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UPS Topologies

Understanding Fundamental UPS Topologies

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Understanding Fundamental UPS Topologies

The definitions of UPS (Uninterruptible Power Supply) topologies have become increasingly misleading over the years to the extent that pros and cons for the designer and user of large scale systems are now lost in myth and uncertainty.

'Static or Rotary' is no longer the useful distinction that it once was. Today, confusion exists in the market place. Some believe that a UPS fitted with a flywheel short term energy store is then a Rotary UPS – it is not. Some believe that all Rotary UPS use kinetic energy storage and diesel engines – they do not. And some believe that there are only two principal UPS topologies (Static and Rotary) when in fact, there are three.

To begin with, consider what a UPS is and how it works.

These devices sit between the normal power source (typically a utility supply) and critical loads. The UPS is designed to provide a conditioned and uninterrupted supply to these critical loads. To accomplish the latter, the UPS is also supplied from a short term energy store (often a battery).

In the event of a utility failure, support of the load must be seamlessly transferred to the short term energy store and maintained while a longer term alternative power source such as a standby generator is made available. Once available, the load is then seamlessly transferred to this alternative power source. Upon restoration of the utility, the process is reversed.

This transferring of the load back and forth is paramount to the proper performance of any and all UPS.

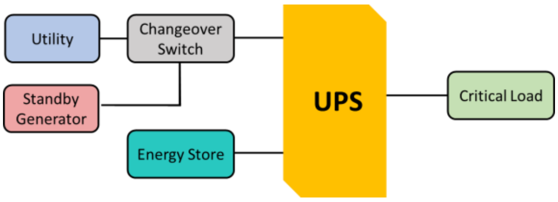

Figure 1. Generic UPS, Utility and Standby Generator arrangement.

For some time, UPS have been placed under one of two classifications, either 'Static' or 'Rotary'. This is however an outmoded distinction that can be quite misleading.

Static UPS (SUPS): Defined as one that produces an output by artificial waveform generation through the high-speed switching of power semiconductors.

Rotary UPS (RUPS): Defined as one using an electrical machine to naturally generate the output waveform.

Whilst these definitions go some way towards indicating how the power conditioning element of a UPS might be accomplished, they infer nothing about the all-important load transfer technique.

In this context, a more meaningful distinction is one that identifies how the short term energy is coupled into the UPS to support the load transfer and how the UPS might be expected to operate under dynamic (changing) electrical conditions such as large load steps, short outages and input voltage swings. This approach can be used to classify UPS topology in a more meaningful way.

The dynamic response and energy store coupling method of a UPS can be fundamentally defined as being either mechanical or electrical.

The more useful definition is perhaps therefore the Electrically-coupled (EC) UPS and the Mechanically-coupled (MC) UPS. The coupling method is important as it plays a significant role in determining system Performance, Flexibility, Reliability, Availability and Maintainability of the UPS and energy store combined.

I. Mechanically-coupled UPS

A Mechanically-coupled UPS connects the energy store with the UPS using a mechanical drive shaft for both charging and discharging. Invariably, this results in an energy storage system in the form of a kinetic energy induction coupling. Energy outflow is largely controlled by the braking (decelerating) of this energy store.

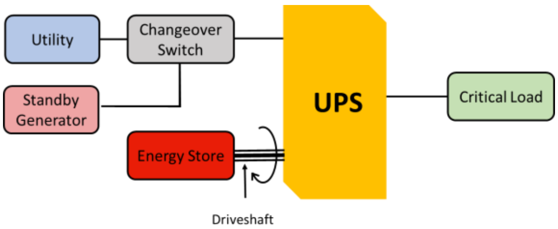

Figure 2. Mechanically-coupled UPS Block Diagram

In more detail, an electrical machine is directly connected to an energy store which has two independently rotating elements, all turning on a common horizontal shaft. The two elements of the energy store rotate at different speeds, one at the synchronous speed for the operating frequency of the system (50 or 60Hz) and the other at a much higher speed in order to store energy. In emergency mode, the energy is extracted from the higher speed element by controlled braking and transferred to the load mechanically. This system results in a long drive shaft and for higher power ratings, the spinning masses on that shaft are considerable.

A Mechanically-coupled UPS exists either with or without a directly coupled diesel engine. When a diesel engine is directly coupled, the technology is referred to as DRUPS (Diesel Rotary UPS) or less precisely as RUPS which simply furthers the confusion.

