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Research Article

Power Quality Issues in Healthcare Centre

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Abstract

This paper describes power quality audit conducted at SDM College of Medical Sciences & Hospital, Dharwad, Karnataka, India. Voltage, current, THD(total harmonic distortion) and power were measured at various points in order to analyze the power quality. The main power quality problem found was unbalanced load, non zero neutral current, and THD with reference to IEEE-519 standards as applied for the hospital cases. The study serve as an awareness for the importance of power quality in sensitive equipment found at hospitals. Recommendations have been suggested in order to mitigate the power quality issues.

Keywords: *Power quality, Total harmonic distortion, Unbalanced loads, neutral current, filters.*

1. Introduction

The healthcare environment comprises of various combination of sensitive electronic loads and other commercial loads. Hence maintaining quality power is essential and critical. Power quality is the term used for overall voltage quality, current quality and nature of output waveform which directly or indirectly affect the loads as well as source (Uma Rao,*et al*,2010). As the medical devices are sensitive, poor quality power affects their performance. Electrical disturbances will lead to lock up of the devices. Power quality problems may arise due to non-linear loads, injection of harmonics, and interaction between medical equipments. Common sources of power quality problems found in hospitals include: inadequate wiring and grounding, high wattage operating equipment, testing of emergency generators, physical plant renovation (Syed,*et al*,). Since power quality problems are cumulative; small power quality events (detectable in an audit) can lead to loss-of-life and eventually premature equipment failure (Syed, *et al*,). An attempt was made to identify the power quality levels to assess the quality of service received from the utility and locates the areas within the hospital where problems arising from instability exists or may develop in the near future.

2. Description of the system

The hospital under study has the following types of power supply.

- Normal Supply (NS) is a direct utility supply (HESCOM) for non-essential areas.
- Essential Supply (ES) is used for areas of medical importance that are not critical to patients in the case of supply interruption. The essential supply is backed up by an emergency generator.
- Uninterruptible Power Supply (UPS)/stabilizers is used for operating theatres, patient monitoring and other equipment that is important to the well being and safety of patients.

The hospital complex under study has incoming supply of 11kV from the utility. Transformer with Δ-Y connection and solidly grounded is used to buck the voltage to 440 volts. The critical medical loads are: X-ray, CT, MRI, ICUs, operation theatres which contains surgical suits etc.

3. Power quality

The definition of power quality given in the IEEE Std 1100 is Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment (Math H. Bollen, 2011). Power quality is the combination of voltage quality and current quality. Thus power quality is concerned with deviations of voltage and/or current from the ideal. Voltage disturbances originate in the power network and potentially affect the customers, whereas current disturbances originate with a customer and potentially affect the network (M. I. Buzdugan,*et al*,2012). Some of the power quality phenomena and their standard definitions are:

3.1 Sag/swell

Voltage sag is a reduction in the supply voltage magnitude followed by a voltage recovery after a short period of time. For the IEEE a voltage drop is only a sag if the during-sag voltage is between 10% and 90% of the nominal voltage (Math H. Bollen,2011). They are caused due to sudden switching of the loads, faults like short circuits.

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Overvoltages with a duration between about 1 cycle and 1 minute are voltage swell. Due to lightening surges, sudden reduction in load, voltage swell occurs.

3.2 Harmonic Voltage Distortion

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate (termed as the fundamental frequency (usually 50 Hz or 60 Hz). The voltage waveform is never exactly a single frequency sine wave. This phenomenon is called harmonic voltage distortion. The main contribution to harmonic voltage distortion is due to non-linear load.

3.3 Harmonic Current Distortion

The complementary phenomenon of harmonic voltage distortion is harmonic current distortion. Harmonic current distortion requires over-rating of series components like transformers and cables. The Total harmonic distortion of voltage/current is a percentage representing the deviation of a waveform from the ideal sinusoid. The formula for current THD is (Tony Hoevenaars, *et al*, 2003):

$$I\ THD = \sqrt{(I_2^2 + I_3^2 + I_4^2 + I_5^2 + ...)} / I_1 * 100\ \% \qquad (1)$$

4. IEEE standards

IEEE Std-519 establishes harmonic limits on voltage as 5% for total harmonic distortion and 3% of the fundamental voltage for any single harmonic. The reference to medical equipment sensitivity provides some indication as to why the limits are even more severe (less than 3% Voltage THD) for special applications such as hospitals and airports(Tony Hoevenaars, *et al*, 2003).

