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SPIKES AND OVERVOLTAGES: KEEPING AN EYE ON THESE DISTUBANCES FOR EFFECTIVE PROTECTION

Abstract:

Voltage spikes and overvoltages on the low voltage AC line are probably a "hidden" disturbance, but the effects in any electrical or electronic device can be dramatic as they can lead to a significant failure or complete destruction. Regardless of what are the technical causes of the transmission and mitigation of these peaks, this paper attempts to explain how they can affect a small IT load (network switches, point-of-sale terminal, or personal computer) and outlines the various alternatives for protecting them. It focuses particularly on the use of uninterruptible power supplies (AC UPS) to demonstrate that even the "smallest" UPS can make a good contribution to protecting your load and stored data.

Perturbances, the hidden source of problems

In almost any electrical or electronic environment, various types of surge voltage can occur that may affect to the devices connected. There are multiple types of surge voltages, and depending on the cause, it can last from a few hundred microseconds up to several seconds, and with an amplitude of several volts up to several thousand volts. Therefore, it is a phenomenon difficult to size and detect, but with a clear impact in case of occurrence.

To be more specific surge voltages (Figures 1) are a special type of perturbance (as swells, sags, overvoltages, harmonics, high frequency noise, etc), with the characteristic of having typically a transient high voltage (around several thousands of Volts) and a short duration of just a few milliseconds (2-3 ms maximum, with very fast ruse times of 1-10 microseconds), and frequently produced by surrounding devices. Surges, by definition, are subcycle events that should not be confused with other longer duration perturbances like swells or temporary blackout. Very short duration and high energy are key to define the surge voltages.

Such an abrupt high voltage can damage the insulation properties of the device and lead to malfunction, such as damage or complete failure of the device. Practically, a surge voltage can cause a complete system shutdown, with the economic and business implications of system unavailability.

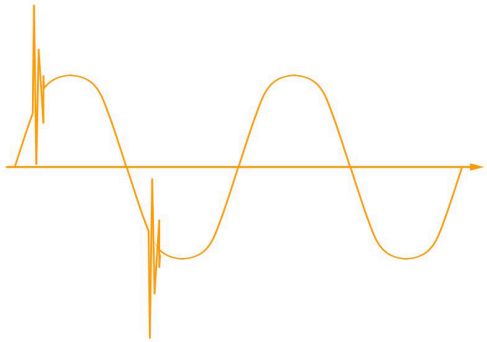

Figure 1: *Example of surge voltage caused by an induced lighting in a 230V AC line*

Important is that this kind of overvoltages or fast transients are in some way unpredictable and of random value or duration. Because they are generated externally due to various phenomena such as lighting or AC switching, they are "outside" our facility. In other words, we perceive the effect of a phenomenon or suffer it outside our control in our facility.

Unfortunately, according to several professional associations that study this phenomenon and compile statistics, the number of devices damaged by these overvoltages does not decrease as more and more electronic devices are present in our daily work. Even more important than the total value of the device concerned is the cost and impact of the downtime of this electronic device.

It is therefore important to be aware of these overvoltages as they can pose a serious risk to any critical IT load or any electrical equipment connected to the AC network.

KEY NOTES

- Do you live in an area with frequent storms and lighting?
- Or perhaps in an industrial area with factories and large electrical machines?
- How critical is your data at home or in your company?
- What is the impact of 1-hour downtime in a commercial system? For example, evaluate in a retail store...

In the digital age, personal or business digital data are of paramount importance, and it is no longer acceptable to lose this information. Let's assume that your small network switch is damaged because of any of these voltage spikes and it takes 1-2 hours to repair. Have you been able to calculate the total costs for repairing such hardware (technician, spares or a completely new item, etc) plus downtime (probably the biggest amount) ?

Perturbances may affect your IT load

The reasons for these dramatic surge voltages can be multiple, but basically there are 3 main sources. Firstly, we can consider the lighting strikes (sometimes referred as LEMPs or Lighting Electromagnetic Pulses), which causes a transient overvoltage that can extend across great distances. A second source can be the intentional switching operations in breakers or switches in the electrical distribution grid, which in turn can lead to induced surge voltage that can spread to electrical cables and reaching household. And finally, the electrostatic discharges (ESD), that occur when exposed conducive parts with different electronic potentials approach each other.

These phenomena represent a serious hazard, especially for sensitive electronic components, IT equipment or any electrical load. It is not required to directly attack the load to be affected, but each of these perturbances can be remotely transmitted using galvanic, inductive or capacity coupling. Even if the coupling method may be the same, please do not confuse it with other types of high frequency EMC or noise filtering problems.

