



Highly Reliable Electrical Power for Information Systems

An Online Continuing Education Course for Engineers

Course Number: E-3003

Credit: 3 Hours / 3 PDH / 3 CPD

Highly Reliable Electrical Power for Information Systems

Eric Hinrichs, BSEE, BA, MA, MSc (cert.)

Defense Information Systems Agency

Executive Summary

Highly reliable electrical power systems are required to serve critical Information Systems (IS) sites, designated as Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) facilities in the Department of Defense (DoD). This course provides an overview of power quality problems, with an emphasis on Information Technology (IT) equipment. Modern technology's sensitive components present new challenges for plant engineers who design, specify, install, or maintain plants and equipment. For example, SCR and diode rectifiers in computers, copiers, solid-state lighting ballasts, and power conversion sections of adjustable frequency drives increase the need to thoroughly address harmonic distortion and its role in overall power quality.

Introduction

The specific aspect of power quality addressed is the buildup of harmonic distortion in contemporary IT facilities. This is due to the hundreds of non-linear power supplies in UPS, PCs, motors, HVAC, routers, switches, and other IT equipment contained in typical IS sites. These equipment affect the overall facility power factor, produce resonance conditions, overload wiring and transformers, generate excessive heat, result in excessive power expenses, and in extreme cases, can present fire hazards.

Means of reducing these effects by the use of specially-designed harmonic eliminator transformers, use of "power factor corrected" power supplies, specifying equipment that meets IEC and IEEE specifications, oversizing neutral wiring, selection of K-rated transformers, etc., will be discussed. The main emphasis will be the measurement of power quality, elimination of problems, and designing telecommunications facilities to avoid power quality degradations in accordance with the NFPA 70 and IEEE 519.

The power industry and the power engineer are confronted with new problems because of the extensive use of a solid state power conversion technology, called Switched Mode Power Systems (SMPS). SMPS consists of various types of solid state switching elements. These switching elements are solid state devices such as: SCR's, DIAC's, transistors and capacitors. These switching devices are used in computers, copy machines, fax machines, telecommunications equipment, solid-state drives and controls, energy-efficient lighting ballasts, and numerous types of DC-Power Loads. These solid state elements degrade AC power by continuously switching on and off producing non-linear or non-sinusoidal wave shapes in the current supplied from the energy source.

A non-linear load (such as the SMPS) uses current in large pulses from the AC source which creates harmonic distortion. These non-linear current pulses can exceed the nameplate ampere rating of the power source and may cause transformers to run hotter than expected, even when these transformers are supplying less than 50% of their rated nameplate capacity.

With non-linear loads, overloaded neutrals are also showing up in three-phase panel boards serving single-phase loads. In some cases the neutral conductor carries 180 Hertz currents, rather than 60 Hertz currents. This phenomenon is called triplen harmonics. Triplens are multiples of three, which do not cancel but are additive in the neutral conductor.

Figure 1 is a recommended medium capacity (up to 2500 kVA) IS facility configured for maximum reliability and power quality.

The system uses one or two pad-mounted service transformers with primary selective feeders to the facility from the off-site power source. This system employs two low-voltage paralleled standby diesel generators, paralleling switchgear, and one or two large uninterruptible power supply (UPS) systems. The main computer or server room would have numerous power distribution centers that supply conditioned power to the load. The kilovolt ampere rating of the transformer shall be sufficient to supply the

