Thermal Issues in Power Factor Systems

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Power Factor Board Thermal Considerations

It is a well-known fact that Power Factor Correction (PFC) systems generate heat, with or without harmonic distortion. Whilst the greater part of this heat comes from the harmonic blocking reactors, capacitors produce significant heat as well, in addition to heating when dealing with harmonic currents. In total, this is approximately 5-7 Watts per kVAr, such that a single cabinet of 400kVAr has the equivalent of a 2.5kW heater running continuously. Therefore, all power factor boards require forced air cooling.

Previously, if harmonic distortion was low or absent, harmonic blocking reactors were omitted from the design and forced air cooling was not always used. If harmonic currents remained low, the capacitors usually survived for an acceptable length of time, able to withstand their own heat. As harmonic currents increased, reactors were added to protect the capacitors, but unfortunately forced air cooling was not always included to counter the excess heat produced by the reactors. Although the capacitors are protected against harmonic currents, the presence of a reactor always requires forced air cooling.

Another consideration is the life expectancy of capacitors. There are many published independent studies that show categorically that capacitor life is proportional to average operating temperature. The cooler they are run, the longer they will last. Also of considerable importance in the design of a system is the maximisation of the thermal separation between the reactors and other equipment, notably capacitors, but fusing and contactors as well. Reactors will comfortably operate some 40-70^{o}C hotter than capacitors and therefore it is essential to ensure that cooling air does not pass over a hot reactor then flow over a cooler capacitor and consequently heat it up.

kVArCorrect power factor trays and systems are designed to thermally isolate the reactors and separate their cooling air flow from the air flow of the rest of the equipment.

How much Cooling is Required?

A rule of thumb is that the temperature rise of cooling air should not exceed 10^{o}C; thus the minimum amount of air flow required can be calculated.

For altitudes up to 1000m use the rule: Air flow (in L/sec) = (Watts) / (temp rise)

In the example of 7 Capacitor steps at 66.7kVAr per step, total 2121W (including reactors & capacitors), the following is true:

Capacitor steps = 2121W
Control power = 18W
Fuses = 105W
Power cable = 125W
Sundry losses = 100W
Total losses = 2469W

Air Temperature Rise = 10^{0}C

Air flow (in L/sec) = (Watts) / (temp rise)

Air flow = 2469W / 10^{0}C = 246.9L/sec = 888m^{3}/hour

The pressure drop over the inlet filter must also be considered, which should be specified in the manufacturer's data sheet. Using a typical value of 80Pa, the example above shows the required fan is one capable of achieving air flow of 246.9L/sec (888m^{3}/hr) at 80Pa pressure. Given that most 150mm fans are rated at about 150m^{3}/hr, 6 fans would be required to achieve the air flow throughout the cabinet. kVArCorrect imports specially selected high flow fans*, each capable of 324m^{3}/hr – meaning for this example, kVArCorrect would supply 4 x 150mm fans, totalling 1,296m^{3}/hr, which allows for partially blocked filters and other abnormalities. The fans should be under thermostatic control to prolong the life of the filter and save on unnecessary runtime. The thermostat average settings should be around 25-30^{o}C.

** As of December 2017, kVArCorrect has further developed this concept and managed to source a single fan capable of providing the same amount of air flow as the 4 units mentioned in this article. The 4 unit option is still available.*

kVArCorrect's Cabinet Design

There are a number of schools of thought about whether it is better to have fans blowing air into a cabinet or fans sucking air out of a cabinet. In traditional systems, fans are often used to blow air into the cabinet at the bottom, where it cools what it immediately hits, and then is deflected through an unknown and unpredictable path through the cabinet to its exhaust point. This uncertainty can result in poor air flow, and even heating some components instead of cooling.

kVArCorrect mounts the fans on the top of the cabinet, towards the rear, to extract hot air from the cabinet. As part of the thermal design of the cabinet, kVArCorrect utilises a chimney effect at the rear of the cabinet. This runs behind all the power factor equipment, and creates a partial vacuum in the whole chamber, as well as a higher vacuum in the chimney itself. Clean filtered air is drawn into the cabinet through low, frontal inlets – in front of the power factor equipment at the bottom of the cabinet. This air will naturally flow through all chassis to the lower vacuum area of the chimney. This ensures that all chassis receive cooling air that is not preheated by the chassis below it in the cabinet. Tests have categorically proved this design to work, and increase the life of the PFC system.

With the fans in the top of the cabinet, they do unfortunately have warm air drawn through them, and this tends to shorten their bearing life. kVArCorrect counters this by using 4 fans instead of the calculated 2.6 required – meaning there is more air flow. The fans are also thermostatically controlled, with an optional alarm module that will shut the system down if there is a fan failure leading to over-temperature in the cabinet. The longer life of the system due to better cooling far outweighs the cost of checking the fans periodically.

Summary

All PFC systems require forced air cooling to extend the life of the capacitors and components. Forced air cooling counters the heat generated from reactors as well as capacitors and other components. kVArCorrect has focussed on this vital concept and has developed a unique thermal design for their systems, which includes thermal separation, targeted air flow, and over-temperature alarms. This design has been proven to achieve maximum cooling throughout the cabinet, prolonging the life of the system.