Reliability, Availability, Maintenance, Return on Assets and Surge Protection?

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Abstract
There's a lot of pressure on process plants these days to invest in order to maximize efficiency. However, addressing a much overlooked and underestimated problem can have a significant positive effect, at a minimal cost. Transient voltages (or surges) are the root cause of up to 30% of premature hardware failures and can be the cause of catastrophic plant failure. Conversely, controlling surge voltages by the strategic application of surge protection devices has been shown to improve the return achieved on plant assets and mitigate the undesirable consequences of a catastrophic event.

Keywords
Surge protection, reliability, availability and lightning protection.

1. Introduction

For many years process plant managers have installed surge protection devices as a precaution against catastrophic damage due to lightning. The most keen are those whose memory of serious trouble is fresh. However, studies have shown that the obvious surge related damage (blackened hardware) is only the tip of a very large iceberg. A recent study by a major European insurance company indicated that lightning and surge are the single most significant cause for control equipment failure. A close second is lack of maintenance. Together surge and maintenance account for over 50% of premature electronic equipment failures.

This article postulates that there is an appropriate level of surge protection, that when applied to a plant, reduces equipment failure directly, increases plant availability and indirectly frees the maintenance team up to perform a more proactive role. Improvements can be measured in terms of Return on Assets (ROA) – a key measure of operational performance.

Surge protection can lead to improvements in ROA in three areas.

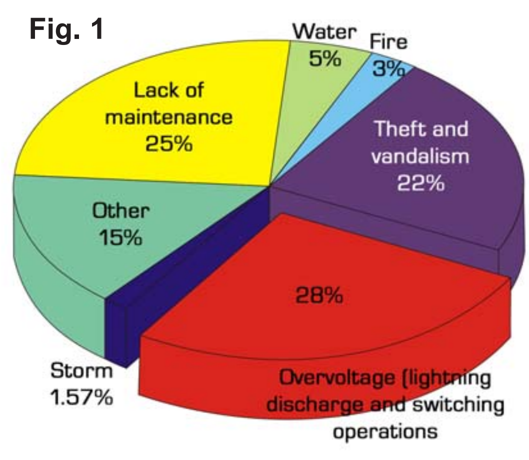
1. direct savings in hardware
   - reduction in premature failures
   - elimination of catastrophic failure
2. increased plant availability
3. indirect savings as a result of a better deployed maintenance crew

2. Underestimating the problem

Surge overvoltages are simply short duration, high magnitude impulses that exist on all electrical (power and signal) lines for a brief time. Common causes can range from lightning strikes to switching of electrical loads [1]. The common belief among plant managers and finance gurus is that their plant does not experience surge-related problems. This belief guarantees that preventative action (such as surge protection) will not be taken. However a closer inspection reveals that a wide range of electronic devices are failing well short of their design life. These failures are just not associated with surge overvoltage by the plant maintenance team.

A study by a major European insurance company illustrates the problem. Over 7700 items of industrial electronics were evaluated. The most significant cause of premature failure was Surge overvoltage. In fact surge damage contributed to 28% of failures. Just as interesting is the next most significant category; lack of maintenance which contributed 25% of failures.

Fig. 1



The intriguing prospect is that much effort and "focus" is devoted to maintenance. However, surge protection could eliminate a substantial number of failures, maximize the design life of hardware and potentially improve the efficiency and availability of the maintenance team.

3. Why are surge voltages a problem now?

Few would argue with the relentless increase in

sophistication of 21st century control and instrumentation architecture. Trends that have been in place for the last decade are accelerating. Control (and processing power) has escaped from the control room and is being rapidly deployed all over the plant in remote I/O, sensors and actuators.

Who would argue that a lightning strike to a modern facility poses a much greater threat to operational performance than a strike to an older generation plant deploying pneumatic control. More importantly who would argue that the next generation of instruments will be more sophisticated than the current offering.
In a similar vein the current trend toward buses (Fieldbus etc.) has obvious and significant benefits to operational performance and installed cost. However, there is also a dark side. One cable is used to connect many field devices, up to 32 in the case of Fieldbus, back to the control host. One surge related incident now has the potential to affect a whole plant area as compared to one device on a 4-20mA loop.

Now is the time to consider surge protection!

