White Paper

Designing for Surge Immunity in International Markets

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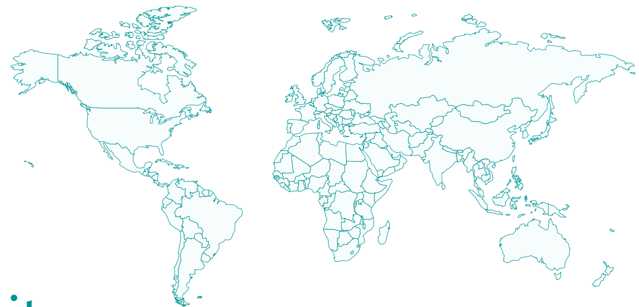

Designing for Surge Immunity in International Markets

Facing Hostile Environments

Background

Surge immunity means the ability of electronic equipment to operate properly, with a low rate of failure, in the presence of abnormal line voltages and surge voltages from load switching and lightning.

Systems integrators in telecommunications and other industries that export to markets all over the world have to design equipment that will operate in electrical environments that may be more hostile than those found in North America or most parts of Western Europe. Power supplies, uninterruptible power systems and telecommunications rectifiers, for international applications, are typically designed to accept an input voltage window of 170 to 270 Vac. In addition, the equipment will have built-in surge withstand capability in accordance with IEC 1000-4-5, if CE marked. It is fairly safe to assume that power supplies and electronic equipment, designed in accordance with IEC standards, will be reasonably reliable in markets with stable power and minor lightning activity. However, conditions encountered in parts of Latin America, Asia, Africa and eastern Europe are often severe enough to cause power supply and sometimes system malfunction.
The principals of TSi Power have identified three factors that drastically reduce system reliability:

- Inadequate infrastructure for the generation and distribution of electricity, causing frequent power outages and large voltage fluctuations.
- Inconsistent wiring and installation practices, locations without TN-S grounding systems (TN-S is the international term for three-phase with grounded neutral).
- Frequent lightning activity, especially when combined with a poor ground, thus causing lightning currents to find a path to ground through the power lines.

Designing for surge immunity requires careful attention to a number of factors that may be more or less difficult to control. Surge immunity, in the context of this paper, means the ability of electronic equipment to operate properly, with a low rate of failure, in the presence of abnormal line voltages and surge voltages from load switching and lightning. This paper will discuss factors that may necessitate enhanced surge immunity.

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Factors affecting equipment immunity

Fluctuating power line voltage

Causes

- Overloaded , inadequate power generation and distribution systems, particularly when large step load changes are present, result in large voltage sags and surges. Voltage fluctuations between 155 to more than 310 V have been observed in the field. Differences between day and night-time voltage of 40 V have also been observed.
- Such conditions are common in Africa, India, Pakistan and China, but can be found in many other areas. Additional power plants and distribution infrastructure is needed in many developing countries. Timely power plant expansion is prevented by political and economic issues, which means the problem is here to stay for the foreseeable future.

Effects

Power supplies can fail for a variety of reasons related to voltage fluctuations, the most common ones are listed below:

- Sags and undervoltages can cause component overheating or destruction, which reduces the life and deteriorates the real reliability as opposed to the estimated reliability, based on steady-state conditions of the power supply.
- Swells and overvoltages can cause component overheating and destruction of MOVs, SCR's and input capacitors that are rated too close to the line voltage. It is fairly common for power supply and telecom rectifier manufacturers to rate input MOVs at 275 Vrms with the apparent objective of reducing the surge remnant voltage, thus providing better surge immunity of the power supply. The author of this paper has observed still-functioning telecom rectifiers where the input MOVs had been completely destroyed by high line voltage.
- Typical EMI filters are not well damped, which can dramatically magnify the effects of voltage disturbances. The result can be oscillations inside the EMI filter during transitional conditions. Severe voltage surges may result from energy release where saturated inductors are looking for a path to release energy.
- Boost converters can be destroyed by voltage swells that cause increased energy storage in input filter, which charges the output capacitor to an unsafe level. The charge level is dependent on the value of the output capacitor and the load levels for the DC/DC converter connected to the output of the boost converter.

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Remedies

Most power supplies, telecom rectifiers and UPS for international applications are designed for a nominal voltage of 230V with an input range of 176 to 270V.
As previously mentioned, input MOVs are typically rated for 275Vrms to reduce surge remnant voltage. Experience suggests that the standard specifications for 230V power supplies are adequate for the majority of installations in major industrial countries.
What to do if the supply voltage falls outside of the standard parameters? One possible solution is to specify telecom rectifiers and UPS that can withstand an expanded input range. The drawback is increased cost for the enhanced equipment and limited competitive selection, thus resulting in higher cost. Specifying equipment with enhanced input voltage range is only economical for new installations, not for retrofitting existing sites.