By far, the most common form of the mechanically-coupled UPS is a DRUPS and this type is analyzed hereon in.

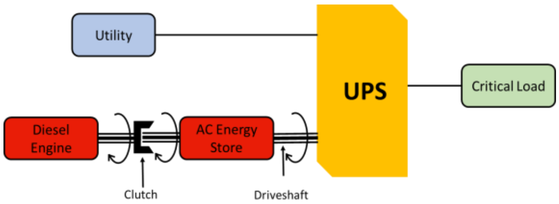

Figure 3a. Mechanically-coupled UPS with Standby Engine (DRUPS) Block Diagram.

With the mechanically-coupled DRUPS the driveshaft is even longer, joining engine to clutch to energy store to UPS in one continuous horizontal shaft mounted on a single base. The shaft connects sizeable and weighty rotating elements that must all be precisely lined up so as to maximize dynamic performance and minimize stresses and vibrations.

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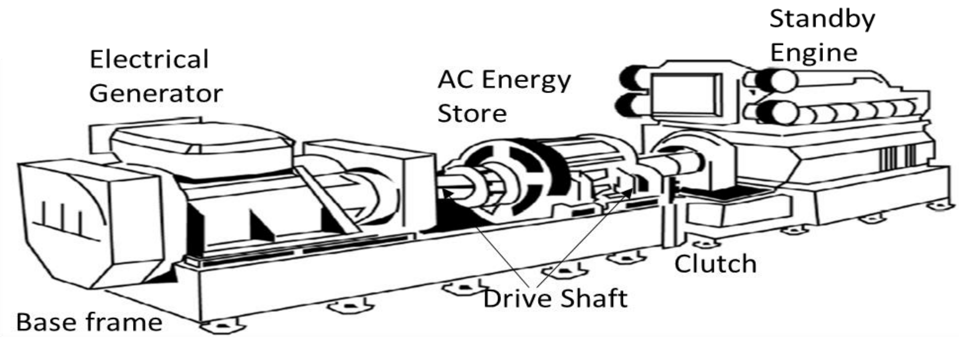

Figure 3b. Typical Mechanically-coupled DRUPS base frame layout

Benefits of MC UPS

Whilst there may be different arguments put forward for the benefits of this type of UPS, they can be boiled down to six major points:

i) The peak efficiency in on-line mode is typically better than some EC UPS.

ii) Loads requiring high peak currents can be handled better than for some EC UPS.

iii) Space can sometimes be saved through the replacement of the traditional battery by the energy storage and by the direct coupling of a standby engine.

iv) The equipment may be operated in a more rugged environment than certain EC UPS.

v) The equipment is more suitable than certain EC UPS for high power applications.

vi) Power capacitors are eliminated from the design which improves reliability compared to many EC UPS.

Limitations of MC UPS

This UPS consists of large mechanical elements which can only be configured in one particular manner and all in the same location on a single driveshaft.

i) The engine is not usually available as a separate source to the UPS which limits flexibility during maintenance and repair.

ii) The single shaft arrangement constitutes a single point of failure for the UPS and standby energy store.

iii) The system uses a series of nested bearings and their overhaul usually needs to take place off site, taking considerable time and expense.

iv) The redundancy and size of the engines (as a minimum) must always match the UPS rating which can lead to the installation of excess engine power.

v) The physics of an induction coupling energy store significantly restricts the useable ride-through time which means that the engine must be made to start as soon as any utility perturbation is detected and must get up to full speed often with the aid of adjustments to the normal engine setup.

vi) Increased possibility of critical load interruptions through human error with annual intrusive maintenance requirements.

II. Electrically-coupled UPS

An Electrically-coupled UPS connects the energy store with the rest of the system using an electrical connection via a DC link. Power semi-conductors are used to control the energy flow for both discharging and re-charging. The DC link allows both batteries and kinetic energy devices to be used for the short term storage.

The Electrically-Coupled UPS is the type most commonly employed.

