

STATIC OR ROTARY? – THAT IS THE QUESTION

Shri Karve, Director of Business Development for MGE UPS Systems considers the selection process for choosing Uninterruptible Power Supplies (UPS) for large Data Centres.

Background

The UPS provides clean power to the critical load. It has a built-in energy reserve in case of brownout or blackout. There are two standards that govern the UPS industry and against which UPS systems are measured: IEC 62040-3 and EN50091-3. Within those standards there are three topologies:

1. Offline (passive standby VFD)
This type of UPS provides mains power to the load with very basic filtering and some surge suppression but no real conditioning. Since this type of UPS is rarely used for Data Centres, that's all we really need say about it here.
2. Line-interactive (VI)
Also sometimes called Delta Conversion, this UPS uses a battery for backup, if static, or a diesel engine if rotary. In the event of a frequency swing, Line-interactive topology only provides voltage correction by use of built-in transformers or chokes, but cannot address the mains frequency shifts without switching into emergency operation.

There have been a number of incidents in the past when critical switching to emergency operation has failed during mains problems, or the batteries were discharged, because the Genset had continuous frequency swings resulting in the UPS staying in emergency operation, draining all the batteries and dropping the load. It is surprising, therefore, to note that some Data Centres are still selecting this standard of UPS.

3. Double Conversion (True Online VFI)
This is the most appropriate UPS for Data Centre application as it is independent of both variations in mains power frequency and voltage. Critical load is provided with fully conditioned mains power, converting AC to DC and back into clean AC energy.

The Double Conversion type UPS system is more compatible with an upstream diesel generator set. Later generations of such UPS now use Active Front-end technology which automatically provides a very high input power factor (0.98) and very low harmonic current distortion (less than 4% THDI) right across the load spectrum.

Static or Rotary ?

UPS Technologies

Within UPS', Static and Rotary are the two main available technologies. For the purpose of this article, for static UPS' we will only consider true Dual Conversion topology; for the rotary UPS we will consider the Hybrid Rotary and the Diesel Rotary types.

The diagrams below depict the technological aspects and the major components for each UPS technology.

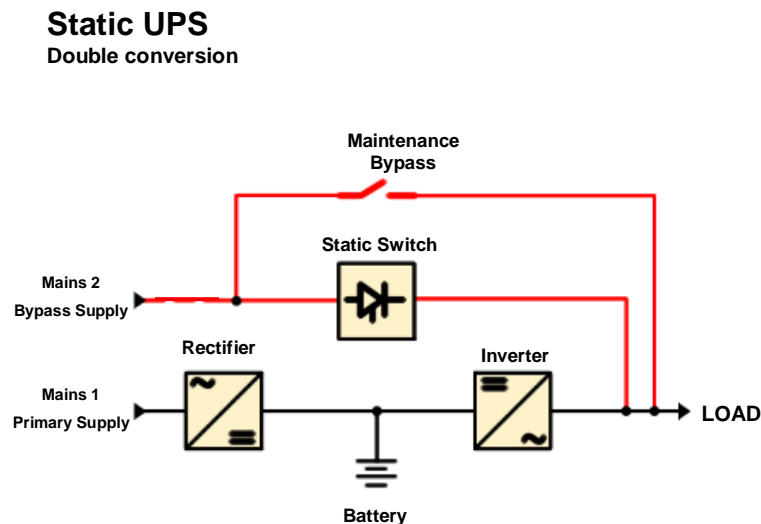


Fig 1: Overview of static UPS technology and functions of main components

A typical Double Conversion static UPS' major components are rectifier, battery bank, inverter and static bypass. Under normal operation, the UPS rectifies incoming mains power and provides float charge to the batteries and supports the load demand. At the same time the inverter converts DC to clean AC, using PWM (Pulse Width Modulation technology) for the critical load. Most of the large UPS' are provided with suitable harmonic filters/conditioners so as to comply with our UK pollution standard BS EN 61000-3-4 and G5/4. In terms of batteries, for large UPS only battery blocks complying with BS6290 Pt IV 1997 should be used, that is, batteries providing a 10 year design life. Multiple battery strings and a high quality battery monitoring system based on Impedance Check technology is also recommended.

Most of the static UPS' need to handle a very high level of non-linear load comprising of various Triple N Harmonics. This type of load may also exhibit leading DPF (Displacement Power Factor); however this should not be confused with True Power Factor (TPF) which needs to be used for sizing UPS'.

Static or Rotary ?

The output of static UPS' generates a fairly clean sine wave voltage to support the non-linear load with a minimum of voltage distortion. Each UPS system should have an external static switch bypass to provide additional support in the event of internal fault or external downstream major short circuit. In order to provide the necessary redundancy, availability and resilience, parallel redundant configuration is recommended. In some Data Centres, design has been set out for Isolated Redundant Configuration. Static UPS' provide exceptional flexibility from the point of view of investment management as UPS' can be added in smaller steps as the client base demand grows.

