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Feature Article

Improve UPS Reliability, THD and Efficiency While Reducing Installation Costs

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When it comes to installing a large 3-phase UPS technical benefits and reliability are high priorities, but installation costs will also highly influence your selection. Advancements in the front-end design of 3-phase UPSs now provide benefits by improving the quality and reliability of installation while actually reducing total installation costs.

Since the advent of computers and other switching devices, nonlinear loads have become increasingly common in the workplace and at home. Switch-mode power supplies are being used to increase power density, and thereby reduce manufacturing costs and size. Computers powered by these nonlinear devices are very sensitive to power disturbances and require a higher level of power conditioning equipment, the most common type being the UPS. Each of the various UPS technologies available today (i.e., off-line, line interactive, ferroresonant, on-line double conversion) have their own advantages and disadvantages, but the main purpose of a UPS is to provide continuous uninterruptible power to sensitive electronic equipment, regardless of utility conditions. A technical and cost comparison of a 225kVA UPS is presented in this article, taking into account the different equipment required to install one technology versus another.

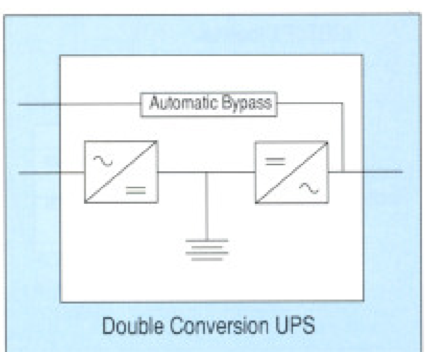

Figure 1. *Double conversion UPS.*

Inverter

In its basic form, the UPS consists of a rectifier/charger, batteries and an inverter. Most 3-phase UPSs utilize on-line double conversion technology (*Figure 1*). When utility power is present, the rectifier/charger converts ac power into dc power to charge the batteries while simultaneously feeding the inverter. The inverter converts the dc power into the ac power required by the sensitive electronic equipment. When utility power is not present (or is inadequate), the power is automatically fed by the batteries to the inverter, ensuring that the sensitive electronic equipment continues its uninterrupted operation.

Since the inverter directly feeds the load, a great amount of emphasis is placed on ways to improve inverter technology. The components used to convert dc to ac power have improved from thyristors to SCR (silicon con-

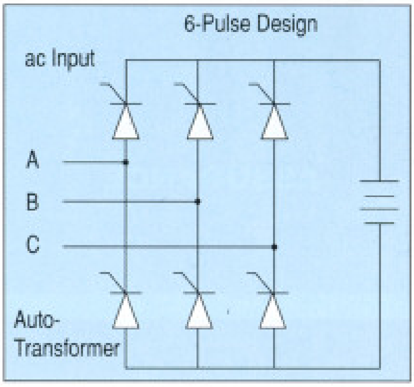

Figure 2. *6-pulse SCR rectifier design.*

trolled rectifiers) and then to IGBT (insulated gate bipolar transistors). Many UPS manufacturers are now utilizing IGBT technology for the inverter. When choosing a UPS, customers normally concentrate on three main specifications: (1) battery time, (2) quality and stability of the power fed to the electronic equipment and (3) overload capability. Therefore, over the past five years the customer demand for a high performing UPS has driven manufacturers to improve their inverter technology.

Rectifier

Just as the inverter is directly responsible for the quality of power feeding the sensitive electronic equipment, the rectifier is directly responsible for the power reflected back to the building s electrical installation, as well as the utility power feeding the building. The following are the three most common rectifier technologies available today for 3-phase UPSs: 6-Pulse SCR rec-

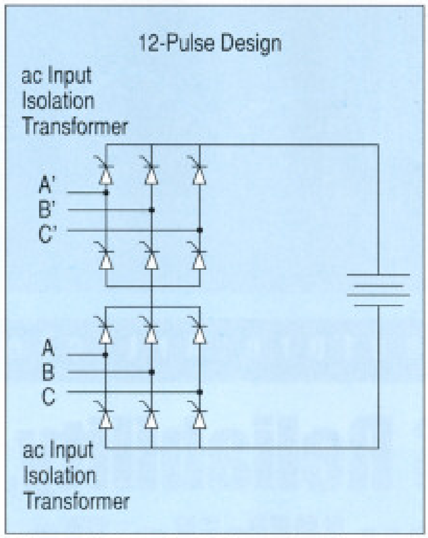

Figure 3. *12-pulse SCR rectifier design.*

tifiers (*Figure 2*), 12-Pulse SCR rectifiers (*Figure 3*) and IGBT rectifiers (*Figure 4*).

