PowerControl

CAPACITORS AND FANS WITHIN UPS SYSTEMS

WHITEPAPER

A proactive maintenance approach ensures a UPS system delivers high quality power at all times enabling maximum efficiency, reliability and availability of critical infrastructures.

UPS systems deliver power using large AC and DC capacitor banks, both of which degrade under operating conditions. This is due to usage as well as ambient conditions such as internal UPS heat. Continual operation of both AC and DC capacitors after they have served their expected life span, exposes the UPS system to a high risk of failure. Fans are also part of a set of replacement components that need attention to enable maximum life expectancy of UPS systems.

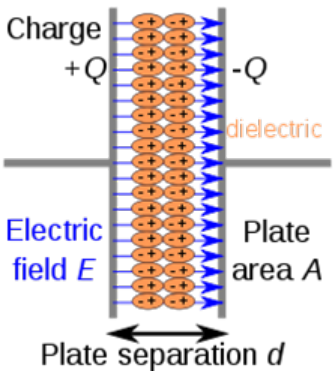
Capacitors are small devices that smooth out fluctuations in electrical voltage. A regular UPS system contains dozens of capacitors of varying types and sizes. Smaller ones to smooth out the power supplied to the UPS processor and larger ones to regulate the power flow into protected equipment.
Like batteries, capacitors and fans also degrade over time. Manufacturers lifespan ratings are typically 40,000 – 45,0000 hours of normal operating life (or 5 Years) for fans and 45,000 – 50,000 hours (or 6 years) for capacitors.

The lifespan of capacitors and fans are subject to change if environmental conditions (premises, load type, usage) are abnormal or harsh for the equipment. When a capacitor fails visible effects are often not seen however, the other capacitors will have to undertake the extra workload, which in turn shortens their useful lives. In many cases, a capacitor failure will trigger the UPS system to switch to bypass mode, during which it cannot protect the critical load.

To maximise the efficiency and performance of a UPS solution, capacitors and fans should be treated as perishable, replaceable items from the start and plans should be made to replace them at or near the end of their rated service life. Power Control engineers can inspect and test the capacitors and either partially or fully replace capacitor banks if required to ensure the UPS system is back up to satisfactory performance in no time at all.

WHAT IS A CAPACITOR?

A capacitor is a small electrical device that can be as large as a mobile phone or as small as a penny. The size depends on the amount of voltage the capacitor is expected to digest (capacity rating). It is generally encased in aluminium or chromium plated casing and contains a pair of conducting surfaces such as metal plates or electrodes. These are separated by a third non-conductive region called the dielectric medium, examples of which are glass, air, paper, plastic, ceramic and even a semiconductor depletion region chemically identical to the conductors. This construction is important as the thinness of the dielectric medium determines the overall capacitance of the capacitor



THEORY OF OPERATION

Using Coulomb's law, first published in 1785 for quantifying the amount of force needed for stationary electronically charged particles to repel or attract each other, a charge on one conductor will exert a force on the charge carriers within the other conductor. Attracting opposite polarity charge and repelling like polarity charges, an opposite polarity charge will be induced on the surface of the other conductor.

A capacitor should be defined by a constant capacitance (C) which is defined as the ratio of the positive or negative charge (Q) on each conductor to the voltage (V) between them.

$$C = \frac{Q}{V}$$

However, charge build-up sometimes affects the capacitor mechanically causing a variance in its capacitance. In this case, the capacitance is defined in terms of incremental changes:

$$C = \frac{\mathrm{d}Q}{\mathrm{d}V}$$

WHAT DO AC AND DC CAPACITORS DO?

AC capacitor: They have similar characteristics to DC capacitors in that they are perishable and have an expected period of useful service. AC capacitors are present to smooth out input transients and reduce harmonic distortion on the utility input to the UPS. More importantly they are directly connected to the critical load output and help to control the waveform of the UPS systems output voltage.

DC capacitor: The DC capacitor is used in UPS applications to smooth out fluctuations in voltage by dampening any changes, attempting to fill out the troughs and eliminate the peaks, maintaining a constant level of voltage. This is also known as 'supply voltage filtering'.

ARE CAPACITORS PERISHABLE?

Yes, they are. When properly designed and manufactured, capacitors show very gradual changes in their characteristics over time, when operated at normal rated voltages. However, the paper, aluminium, foil and electrolyte inside the capacitor all break down at the normal rate for those perishable materials. Additionally, poor operating conditions such as excessive heat and increased current can hasten this process. These mediums start to degrade and age both physically and chemically, whilst beginning to lose their capacitance. The capacitor eventually will stop being able to do its job.

NUMBER OF CAPACITORS IN A UPS AND THEIR LIFETIME

There is a magnitude of different capacitors inside a UPS solution, each designed for specific roles. A small PC can contain up to 50 capacitors and a three phase UPS system may contain hundreds.

Capacitors have an operational lifetime calculated according to their rated voltage, current, ambient temperature and resistance to heat. In situ, the expected service life based on the manufacturer's recommendations and the operating temperature of the UPS can be estimated. It is important to remember that the hotter the operating temperature, the shorter the life.

