Solid State Lighting: India's Power Quality Study

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Abstract:

Energy savings and emission reduction are important for sustainable growth. Light Emitting Diodes (LED) has been proven to be the most promising technology with potential to save lot of energy and contributes significantly to emission control. However, the market penetration of the LED is limited by initial purchase cost and reliable technology. This paper presents the issues faced while incorporating the Solid State Lighting solution for Indian power supply system.

Introduction:

Remarkable growth of Solid State Lighting (SSL) is consistently replacing the legacy light sources (Mercury Vapour lamp, Sodium Vapour lamp, Incandescent bulbs) in indoor and outdoor applications. Due to technology revolutions in SSL we have higher lumens/watt and greater thermal dissipation. However, the initial cost of installing indoor & outdoor LED lighting can be as much as 20 times the cost of normal incandescent bulb; this cost can be justified and payback is established based on the lower wattage demand, lower maintenance cost, and longer lifetime it offers. In order to protect outdoor LED lighting from failing within an investment payback period of about at least 2 years, the lighting must offer high durability and reliability. The issues with the power quality of the Indian grid, can damage lighting fixtures, pose a significant threat to indoor & outdoor LED lighting installations.

India's Power Quality Scenario:

Power quality offered by Indian power sectors is sub-standard and the basic cause of decline in quality is because of widening gap between demand & supply. Frequent power cuts, inadequate transmission and distribution system, regular breakdowns and load shedding, theft of power, lack of service culture, low and high frequency regime in the power grid for about 60% of the time during the year, 220 kV system voltage goes to 165 kV and 400 V system goes below 300 V, harmonic levels touch 22% THD are responsible for loss, mal operation or damage to consumer equipment. [1]

High distribution-line losses are among the most vexing problems in the Indian power sector. India's aggregate technical and commercial losses average about 25% of electricity which is very high as compared to developed countries.

T&D (transmission and distribution) and AT&C (aggregate technical and commercial) losses as per Government of India Ministry of Power Central Electricity Authority

New Delhi, Executive Summary Power Sector January-16 [2]

	2010-11	2011-12	2012-13	2013-14
T&D Losses	23.97	23.65	23.04	21.46
AT&C Losses	26.35	26.63	25.38	22.7

Table 1

The World Economic Forum carried out power supply survey of various countries. As per their 'The Global Competitiveness Report 2015', on the rating point of 1 to 7 for poor to excellent position of power supply to meet business needs of consumer was given as below table 2: [3]

Quality of electricity supply				
Switzerland	6.8		Japan	6.3
Norway	6.7		Italy	5.9
Netherlands	6.6		China	5.2
United Kingdom	6.6		Sri Lanka	4.8
France	6.5		Indonesia	4.3
Ireland	6.4		South Africa	3.6
United States	6.3		India	3.4

Table 2

Out of 144 countries rated India stands at 103rd position in power quality. [3]

Power quality has been a major issue in today's industrial, commercial, residential, military and medical environments. Poor power quality may lead to disastrous consequences like break-downs, production interruptions, excess energy consumptions etc.

For example, in the hospitals where power quality issues are becoming more important due to greater impact on sensitive medical equipment which utilizes microprocessor controls and switched DC power supplies. Medical devices driven by electric power have come to be commonly used in hospitals and rapid changes of voltage or current can easily cause them to fail or does not respond as per the desired control action. Externally and internally induced power surges and harmonics can have a dramatic effect on equipment performance. 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. Some equipment such as X-ray, computerized axial tomography and magnetic resonance imaging are considered as polluting ones due to their high amount of harmonics and voltage transients produced on the electrical power supply when in operation, while other equipment, connected to the same power supply, are considered sensitive or victim ones, presenting failure or producing wrong results. [4]

Power Quality:

The definition of power quality given in the IEEE dictionary [5] originates in IEEE Standard 1100 (better known as the Emerald Book) [5]: Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment. “High power qualities” implies safety, reliable service and lower initial and operational costs. Power quality is concerned with deviations of the voltage from its ideal waveform (voltage quality) and deviations of the current from its ideal waveform (current quality). Such a deviation is called a "power quality phenomenon" or a "power quality disturbance." Some of the power quality disturbances are,

i. Impulses/Transient: Transients or surges are defined as a transient wave of current, voltage or power in an electric circuit. High magnitude for extremely short duration.