6-Pulse Rectifier Technology

A 6-pulse rectifier demands six pulses of current for every 60Hz cycle. The waveform captured on an oscilloscope at the input of a UPS with this technology (*Figure 5*) is not remotely close to being sinusoidal. This means that a large percentage of the total harmonic distortion (THD) will be reflected back to the electrical installation. The levels of THD normally measured at the input of this UPS are approximately 33% at 100% load and 55% at 50% load. These levels of harmonics are much higher than recommended by IEEE 519. Manufacturers attempt to lower their input harmonics to 10% by providing a passive input harmonic filter.

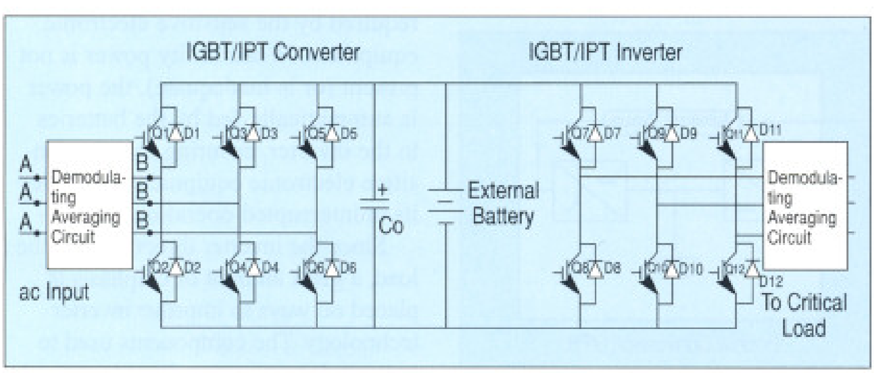

Figure 4. *IGBT rectifier design.*

CAUTION #1: *The input passive resonant harmonic filters claim to lower harmonics to 10%, but only at 100% load. Since most UPS installations are not working at 100% load, this means that the THD (even with filters) will be higher than the IEEE 519 recommendation.*

CAUTION #2: *The input power factor of a UPS utilizing this technology is approximately 0.8. This means that there will be some power factor correcting capacitors and/or filters required upstream on the electrical installation. The power factor correcting capacitors will possibly cause a resonant circuit with the harmonic filter creating more problems than those intended to be solved by the harmonic filter. If a light load is used, the power factor becomes leading with filters and will cause a generator to shut down.*

The 5th and 7th harmonics are predominantly high when utilizing a 6-pulse rectifier. These harmonics cause heating problems to power factor correcting capacitors, generators, cables, breakers, transformers, etc. For this reason, the building s electrical system must be oversized. This over-sizing reduces efficiency, tremendously increases installation costs and, in some cases, increases floor space.

12-Pulse Rectifier Technology

A 12-pulse rectifier is an improvement over the 6-pulse rectifier. Twelve pulses can be counted on the input current waveform captured on an oscilloscope (*Figure 6*). This waveform looks more sinusoidal than the 6-pulse rectifier waveform, hence its lower THD value. The levels of THD normally measured at the input of this UPS are approximately 15% at 100% load and 25% at 50% load. The same types of problems are experienced with a UPS having this technology as those found on a UPS with 6-pulse rectifier technology. The 11th and 13th are the predominant harmonics present with 12-pulse rectifier technology.