4. Purported mitigation techniques

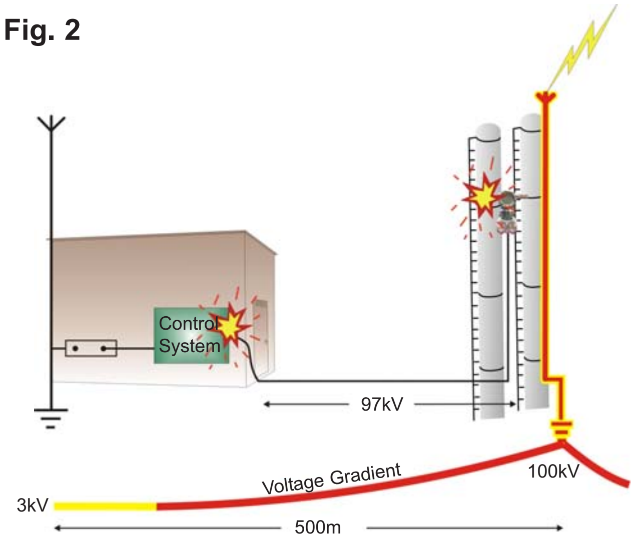
There are many techniques adopted in a process plant that do have a beneficial effect in reducing the magnitude of the surge threat. Unfortunately the inexperienced often overestimate this beneficial effect. The phrase, "We don't need to use surge protection because we have……. .." is a common cry, (fill in the blank with, lightning protection, earthing, bonding, or a UPS etc.). The following paragraphs explain the erroneous nature of such assumptions. A more rigorous evaluation is detailed in the references.

4.1 Structural lightning protection and earthing

Structural lightning protection comprises an air terminal, down conductors (or contiguous metal structure) and an earthing system. The purpose of which is to safely route lightning current to ground [2], [3].

In the example shown in Fig 2, lightning hits the air terminal on the stack and, as you would expect, current flows into the earth. The structural lightning protection has indeed done it's job - providing a point of

Fig. 2



attachment for the lightning channel and a safe path to earth. Some would believe that that's the end of it, but lightning current does not miraculously disappear. Ground has resistance.

Let's assume the facility has a good, low impedance earth of 1 ohm. Close to the point at which the current enters the ground a potential of 100kV will be developed (for a 100kA strike). This voltage will decay as you move further away from the stack. At several hundred meters the voltage will be a few kV.

The result of this potential gradient is that 97kV exists between the control room and the stack structure. The fact that 97kV appears between the stack and the control room is not actually a problem until you connect an instrumentation cable between a transmitter on the stack and the control room.

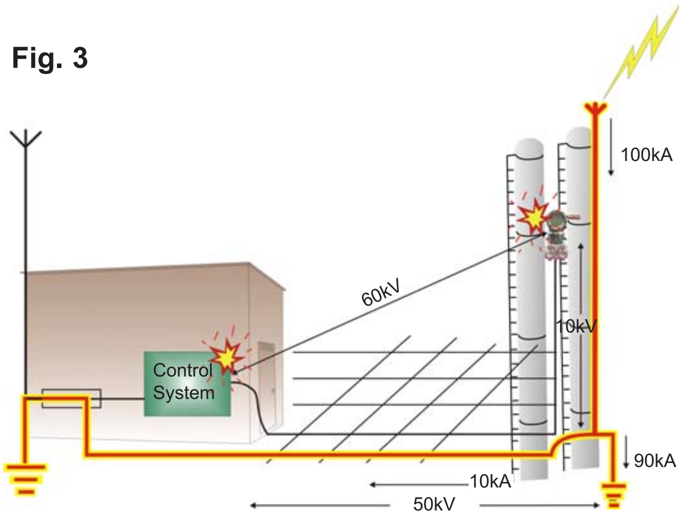
Once an instrumentation cable links the two points, the shear magnitude of the 97kV will break down the isolation of the transmitter and allow a small portion of the lightning current to flow in the instrument cable.

So, the simple installation of structural lightning protection does NOT eliminate the risk to electronics.

4.2 Site Equipotential bonding.

The obvious solution to this 97kV problem is to provide a continuous bond between all of the parts of the plant (grid rebar system) [4]. In fact most plants will be constructed using an equipotential earth grid of some type. So does bonding across the plant eliminate this problem?

