Session Number: 5

Electrical Ornaments or Profitability Enhancers?

The Evolution of Surge Protective Devices

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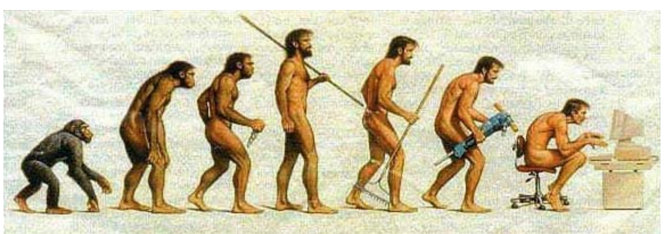
Abstract

The globalization of everything digital brings with it tremendous advancements in the ways in which we live and approach life. Digitalization has been promoted as the shortest route to an easier and more productive life.

Unfortunately for many, the fullness of the digital age has been derailed somewhere between invention and implementation. The unfortunate truth is that many of the trumpeted benefits of technology have yet to be realized.

The implementation of technology demands attention in the arena of electrical distribution. The field of power quality and more specifically transient surge protection holds the key to obtaining the full benefit of electronic equipment. Yesterday's designs are insufficient to protect today's electronics. The evolution of protection devices from passive clamping to frequency attenuating technology is paramount for enhanced profitability.

Introduction



The word – "technology" evokes an entire spectrum of emotions – and as the adage states, "Technology is great… when it works!"

It would certainly suffice to say that most people have a love/hate relationship with technology. Many early adopters just love the latest technology… from the original "Motorola® DynaTAC 8000 mobile phone to the Apple® Iphone 4 or from the Radio Shack® TRS80 computer to the Acer® Iconia dual screen laptop. If it's new, these early adopters really want to get their hands on it. However, with the transition from the Information age in the early 1970's to the Digital Age circa 1985 our personal lives not only became more globally mobile and accessible, but within a few short years, radically more technologically dependent.

Consider life today. Regardless of where you call home, we find our lives techno-controlled and microprocessor dependent. From what awakens us in the morning to where we get our news from to how we get to our offices, civilized life is based around advancing technology. It obviously does not stop there, once we arrive in our places of employment – the microprocessor age rules predominately everything!

The global trend towards digitalization has been and will continue to be of eventual benefit to all concerned. The pathway to those benefits, however, have pot-holes and detours that without proper implementation of another field of technology, might not be fully realized and enjoyed.

At Issue

The swiftness of which processing speed has increased and the corresponding market price decreases in the last 15 years is almost beyond comprehension. In his 1965 paper “Cramming More Components onto Integrated Circuits” Gordon E. Moore stated at that time that he believed that the number of components in integrated circuits would continue to double every year for “at least the next 10 years”. He was scarily accurate. That pronouncement has evolved into “Moore’s Law” and for the most part states that transistors in chips will continue to double every 2 years up until 2015-2020.

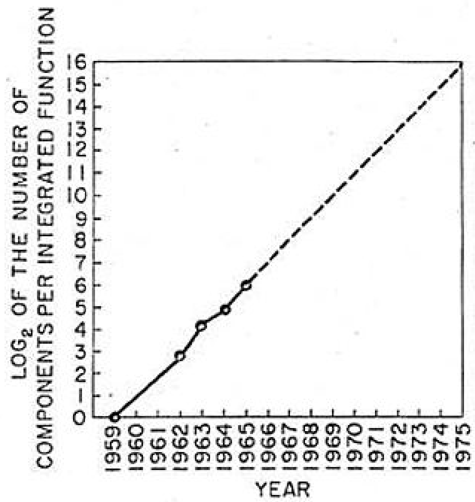


Fig. 2 Number of components per integrated function for minimum cost per component extrapolated vs time.

What Mr. Moore may not have foreseen was the corresponding rapid affordability of integrated circuits and societies dependence on their proper function.

