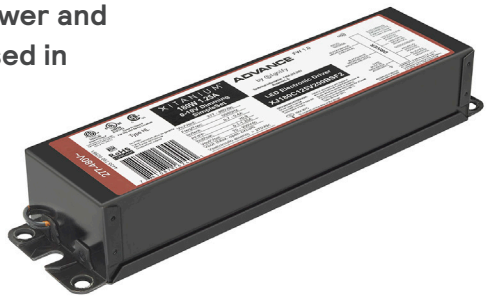
ADVANCE

Poor Power Quality: Symptoms, Causes, Effects, and Lighting Reliability

LED drivers are the power transformation device that takes in AC power and converts it to a DC power that's suitable for the type of LED array used in the fixture. In addition, most LED drivers provide an output which is isolated from the input mains, which also means the drivers sustain the brunt of any voltage disturbances and transients that occur on the AC power feed, and therefore are first to fail. A significant cause of distress in outdoor and industrial lighting is related to poor power quality of the incoming line. The effects can range from annoyance of the occasional flickering or flashing of lights to elevated rates of failures in more extreme situations.



Symptoms of Poor Power Quality

Generally, an unusually high rate of failure of lighting fixtures can be a signal of poor power quality. Often this is observed where there are multiple concurrent failures (say a whole row of fixtures on a circuit) fail all at once. Sometimes the failures can be a bit more random and can generally resemble and EOS (electrical overstress) type symptoms with no specifically identifiable root cause. This is often observed where the lighting equipment shares the same circuit as heavy machinery or high-power switching loads. Commonly, such sites were using conventional magnetic HID or fluorescent lighting and after converting to LEDs, they suddenly encounter a higher failure rate. HID or fluorescent lighting is by nature immune to mains disturbances because they use heavy and expensive and low-frequency magnetics. The lower cost, higher efficiency, light weight and compact designs of a LED driver comes with a penalty of reduced immunity to sustain such power quality issues, thus for outdoor applications – premature failures can happen more frequently.

The symptoms of poor power quality can manifest themselves in a few different ways.

1. Often, these are seen as voltage swells. This is when the voltage on the electrical system exceeds the nominal voltage for a short duration, sometimes even one AC cycle or more.
2. Sometimes, the electrical system is susceptible to voltage sags or short/long interruptions, which can last from a few milliseconds to a couple of seconds, and although most of the times this does not cause a hard failure – it can cause some unintended operation or lock-out type failures where the lighting equipment does not auto-recover and needs a power cycle to recover. This can occur especially when using poorly designed products.
3. Voltage fluctuations cause periodic excursion of longer durations of the RMS value of the AC supply about the nominal value which can often vary quite significantly – well beyond what's allowed per the NEC and NEMA specifications.
4. Harmonic distortion and noise are observed when the AC mains waveform being distorted compared to a sinusoidal reference and can be objectively referenced with a V-THD measurement on the electrical power system.
5. Transient Line Surge occurs when high transient voltages are induced on power lines from lightning or conducted from heavy electric machinery, which affects all the devices on that power system.
6. Dropped neutral type of failures generally occur in balanced three-phase system with a whole row of fixtures fails at once, and failure mode resembles high voltage being applied to the drivers.

Mitigate Poor Power Quality

Causes

Naturally, different symptoms described here are caused by a variety of factors, some which are fairly apparent, but some may be quite difficult to diagnose. Often, when one suspects power quality as the culprit, it is advisable to employ a power quality monitoring system that can log the AC voltage and help identify the specific type of power quality issue.

Voltage swells on one hand and voltage sags or short interruptions on the other, can be two sides of the same coin – often occurring where the electrical system has sudden increase or decrease in load demand, and the system takes a short time to restore the nominal operating conditions.

More severe cases can occur where the site uses an electrical transformer where the secondary of the transformer is not grounded, and the electrical system can float – causing undefined voltages to ground. Conventional lighting may have been immune to these types of voltage fluctuations, but LED drivers are susceptible to failure.

Lightning surges are usually tied to electrostatic or thunderstorm activity, but it does not always involve a lightning strike. Electrostatic activity can induce high transient voltages on electrical power distribution systems, which can affect electrical substations and transformers, which further pass the energy downstream. Surges can also occur when highly inductive machinery is suddenly turned off and interruption of the current drawn causes a voltage kick-back which resembles a high transient surge voltage. Among the various causes of surges mentioned in the standards, the ones most likely to affect outdoor and industrial lighting systems are:

- Direct lightning strikes on distribution lines (energy is conducted through the power lines)
- Lightning strikes near to a building/structure (creating induced surges)

Dropped neutral failures occur in three-phase electrical systems, where an intermittent or permanent disconnection of the neutral causes two phases to be directly applied across two rows of fixtures, and by nature since LED drivers are constant power devices, and the voltage does not balance equally, causing one side to see much higher voltage than the other – effectively taking out a whole row of fixtures.

Power systems can have high harmonic distortion and noise often arising from non-linear loads like power electronics equipment, motor controls like VFD (variable frequency drives), etc. especially if the system design does not consider how the harmonics from various equipment interact with each other and distort the line.

Impact of Poor Power Quality

Depending upon what causes the power quality issues, the impacts can be quite varied.

For example, voltage sags and swells can cause electronic devices to malfunction or shut down completely. Voltage fluctuations can cause flickering lights and damage to sensitive equipment or temporary loss of function, occasionally requiring a hard reset of the lighting system.