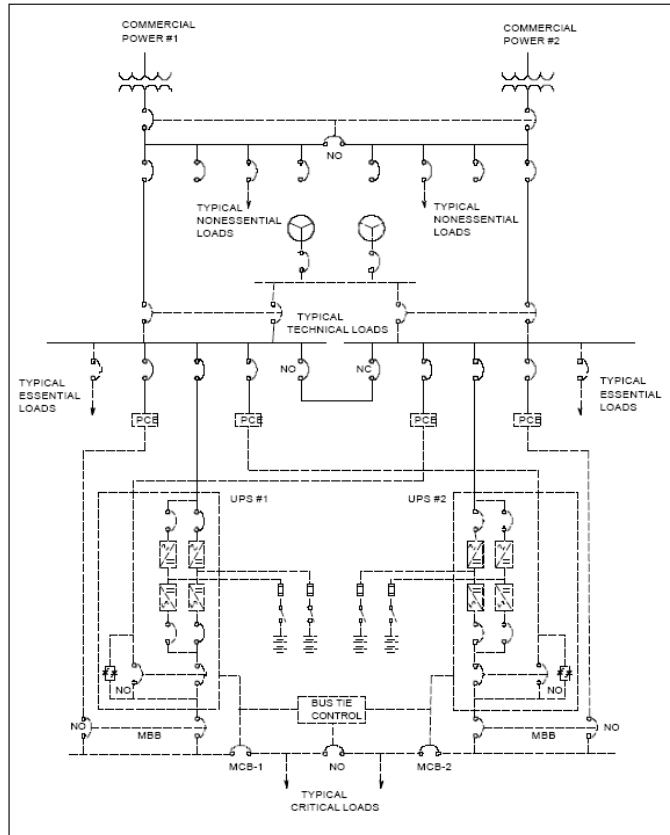


Fig. 1 Medium IS Facility

peak demands of the C4ISR site technical

facilities and any non-essential support facilities continuously without exceeding the 65°C (149°F) thermal rating in an ambient temperature typical for the site. The transformer shall have provisions for the future addition of fans. The kilovolt ampere rating may be reduced to 90 percent of the peak site demands if a double-ended substation is used, but the transformer shall be equipped with one stage of fans, with provisions for the future addition of a second stage.

System- or source-generated disturbances to IS facilities can include sags, surges, switching transients, frequency variations, high or low voltages, power outages, or harmonic distortion. Power degradations, with the exception of harmonic distortion, may result from faulty generation or regulation equipment, poor wiring techniques, improper grounding, or overloaded or unbalanced circuits. Harmonic distortion, on the other hand, is an inherent characteristic of power generation equipment and nonlinear switching power supplies. The performance of some electronic equipment will be affected by odd

harmonics (third, fifth, seventh, etc.) which are of sufficient amplitude to cause distortion. “Isolation from the power grid using transformers, motor generators, UPS etc., usually solves power quality problems (MIL-STD 419, paragraph 4.4.2).” But total harmonic distortion is a main operational problem even when on-site power systems are used, since it is generated internally.

Nonlinear loads cause harmonics to flow in the power lines. Harmonics are unwanted currents that are multiples of the fundamental line frequency (50 or 60 Hz). Fig. 2 shows how the 3rd harmonic of the power line frequency sums in a typical power system. These harmonic currents can overload wiring and transformers, creating heat and, in extreme cases, fire. In information technology power systems it is important to know how to identify and to eliminate these harmonics.

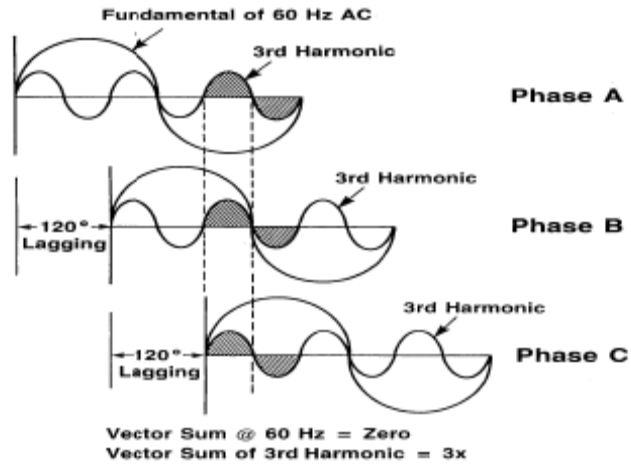


Fig. 2 Third Harmonic Addition

The load itself will draw a current wave made up of the 60 Hz fundamental frequency of the voltage source plus 3rd and higher order odd harmonic (multiples of the 60 Hz fundamental frequency), which are all generated by the non-linear load. It is not uncommon for portions of an industrial power system to have 15 to 25% of Total Harmonic Distortion (THD). THD is defined in the Institute of Electrical and Electronic Engineers (IEEE) Standard 519-1992 as:

$$V_{THD} \%_{\text{fundamental}} = \left(\frac{\sqrt{V_1^2 + V_2^2 + V_3^2 + \dots + V_n^2}}{V_{\text{fundamental}}} \right) \times 100$$

The amount of voltage distortion that can be tolerated on a power system is dependent upon the equipment connected to it and the equipment’s susceptibility to nonsinusoidal waveshapes.

Therefore, THD is the percent of odd harmonics (3rd, 5th, 7th, ..., 25th, ...) present in the load which can affect the transformer. This condition is called a "Non-Linear Load" or "Non-Sinusoidal Load".

In practice, it is far easier to use standard power quality monitoring equipment to determine the presence of harmonics, as shown in Fig. 3. The harmonic distortion for each phase is indicated, i.e. Phase A is black, Phase B is red, Phase C is blue. The magnitude of each harmonic is given in comparison with the fundamental power line

frequency. Most equipment also gives a table with the measured values of the individual harmonics.