Fig. 3

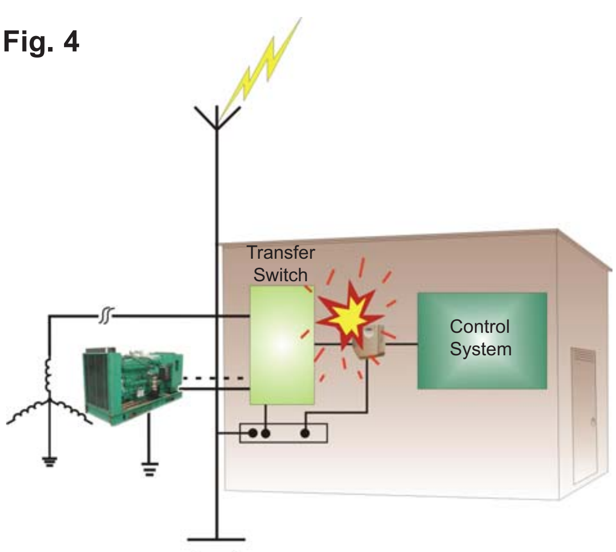


Not quite. While bonding has a positive effect on the installation, due to the inductance of the bonding and the stack itself, a voltage will still develop. In fact 60kV exists between the control room and the transmitter mounted on the stack. As can be seen in the diagram, the transient voltage peak has been reduced from 97kV to 60kV. Certainly equipotential bonding makes an improvement but the resulting surge voltage is still orders of magnitude higher than the susceptibility of the plant equipment.

4.3 Uninteruptible Power Supplies

Another piece of equipment commonly considered as providing surge protection is a UPS. An Uninterruptible Power Supply is an investment in a large plant, installed to provide continuous power for

Fig. 4



a defined period of time after loss of the utility supply. Typically this allows time for generator start up.

Few realize that this back-up system is itself vulnerable to large magnitude surges, specifically in three ways.

Firstly, the automatic transfer switch is a sophisticated microprocessor controlled device, which is itself vulnerable to surge. Damage here may prevent changeover to the generator or auxiliary supply. Secondly, control lines run from the automatic transfer switch to the generator. These lines tell the generator to start prior to operation of the changeover switch. Surge damage to this connection (either at the generator end or the transfer switch) means no back up supply when the UPS batteries run out.

Finally the front end of the UPS is basically a rectifier which can be damaged by severe surges as can the automatic bypass. So while a UPS system provides a valuable function to the site and a modest amount of protection against surge, its surge protective function should not be overstated. Indeed in many cases the UPS is a valuable asset whose function should be adequately surge protected.

To summarize there are many techniques currently in use that do indeed have a mitigation effect on lightning and surge voltages, however we must be very careful not to overstate their efficacy.

5. Financial justification

The desirability of operating electronics in a controlled transient environment is obvious. Will electronic systems operate longer in environments where surge voltages are controlled to tens of volts as compared to kilovolts? Of course! Non-catastrophic surges act on electronics like grit in a bearing, gradually wearing away until the bearing fails prematurely. Control and instrumentation systems are significant assets with design life of 20 years or more. An uncontrolled surge environment can reduce the useful life of these assets significantly.

Surge Protection devices provide that controlled surge environment [5], thereby removing one of the most significant causes of premature electronics failure. The problem for those who have not witnessed a catastrophic problem is how to justify the expenditure.

6. Return on Assets

A common question, once the plant manager understands that equipment is indeed failing prematurely, is how to justify the expenditure on surge. The finance team will immediately question the Return on investment (ROI) in surge. Unfortunately ROI is a ineffective tool for evaluating whether or not surge protection should be deployed, since the calculation does not take into account the consequences of a sudden breakdown or failure. A better measure would be Return on Assets (ROA) [6].

Return on Assets is defined as operating income divided by total assets. The higher the value the more efficiently the plant is using its assets. Clearly plant assets that are not contributing to income can impact ROA, or worse non functioning assets, that are contributing to a loss of income, have a negative impact on ROA. With this in mind we can evaluate the effect of surge voltages on plant operation.

Review the “electronic assets” of the plant, what would be the improvement in availability (and hence ROA) if 25% of the premature equipment failures could be eliminated?