Another possibility is to add external voltage regulation devices, which can be cost-effective if the regulation device is sized and installed correctly. Modern voltage regulators can be both cost-effective and reliable, if applied properly. The use of an external voltage regulator makes it possible for the user to specify the best possible equipment without worrying about input voltage range specifications. This approach might be more cost-effective, particularly for existing installations.

Look for the following when specifying voltage regulators:

- Dynamic stability with all kinds of loads including power-factor-corrected,
- Input voltage range should be at least 160 to 300 V,
- Over voltage cut-off circuit,
- Low heat loss,
- Low wave form distortion,
- By-pass switch to be used when unit fails,
- Internal MOVs and capacitors should be sized to withstand 400 Vrms.

Lightning surges

Causes

There are a number of areas in the world that experience a higher-than-average number of lightning days. Such areas are easily identified from an isokeraunic map.

Electrical installations are affected by both direct and indirect lightning. A direct hit to a structure may produce 100 kA or more of a 10 x 350 µs wave form according to IEC 1024

- Electrical installations are affected by both direct and indirect lightning. A direct hit to a structure may produce 100 kA or more of a 10 x 350 µs wave form according to IEC 1024.
- Equipment installed close to the electric service entrance is exposed to considerably higher amounts of energy and may be subjected to the IEC 1024 wave shape above. Equipment installed more than 30' (10 m) from the service entrance is subjected to the much milder ANSI/IEEE C62.41-1991, Category B3, Combination Wave, 3000A, 6000V, as the energy has dissipated somewhat before reaching the equipment.A poor physical ground such as rock or dry sand causes lightning current to divert to the power line in order to find a path to ground.
- Incorrectly implemented site grounding may result in lightning current seeking a path to ground through equipment frames and power supplies.
- Use of non-TN-S grounding systems (TN-S is equivalent to three-phase with grounded neutral) can contribute to excessive surge voltages between power carrying conductors and ground.

Effects

Power supplies and the semiconductors used in electronic equipment can fail for a variety of reasons related to surge voltages from lightning and load switching—the most common threats are listed below:

- Destruction of power supply front end including EMI filter, MOVs, fuse holders and other components. Damage to chassis components and equipment frames that carried lightning current. The damaged equipment is usually located close to the electric service entrance and is installed in a region with a high number of lightning days. Typical wave shapes and currents are defined in the IEC 1024 standard.
- Surge voltages can cause damage or destruction to power semiconductors in the power supply.
- Surge voltages can cause false triggering of power supply SCRs and other components, thus causing short circuits that destroy components.

- Nuisance alarm tripping can result from surge voltages triggering detection circuits in the power supply.
- Semiconductor damage can occur as a result of surge voltages getting past the power supply, on to the logic board. The majority of semiconductor devices are intolerant to surge voltages that exceed their voltage ratings. Semiconductor damage occurs when a high reverse voltage is applied to a PN junction that is in the non-conducting state. Semiconductor junctions may avalanche at small points because of the non-uniformity of the electric field. Thermal runaway may result due to localized heat build up, thus causing the melt-through that leads to the destruction of the junction. Note, even a fast surge of a few microseconds may cause a semiconductor to fail catastrophically or cause degradation that shortens its useful life.
- System malfunctions including error messages, reboots, lock-ups, disk drive read/write errors are well known symptoms of surge voltage disturbances.
- A higher-than-average number of service calls and circuit board replacements is the definite confirmation that a system may be exposed to surge voltages that exceed the built-in system immunity.

Remedies

Power supplies, telecommunications rectifiers, UPS and other electronic equipment carrying the CE label have a certain built in level of surge immunity. What factors indicate the need for enhanced surge immunity? The presence of one or all of the following factors should warrant external surge protection in order to strengthen system immunity:

- Critical loads such as base transceiver stations (BTS) and nodes for wireless-in-the-local-loop applications as well as other outdoor enclosure installations often require additional protection,
- Inadequate infrastructure for the generation and distribution of power causing frequent power interruptions and unstable line voltages,
- High nominal line voltage,
- Non-TN-S grounding systems,
- High number of lightning days,
- Poor physical grounding conditions,
- Geographic locations where service calls are very expensive.