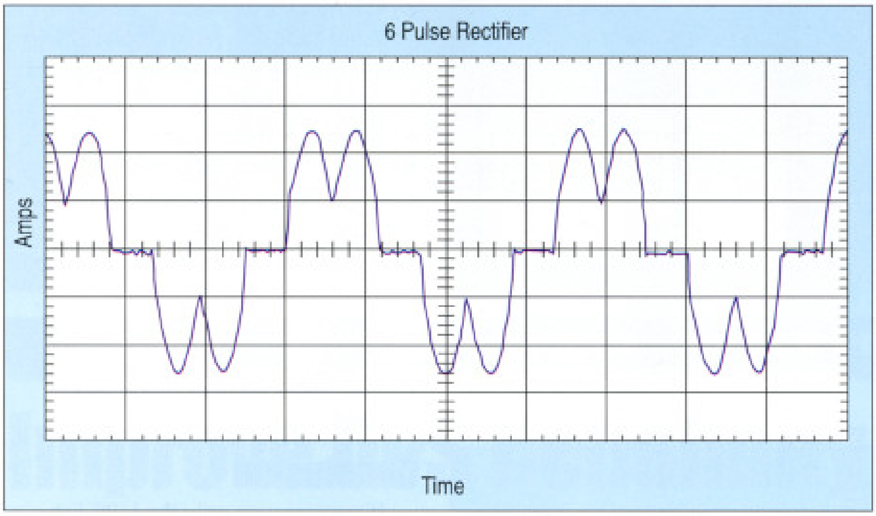

Figure 5. *Input waveform of a UPS utilizing 6-pulse SCR rectifier technology.*

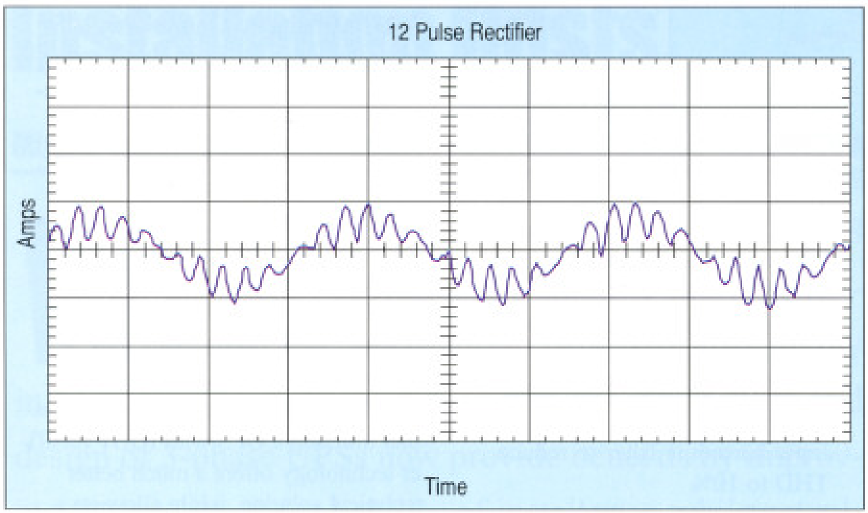

Figure 6. *Input waveform utilizing 12-pulse SCR rectifier technology.*

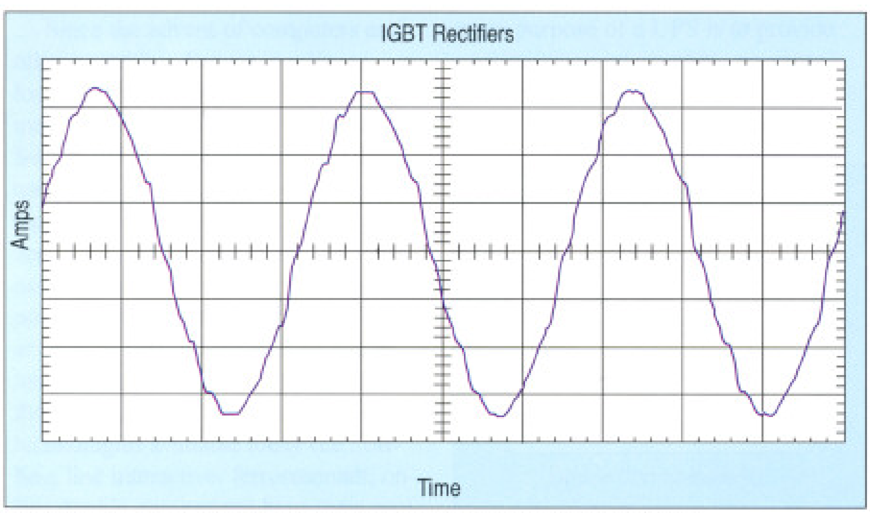

Figure 7. *Input waveform of a UPS utilizing IGBT rectifier technology.*

IGBT Rectifier Technology

The IGBT rectifier technology, working at a 6kHz frequency, revolutionized the UPS industry. The input current waveform captured on an oscilloscope of a UPS utilizing IGBT rectifier technology (*Figure 7*) shows a completely sinusoidal current waveform. This current waveform is similar to that of a resistive load (such as a light bulb) and it has a measured THD of less than 3% at 100% load, and a maximum of 5% at 50% load. These extremely low levels of harmonics are achieved without the use of any passive resonant harmonic filters. Since no harmonic filter is required, there is no risk of having a resonant circuit problem. The input power factor is 0.98 lagging, so that there is no need for power factor correcting capacitors. With this high power factor value, the input current consumption is much less than that required by those UPS with a 0.8 input power factor. It is important to note that even at 0% load, the power factor is lagging, which means that it will not affect the generator s operation.