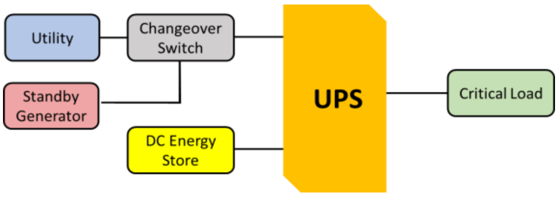

Figure 4. Electrically-coupled UPS Block Diagram

In the electrically-coupled UPS, an electrical inverter (which converts DC to AC) is connected to the short term energy store - a battery or a kinetic energy store. Power flow towards the load is invariably controlled by this inverter. Power flow into the energy store may be by virtue of the same inverter or by a separate charging rectifier (which converts AC to DC).

Synthesized Generation:

The inverter is typically designed in one of two ways. One way uses complex circuitry with power semiconductors that switch rapidly on and off to simulate a basic waveform which is then filtered using power capacitors to create a sinewave. This is referred to hereon in as a Static UPS.

Natural Generation:

The second way is to use a far simplified and more rugged circuitry with power semiconductors that switch at a slower speed to produce a basic waveform which is then filtered using an electrical machine in place of the power capacitors, to produce a sinewave. This is referred to hereon in as a UB UPS after the special 'UNIBLOCK'™ electrical machine used in the filter stage of the UPS.

Both the Static UPS and the UB UPS are electrically coupled devices.

Benefits of EC UPS

The electrically-coupled UPS exhibits a number of advantages over the MC UPS.

i) Partial load efficiency is typically better reaching around 3% difference at 25% load. This can sometimes reduce energy consumption and running costs.

ii) Greater flexibility for system expansion and configuration. The MC UPS tends to have a 1:1 relationship between engine and UPS power and often, they cannot be operated independently of one another.

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iii) Energy store options allow ride-through autonomy to be selected between seconds and minutes in conjunction with optimising other design criteria.

iv) Lower maintenance requirements and for some manufacturers, free of annual maintenance altogether, leading to improved Availability and lower operating costs.

v) Standby generation and UPS can be configured differently to suit the electrical requirements and physical constraints.

Additional Benefits with UB UPS

Further to the advantages for all Electrically-Coupled UPS, the UB UPS will provide the following added benefits over Static UPS:

i) Reduced component count and elimination of wear components such as power capacitors and electric fans raises the mean time between failure of a single unit typically by a factor of 10 (thousands of hours to millions).

ii) Normal on-line mode efficiencies are typically higher than synthesized UPS in the economic operating range above about 35%, saving more energy and further reducing costs without compromise in necessary protection of the load.

iii) Larger capacity single units save significant footprint and afford much higher Availability by elimination of the need for unit paralleling to achieve higher power ratings.

iv) Overload and fault characteristics are inherently better in emergency mode and when the bypass function is unavailable.

v) Paralleling of 50-300kW units is not required to achieve the modern day power string demands in large data centres. This automatically leads to far higher Reliability and Availability.

vi) Easily employed at either low or medium voltage and can be utilized with upstream or downstream standby generators.

vii) Comfortable working with renewable/alternative energy sources and is capable of offering both stabilization and bi-directional power flow for feeding energy back to the utility.

vi) The most advanced and capable UPS for deployment in an isolated-parallel system.

III. Conclusion

Classifying UPS as either Static or Rotary is insufficient in indicating the differences surrounding performance, maintenance, reliability and flexibility, especially in the context of the modern large-scale data centre.

The mechanically-coupled UPS is less versatile than its electrically-coupled counterparts for many applications. Its mechanical nature inevitably leads to higher maintenance requirements and longer repair times for some faults.

The electrically-coupled UPS benefits from the faster dynamic response of electrical energy transfer and from generally lower losses at typical design operating loads, making it more cost effective and environmentally friendly to run.

The complexity of the Static topology serves to reduce the mean time between failure (MTBF), whereas this is high for the other two topologies. However, for the MC UPS, the average repair time (MTTR) tends to be much longer than the other two topologies. The MTBF and MTTR are used to calculate the Availability (or Uptime) of a UPS and in this arena, the UB UPS scores well.

The UB version of the EC UPS takes matters a step further by enhancing the Availability and efficiency profile, offering wider design flexibility and saving on infrastructure for large scale installations.

The modern day data centre operator is invariably looking for an economic UPS solution that has a sustainable profile, exhibits high Reliability and high Availability (low downtime), is flexible and requires little or no intrusive maintenance. The UB electrically-coupled UPS can do just that. At the same time, the rugged nature of the UB UPS combined with its performance also makes it well suited to industrial applications.

Piller Group GmbH
info@piller.com

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