# Powering THE INTERNET
# An Introduction to UPS

## PART 3 ENSURING A HEALTHY POWER SUPPLY BY USING THE CORRECT PULSE RATE

by Shri Karve

In the last of his articles on Uninterruptable Power Supplies, Shri Karve of MGE UPS systems examines the pros and cons of 6-pulse rectifiers versus 12-pulse rectifiers in the battle to ensure high quality power for today's demands.

Although a marginal factor over the past decade, the amount of harmonic current disturbance experienced by electrical installations is increasing continuously. This rise can be tracked to the vast growth in computer use, telecommunications and power electronics, all of which represent non-linear loads that cause harmonic disturbance. This phenomenon concerns most of today's electrical distribution systems, whether in the commercial, industrial or residential sectors, and has a negative effect on most installations including assembly lines in factories, data processing equipment, and co-location sites.

The eroding quality of electrical power should be of great concern to all end users. If we take, for example, the ISP sector, downtime caused by low quality power could potentially cost £millions. A simple power spike could easily cause an ISP's servers to fail and the knock-on effect to users would be catastrophic. Entire businesses could be off-line for lengthy periods of time with a potential loss of earnings measured in £millions.

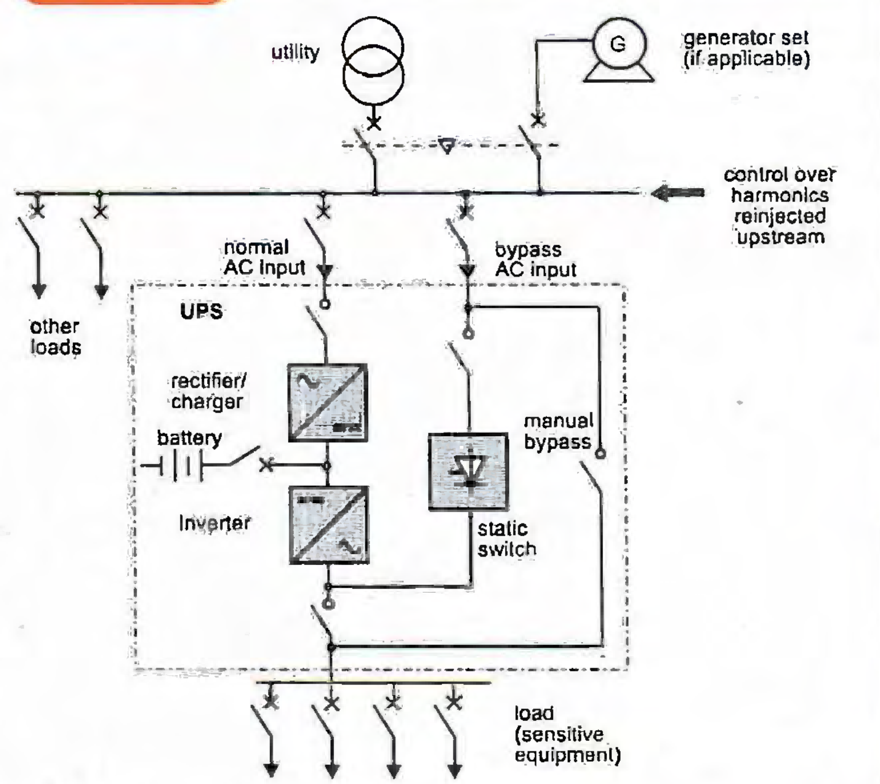


Figure 1. Typical UPS configuration

### How to 'Rectify' Harmonics

The presence of harmonics in the upstream circuits is due to the fact that UPSs use a rectifier to draw power from the input AC distribution system. The rectifier charges the battery at a constant voltage plus supplies DC power to the inverter. Without the necessary conditioning equipment, harmonic disturbance re-injected in the mains will ultimately affect other sensitive equipment sharing the same network. Figure 1 illustrates the typical configuration of a UPS system.

Traditionally, UPS vendors use either 6-pulse or 12-pulse rectifiers to covert AC to DC. The 12-pulse rectifier is achieved through the combination of two 6-pulse bridge rectifiers and a phase shifting transformer. However, due to a significantly higher component count than the 6-pulse rectifier (an extra rectifier and a phase shifting transformer), the 12-pulse rectifier suffers reduced reliability and lower efficiency when compared to its 6-pulse counterpart. The mean time between failure (MTBF) is of critical concern when selecting a UPS system; the higher the MTBF the better, as this obviously means that the UPS will function efficiently for longer periods between repair. Unfortunately, the 12-pulse rectifier demonstrates a relatively low MTBF when compared to the 6-pulse.