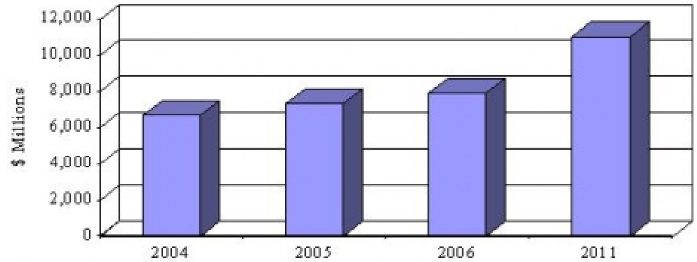
In the last 15 years we have witnessed the reduction of the operating voltages in correlation with the exponential rise in processing speed. As processing speed increases the necessity for electrical environmental stability grows. This growth rate is less demanding than either slope of the above curves of processing speed or operating voltage decreases. Yet the demand for stable electricity supply is there and growing even more critical into the second decade of the 21^{st} century.

The definition of environment is twofold. One is the actual operating temperature – integrated circuits – for the most part require a climatically controlled environment and secondarily and as important, is a stable electrical environment. Given the fact that within a computer chip there are essentially no “moving” parts – nothing to otherwise maintain, if we can provide the above two, then a computer processor should become obsolete before it ever were to actually fail.

Electrical Pollution

What is electrical pollution? Most simply it is the corruption of the sinusoidal wave form. Among others these events can take the form of voltage distortions, current distortions or a combination of both, complete loss of power, temporary high or low voltage conditions. An entire industry was birthed in the mid/late 1980’s to address such anomalies.

Despite inauspicious beginnings this industry has seen increases that rival the speed at which microprocessor operating speed has doubled. That industry is known as the Power Quality industry and by some estimates is globally expected to exceed $11 Billion in 2011according to BCC Research and will be comprised of a myriad of equipment; dominated by uninterruptible power supply systems (UPS), voltage regulators, harmonic filters, surge suppressors and lightning arrestors.



As noted above the successful, long term operation of microprocessors is dependent on a secure, stable, electrical operating environment. The power quality product market does encompass a wide variety of technologies and equipment, at this writing BCC Research does also indicate that over 70% of these expenditures are for UPS's, and yet that has not produced even near the expected or desired benefits for the processors that drive industry and commerce today.

Events Defined and Expanded

The electrical event that produces the most significant downtime is the transient, (also known as spike, or surge). Generally these terms refer loosely to the same event. According to the IEEE 100 A-Z guide, a transient is defined "as a change in the steady-state condition of voltage or current, or both"; and according to IEEE 1100-2005 "a transient is a sub-cycle disturbance in the ac waveform that is evidenced by a sharp, brief discontinuity of the waveform. May be of either polarity and may be additive to, or subtractive from, the nominal waveform." In both definitions it indicates a change in the fundamental frequency of the sine wave.

Sources of these events are categorized as being externally generated or internally generated. Again referring to IEEE C62.72-2007:

"Surges that occur in low-voltage ac power systems, and impinge on a PDS from outside a facility, originate primarily from two sources. These sources are lightning and switching.

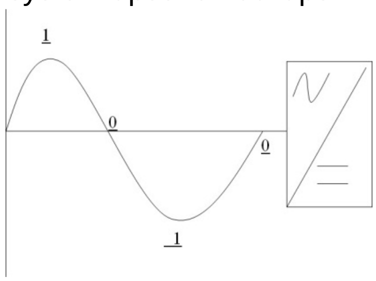
> a) *Lightning surges*. Lightning surges are the result of a direct flash to the power system, to the structure of interest and nearby structures, or to the soil. Distant lightning flashes can also induce voltage surges in the circuits of an installation.
> b) *Switching surges*. Switching surges are the result of intentional actions on the power system, such as load or capacitor switching. They can also be the result of unintentional events, such as power system faults and the subsequent corrective actions."