Figure1

ii. Interruption: An interruption is defined as the complete loss of supply voltage or load current. Depending on its duration, an interruption is categorized as instantaneous, momentary, temporary, or sustained. Duration range for interruption types are as follows: [9]

Instantaneous 0.5 to 30 cycles
Momentary 30 cycles to 2 seconds
Temporary 2 seconds to 2 minutes
Sustained greater than 2 minutes

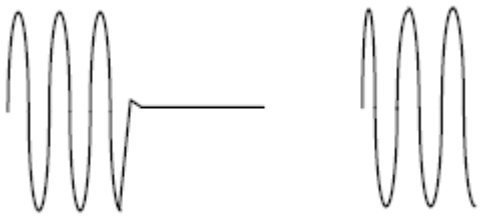

Figure2

iii. Voltage Sag: A momentary voltage dip last for a few seconds. Sag is a reduction of AC voltage at a given frequency for the duration of 0.5 cycles to 1 minute's time.

Figure3

iv. Voltage Swell: A momentary voltage rise which last for a few seconds. Swell is the reverse form of sag, having an increase in AC voltage for duration of 0.5 cycles to 1 minute's time.

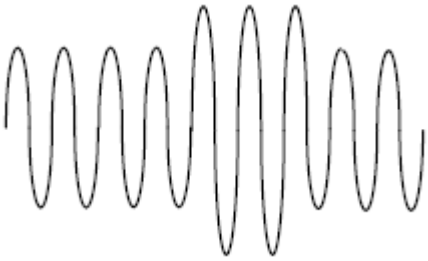

Figure4

v. Harmonics: 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). Harmonics are non-fundamental frequency components in the distorted voltage/current/power frequency waveform.

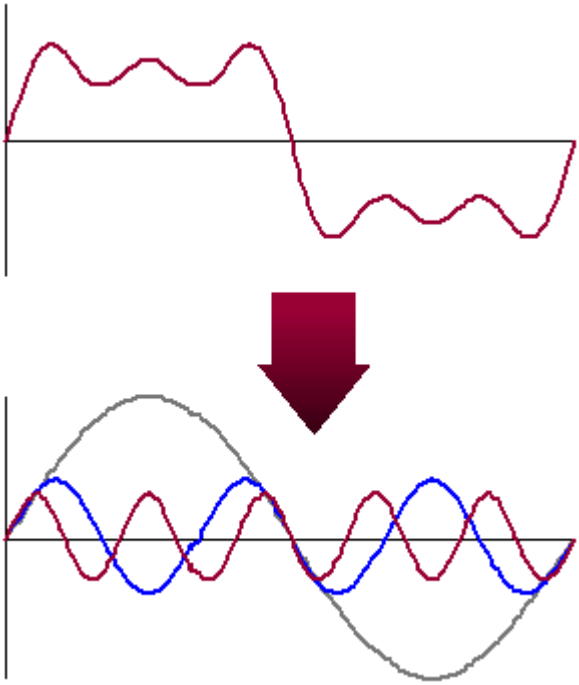

Figure 5: Distorted Wave Composed by the Superposition of a 50 Hz Fundamental and Smaller Third Harmonic and Fifth Harmonics.

The overloaded distribution system and causes low voltage, voltage dips problem and generate heavy harmonics in power system. [4] [9]

vi. Voltage Fluctuations: Voltage fluctuations are systematic variations of the voltage envelope or a series of random voltage changes.

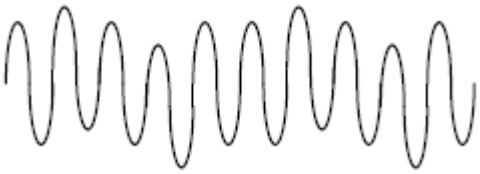

Figure 6

vii. Frequency Fluctuations: Variation in frequency from the nominal supply frequency above/below a predetermined level, normally ± 0.1%. At any point in time, the frequency depends on the balance between the load and the capacity of the available generation. When this dynamic balance changes, small changes in frequency occur.