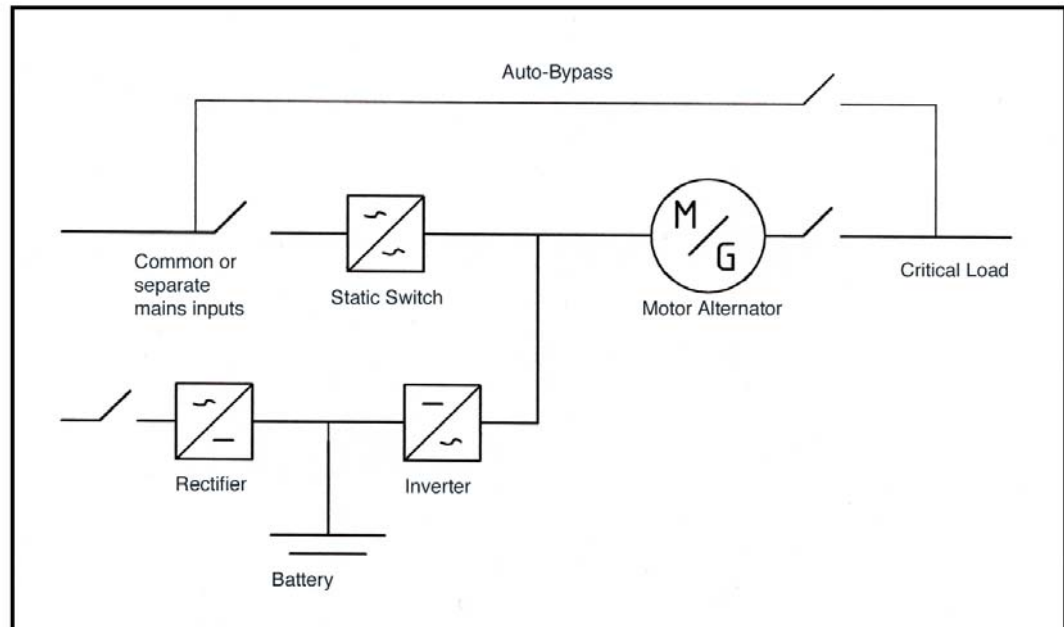


Figure 2: Hybrid Rotary UPS

It would be appropriate to question why is this type of technology being used for UPS design. The background to its use is that some 20-25 years ago most static UPS were using Thyristor technology for the inverter stage. Compatibility of Thyristors was rather poor compared to the current situation where static UPS' use IGBT transistors with PWM which provides clean sine wave. In view of this, the Hybrid Rotary UPS was designed in the past as a solution to provide better compatibility with non-linear loads compared to the old static Thyristor technology. However, there is no need to use this type of design because for the last 12-15 years, IGBT usage on static UPS' has been providing clean output sine wave for the load.

The major components in Figure 2 are a combination of a typical static UPS together with a rotary component (Motor Alternator Set). The principle of operation for this system uses a static switch and motor alternator path during normal operation. If the mains power quality deteriorates, then the system uses rectifier inverter path. Since this system uses more components than a standard static UPS, the MTBF figure and efficiency will be inherently much lower than a typical static UPS.

Static or Rotary ?

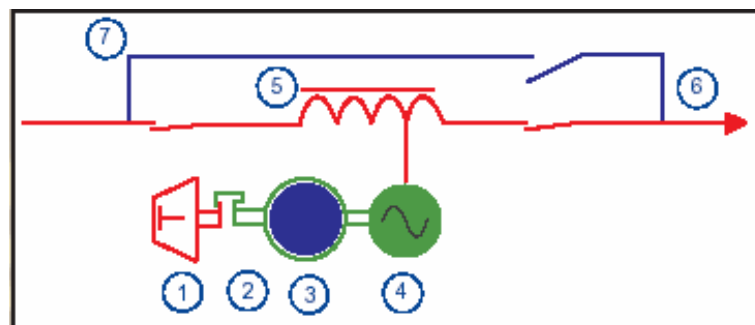
All rotating machines need a high degree of maintenance and it is extremely expensive to maintain Hybrid Rotary systems compared to the static UPS. As an example, operational temperatures are a critical factor in maintaining integrity of the bearings and the lubricant. Lubricant life can be halved if the bearings are running at just 20°C higher than the designed temperature. The rotary UPS with no built-in redundancy also has an exceptionally long MTTR - the replacement of bearings can take as long as 24-28 hours leaving no real protection for the load.

Since static UPS' use fast switching (2 kHz/sec) PWM technology to generate sine wave, they have a high degree of flexibility and compatibility compared to the motor alternator using fixed winding to generate sine wave. In addition, a rotary system will generate a much higher noise level (82dBA 800KVA) compared to a static UPS which, at the same rating, will not exceed 72dBA. Looking at sub-circuit fault clearing capacity there is hardly any difference between a typical static UPS and the Hybrid Rotary UPS. In fact, due to the major market shift in the UPS industry, a lot of Hybrid Rotary manufacturers have now started to offer static UPS'.

