APC

APPLICATION NOTE #47

How APC designs AC power capacitors into large UPS systems

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Abstract

This application note will explain how APC's Silcon and InfraStruXure UPS systems are designed with regard to maximizing the lifetime of its AC power capacitors.

Introduction

AC capacitor failures have been known to create failure modes that cause unexpected and undesirable loss of redundancy or a critical load drop, even in fault tolerant or paralleled UPS installations. Therefore, it is important to minimize the total number of predicted capacitor failure occurrences over the life of the system. The design of the UPS can and does have a dramatic impact on the frequency of capacitor failures. This application note will explain how APC's Silcon and InfraStruXure Type C UPS systems are designed with regard to maximizing the lifetime of its metallized film AC power capacitors. To understand more about capacitors in general please refer to APC White Paper #60, "Avoiding AC Capacitor Failures in Large UPS Systems".

What are the critical factors?

There are four critical factors to consider when applying metallized film AC capacitors to large UPSs:

- Voltage stress: Voltage stress is measured in volts per micrometer (V/µm) and is a direct result of the steady state RMS voltage applied across the capacitor terminals. The higher the applied electric voltage, the more likely it is for the voltage potential to overcome the dielectric withstand capability over the life of the capacitor, leading the capacitor to catastrophically fail short. This is by far the most critical factor for an AC capacitor because the voltage across its terminals will remain relatively constant regardless of percentage load on the UPS.
- Current pulse handling capability: Under normal operation, UPS applications generally do not stress capacitors with high pulse currents. However, if not designed properly, it is possible for high peak currents to degrade the connection between the film and the end spray which may result in reduced performance or cause the capacitor to fail open. The worst case for peak current would be a catastrophic failure of the capacitor due to localized high voltage arcing that leads to dielectric breakdown and thermal runaway.

- Peak voltage: Peak voltages across a capacitor are typically higher then the withstand voltage of the dielectric and generally present themselves as high frequency spikes as a result of utility events or state changes in a UPS. Due to the self-healing characteristics of metallized film capacitors, the damage inflicted by peak voltages are mitigated. However, these damaged areas of the capacitor accelerate the dielectric breakdown, which can lead to premature capacitor failure.
- Thermal stress: Thermal stress is responsible for breaking down the dielectric film, thereby degrading its ability to withstand the voltage potential across the capacitor. A capacitor is composed of various materials, all with some inherent resistance, that together cause an Equivalent Series Resistance or ESR. Heat is generated as a result of this resistance otherwise known as I^2R power loss. Inherent impurities in the capacitor film will chemically react over time, but are accelerated as temperature increases. The higher the operating temperature of the capacitor, the more its electrical and / or physical properties change over time.

How does APC design with regard to these critical factors?

APC constantly strives to design and manufacture highly reliable products. This of course is no different for the Silcon and InfraStruXure UPSs. APC realizes that AC capacitors are one of the leading causes of UPS failures throughout the industry and goes through great lengths to ensure maximum AC capacitor lifetime.

There are two principal applications of AC power capacitors employed in the APC Silcon UPS and APC InfraStruXure Type C UPS. APC uses AC capacitors utilizing wrapped metallized film construction, which are used for both input and output filters. The power factor correction for these UPS units is performed via an active IGBT front end. The AC input capacitors are located upstream of the delta transformer and are responsible for filtering the high frequency ripple generated by the delta inverter thereby reducing harmonics injected onto utility. The AC output capacitors are located downstream of the main inverter and are responsible for filtering the main inverter switching frequency so as to provide a smooth sine wave to the critical load. Both of these UPS models are based on the Delta Conversion on-line topology. Each critical design factor, mentioned above, is taken into consideration in the design of the Silcon and InfraStruXure Type C UPSs.

Voltage stress: The AC capacitors in the Silcon and InfraStruXure Type C UPS families are always connected line-to-neutral. This is because of the lower voltage stress applied to the capacitors. Although a higher rated capacitor can be used in a line-to-line configuration, as the voltage potential across a capacitor increases, it becomes more difficult to prevent corona effects since metallized film capacitors are never perfectly impregnated with oil. All models in both of these product families use AC capacitors that are de-rated by at least 37% and most importantly have a voltage stress less then 45 V/µm across the capacitor film.

- Input filters - Due to the conservative de-rating design of the input capacitors, input voltage variation due to load is still far below the rated capacitor voltage.

- Output filters - The main inverter maintains a constant rms voltage (277 or 120 depending on the model) across the output AC capacitors. This steady state output voltage is controlled by the main inverter and is completely independent of percentage load on the UPS.

Current pulse handling capability: Both the delta and main inverters are current limited to peak currents that are below the capacitor peak current capability.

- Input filters - The input filter is susceptible to external transient peak currents since it's on the input of the UPS. To protect the input AC capacitors from these high peak currents, a common mode choke is located upstream. This choke not only protects the input capacitors from high peak current events, but also reduces electromagnetic interference (EMI).
- Output filters - The output filter is less susceptible to peak currents then the input filter due to the impedance of all the other components downstream of the input capacitor. The output filter is mainly protected by the same common mode choke as the input capacitors as well as the impedance of the delta transformer. Both the choke and delta transformer are located upstream of the output filter.

Peak voltage: High frequency peak voltage at the UPS input can occur at any time during normal UPS operation.

- Input filters - Like in the case of peak currents, the input filter is susceptible to peak voltages since it's on the input of the UPS and likewise relies on the upstream common mode choke.
- Output filters - The output filter is less susceptible to peak voltages then the input filter due to the impedance of all the other components downstream of the input capacitor. Once again, the output filter is mainly protected by the same common mode choke as the input capacitors as well as the impedance of the delta transformer.

Thermal stress: As time goes on, the heat generated from the capacitor's inherent power losses causes dielectric degradation. This means that as the capacitor ages, its ability to withstand the applied voltage across its terminals is continually compromised. This is precisely why de-rating AC capacitors is crucial in extending their lifetime. Thermal stress in both the Silcon and InfraStruXure Type C is reduced by means of locating both input and output capacitor banks in a forced airflow stream.

Conclusion

APC realizes that AC power capacitors have historically been the primary cause of UPS field failures throughout the industry. And even today, AC capacitor failures plague some UPS designs. By understanding the mechanisms that cause AC capacitors to fail, APC has designed their large Silcon and InfraStruXure Type C UPSs to extend the life of their AC capacitors. This design benefits from a conservative application of the four critical design factors for AC capacitors. Ultimately the most important factor is voltage stress across the capacitor film. Not only is this steady state voltage stress completely independent of the percentage UPS load, but most importantly it drives the lifetime of the capacitor by a factor of 8

About the Author:

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