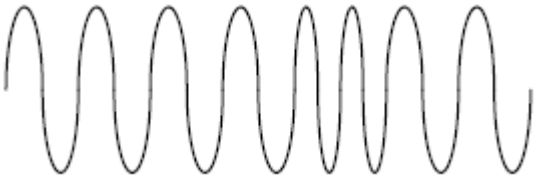

Figure 7

Effects of Power Quality:

Disturbance Category	Effects [4]	Possible Causes
Transients	This can cause loss (or corruption) of data, Physical damage of Electronic equipment like PCB cards, SMPS and system halts. For Example, Voltage transients may cause a microprocessor to read voltage levels incorrectly, resulting in incorrect data processing (ones being read like zeros) or altered stored data/setting.	Lightning, ESD, switching impulses, utility fault clearing, switching of inductive/capacitive loads
Interruptions	This may cause equipment damage, ruination of product, the cost associated with downtime, clean up, and restart.	Switching, utility faults, circuit breaker tripping, component failures

Voltage Sag	They can cause equipment damage, data corruption, errors in industrial processing, data errors, flickering of lights, degradation of electrical contacts, semiconductor damage in electronics, Insulation degradation.	Start-up loads, Utility faults, load changes
Voltage Swell	They can cause equipment damage, data corruption, errors in industrial processing, data errors, flickering of lights, degradation of electrical contacts, semiconductor damage in electronics, Insulation degradation.	Start-up loads, Utility faults, load changes
Harmonics	They can cause overheating of rotating equipment, transformers, and current carrying conductors, premature failure or operation of protective devices (such as fuses), harmonic resonance, blinking of incandescent lights, Transformer Saturation, Capacitor Failure – Harmonic Resonance, Circuit Breakers Tripping – Inductive Heating and Overload, Computer Malfunction or Lockup - Voltage Distortion.	Electronic loads (non-linear loads)
Voltage Fluctuations	This may cause Flickering of incandescent lamps, System halts.	Transmitters (radio), faulty equipment, ineffective grounding, proximity to EMI/RFI source
Frequency Fluctuations	This may cause synchronous equipment failure.	Intermittent operation of load equipment

Table 4

Reactive Power:

While active power is the energy supplied to run a motor, heat a home, or illuminate an electric light bulb, reactive power provides the important function of regulating voltage. If voltage on the system is not high enough, active power cannot be supplied. Reactive power is used to provide the voltage levels necessary for active power to do useful work. Reactive power is essential to move active power through the transmission and distribution system to the customer. When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines. You can't neglect demand of the reactive power from the consumer end otherwise this will cause to change the voltage of the power system on a large scale. This may be Under

voltage (in case when supplied reactive power is lesser than the demanded) or Over voltage (when supplied reactive power is more than demanded). Actually we can't expect ac power systems without reactive power demand/supply because reactive power demand occurs because of the presence of inductive loads.

Growing use of non-linear loads such as semi-conductor devices in power/control circuits of household electrical items and industrial devices, lot of distortion in the voltage/current waveforms has been experienced. Examples are railway electrification, computers, fluorescent lights, TVs, arc/induction furnaces, rolling mills and induction motors with speed control devices. These loads create harmonics. The harmonics flow through the distribution system and may be transmitted from one consumer to other consumer. The harmonics create extra heating of rotating machines and cables, can cause mal operation or failure of consumer equipment, introduce noise to communication circuits, stress insulation level of equipment, create flicker, make unbalance and demand more reactive power. [1]