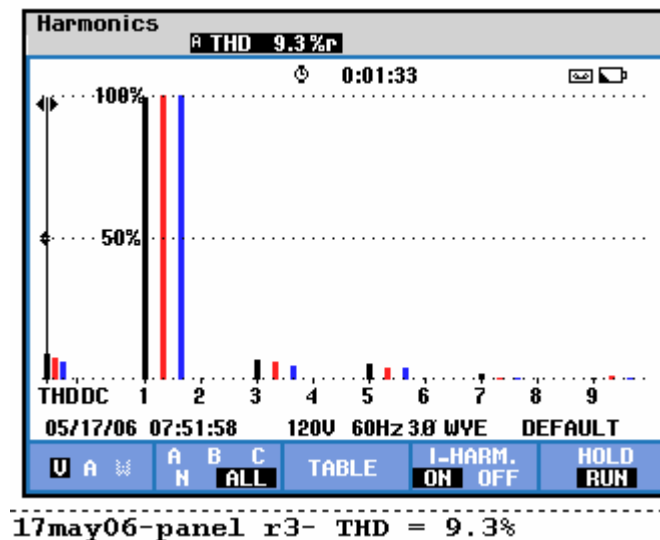


Fig. 3 Measured Harmonic Values

The IEEE-519-1992 standard lists a “Recommended Practice ...” specifically singles out electronic equipment (section 6.6) and highlights its sensitivity to distortion of the supply voltage waveform. It lists the consequences of excessive distortion - erratic equipment functioning and premature failures. Recommended limits are set at 5% Total Harmonic Distortion (THD) with no individual harmonic exceeding 3% of the fundamental. If it is determined from the electrical load analysis that the voltage THD will be greater than 5 %, or that any individual frequency voltage harmonic exceeds 3% of the fundamental, the power system shall be stiffened. Acceptable methods for stiffening the power system and reducing the effects of harmonics include:

- Increasing the transformer sizes
- Increasing the sizes of conductors and connectors
- Adding additional transformers and conductors
- De-rating transformers and motors and/or replacing them with larger ones
- Using only IT equipment complying with IEEE 519 or other relevant industry standards which limit the generation of harmonics
- Redistributing loads to balance three-phase load currents (as well as harmonics)

Balancing phase line currents will not necessarily reduce neutral current.

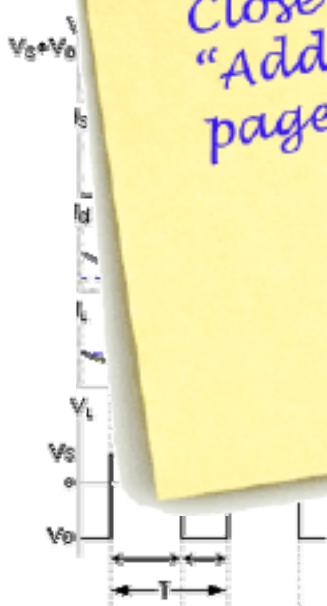
Balancing the phase load currents in a 208Y/120 volt three phase system (making load currents equal in each phase) will normally reduce neutral current to zero if load currents have an *undistorted* sinusoidal wave shape. However, **when load currents occur in short pulses, they are rich in harmonics. The 3rd harmonic and odd multiples of**

3rd (i.e. the 9th, 15th, etc.) will not cancel each other in the neutral. In fact, the neutral current consisting of these harmonics can be as high as 1.73 times the phase current. If the neutral conductor is the same size as the phase conductors, the heating in the neutral can be as much as three times the heating effects present in each phase conductor.

It is important to note that harmonic values will often change during the day, or the time of the year, as different loads are turned on and off within the facility, or in other facilities on the same electric utility distribution system. It is recommended that a harmonic monitor or power quality monitor with harmonic analysis capability be used to monitor harmonic values over a period of time for a representative load. This will help to identify the presence of harmonic currents, as well as the magnitude of the currents, as they change over time. The presence of harmonics can also affect the performance of the power system, and the presence of harmonics can also affect the performance of the power system.

N

Mo
hav
or S
inte
mai
trans
RFI.
sawto



To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

Close this window and click "Add to cart" on the product page.

cause they supply", ncy he power the MI and

Fig. 4 Switched Mode Power Supply

Fig. 4 shows the smoothed load current, I_L , of a flyback regulator SMPS which approximates a DC voltage. Hundreds of SMPSs in a typical IS facility produce