In addition to the previous points, these surge voltages have two characteristics that require a special attention:

> Random effect: even if the probability increases of meteorological phenomena increases, they are not fully predictable (distance, protections, etc), so it is quite difficult to estimate when or how frequently they may happen.

> Indirect effect: even if nothing is immediately destroyed, the increased stress from these peaks can lead to premature failure of operating costs or critical components.

In summary, it should be noted that these peaks or overvoltages may pose a serious risk to electrical or electronic equipment and therefore require adequate protection. This can affect to individuals (desktop PCs or printers), small business systems (POS, networking, WIFI repeaters) and especially business applications where the consequences of a failure are severe, not only in terms of damaged equipment, but primarily due to downtime (no business continuity).

Figure 2: *Point-of-Sale (POS) in a retailing store*

For example, we can consider the case of a telecom operator, where a mobile phone cell failed and without operation for several hours, or alternatively a retail store with multiple lines stopped and dissatisfied customers waiting to pay their products in the basket. As pointed above, would you like to roughly estimate the cost for 1-2 hours downtime in such retail shop?

Therefore, there are several levels of protection, depending on whether they are required only for the hardware integrity (no damage) or at a second level of process immunity (business continuity).

To protect the terminal device in the most critical loads or harsh conditions, it stars with a series of protective devices in the outdoor overhead lines (typically referred as surge arresters). In addition, there are the inner linings and finally the terminals

or distribution circuits with the SPDs, also known as surge protection devices. These SPDs are semiconductor devices, the most frequent being MOVs (Metal Oxide Varistors). These devices can clamp the transient voltage when it exceeds it the nominal threshold value. Once the voltage exceeds this threshold value, the current can flow thought the MOV, and it limits the transient voltage when it exceeds the nominal threshold. In most AC power applications, the SPDs are performed with these MOVs devices due to their high-energy capability, reliable clamping voltage and maintenance-free operation, while more severe environments may require additional hybrid filters. SPDs are intended to prevent high energy and short duration transient voltages, not to sustain long-term (seconds or minutes) overvoltages.

Other type devices which can be used as SPDs are gas tubes, hybrid filters, SADs, etc. but typically used in more complex installations.

When selecting MOVs for surge protection, the selection should be based on clamping voltage, maximum current that can be diverted, response time, surge duration, etc. Sometimes all this information is consolidated in the energy or "Joules rating", as it is a combination of the previous parameters. While important, several industry papers do not recommend to use that "Joule rating" as a unique selection criteria as it may provide misleading or conflicting information.

To avoid this type of confusion, and because of the "random" occurence of this surge protection (no lighting strike and induced effect will be the same), industry and international agencies have created several norms to define test methods and test surge waveforms that help to characterize the performance of each SPD.

In Europe EN61643 is used for SPDs devices, while in the USA and Canada, it is preferred to use IEEE C62.41.2 for characterization of the surge voltages, and IEEE C62.45 for testing (other standards may apply to certain products) or UL 1449. In the case of the UPS, there are several tests on fast transients and burst voltages during product testing to verify compliance with the specific standard for UPS.

How to protect your critical load

To elaborate the right strategy for immunity against surge and fast transient voltages, a combined approach or a global strategy with multiple protection devices connected along the distribution lines is required.

Depending on the location or building, an initial degree of protection must be achieved with surge arresters and a proper grounding system in the utility side. This is more a task for your facility manager or the AC distributor.

A second level of protection can be achieved with surge protection devices (SPDs) or using uninterruptible power supplies (UPS) that include this SPD. A UPS will also provide some power backup in most serious cases of a complete power outage.

Then probably the next question will be "How much protection do I need? Which devices should I use?" Excessively conservative design for surge immunity will drive the complexity and cost extremely high, but in general, a trade-of based on risk analysis is an inescapable element of equipment design and susceptibility, together with the maximum cost. However, surge protection specialists do not believe it is possible to achieve 100% coverage due to the random behaviour of interference, but the addition of these SPDs will mitigate the effects.

Several UPS are designed with these MOVs on the UPSs input power lines (and in data line protection connectors if available). These surge components are installed to protect the UPS and specially to filter these surges to the load at the UPS output.

Users frequently search the technical UPS documents for the "Joule rating" of the MOVs or surge protection devices (SPDs) connected to the UPS or data line input. Effectively Joule is a reference to the ability to protect the load connected downstream, but it is a single parameter. Joule, is a measure of energy, so that it combines the clamping voltage, current absorption and duration. Therefore, several manufacturers specialized in surge protection advise about the limitation of using this single parameter.