### More, or Less?

Reliability is just one concern when considering the best ways to reduce harmonic distortion. To allay such problems and fears, UPS vendors must implement more efficient systems to reduce total harmonic distortion (THDI). One must remember that it is the rectifier that causes a great deal of harmonic distortion. Generically, the total harmonic distortion current (THDI) of a 6-pulse rectifier is around 35% while the 12-pulse commonly experiences THDI of approximately 12%. Both values fall well short of current standards for the maximum THDI - IEEE 519-2 (USA) stipulates that the THDI level must not exceed 5.5%. Therefore, to limit THDI levels in either scenario, one must implement a harmonic filter. The typical dominant harmonics for a 6-pulse rectifier are 5th and 7th (6±1) whilst for the 12-pulse are 11th and 13th (12±1). However, with the 12-pulse rectifier, one must also address the 'skin-

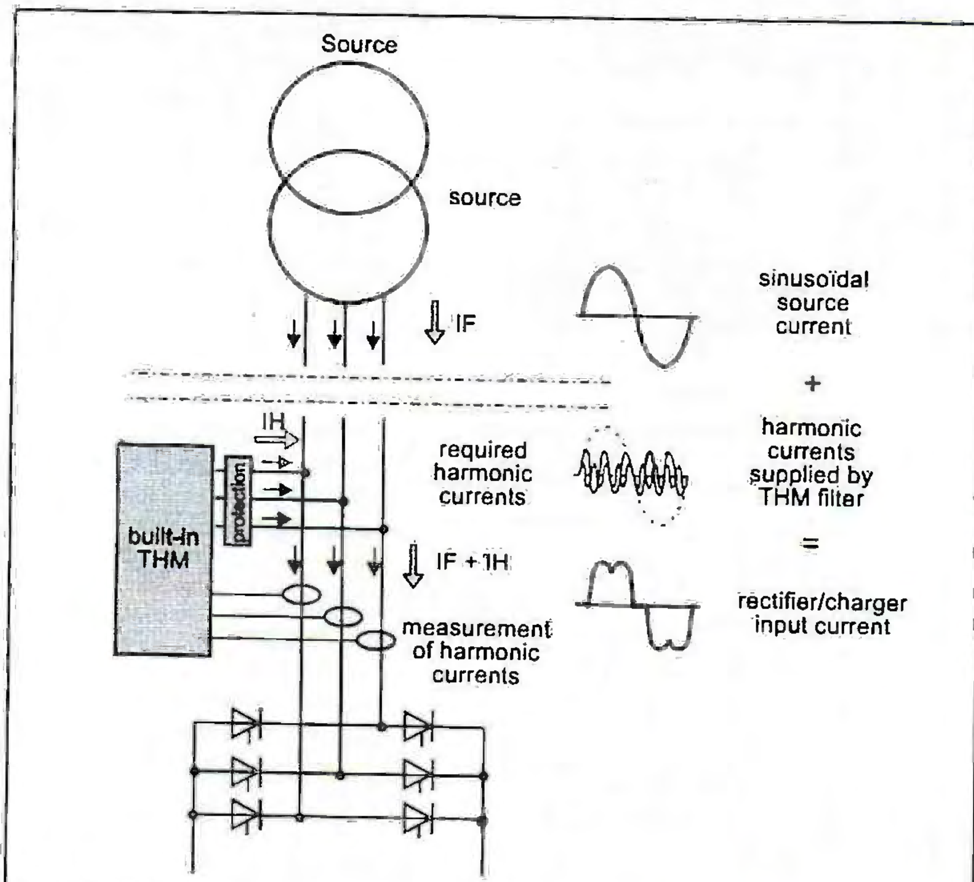


Figure 2 THM system

effect' $\{ d = 1/2\pi \sqrt{\rho \times 10^5 / f} \}$ (1) phenomenon, which reduces the penetration depth of current flow at higher harmonic level, e.g. if at 50 Hz. the penetration depth is 9.3 mm then it will be reduced to a level of 2.8 mm at 550 Hz (11th harmonic). Figure 2 illustrates the components involved in a typical UPS with THM in dealing with harmonic distortion, and highlights how the THM system eliminates the corresponding harmonic currents depending on the harmonic spectrum of the rectifier current.

In essence, one must weigh up the benefits of utilising a 6-pulse rectifier with a single additional filter plus increased reliability to reach the desired 5.5% THDI, or a 12-pulse rectifier with the same additional filter. However, the 12-pulse rectifier has a much higher component count, which equates to a drastically lower MTBF value. To this end, to achieve the same 5.5% THDI, one must realistically choose a 6-pulse rectifier due to its far superior MTBF.