Failures may be evident any time after the manufacturers rated service life and increase in chance as the capacitors get older. It is recommended that a full replacement of all capacitors is scheduled after around 6 years of operation. When a capacitor fails any visible effects may not be seen, however, the other capacitors will be overworking, which in turn will reduce their lives. In many cases, a failed capacitor triggers the UPS system to switch to bypass mode, during which time you are unprotected. When selecting a UPS system great consideration should be given to the type of capacitors within the unit. Compromising on capacitor quality will result in a large depletion of UPS performance over time.

CONSIDERATIONS TO ENSURE LONGEVITY OF CAPACITORS

A lifespan is calculated taking into consideration voltage and operating temperature. Logic is followed by assuming that by overstepping the design limits, the useful life of the capacitor can be shortened. For example:

Overworking- Capacitors may be more likely to fail if they have to filter unusually large amounts of voltage noise or disruptions to the sinewave (transients). The harder it works, the sooner the capacitor will have to be replaced.

Excessive Current – Capacitors do not work well under continued over current exposure. Such as the current exceeding the rating of the capacitor, determined by the manufacturer. Short periods of excessive ripple are usually harmless as long as the capacitor does not have to overheat to compensate.

Excess Heat - Whether it is the outside ambient temperature or the heat from inside the capacitor that is excessive, the heat will eventually cause the solution inside the capacitor to evaporate, allowing the UPS system to build up unsafe pressures and cause failure.

The excess heat can quite possibly be from either a clogged or obstructed air source or simply the outside weather.

FAILURE OF A CAPACITOR

A capacitor can fail whilst it is working normally and quite simply just stop doing what it was doing. This kind of failure often goes unnoticed and can be called a failure in an "open" position. Alternatively, a capacitor may develop a leak of the dielectric medium or even vents with a loud pop, often called a fail in a "short condition"

Spilt liquid during a leakage can cause the conductive medium to make unexpected connections and interact with other components in the UPS system. Many UPS solutions with this conductive material have a scored end on the capacitor that allows the corrosive electrolyte to gently leak, trying to prevent too much disruption or damage.

The damage caused when a capacitor fails heavily depends on where the capacitor is and the overall health of the remaining capacitors. For example, if the capacitors are operating well below their expected voltage, the remaining capacitors may be able to take over a failed capacitor with little effect on the operation.

A failed capacitor in the powertrain can reduce the unit's overall filtering capability but may not render the unit non-functional. However, when a capacitor in the powertrain fails on a three phase UPS, it will transfer it into bypass mode. At this time, although the UPS is operational it isn't protecting any equipment. In the very odd case a failed capacitor may disrupt power to the on board computer, however, most UPS solutions will have a controlled shutdown if this was to happen, but any sort of shorting out or foreign leakage inside the UPS system is not good for operation long term.

WHY YOU SHOULD REPLACE THE CAPACITOR EVEN IF THE UPS IS STILL WORKING

When an individual capacitor fails, it is often a sign that the other capacitors may also be under stress. There may be obvious signs such as leakages and splits, but a visible inspection would not reveal that any capacitors may have failed in the "open" condition. Left unchecked, the failure could trigger more failures and in turn, reduce the operational integrity of the unit. By the time a decrease in performance has been identified, the cost of the inefficiencies and possible breakdowns will be far higher than if end of life capacitors had been changed at the recommended intervals.

AC FILTER CAPS – Failure of AC caps will disrupt the input power factor to the UPS. This means the kVA supplied to the UPS solution will increase and could affect the operation of a generator if the match is based on a near unity input power factor. The efficiency of the overall system is impacted as the input cables and switchgear will be under more stress and heat up without any significant increase in the kW load.

DC CAPS – A failure of the DC capacitors in the DC bus results in a larger AC ripple current. This is due to the DC capacitance available to smooth the effect of switching frequencies being diminished. Adding additional stress on the other components and also reducing the efficiency of the system. The biggest impact however, will be seen on systems that have the batteries connected directly to the DC bus as this ripple current and voltage will also be transferred to the other batteries. An AC voltage and the current passing through batteries causes them to heat up leading to an increased rate of degradation. This also effects the UPS (mainly legacy units) as they will often be acting as an additional buffer to the DC capacitors and assist in supporting the DC voltage in the UPS. As the condition of the capacitors worsens, it will add additional stress to the batteries, and likewise as the condition of the battery worsens it adds further stress to the capacitor.

Furthermore, whilst an exhausted capacitor will work when charged if the UPS system was turned off and the capacitor discharges, it is unlikely it will turn back on as the capacitor will not hold the required level of charge to get voltage.

The biggest factor in ensuring capacitors and fans live through to their expected service life is by ensuring the ambient temperature, humidity and cleanliness of the environment is controlled around the UPS.

CONCLUSION

A preventative approach is paramount to maintaining healthy UPS components. When capacitors are proactively changed when recommended, it protects the UPS system against major failure and reduces the risk of unplanned downtime. Maximised performance can be achieved with careful planning by replacing these components towards the end of their rated service life or just before.

Our engineers will ensure UPS systems are thoroughly checked and back up and running to full efficiency and reliability. Our factory trained, first class engineers have access to the largest stock of replacement parts in the UK, held in our own state of the art UPS testing facility, Power Control is one of the largest independent UPS companies in the UK and we have engineers positioned across the UK and are available to undertake your capacitor and fan replacements immediately. Please contact one of our maintenance service team to arrange your visit today.

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