Powering Business Worldwide

Thought Leadership White Paper

Power Factor Correction Capacitor Technology

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Executive summary

When considering the relative merit of the various technologies available for power factor correction (PFC) applications it is helpful to understand the construction types of specific capacitors. Construction details include case type, dielectric material and cooling or insulating fill and conducting material (electrode). This white paper explains the different capacitor technologies available today and outlines critical features to look for when evaluating these devices.

Case Type

The capacitor elements are contained in either a tank or a cell case. These cases are often metal for PFC application although cases made of plastic have also been used by some manufacturers.

Tank case arrangements are welded metal cans where the phase connections and discharge resistors are internal to the case. These are typically large capacity (high kVAR) units with multiples of internal capacitor elements and are primarily used in medium and high voltage capacitor cell construction. They require more precise fill-media processing, are more expensive and are rarely rupture protected. Some feature self-healing dielectric systems.

Cell case arrangements usually contain single capacitor elements. These types of capacitors are typically used for lower voltages (<1,000V) and are almost always rupture protected and feature self-healing dielectric systems. They utilize a "building-block" design which standardizes their manufacture for flexibility and quality consistency. Their higher energy density gives them a decided size and cost advantage for general PFC applications.

Dielectric Material

The three dielectric materials widely available and used in capacitors are oil, kraft paper and polypropylene film.

Capacitors using an oil-impregnated kraft paper as insulation and a separate metal film system are an older design which results in higher heat losses. These higher losses are due to the paper properties as an insulator. Capacitors with this design have less energy density and are therefore now reserved for use in higher voltage applications in tank cases. These capacitors are generally designed with much higher tolerance for overload.

Capacitors can also be constructed utilizing metallized paper and an oil-impregnated all film system. This design features lower heat losses and higher energy density than the separate paper and metal film construction, while offering self-healing functionality. This design does however require a costly vacuum oil fill media process.

Metallized polypropylene (MPP) is a non-impregnated all film system. It features the lowest heat loses with excellent self-healing properties. MPP provides very high energy density and can be configured in a wet-oil filled version, dry-type gel filled version or a dry filled version. Despite its non-impregnated status (that means the fill media is not part of the dielectric system), oil fill processing is still recommended for cells with voltages higher than 400V to help minimize partial discharge damage and to facilitate heat dissipation.

Eaton's Resinol® filled capacitor is unique as it employs an oil based liquid fill (room temperature poured), thus assuring penetration of the media into the capacitor end connections but the liquid fill contains specially formulated additives that help reduce the potential for partial discharge. When compared to dry systems, Resinol® has much better heat transfer capabilities. When compared to common oil filled systems, Resinol® reduces damage due to partial discharge events.

Conducting (Electrode) Material:

Discrete aluminum foils with taps are used in paper/film systems to connect the individual capacitor elements. While this type of electrode system has excellent current carrying capability, the construction is expensive. This electrode is not self-healing and hence the dielectric materials are usually thicker to provide adequate transient voltage capability. This also adds to their size and cost and a single localized fault will render the entire capacitor useless.

Metallized Paper and Metallized Paper/Foil systems were developed in Europe to provide self-healing properties to these types of capacitors. The vacuum deposited conductor (usually zinc or aluminum) is so thin that current in-rush from dielectric faults causes localized vaporization of the electrodes thus "clearing" the instantaneous short circuit condition and allowing the capacitor to “self-heal”. These types require oil-impregnation because of the paper being used as the dielectric for the electrode and are thus more expensive to manufacture. Because of the gas build-up over time due to localized faults, these systems require rupture protection.

Metallized Polypropylene systems use the dielectric material itself to be the electrode carrier. This results in using less material and are simpler to manufacture. They have the highest energy density and have distinct size advantages over competing styles. Recent advances in fill media has allowed non-impregnated type fills that do not require the fill media to be between the dielectric sheets for transient voltage capability and can therefore just be room temperature poured instead of impregnated.

The most common differentiation by specifying engineers seems to be focused on “wet” vs. "dry" type of fill media but it is probably more accurate to think of different capacitors in terms of impregnated and non-impregnated capacitor cells. Impregnated systems depend upon the fill media to provide both dielectric constant and dielectric strength to the system. Processing these systems is more demanding and expensive because of the need to remove traces of moisture from the dielectric and insulating materials themselves.

Non-impregnated capacitor systems only use a liquid media for end connection transient capability, heat transfer and insulating performance, they do not rely on the liquid media for added dielectric insulation. The most important benefits of using non impregnated type capacitors is their self-healing ability and their high energy density combined with their lower losses and cost.

About Eaton

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Eaton is a power management company providing energy-efficient solutions that help our customers effectively manage electrical, hydraulic and mechanical power. A global technology leader, Eaton acquired Cooper Industries plc in November 2012. The 2012 revenue of the combined companies was $21.8 billion on a pro forma basis. Eaton has approximately 102,000 employees and sells products to customers in more than 175 countries. For more information, visit www.eaton.com.

About the Author

Shree Sathe has been the Lead Product Applications Engineer for Eaton's Power Quality group since 2006. Prior to working for Eaton Shree worked as a consulting engineer for 15 years in various countries including Australia, Singapore and India. Mr. Sathe is also a certified professional engineer in Australia. Shree now leads the new product development and application of new technology solutions offered by Eaton's Power Factor Correction product line.