

A New Mitigation Strategy for Failures in Metallized Polypropylene Capacitors

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Abstract

Metallized film capacitors utilizing polypropylene dielectric have become the component of choice in critical applications because of their low dielectric loss and superior breakdown voltage strength. There are some concerns that in certain applications metallized polypropylene capacitors can fail in a manner such that the failure poses a hazard to the equipment and personnel. FuseacTM is a thermal fuse technology designed to protect against common capacitor failure modes in high power AC and DC applications. FuseacTM technology will deploy upon sensing a temperature beyond its preset limit and electrically disconnect, providing protection against catastrophic failures by rendering the capacitor electrically open.

Background

Metallized polypropylene dielectric for capacitors is fabricated by vapor depositing an aluminum or zinc-aluminum metal electrode to a polypropylene substrate that serves as the dielectric. This structural profile promotes self-healing at a fault by vaporizing the electrode at the point of the fault. Older technology film-foil capacitors using heavy foil electrodes in the windings would fail as a short but the foil was too thick to vaporize and the failure could not be reversed.

Metallized electrodes do not fail as a permanent short. At the failure point there

is a momentary short where the energy stored in the capacitor creates a short-duration high current which causes the metal at the fault point to vaporize. Although this can prolong the life of the metallized polypropylene device, certain precautions must be taken to assure that the device does not destroy itself after multiple self-healing cycles.

Film-foil capacitors which fail as a dead short can be protected with fuses or current sensors to alert the user of a high current condition. However in metallized polypropylene devices many self-heal cycles can result in excessive leakage currents and increased power losses.

Metallized polypropylene capacitors fail differently depending on whether the application is in a DC or an AC circuit. DC applications with excessive self-heal cycles will exhibit an increased geometric center or "hot spot" temperature which decreases the breakdown voltage of the dielectric.

In AC applications the low resistance short due to self-healing will vary from a few ohms to a few hundred ohms. (New capacitors exhibit a resistance in the micro-ohm to the milliohm range.) This higher ESR contributes to higher I^2R generated heat. As core temperature increases, the dielectric strength of the capacitor is weakened which leads to further dielectric breakdown.

Failures in both DC and AC applications are thermally generated. Since the failure in AC applications is more likely to result in

combustion (as opposed to an open circuit in DC circuits), and combustion failures have been observed with less than 10% increase in line current, a method to monitor the core temperature of the capacitor for “hot spots” was needed so that the device can be electrically removed from the circuit before combustion occurs.

Failures in Metallized Polypropylene Capacitors

Failures in metallized film capacitors can be triggered by excessive total line frequency and PWM current above rating; excessive AC voltage above rating; transient voltage spikes above the dielectric withstanding voltage (DWV) rating; ambient temperatures in excess of 85°C; terminal connection problems relative to shock or vibration; exceeding packaging environmental conditions including moisture; excessive clearings or corona induced from an uncontrolled event. Conventional AC capacitor protection considerations include current sensing controls such as electrical fuses, management of voltage overrun conditions, heat management including ambient control (fan/cooling), thermal sensing on the body of the capacitor, and capacitor placement/location, e.g., isolation from heat sources. These are issues associated with these types of protection.

In AC circuits using metallized film capacitors protected by electrical fuses, dielectric flaws, stressed by one of the aforementioned events, can create internal momentary current spikes as partial discharges generate self-healing. The capacitor remains functional in the circuit through self healing and the electrical fuse remains closed which can lead to catastrophic failure. External thermal sensing attempts include monitoring the

temperature difference between the “hot spot” and the external case. The external case temperature can be markedly lower than the internal hot spot, depending on the diffusion of heat through the dielectric and case (independent of ambient). The rate of heat transfer from the “hot spot” to the external case is often too slow to detect a critical condition and physical placement of the capacitor relative to ambient cooling can affect a case-mounted sensor. ECI’s thermally activated electrical disconnect, known as Fuseac™, deploys an internal thermal fuse that is triggered by temperature. Advantages of this type of thermal fuse include failure detection and disconnect before a fire condition. Fuseac™ also allows a rigid connection to the unit with no mounting restrictions. Other advantages include enclosed dry construction (no oil or electrolyte), no case ruptures during disconnect, smaller size, lighter weight and cost effectiveness. Compare these advantages to a mechanical disconnect capacitor construction with a break away connection triggered by gas build up within the case. Mounting for mechanical disconnect devices requires flexible connecting lines, sufficient space for expansion above the connections, and is restricted to a vertical orientation. Gasses created during self-healing create intentional case deformation to disconnect the capacitor. Potential rupture of the package can result in oil leakage and system contamination. Fuseac™ is a marked improvement over conventional mitigation strategies and directly addresses these critical application and reliability issues.

Fuseac™

Fuseac™ is a thermal fuse technology designed to protect against catastrophic capacitor failure potential resulting from

common capacitor failure modes in high power AC and DC applications. Fuseac™ technology will deploy upon sensing a temperature beyond its preset limit and electrically disconnect, providing protection against catastrophic failures by rendering the capacitor electrically open. ECI's UL certified 5MPF series AC capacitors employ Fuseac™ technology at 300, 600 and 900vac ratings for inverter output filtering. Fuseac™ can be incorporated, on request, in a host of Electronic Concepts, Inc. products, especially for designs needing added overheating protection.

Quality and Reliability

Self-healing metallized polypropylene capacitors fail due to avalanche breakdown caused by multiple self-healing events as temperature increases. Incorporating Fuseac™ in the capacitor will safeguard against these catastrophic temperature-generated failures, but additional measures are also taken during the manufacturing process to characterize potential failures in the metallized film. Some of these safeguards include:

- At incoming inspection of the dielectric film both voltage fault tests and avalanche tests are employed to assure film integrity.

- To assure clearing events are minimized, an overvoltage potential in excess of the rated DWV voltage is applied during capacitor production.

While these measures significantly improve product reliability, they cannot prevent clearings due to voltage transients or excessive temperature excursions during the

product application. An additional means is required within the device to assure the safety of both equipment and personnel. This is accomplished by incorporating Fuseac™ in the polypropylene film capacitor. Unlike mechanical safety mechanisms described earlier, Fuseac™ disables the capacitor before it reaches combustible temperatures, thus offering an additional safety margin in critical applications.

Conclusion

Polypropylene film capacitors offer many advantages in large power applications. Their physical size and higher bandwidth make them highly suitable as a preferred alternative to other technologies. Process controls and monitoring contribute to their reliable field performance. The addition of Fuseac™ temperature protection makes them even more desirable for applications where high reliability, circuit protection and isolation are imperative.