Table 1: Maximum Voltage harmonic distortion

	for hospitals/air ports)	General system	Dedicated system
Notch depth	10%	20%	50%
% THD voltage	3%	5%	10%

Table 2: Maximum Current harmonic distortion

(I_{SC}/I_L)	% THD
< 20	5%
20-50	8%
50<100	12%
100-1000	15%
> 1000	20%

Where I_{sc} is maximum short circuit current at PCC and I_L is maximum load current at PCC.

To define current distortion limits, IEEE Std-519 uses a short circuit ratio to establish a customer's size and potential influence on the voltage distortion of the system. The short circuit ratio (I_{SC}/I_L) is the ratio of short circuit current (I_{SC}) at the point of common coupling with the utility, to the customer's maximum load or demand current (I_L). The following tables specify the standards (Tony Hoevenaars, *et al*, 2003).

5. Case study

The methodology employed was taking the measurements of voltage, current, % voltage THD, % current THD at few medical load points and other miscellaneous loads using an Energy audit kit (MECO make) at SDM College of Medical Sciences & Hospital, Dharwad, Karnataka, India. The data obtained were compared against the IEEE 519 standards for analysis.

5.1 X-ray

Here X-ray equipment is fed from essential three phase supply. But no stabilizer is employed. X-ray circuit consists of primary and secondary sections. Primary will get normal three phase supply and the secondary will step up the voltage in terms of kV which will inturn builds up the capacitor to charge when the circuit is closed (when exposure button is pushed) . When pre-selected charge is reached, the capacitor completes the circuit & sends the charge to the x-ray tube. The voltage THD was found to be 5%, which is more than IEEE 519 standard.

5.2 Computed tomography (CT)

CT scan uses powerful x-ray technology that circles the body as the patient, lying on a moving, flat table, passes through a very shallow tunnel, commonly referred to as the donut. The fast moving parts of the x-ray source and detectors are within the donut and out of sight. As the X-ray assembly rotates around the patient's body, the scanner produces images in thin slices which a computer reconstructs into sharp, three-dimensional (3D) images of the scanned body part. CT is fed from UPS in this hospital. The THD for current under operating condition was 5%, voltage THD was found to be within limits.

5.3 MRI (Magnetic Resonance Imaging)

An MRI (or magnetic resonance imaging) scan is a radiology technique that uses magnetism, radio waves, and a computer to produce images of body structures. The MRI scanner is a tube surrounded by a giant circular magnet. The patient is placed on a moveable bed that is inserted into the magnet. The magnet creates a strong magnetic field that aligns the protons of hydrogen atoms, which are then exposed to a beam of radio waves. This spins the various protons of the body, and they produce a faint signal that is detected by the receiver portion of the MRI scanner. The receiver information is processed by a computer, and an image is produced.

MRI is fed from UPS in this hospital. A phantom bottle assy and a head coil was used as a simulator instead of patient. The voltage THD was found to be closer to the limits, but the current THD was 7%, and was more than current distortion limit for the system's I_{SC}/I_L ratio. The ratio is 20 for this system. From table 2, THD should be within 5%.

5.4 Cathlab

Cardiac Catheterization is a complex medical procedure that is used to diagnose and treat a wide variety of heart conditions. During cardiac catheterization, a narrow tube called a catheter is inserted into the femoral artery near the groin with a plastic introducer sheath. The catheter is guided through the blood vessel to the coronary arteries with the aid of an x-ray. The procedure is performed by a cardiologist in a specially equipped room know as a Catheterization laboratory (cath lab). The most used cathlab equipment consists of an x-ray generator, contrast, and catheters (Adam Pegan, *et al*,2011).

The CATHLAB was fed from UPS. The voltage THD was found to be 4%, which is exceeding the standards prescribed for hospital premises.

5.5 Surgical suits

The supply to the surgical suits was highly distorted. Both current and voltage distortion were beyond limits. Another observation was found to be of unbalance in three phases. This results in neutral current to flow back to the transformer.

5.6 Other loads

These loads consisted of pharmacy, administration blocks, store, lift panel, supply to surgery OPD. This implies that load is of mixed type. Lot of current harmonic distortion was observed along with unbalanced load current. The neutral current was high. At the main panel also, current distortion was found to be 7%.

6. Observations

The analysis of the system highlighted some aspects. They were high THD a unbalanced load currents. These both contribute to high neutral current which will flow back to transformer neutral resulting in excess heating of the neutral cable. As the THD increases, the neutral current also increases (Robert Arthur,1996).