## Harmonic Filters

Traditionally, 12-pulse rectifiers were implemented in the past due to poor availability of high quality harmonic filters. Today, however, the choice is far greater, allowing the 6-pulse rectifier to come to the fore. There are four main types of harmonic filter:

### 1. Series Connected Choke

This is the most economical and most utilised option throughout variable speed drive (VSD) applications. The choke is connected in series with the VSD, thus reducing THDI from 67% (a raw 6-pulse rectifier) to approximately 35%. However, this technology is very basic and less effective at lighter loads, therefore not employed by the majority of UPS vendors.

### 2. Phase Shifting Transformers

This solution utilises multiple 6-pulse or 12-pulse rectifiers, with phase shifting transformers situated between rectifier units. For example, if two 12-pulse rectifiers are phase shifted, THDI is reduced to c.7%. For two 6-pulse rectifiers, this figure equates to c.10%. However, other design criteria need to be analysed when evaluating such a solution:

1. Skin effect, as the phase shifting will create higher harmonic resultant currents (11th & 13th and 23rd & 25th), depending on the bridges being phase shifted.
2. Inherent inrush current required by the phase shift transformer.
3. Additional physical space required for the transformer and external logistics, e.g. extra heat generated.

| Number of UPS units | Dominant harmonics | Phase shift | Redundant operation | Downgraded operation * |
|---|---|---|---|---|
| | | | Sn to Sn | Sn |
| 2 | 12k +/- 1 | + 30° | < 10% | 30% |
| 3 | 18k +/- 1 | +/- 20° | 5% | 13% |
| 4 | 24k +/- 1 | +/- 15°, + 30° | < 3% | 12% |
| 5 | 30k +/- 1 | +/- 12°, +/- 24° | < 3% | 9% |
| 6 | 36k +/- 1 | +/- 10°, +/- 20°, + 30° | < 3% | 7% |

* Downgraded operation = UPS-unit failure or disconnected for maintenance

Table 1. THDI levels with phase shifting transformers

### 3. Passive LC Filters

This is the basic harmonic filter, specifically tuned for certain harmonics utilising a combination of chokes and capacitors. Typically, for 6 pulse rectifiers, LC filters can reduce THDI from 35% to 5.5%, whilst 12-pulse is reduced from 12% to nearer 6%. Passive LC filters are a popular and common solution used throughout the UPS industry, but it cannot be ignored that the filtering achieved is directly related to the percentage load that is presented to the UPS, i.e. the higher the load, the lower the THDI (inversely proportional). Similarly, this has an impact on the input power factor as seen on the mains side.

### 4. Active Harmonic Filters (Conditioners)

This is perhaps the optimum solution, as it reduces the inherent weaknesses of most of its predecessors. In effect, due to the fact that the active harmonic conditioner is a current injection device, it is not dependent on magnitude of UPS load current but purely cleans harmonic pollution between the 2nd and 25th harmonic. With the correct selection, THDI levels can be maintained at c.4% irrespective of load and other criteria (this exceeds the requirements of industry standard EN61000-3-4).

Another advantage of the active harmonic conditioner is that it can be installed as a retrofit, and has no risk of resonance. Utilisation of an Active Harmonic Filter does not have any detrimental effect on the MTBF value of the system, since it is a parallel device. Despite the higher initial capital outlay required to install such a device, the return on investment (ROI) is achieved through its ease of installation, superior performance and reduced footprint – some vendors now manufacture UPSs with integral active harmonic conditioners reducing footprint size even further. Such a device more than exceeds today's pollution standards and pre-empts future regulations, whilst offering fast-switching and rapid reaction within two cycles, thus delivering a total harmonic management (THM) solution. (see table 2)

