The Benefits of Flywheel technology

Rob Tanzer, Technical Support Manager of Chloride, discusses the benefits of UPS systems utilising flywheel technology to provide critical backup power in data centres.

Data centres are totally reliant on a consistent supply of clean power and any deviation from this creates severe repercussions. Therefore, Uninterruptible Power Supply (UPS) systems, such as those supplied by Chloride, are installed as the default backup source for protecting against this type of scenario, and the majority of them have traditionally relied upon batteries to provide this.

Typically, when a power interruption occurs, the UPS system draws power from a bank of batteries to provide 'ride-through' power to keep servers online until the diesel generator can start up and begin powering the facility. However, as data centres struggle for space, the smaller footprint of flywheel-based UPS systems, which take up considerably less space than battery banks, are presenting a very viable and attractive alternative. Coupled with their longer life cycle, lower cost of maintenance and their environmentally friendly credentials as a result of not using hazardous and toxic chemicals, flywheels provide some obvious advantages over conventional battery systems.

The origins and use of flywheel technology for mechanical energy storage began several hundred years ago and was developed throughout the Industrial Revolution. During the 1960s and 1970s, NASA sponsored programs proposed energy storage flywheels as possible primary sources for space missions. However, it wasn't until the 1980s when the necessary components, such as magnetic bearing systems and high power density motor-generators came into existence, that the technology was able to develop into the many current forms of energy storage that flywheels can now provide.

A flywheel energy storage system is basically a 'mechanical battery' that stores energy kinetically, in the form of a high speed rotating mass. When a utility outage occurs, the energy stored by the rotating mass is converted to electrical energy through the flywheel's integrated motor generator and then passes through a bi-directional IGBT power converter. The system is designed so that the stored energy within the flywheel is sufficient to provide the required DC back-up power for a UPS system until the utility supply returns, or until the standby diesel generator comes online, and takes over the supply of power to the UPS system. As an example a single flywheel unit would support a 150 kVA UPS running at a typical 75% load for 30 seconds. Since 98% of all power outages last less than 10 seconds and most modern diesel generators can start and take load within 15 seconds, this makes flywheel bridging without batteries, perfectly feasible. Once either the utility is restored or the generator provides power to the input of the UPS, the flywheel system is re-charged by taking current from the DC bus of the UPS until it is back up to full speed and its normal fully charged mode. Thus a flywheel can be regarded as a direct replacement or alternative to batteries. The additional inherent ability to recharge quickly makes the system more resilient than batteries due to the fact that, after a full discharge, flywheels can be fully recharged within as little as two minutes, whilst batteries always take many hours to achieve 100% capacity. If the standby generator set requires a longer time before accepting the critical load, flywheels can be paralleled for extended run time or power. Unlike lead acid batteries, there are no limitations on the numbers of flywheels that can be paralleled.

A flywheel's energy is created by means of a rotating mass, which is related to the inertia of the rotor (the weight of the mass) and the square value of its rotational speed (Revolutions Per Minute) or velocity, which is derived by the following formula: $E=kM\omega^2$

- k - Depends on the shape of the rotating mass
- M - Mass of the flywheel
- ω - Angular velocity

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There are basically two categories of flywheels available in the market: High Speed (RPM) flywheels, which are relatively light; and Low Speed (RPM) flywheels, which normally operate at less than 10,000rpm and are much bulkier and heavier. Modern high speed flywheels operate with lower losses because they operate in a vacuum. The vacuum reduces friction to minimal levels enabling much more efficient operation practically eliminating friction on the rotating mass. It can be seen from the above equation that the energy stored in a flywheel is proportional to the square of the rotational speed, and thus it follows that using high speed rotation enables the same stored energy to be achieved with a much lighter flywheel. In addition, the smaller mass of the flywheel facilitates the possibility of the flywheel being fully levitated on magnetic bearings resulting in the elimination of mechanical bearing. Another advantage of flywheel technology is their ability to operate over temperatures between 0°C and 40°C, thus eliminating the need for expensive air conditioning installations. Maintenance costs are reduced and they have a greatly increased life over traditional battery systems.

Since high speed magnetically levitated flywheels do not rely on mechanical bearings they are mechanically relatively simple. Unlike lead acid cells, which can deteriorate with age or repeated discharge, flywheel systems have a more predictable lifespan. Batteries tend to have a lifespan of around 5-7 years, whereas flywheels will have a lifespan in excess of 20 years. Also, flywheel technology is more environmentally friendly since they do not use toxic chemicals that are characteristic of lead acid batteries, thus making disposal at end of life far less onerous.

The fact that the flywheel module uses magnetic levitation means that there are no bearings to wear out and thus maintenance is minimal. All that is required is an annual inspection of fans, filters and settings and so downtime is massively reduced. Even the routine of changing the small vacuum pump can be carried out without the flywheel being taken off-line. Once installed, the flywheel system should remain operational for a period of 7 years before needing to be shut down to change the small number of DC Capacitors used.

Another factor that should be taken into consideration is the fact that multiple flywheels can be used in parallel for increased power or for longer support time. They can also be used in parallel with batteries to provide an added element of security. This can be especially useful in situations where batteries and other storage devices may fall short. Flywheels can be programmed to be the first line of defence against outages, so the batteries are never cycled until the flywheel has exhausted its energy. This set-up shields battery banks from virtually all cycling events, preserving battery capacity for longer disturbances. Consequently, this 'battery hardening' effect extends battery life expectation and improves UPS reliability.

Chloride's partner, Vycon, has been at the forefront of developing Flywheel systems and this technology, has emerged as a viable alternative to conventional battery solutions. It has especially proved itself to be an excellent solution for constantly cycling power applications and it is certainly being lauded for its green credentials. Working in conjunction with a backup generator, flywheels can contribute to a total solution that will benefit any data centre, providing a long-term return on investment, lower operating costs, lower total cost of ownership, as well as having the potential of taking up a lot less valuable space.

About the author

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Rob Tanzer is Technical Support Manager for Chloride Power Protection. He has worked in the UPS industry for over 30 years and has experience and knowledge of most of the different types of static and rotary UPS systems currently in service today.

Rob is the author of several published technical papers covering UPS systems, thyristor power switching devices and different aspects of UPS systems applications.