Rotary UPS' have limited investment flexibility since the smallest machine available is rated at 500KVA. This type of rotary UPS can be categorised as Dual Conversion topology with certain pre-qualifications:

- Typical initial cost can be at least 30-40% higher than a comparable static UPS system
- System efficiency is much lower (89%) and hence the running cost will be much higher by thousands of pounds sterling than a similar static UPS
- With this design there is no Galvanic Isolation available since the motor/alternator has a common magnetic circuit

Diesel Rotary UPS



- | | |
|---------------------------|-------------------|
| 1 - Diesel Engine | 5 - In line Choke |
| 2 - Free Wheel Clutch | 6 - Critical Load |
| 3 - Kinetic Energy Source | 7 - Mains Input |
| 4 - Synch. Machine | |

Figure 3: Diesel Rotary UPS

Static or Rotary ?

Figure 3 shows a typical Diesel Rotary UPS system. This type of unit was designed almost 35 years ago and uses fairly basic components and technology. In-line conditioner Choke between mains input and the load generates unwanted phase shift. It also uses a series of components, namely synchronous machine, kinetic energy storage source, freewheel clutch, and finally, a diesel engine. Under normal operation the synchronous machine runs as a motor to drive the kinetic energy source.

This type of UPS falls under Line-interactive (VI) topology since it cannot correct mains frequency fluctuations. In the case of major frequency fluctuations from the mains power this unit will start to operate in emergency mode by cranking up the diesel engine whilst at the same time using the kinetic energy to support the critical load whilst the diesel is coming up to its 1550 rpm. If the diesel fails to fire within 3-5 seconds, the critical load will have to drop out if there is no redundant UPS available since the kinetic energy backup is limited in seconds.

There are several weaknesses within this type of design:

- Inner bearings within the kinetic energy source cannot be lubricated under routine schedule
- Diesel engines have a very high component count and therefore a very low MTBF and very high MTTR for the system
- Anti-pollution by-laws in certain cities may not approve the use of a diesel engine for such applications without a catalytic converter
- Often the slew rate and/or the frequency window (ΔF) are widened to reduce frequent starting of the diesel engine but sacrificing the power quality demanded by the Data Centre
- There is a major limitation with regard to impact load (100% step load) performance exhibited by such UPS' as it can take as long as 120 msecs to reach steady state condition whereas a static UPS can easily achieve this condition within 20 msecs
- Synchronisation between multiple parallel UPS' of this design can take up to 10-15 secs assuming that there are no impact load conditions at the time. This timescale is extremely long when compared with a static UPS which barely takes 1 or 2 msecs. Since most of the Data Centres using such a design will have redundant design philosophy this contradicts the basic operational requirements of a diesel engine as they need to be run on full load for longer periods rather than running on partial load for just 30 minutes or so
- Diesel Rotary systems cannot be easily retrofitted into a large building say on 10th floor as structural design needs to be taken into consideration. A typical 600 KVA diesel UPS can weigh as much as 13 tonnes of concentrated loading
- Noise (diesel engines are noisy (112-120 dBA)), exhaust gas emission, bulk fuel storage tank, an exceptional amount of cooling and many other similar problems must be overcome.
- Since this is a rotating type UPS the vibrations being transferred to the building structure may cause a resonance situation with the natural frequency of vibration of the building
- Since the system efficiency is very low (around 84%), running costs can be exceptionally high when compared to similar static UPS

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- When maintaining the Diesel Rotary UPS system simply replacing the bearings in the kinetic energy source (even a simple component swap) can take in excess of 36 hours. Furthermore, carrying out this procedure would require a crane suitable for lifting the heavy (3 tonnes for 600KVA) kinetic energy module. As well as maintenance costs for these units being exceptionally high, the initial UPS project cost can be almost 50-60% higher than that of a similar static UPS

When choosing a Data Centre's UPS system all the points raised in this article need thorough examination to ensure the high reliability which is demanded by clients' critical loads. This is driven by two components of the Availability measurement, i.e., the need for very high MTBF and the shortest possible MTTR. Any single point of failure should be eliminated and the system should provide clean output voltage waveform to support the critical IT Server farms. Remote monitoring of individual UPS' and the critical components of the same is imperative, possibly using an IP address for each critical part of the Data Centre. Consideration should also be given to the anti-pollution lobbies both from the environment aspect and also the harmonic pollution viewpoint. It is due, in fact, to environmental limitations and ease of expandability with base level investment that the majority of Data Centres across the world use static UPS.

New technologies are reaching the market, typically static UPS' with Super Capacitors for short-time backup and also Fuel Cell technology being used in UPS design. For more details, please see www.mgeups.com.