Important Note: *The low levels of THD and the high value of power factor permit an electrical installation to use a 1:1 ratio of the UPS to the transformers and generators. The lower current consumption allows for smaller wires, breakers, transfer switches, etc. The savings on an installation in which a UPS with IGBT rectifier technology is used can be substantial.*

Comparison

A comparison between an installation of a 225kVA UPS utilizing a 6-pulse rectifier and 225kVA UPS utilizing IGBT rectifier was performed. (Note that the manufacturer s suggested cable, breaker, transformer and generator sizes were used.) The electrical installation was calculated with the same distance and the same manufacturers for all of the previously mentioned electrical elements except for the UPS.

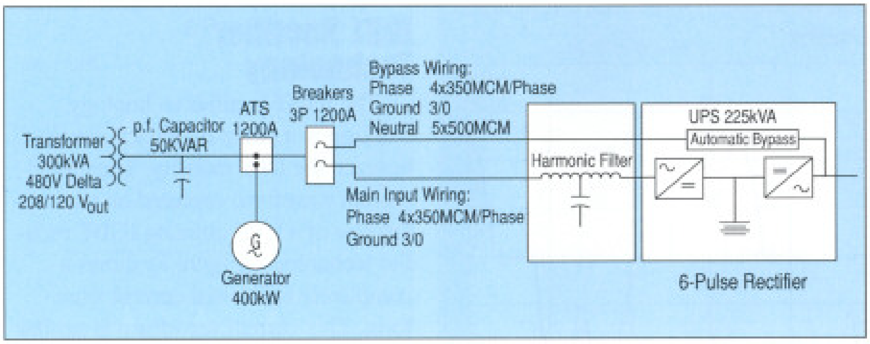

Figure 8. *One-line diagram of an electrical installation for a UPS utilizing 6-pulse SCR rectifier technology.*

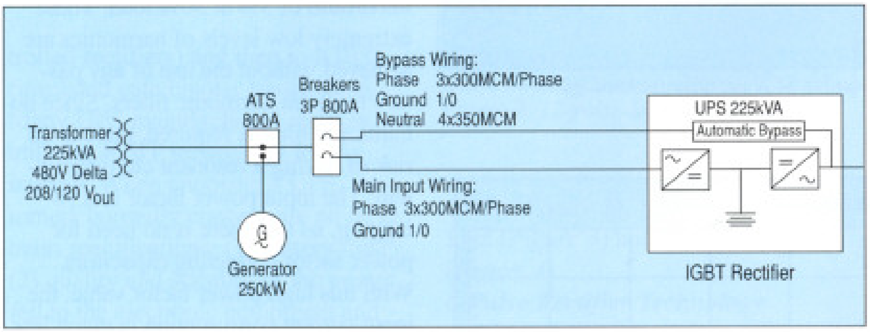

Figure 9. *One-line diagram of an electrical installation for a UPS utilizing IGBT rectifier technology.*

The one-line diagram (*Figure 8*) of an electrical installation for a UPS utilizing a 6-pulse rectifier technology shows that the following is required:

- 225kVA UPS (no batteries)
- 300kVA transformer
- 400kW back-up generator
- 4 X 350MCM wire per phase (main input and bypass)
- 5 X 500MCM wire for neutral of the bypass
- 3/0 ground wire (main input and bypass)
- 1200A automatic transfer switch for the generator
- 3P 1200A breaker (main input and bypass)
- Input harmonic filter to reduce THD to 10%
- Power Factor Cap. Bank to increase power factor to 0.90

The one line diagram (*Figure 9*) of an electrical installation for a UPS utilizing an IGBT rectifier technology shows that the following is required:

- 225kVA UPS (no batteries)
- 225kVA transformer
- 250kW back-up generator
- 3 X 300MCM wire for the neutral of the bypass
- 1/0 Ground wire (main input and bypass)
- 800A automatic transfer switch for the generator
- 3P 800A breaker (main input and bypass)

Conclusion

If we compare only the UPS list prices, the UPS having the 6-pulse rectifier technology is approximately $14,000 less than with the higher IGBT technology. On the other hand, if we compare the customer's *actual* costs, taking into account the generator, filters, power factor correction capacitors, cables and breaker sizes required for a 6-pulse rectifier UPS, the cost comparison changes. Because the IGBT rectifier technology does not require as many features, the cost of UPS with the IGBT rectifier technology can be substantially less expensive in the long run (approximately $69,000 less). This establishes that utilizing a UPS with IGBT rectifier technology offers a much better technical solution, while allowing a reduction of overall costs.

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