Most surge activity originates from within the typical facility, as much 80%, depending on the complexity of the operations. These are the surges/transients referred to above as switching surges. These transient events are created by the normal ON/OFF operations of electric loads, and the inductive load "kick" created by motor stop/start operations.

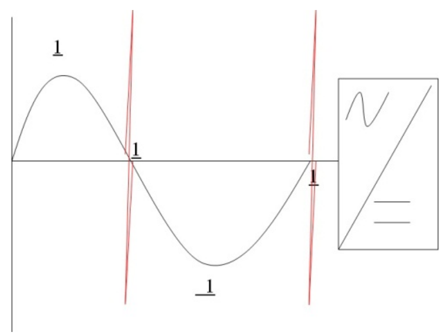
Another key creator of surge activity is the energizing of power factor correction capacitors. These types of events are far from catastrophic, and often times the immediate impact are rarely witnessed.

These occurrences may not even create system upset in microprocessor based operations, but what they will cause is a phenomenon coined as "electronic rust" or "computer chip cholesterol." Put simply these low level transient events make their way through the power supply to the DC logic and into the heart of chip where they create heat related stress along the traces. As this transient meets resistance it converts to heat and begins to build "plaque" along the trace until eventually the trace is broken or the data flow is totally interrupted and shuts the processor down. The shutdown occurs all without any plausible explanation. The chip has just experienced a nervous breakdown due to stress.

At other times these switching type transients are unknowingly responsible for system upset or lockups. In viewing the sine wave in terms of binary data, with 0 representing 0 or 180° and 1 representing 90° or 270° we view the sine wave as represented in this graph.



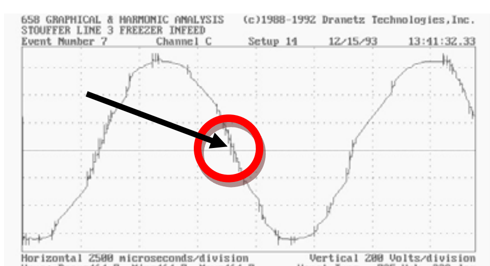
However, due to the presence of SCR/VFD created ringing transients we may quickly arrive at the supposition that when the 0 crossings are distorted due to the presence of these events, a series of false zero crossings are created; thus problematic issues occur in logic controllers that rely on the proper translation of these 1's and 0's into and through the invertor to correctly function at the DC logic level.



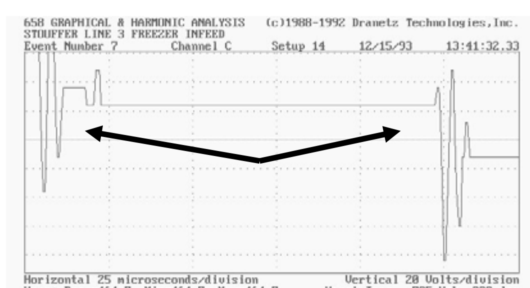
In the current Digital Revolution these types of events have become the nemesis of achieving the plethora benefits of the from the continually evolving microchip.

Effects Witnessed

The impact of catastrophic lightning events is dramatic. The energy released in a direct or even indirect lightning event is impressive to say the least, with problems ranging from vaporized electrical switch gear to charred remains of what was formerly a lightning arrestor or surge suppressor. The more subtle oscillatory transients are where the true focus is required.