Review each asset, from individual component (actuators, sensors etc.) through to process cells and plant modules, how does failure of this equipment effect plant operations and hence profit?

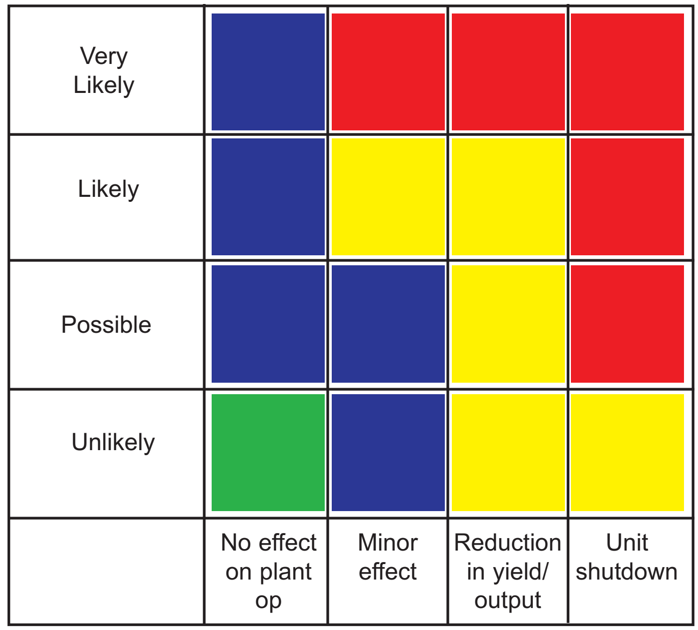
By asking questions such as these we can prioritize the application of surge protection to equipment whose failure would have the biggest negative impact on ROA.

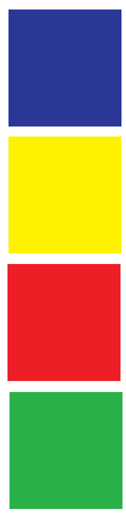
The next dimension to this story is risk. If the risk of a surge problem is extremely small, it will be difficult to justify surge protection in all but the most critical of applications.

7. Risk.

An intensive Reliability Availability and Maintenance (RAM) [7] program has been shown to reduce maintenance expenditure and increase plant availability. We can use the basic tenant of a RAM analysis, risk management, to provide insight into where surge should be applied to achieve the greatest improvement in ROA.

Plant engineers are encouraged to understand the risk of surge related reliability and availability problems. Perhaps the easiest technique is to develop a risk matrix reflecting the probability of occurrence vs the consequences.





Surge must be justified in terms of hardware savings alone.

Surge protection is probably justified with ROA gains based on increased availability.

Surge protection mandatory, Plant ROA at severe risk.

Surge protection will provide little benefit

7.1 Explanations of risk.

Very likely
Sensors located on tall structures (>10m), stacks etc. Islands of equipment – located some distance from the main plant but connected by power and instrumentation lines.

Likely
Long runs of instrumentation cable (greater than 100m). Unprotected power systems, risk increases if the facility has an overhead power feed.

Possible
Typical plant power and instrumentation topology

Unlikely
Self contained units with short instrumentation cable runs and a protected power supply.

This is a much simplified decision matrix, but it demonstrates the basic concept of installing or specifying surge protection in areas most likely to have a detrimental effect on operational performance and hence ROA.

8. Conclusions

Experience dictates that plant engineers tend to underestimate the impact of surge voltages, both in terms of the cost of premature failure of electronics and the impact on plant availability and hence ROA.

Between 25 and 30% of premature hardware failures can be attributed to surge voltage.

Current industry trends suggest that surge related failures are likely to increase as electronics become more sophisticated. Further the impact of a single surge related problem is likely to have a greater impact on operations in today's and future plants.

The old wives tales will provide less and less comfort. "We don't need to worry, we have a full lightning protection system and the best earthing system available!" Oh really?

View the control and instrumentation system as an asset whose function provides the operational return (profit). Which of these assets if disabled or subject to prematurely failure, will have the most significant impact on plant operations?

Finally review the risk exposure of these assets to surge related damage. Protect the hardware that has the highest impact on ROA and is at risk to damage from surge.

In today's ever more complex process environment, a properly designed surge protection plan is a key step in improving plant reliability, increasing availability and hence maximizing Return on Assets.

9. References:

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