enclosure.

For painted sheet-steel enclosure, <u>k = 5.5 W/m² °C</u>

S = Open surface area of the panel (in sq. m) can be calculated using one of the below formulas:

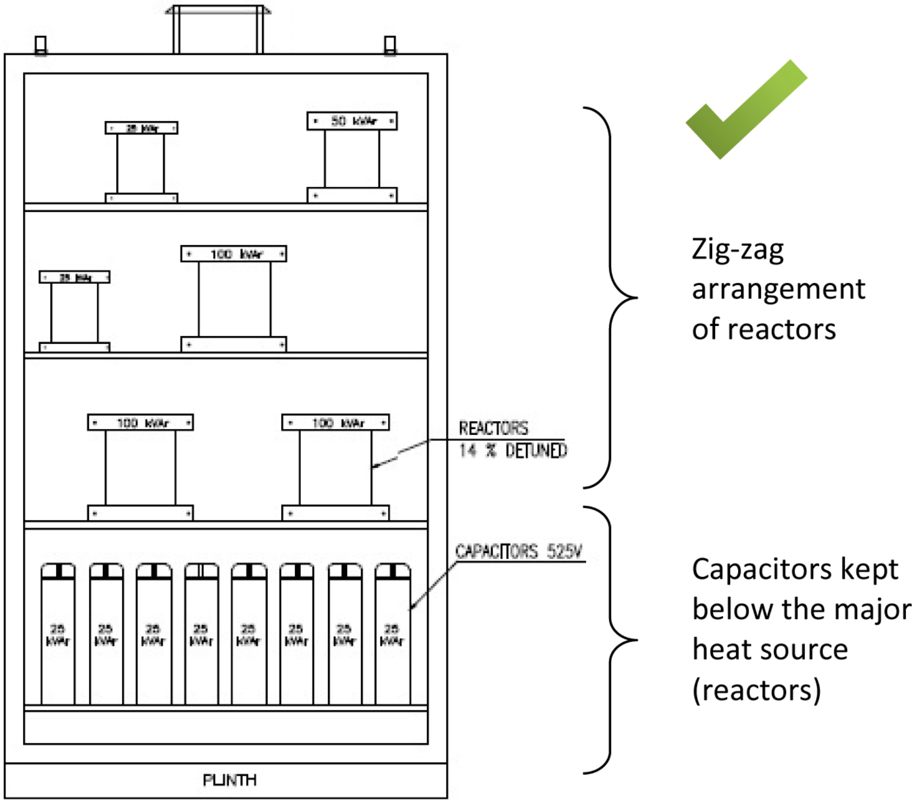
	Position of the enclosure	Formula for calculating S (in sq. m) as per IEC 890
	accessible on all sides	S = 1.8 x H x (W + D) + 1.4 x W x D
	placed against a wall	S = 1.4 x W x (H + D) + 1.8 x D x H
	end of a row of enclosures	S = 1.4 × D × (H + W) + 1.8 × W × H
	end of a row of enclosures with back against the wall	S = 1.4 × H × (W + D) + 1.4 × W × D
	intermediate in a row of enclosures	S = 1.8 × W × H + 1.4 × W × D + D × H
	intermediate in a row of enclosures with the back against the wall	S = 1.4 × W × (H + D) + D × H
	intermediate in a row of enclosures back against the wall with top part covered	S = 1.4 × W × H + 0.7 × W × D + D × H

T_d = Desired Maximum temperature inside the enclosure
Ta = Ambient temperature

This is a simple method of thermal management and fan selection, which is suitable for majority of the panels. At the same time, some other aspects like position of mounting various equipments in the APFC panel should be taken care.
Some of them are as follows:

- Capacitors should be kept below the reactors, which are the major heat sources. This is because the reactors would increase the ambient temperature around the capacitors and the elevated temperature would reduce the life of the capacitors.
- The reactors should be mounted in the zigzag position (as shown in the below figure), in order to ensure better heat flow. If the reactors are kept one above other, the bottom most reactors would heat up the other reactors that are mounted above them.
- Thyristor switching modules should be mounted vertically (position of heat sink should be parallel to the air flow direction) and in zigzag positions. TSM panel should be non-compartmentalised design for better heat dissipation.
- Reactors and capacitors should be mounted over channels to allow free flow of air. Flat base plates are not recommended.
- The panel should not be compartmentalised. Compartmentalised design would lead to heat accumulation in the panel.

- For reactors and TSM, a clearance of 100 mm should be maintained in all directions.



Hence, in APFC panels, a proper thermal design would pave way for maximising the life of important equipments like capacitors, thyristor switches, reactors and other switchgear.