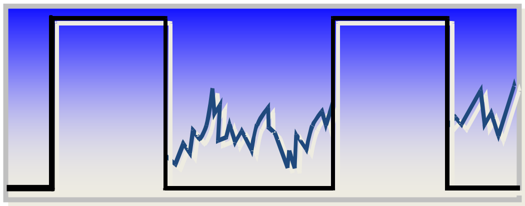


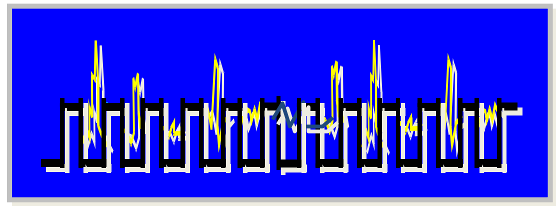
Why the sudden proliferation of such transient events? What has changed so dramatically in the last 15 years to raise alarm on a global scale? In reality, not much. These same events were captured by disturbance analyzers in the early 1990's. Note the point in the red circle. This event expanded in the following figure illustrates what in fact amounts to nine "false" zero crossings of the sine wave. These graphs were from a processing facility in 1993. These events caused random lockups and shut downs of the line resulting in the loss of tens of thousands of dollars in products.



These issues have exponentially increased due to the processing speed of the chips in operation today.

Why? In the graphs below we see the impacts of decreased operating voltages and increases in operating speed and the same levels of transient events. The same level of transients in 1990 on a 400MHz processor are data corrupting menaces on a 2010 Quad Core processor.





The foundation of the power quality pyramid is transient voltage surge protection equipment or the surge protective device (SPD) as referred to in ANSI/UL 1449-2006 and IEC 61643-1. It is this device to which we must now turn our attention if we are to provide a viable solution for eliminating he number one profit thief in the electronic world - downtime.

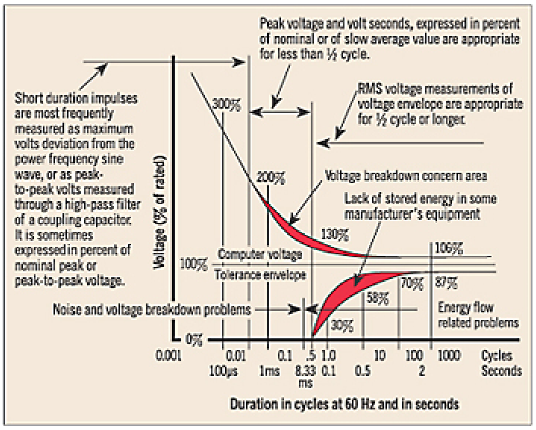
Surge Protective Devices

Over the last 25 years the evolution of the surge protective device (SPD) has been impressive. The SPD has evolved from a single component gas discharge tube, spark gap, or other nonlinear resistive type device as in an MOV (metal oxide-varistors) to a multi-component hybrid network of a variety of components. The science of surge protection has produced a widely successful range of products that can address every manner of AC and DC power circuits, along with telecommunication, data and telemetry equipment.

It hardly appears necessary to recap the purpose for units or the method of operation of the individual components. However it is worthy noting that globally, there is not yet a true SPD performance standard in place. There exist a myriad of safety and operational norms designed to protect not only equipment but personnel as well.

The difficulty this presents to the buying public is how to accurately make a comparison between Brand A, B, or C of surge protective devices. What criteria should be considered? What criteria is non-essential? Beyond this, there is the engineering skirmish about which primary body of engineers is more right than the other. Is IEC the “best”? Is IEEE the most efficient?

The primary objective of the utilization of SPD is to, of course, protect electrical/electronic equipment from damage due to spikes and surges. But what is does that actually entail? It means providing an acceptable electrical operating environment to the connected loads.