There are 5 regional grids in India which are weakly interconnected through HVDC/HVAC links. National grid is still not operative. Surplus power available in eastern and north-eastern regions cannot be transmitted to short supply northern and southern regions. The power system lacks reactive power during summer peak period when agriculture load to 20 million pump sets [2] is at the peak. The system starves of reactive power. For example, [1] in northern region, the shunt capacitors working capacity is 10813MVAr against the requirement of 15030MVAr. Thus there is shortage of reactive power by 30%. The system voltage goes very low i.e. 220 kV system touches 165 kV, 400 V LT system voltage goes to 300 V or even less. The system frequency remains low (<49 Hz) and high frequency (>50.5 Hz) for about 60% of the time during the year. Low frequency is unavoidable due to power shortage. Low frequency and low voltage has occasionally resulted in grid failures, blackouts, causing damage to equipment. The heavily loaded transmission and distribution system create voltage sags, swells and magnify unbalance in the system.

Power Theft:

The theft of power overloads the distribution system and causes low voltage, voltage dips problems. As per study, about 30% of electricity is stolen in India. The utilization of theft power in India in following field: [4]

- Domestic: In domestic generally the loads are mobile charger, inverter, freezer, television, amplifier, microwave oven, CFL, induction cooker, press iron, heater, fan, laptop, desktop

computer, printer, monitor, scanner, water filter, vacuum cleaner, motor (1/2 Hp, 1Hp) etc. [4]

- Small commercial place (bypassing meter connection): in small commercial place generally the loads are mobile charger, inverter, freezer, television, amplifier, microwave oven, CFL, induction cooker, heater, fan, laptop, desktop computer, printer, monitor, scanner, water filter, vacuum cleaner motor (1/2 Hp, 1Hp,3 Hp) Photostat machine. [4]
- Agriculture: In this filed generally large no of AC motor (3 Hp, 5Hp, 7Hp) are used may be on fixed monthly charge or power stolen. [4]
- On road vender: These days many of road side vendors use non-linear device for his commercial purposes such as microwave oven, induction cooker, CFL, amplifier, mixture, fan etc. [4]

All the reasons discussed above are basic cause of the deterioration of power supply in India. About 100% load is non-linear load in nature and generate heavy harmonics in power system without following the quality standard, metering rule and without penalty. It means the 40% harmonics is generated in the power system by thieves. [4]

Consumer is the Victim:

In the Indian scenario, power quality issues are of increasing importance these days due to the enhanced use of sensitive equipment such as adjustable speed drives, medical electronic systems and switched mode power supplies. It is an important issue for electricity consumers at all levels of usage, particularly industries including service sector (especially IT/ITES and Health sector). All this add to cost of electricity supply to the consumer. The consumer has to bear the cost of servicing the equipment. Generally, the consumer has to pay some money to utility staff for expediting various services such as change of meter, change of transformer, rectification of faulty line etc. Major electronic/electrical utility making companies give guarantee/warranty for certain period of time but still a follow up is needed with the servicing company. Servicing person or agencies may ask to bring the equipment to their service centre or service person attending the problem will be queued and will have to wait for the turn. Especially for street lights or flood lights the repair/replacement cost is higher (cost of repair + cost of crane).

Conclusions:

Consumers and the economy bear a large burden due to the poor quality of power supply. Due to this State Electricity Boards remain financially sick and are unable to attract finances for investment. The electricity consumption per capita for India is just 566 KWh and is far below most other countries or regions in the world. Even though 85% of villages are considered electrified, around 57% of the rural households and 12% of urban households, i.e. 84 million households in the country, do not have access to electricity. Electricity consumption in India is expected to rise to around 2280BkWh by 2021-22 and around 4500BkWh by 2031-32 [4]. For India to reach surplus electricity and make its power distribution system better, it will take longer time. Consumers are increasing year after year and India is moving towards an industrial revolution through "Make in India" consumers equipment are and will be victims to the power quality issues.

Electrical/Electronic system design engineers can design systems (switched power supply, Driver circuit for LED lighting etc..) such that the designs are not adding harmonics or any other power quality issue to the grid but the real challenged posed by the Indian power supply system is to create a design which will not fall victim to the already messed up grid. Designers should be looking for innovative model to protect the high volume applications such as LED lighting or any other application from the Indian power quality issues for increasing their durability and reliability.

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