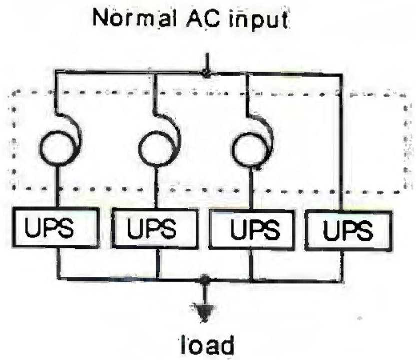


Figure 3. Typical parallel UPS installation with phase shifting transformer

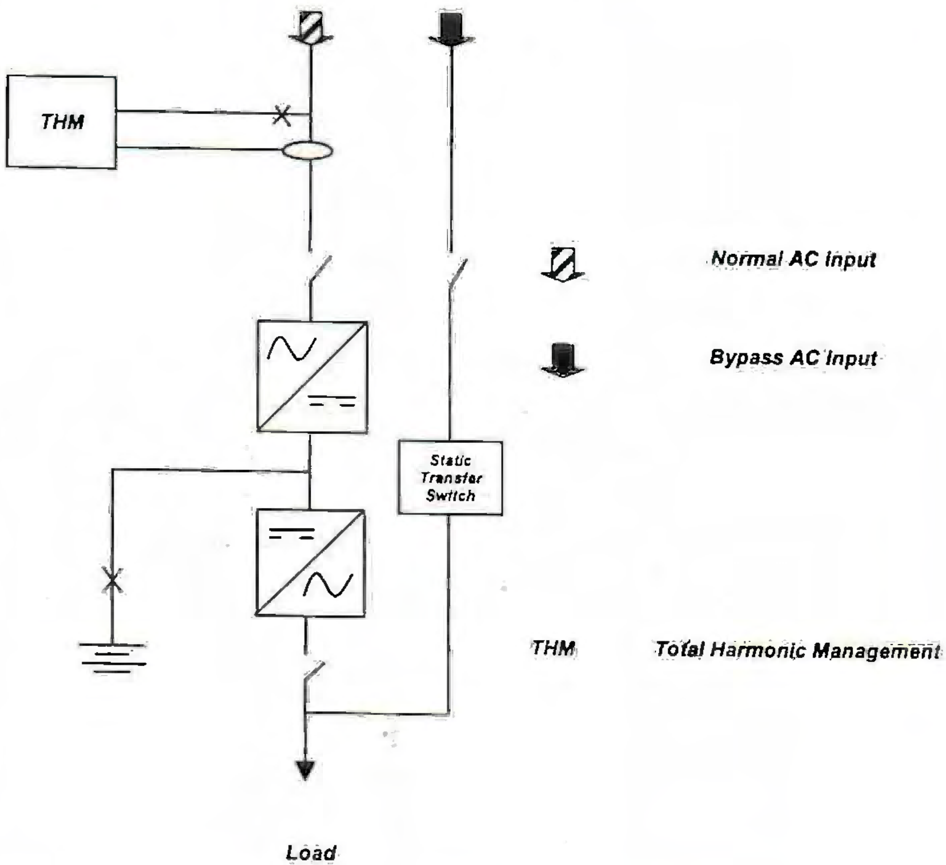


Figure 4. Simplified installation Diagram

With its lower component count and higher MTBF, 6-pulse rectifiers offer end-users far greater efficiency and effectiveness. In relation to THM, combining 6-pulse rectifying technology with active harmonic conditioning produces reduced THDI levels and equally important, yet more difficult to quantify, enhancements in the end users' peace of mind.

As for the future, with the advent of more efficient 6-pulse rectifiers and integral active harmonic conditioners reducing physical footprint and capital outlay, official pollution standards can be met with relative ease, whilst providing low THDI.

## About Shri Karve

Before joining MGE UPS in 1992, Shri held sales management positions with a number of dynamic and static UPS manufacturers. With a BSc in Electrical Engineering, his career path developed from design engineering, where he spent eight years designing rotating machines, motors and alternators. Considered today as one of the leading authorities on UPS and active harmonic conditioners, Shri is frequently asked to speak at international conferences and symposiums, and has published many papers that include power quality problems and the use of active power conditioners for total harmonic management.

1. d = depth of current penetration in mm; f = frequency in Hz; ρ = resistivity of conductor

## Conclusion

With demand for power growing at such a rapid rate, the technology employed to cope with harmonic distortion and to protect this power must evolve at an equally fast pace. Simultaneously, strict pollution standards dictate that THDI levels cannot exceed 5.5%, thus creating a more stringent benchmark for UPS vendors.

Traditionally, UPS vendors chose 12-pulse rectifiers to convert AC to DC current, but with this practice came low reliability. Despite the relative efficiency of 12-pulse rectifiers (c.12%), the consequence of their high component count was a low MTBF, higher running cost and risk of Skin Effect on cables.

| Hk | % H1 | | | | |
|---|---|---|---|---|---|
| | Limit of IEC 61000-3-4 | Without filter | LC Filter | 12-Pulse | THM |
| H3 | 21.6% | - | - | - | - |
| H5 | 10.7% | 32% | 2.9% | 2.8% | 2.5% |
| H7 | 7.2% | 3.5% | 1.9% | 1.5% | 1.5% |
| H9 | 3.8% | - | - | 6 | - |
| H11 | 3.1% | 7% | 3.8% | 9.1% | 2% |
| H13 | 2.0% | 2.7% | 1.9% | 4.7% | 0.5% |
| H17 | 1.2% | 2.5% | 1.7% | 1% | 1.1% |
| H19 | 1.1% | 2.1% | 1.3% | 0.7% | 0.9% |
| HDI | 25% | 35% | 6% | 10% | 4% |

= Non Compliant Figures

Table 2.