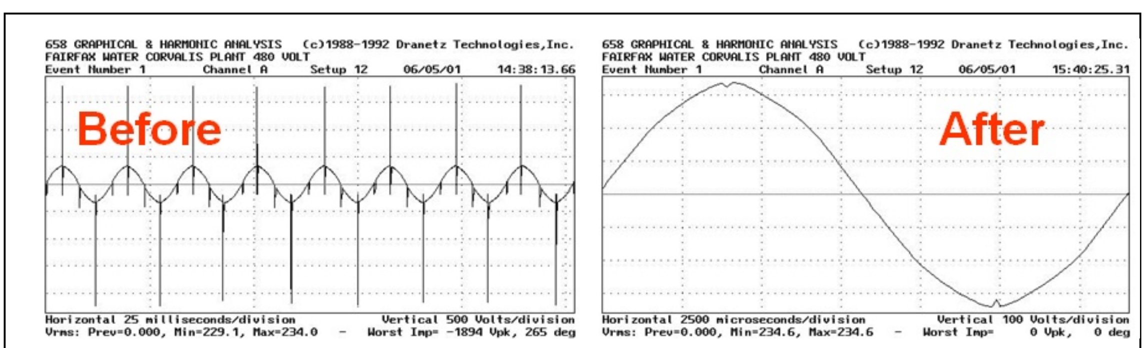
The most oft quoted standard is the CBEMA curve. From "Understanding the CBEMA Curve (www.marcspages.co.uk): " To simplify matters the Computer and Business Equipment Manufacturers Association came up with a curve wherein the voltage deviation from the norm is the only factor taken into account. It is felt that equipment fitted with a filter should be able to withstand greater deviations the shorter the timing of the deviation.

And so the CBEMA curve was born. It effectively encompasses all the factors involved with voltage deviations, from long term through to high-speed distortions of the waveform." The author goes on to say that while in every case his propositions might not necessarily be true and elaborates on this further in the document. Prime point being that even with attempts to define the environment, there is still significant disagreement amongst this community.

The objective is – to protect equipment and give it the best electrical environment possible. The idea is to – provide a sine wave that is as close to nominal as is economically and physically feasibly possible. And finally the desire it to develop an SPD with the lowest let-through voltage given a set of defined, industry standards and accepted test wave forms.

The means to obtain this objective is found in the circuit design or topology of the SPD. In terms of circuit topology the most widely utilized version is that of a threshold clamping type circuit. Threshold clamping is defined as a point above and below the sine wave at which above this level the circuit conducts to remove the excess voltage and current from the electrical circuit which has been disturbed. This is the accepted method of operation since SPD devices were first introduced in the mid 1960's.

The second type of technology is one that deserves the most significant consideration and implementation. As discussed electronics today demand a higher level of protection and a much purer sine wave in order to obtain optimal function. The terminology for this type of topology is a frequency-attenuating network. This circuit is one in which both the voltage level and sine wave frequency are monitored. This is performed in such a way as when a transient event occurs the circuit responds to return the sine wave to its normal state, predominately free of deviations from the norm.

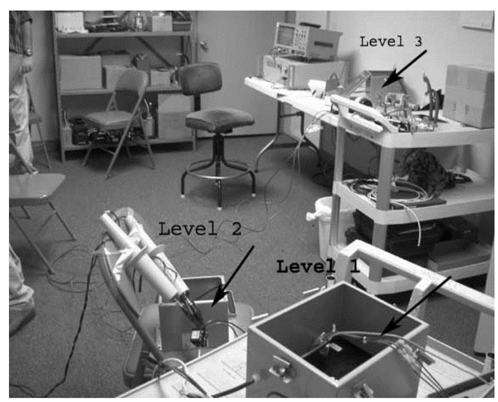


The effective elimination of low level oscillatory transient events occurring inside the envelope of the sine wave is one of the most beneficial and immediate methods of obtaining significant reduction of system lock-ups and unnecessary resets – thus leading to much more immediate return on investment and the optimal protection of high speed microprocessor based systems, e.g. PLC's, timing controls, robotic control systems, RTU's, Variable Frequency Drives etc.

Implementation Strategies

The concept of cascading suppressors (the connecting of SPD's from main panels to directly fed sub-panels) in buildings as a recommended practice as far back as IEEE 1100-1999 and has been in practice since the early 1990's. It is the de facto standard for systematic mitigation of large surge current impulses. The proper coordination of the cascaded SPD units is somewhat critical to understand, but nonetheless effective to dissipate significant amounts of energy.