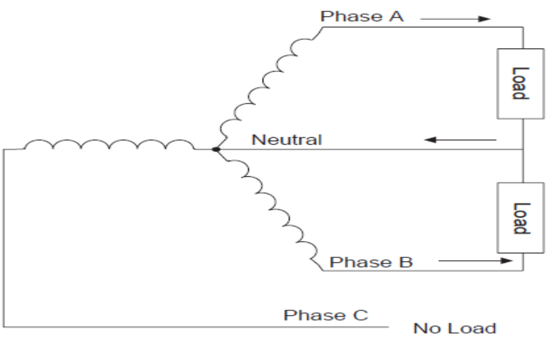
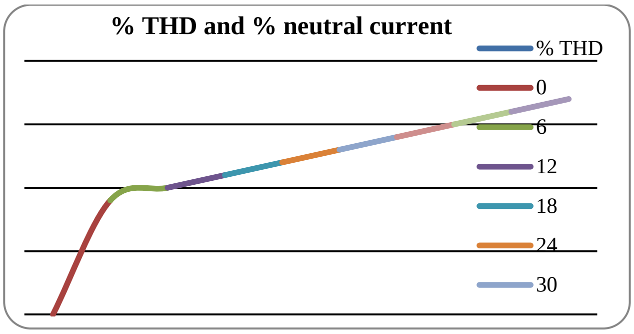


Figure 1: Unbalanced line loads and neutral current.

Table 3: Relationship between %THD Versus Neutral current



The table-3 suggests that as the THD increases, the distorted current add's up to the neutral current and thereby increasing the neutral current. Figure-1 states that, due to unbalanced loads, there will be non-zero neutral current. These two factors will decrease the life of the neutral cable and also the transformer will be overheated.

Table 4: Data measured at the hospital at different sites.

Site	Vrms volts	Irms Amperes	%V THD	%I THD
PCC Panel	400	1040	5.2	6.1
Office and surgery OPDs	390	25	3.3	17
Office loads	385	12	4.3	7.3
Surgery suits	400	18	3.2	6.2
CT scan (on condition)	380	45	2.8	4
MRI scan(on condition)	395	25	2.5	7
Cathlab(idle)	400	0	4	0
Utility power to cathlab	400	5.5	5	8
X-ray(on state)	390	-	5	3.1

7. Recommendations

To reduce the high THD, a passive filter, or an active filter can be used locally. Zig-zag transformers can also be employed in order to reduce zero sequence harmonics. Another type, k-rated transformer can be used. The K-Factor conveys a transformer's ability to serve varying degrees of nonlinear loads without exceeding the rated temperature rise limits. K-Factor rated transformers are preferred over oversized (derated) conventional transformers because they are designed to supply nonlinear loads, are equipped with 200% rated neutral bus, and are likely to be smaller and less expensive. Derating a standard transformer is only a temporary fix that often translates into lower efficiency operation. Sharing of neutral wires is to be reduced, or oversizing of neutral wires is to be done. Installation of custom power device like, Unified Power Flow Conditioner which will tackle almost all the power quality problems can be thought of in the near future.

Conclusion

This paper has presented a description of power quality studies carried out at a hospital in India. The main problem was found to be non zero neutral current and high THD. The study shows importance of power quality monitoring to be done at regular intervals.

Acknowledgment

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References

Uma Rao, *et al*, (2010), Power quality issues with medical electronic equipments in hospitals, *International Conference on Industrial Electronics, Control* . Page(s): 34 – 38, Print ISBN:978-1-4244-8544-4.

Syed M. Islam, *et al* , Power quality issues in hospitals. *Published by MAT JIBRUD.* itee.uq.edu.au.

Math H. Bollen,(2011) A text book on Understanding Power quality problems Voltage Sags and Interruptions.*Wiley India publications.*

Tony Hoevenaars, *et al*, (2003)Interpreting IEEE Std 519 and Meeting its Harmonic Limits in VFD Applications. *Copyright Material IEEE* Paper No. PCIC-2003-15.

Robert Arthur,(1996) ,Neutral Currents in Three Phase Wye Systems. Published by *square d, oshkosh, wisconsin*.

Adam Pegan, *et al,(*2011) Cardiac Catheterization Laboratory,*operations management paper*.

M. I. Buzdugan, et al, (2012), Some Power Quality Issues in Hospital Facilities, *International Conference on Renewable Energies and Power Quality.*