Look for the following when specifying external surge protection devices:

- A primary protection device is required to handle the primary lightning threat that is defined by IEC 1024.
- A secondary protection device is required to divert the remnant of the primary device.
- Surge protective devices (SPD's) need to be coordinated in accordance with the requirements of IEC 1312. Coordination is essential for proper performance of SPD's. Incorrect coordination can result in the "vulnerable equipment" absorbing most of the energy created by the surge.
- The clamping voltages of SPD's must not be rated too close to the power line voltage. This is especially important in locations with large voltage fluctuations.
- SPD's should have an internal disconnect to take them off line in case of failure. Failure conditions should generate an alarm.
- SPD's should be easy to replace in the field.
- Protection should be provided between line and neutral as well as neutral to ground.

- An isolation transformer should be added for non-TN-S systems in order to provide the neutral-to-ground bond that is essential for good surge protection.
- Spark-gap and gas-discharge-tube devices cause follow-on short-circuit current, which requires careful control not to cause problems. Careful attention should be given to ensure that follow-on currents do not cause disruption of the "vulnerable equipment." Proper down-stream inductance is required to ensure that spark gaps fire at the correct voltage level.
- A hybrid SPD may be used if it meets the above requirements.

Installation and wiring practices

Causes

The U.S. and Canada have consistent rules for grounding and bonding at the service entrance, but these vary between countries throughout the world. Some grounding systems actually contribute to surge voltage problems.

Installation and wiring practices are very important to ensure a reliable installation. Electrical installations in the U.S. have to conform to the National Electric Code and local inspectors enforce these and, in some cases, additional local requirements before approving a particular installation. It is often difficult, even in the U.S. and Western Europe where similar requirements exist, to ensure consistent quality practices. The U.S. and Canada have consistent rules for grounding and bonding at the service entrance, but these vary between countries throughout the world. Some grounding systems actually contribute to surge voltage problems. Some common problems are listed below:

- Inadequate wire size or type,
- Long overloaded wire runs,
- Too many loads on a branch circuit,
- Incorrect circuit breakers,
- Poor connections,
- Ground currents due to incorrect wiring,
- Poor ground and conduit connections,
- Systems that do not have a clear path to ground for fault currents have to rely on ground fault detection that sometimes malfunctions,
- Mixing electrical equipment that is designed for different standards,
- Incorrect grounding of distribution/isolation transformers,
- Overloaded utility transformers,
- Incorrectly applied surge protection devices.

Effects

The effects on the "vulnerable equipment" can vary from insignificant to major, sometimes intermittent malfunction. It can be very time consuming and costly to diagnose and correct problems, especially when the installation is far away in a country with different languages and customs. Those with experience from solving similar problems in North America will attest that fixing electrical problems can be a challenge even where one is familiar with language and customs. Some typical effects are listed below:

- Load induced voltage changes can cause equipment lock ups,
- Load induced over voltage can cause failure of surge protective devices,
- Incorrect grounding can cause excessive surge voltages, particularly from lightning,
- Poor wiring connections can create surge voltages that damage or upset equipment.

Remedies

- The following is suggested when planning site power:
- Develop universal wire size recommendations in both AWG and square mm,
- Develop one set of recommendations for countries that do not use North-American-style metallic conduits,
- Do not use conduit as ground,
- Provide dedicated circuits to the "vulnerable equipment,"
- Use breakers that are rated for universal use (UL, CSA and IEC),
- Make sure that terminations and connections are properly checked before approving the installation,
- Establish a TN-S grounding system.
- Ideally, design and build a power distribution module that can be used anywhere in the world and that is approved by the major safety agencies. Develop simple installation instructions in the appropriate languages.

Summary

- Many equipment malfunctions can be traced back to inadequate infrastructure for power generation and distribution, inadequate installation practices and significant lightning activity coupled with poor grounding systems.
- Installation and grounding practices vary from country to country and are not always enforced.
- Surge-immunity enhancement is often required for installations per above.
- The selection and coordination of surge protective devices require careful attention and planning.
- A standardized approach is the best way to ensure consistent system performance.

About the Author:

Mr. Peter Nystrom has been active in the power protection industry since 1979 and is the founder of two companies. He has also been active as a consultant to major telecommunication equipment manufacturers for several years. Since 1998, he has been the CEO of TSi Power Corporation (located in Wisconsin, USA), a manufacturer of UPS, line conditioner, automatic voltage regulator, and dc to ac inverter systems designed to meet the challenging international power conditions.

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