For example, you may have a UPS with a high Joules rating at the input, but if your clamping voltage is too high, you can still cause surge damage. This clamping voltage refers to the amount of voltage that is not suppressed by the SPD, so having a SPD with a high clamping voltage can cause that the spike is not filtered properly.

In summary, the total amount of Joules required for the right surge protection depends on the criticality of the load, the geographical area, lighting protection zones, the use of separate surge arrestor in facility, clamping voltage, etc.

Vertiv has several UPS products that include this type of surge protection devices at the input, such as Liebert® PSP, or Liebert® PSA. They provide surge protection in the input AC power line, plus a separate connector (RJ45 or RJ11) so that the data cable can be also connected separately and filters these peak voltages that can be induced by the data cable. They are the perfect solution for small workstations, individual PCs, point-of-sales (POS) or VoIP equipment that demand small power consumption and ensure they can work in the event of a power outage; and ensure that they work in the event of a power failure and can be easily shut down if needed in the event of a prolonged power outage.

For these UPS products, they can provide separate outlets for surge protection of connected devices where power backup is not critical (example small printers), but also power outlets that include both surge and backup.

Figure 3: *Liebert® PSA UPSs*

In addition to these features of power protection, its small and compact size, together with the "zero acoustic noise" (no fans due to the high efficiency), make it a very attractive solution for distributed equipment such as these POSs and networking terminals.

Finally, even if this paper has focused on protection against surge voltages in the AC line voltage, the thread caused by these electrical disturbances can also be in telephone or network data lines. Most of the attention is focused on the power lines, but communications lines in any office can "import" the same type of transients (lines coupling). Therefore, it is useful to choose a similar protection approach for a complete protection.

For terminal applications such as laptops, computers, small switches or hubs, this is the reason why several desktop UPS provide a couple of connectors, typically RJ45 or RJ11, for that mission. Do not confuse them with other connectors such as the USB or DB9 (RS232) that are intended for the UPS communications. As an example, these data line connectors for surge protection on data lines are represented in Figure 4, and they are always combined in a couple of connectors.

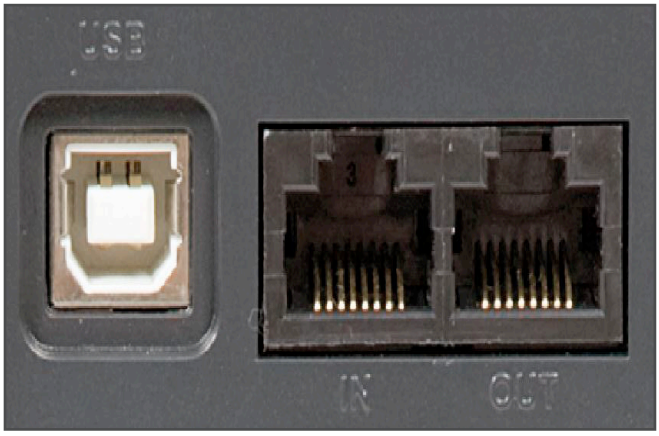

Figure 4: *Data line surge protection (right) and USB port (left)*

As mentioned above, for more complex installations with frequent or high energy surge voltage, it may be recommended a more complex installation with surge arrestors, isolation transformers, UPS, socket strips including individual protection, etc. may be recommended, but requires a separate analysis by experts with proper coordination.

Conclusions

This paper has briefly analysed the impact that a spike or surge voltage may have on an electrical or electronic device. The solution is not simple, but in most cases, it relies on a coordinated solution, which is a staged or cascaded approach, with SPDs and a single-phase UPS element downstream.

There are several UPS technologies, each of them having their own advantages for surge suppression, but in applications such as retail, POS, desktop PCs or small VoIP equipment, the use of even a "small" off-line or line interactive will provide an extra level of surge protection. In addition, in the event of a complete power failure, the UPS provides backup power and performs a clean shutdown of the operating system when needed.

Finally, it has been analysed what level of surge protection a UPS can provide. Typically, it is defined in the UPS datasheets as "Joule rating", but this parameter is not the absolute metric to understand which UPS can provide a better protection.

KEY NOTES

- Surge voltage can be induced in both power or data cable lines
- Cost due to operation downtime are more expensive that hardware costs
- Protection with SPDs requires a complete approach based on a cascade use of protection devices
- Joule rating cannot the unique or relevant parameter for SPDs selection
- For terminals, a desktop UPS may contribute importantly to protect against surges using internal SPDs, and provide backup time in case of a blackout

Miguel Rascon
Product Manager Single Phase UPS Systems
EMEA
Vertiv Integrated Systems GmbH

VertivCo.com | Vertiv Integrated Systems GmbH, Mariakirchener Straße 38, 94424 Arnstorf, Germany

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