Harmonic distortion can interfere with the function of the control circuitry inside the driver to cause undesirable operation, or even failures over time. It also causes overheating of electrical cables and equipment, interference with communication or measurement systems or nuisance tripping of circuit protection. Even within a balanced three phase system, it is possible for the neutral (that expects near zero current, and hence not sized accordingly) to experience overheating because of distorted voltage waveforms.

Dropped neutral failures by nature damage many products at one time, and if the specific cause of disconnection is not diagnosed – this can lead to recurring failures which can quickly become costly to maintain. Additionally, the service interruption in heavy industrial environments can be a safety hazard to the occupants, and downtime for repairs can have productivity and financial impacts. When sections of lighting are inoperative in street and area lighting, these can go from annoyance to safety issues, especially where good lighting is imperative.

A surge protection device (SPD) does not protect against all forms of power quality issues. These operate on the basis of diverting energy away from the equipment to be protected when a certain voltage threshold is reached and the device activates. For example, when a mains surge hits the input of the driver, there is a large increase in voltage in a short duration of time. Typically, LED drivers have voltage suppression components at the input, which behave as a voltage-controlled switch, activate at a certain threshold and help to bypass the energy such that the rest of the circuit downstream does not experience the full surge voltage thereby protecting it. However, higher the energy of the incoming surge (higher voltage or longer durations) – at some point the capacity of the circuit to withstand the excessive voltage is exceeded and the driver fails. Surge protection devices undergo degradation (of the surge withstand capability) over the lifetime of the product, when it experiences recurring surges, especially if they happen quite frequently. In addition, surges and voltage fluctuations that stay below the activation threshold will simply pass through to the equipment unabated, and lead to failures downstream, despite using a surge protector.

Mitigate Poor Power Quality

Mitigation Techniques for Power Quality

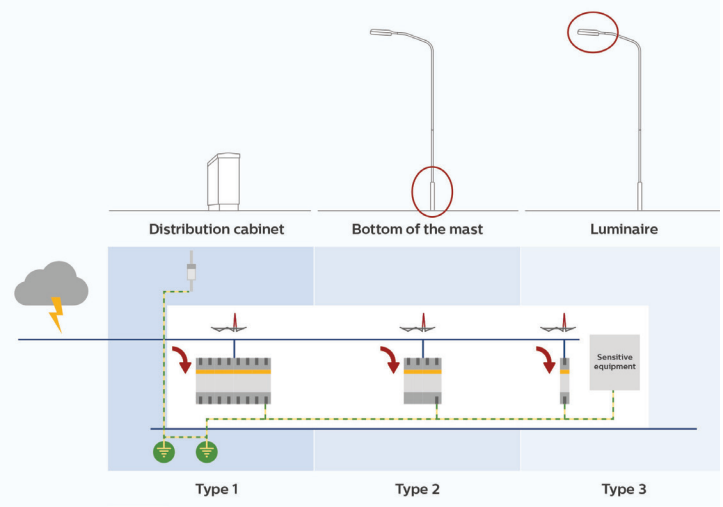
In general, end-customers always expect the utilities to provide “clean” power and don’t believe they should pay for the solutions. The best approach is a combination of efforts, which also spreads the cost burden of improving overall system reliability. These range from installing surge protectors, voltage regulators, and power conditioning equipment, as well as upgrading electrical systems and equipment to meet modern standards. Utilities partner with equipment manufacturers and standardization bodies to set guidelines on performance levels and specifications / qualification criteria for tenders. In the case of harmonic distortion, it is recommended to position non-linear loads upstream in a power system (avoid locating where short circuit power decreases). Other methods can be separating sources to distribute the loads on different circuits. There are power conditioners (or “line tamers”) which can be applied to filter out the harmonic content. For example, power stations cannot use their own power to run their equipment, so they generate a clean source using power conditioners to prevent loss due to transients.

Lighting equipment can be made less susceptible to power disturbances and dropped neutral type phenomena by using products like Xitanium DuraVolt which is a robust solution that can survive quite extreme power quality conditions, well beyond the typical LED drivers used in the market. Also, using drivers which have a higher surge withstand capability to begin with (say 6kV/3kA) allows a more robust design. Obviously, there are boundaries, and at some point – investing in improving the electrical system feeding the lighting does become imperative.

If the cause of poor power quality is voltage surges, the most effective approach to protect large installations of lighting equipment against surge is by cascading multiple protective stages. Each stage combines the necessary balance between discharge capacity and voltage protection level. In this way, a first stage (typically a Type 1 or Type 2 SPD) provides robustness, thus diverting most of a spike’s energy, while a second stage (typically a Type 2 or Type 3 SPD) provides more robust protection. As a result, the peak voltage reaching the equipment is kept below the critical failure level.

European standards EN 60.364-5-534 and EN 62.305-1 require that protection against these types of electrical disturbances be provided by a Type 2 SPD. The protection solution is installed into the distribution circuit panel board, located upstream from the main circuit breaker. The distance between the protection circuit and the luminaire must be as short as possible to guarantee proper protection. If the distance between a protected distribution panel and several luminaires is more than 60 feet, a second protection stage (of Type 2 or 3) is recommended within the luminaire, even if the protection level of the first stage seems to be enough.

(Refer to diagram below)



Above: Typical cascading of surge protection types in a public lighting installation

Conclusion

Poor power quality is a significant issue that can lead to costly equipment damage, reduced productivity, and safety hazards. However, by understanding the causes and effects of poor power quality and implementing the right solutions, individuals and organizations can improve power quality and avoid these negative impacts.