In October 2005 testing was conducted at the Surge Suppression Incorporated laboratory to validate some cascade scenarios for a paper presented at the Transmission & Distribution Conference and Exposition: Latin America, 2006. From that testing some quite significant information was discovered.



The test set up was two of the threshold clamping devices connected in parallel to wiring that was 1.5 meters in length as shown. The surge generator would then release a 20kv/10ka combination wave impulse as referenced in ANSI C62.4. Measurements made at level 1 and level 2 showed less than a 100 volt difference between the let through voltage at these two points.

However when applying that same test impulse to the technology referenced as frequency-attenuating, the difference was over 900 volts between Unit 1 and the residual voltage measured at Unit 2.

Additional testing also revealed an even greater benefit when using the frequency-attenuating technology in conjunction threshold clamping unit in close proximity of each other, as would be found in a typical control cabinet situation in a production facility.

This resulting test data is presented in the following chart.

Note the chart:

Test Setup 1	**Measurement Point**	**Applied Surge** 6kv/500A	6kv/200A	2kv/67A
Unit A to Unit B	Unit A - Threshold Unit	786 v	598 v	211 v
1.5 m wire between	Unit B – Frequency Unit	295 v	102 v	39 v
Test Setup 2	**Measurement Point**	**Applied Surge** 6kv/500A	6kv/200A	2kv/67A
Unit A	Threshold Unit only – 15cm leads	973 v	908 v	771 v

The impact of the frequency-attenuating technology is dramatic. Note the residual voltage from Test 1 under Unit A for the A1 2kv ring wave is 211v with a frequency attenuating unit as the 2nd level. Under Test 2 that same test with only the threshold unit being tested that residual voltage is 771v. Given this amount of let through voltage, it is much more evident now how damage or system upsets occur in electronic equipment that is protected by only one SPD and with only the threshold clamping type of technology.

Cascading SPD units is the best manner of protection for facilities and is beneficial in many other applications as well; however with the utilization of the frequency attenuating technology the results are dramatically improved bringing that operating environment for the most sensitive equipment to an almost negligibly impacted sine wave, with a residual voltage of only 39 volts. This level of protection is impossible to achieve with the typically accepted threshold clamping SPD unit.

IEC 61643-1 or IEEE C62.41.2-2002

Standards are vital, necessary and important. However, standards do not provide return on investment and protect equipment. There continues to be an evolution of all standards, as the body of knowledge increases and matures, so should the standards. What cannot be relegated to standards are the benefits from proper technology implementation.

At the present time IEC 61643-1 contains no reference to the widely accepted 100 kHz ring wave – oscillatory transient. It is this disturbance that currently disrupts electrical networks throughout industry. It is a variation of this disturbance that currently causes system upsets, lock-up, shutdowns and restarts. When there is an absence of visible change, as referred to in ANSI C62.72-2007, and yet latent failure occurs, the culprit can be found in the probable tens of thousands of oscillatory, low voltage/current level transient events.

The widespread usage of SPD’s throughout the distribution boards of any facility that relies solely on the threshold clamping topology will never provide the same benefit that is achievable with the proper implementation of these complementary technologies. The survey and recommendation of installing threshold clamping at non-critical loads and frequency-attenuating devices at critical loads will prove to provide the optimal return on investment.

Why IEC 61643-1 does not make reference to this transient event can only be determined by those on the committee. However, laboratory testing and real world implementation provides ample evidence that this standard of design and recommendation has virtually little impact on mitigating these types of transient occurrences.

Summation

In summation, surge protection devices have been utilized for more than three decades. Their prime purpose is to protect and prevent losses to electrical and electronic equipment by removing the excess and unusable energy contained in surge events. The specification most desired, as explained above, is the lowest reasonably attainable let through or residual voltage when submitted to industry acceptable test protocols.

Surge protection devices are no longer an option; they are a necessity. The microprocessor-based equipment that was exactingly designed in the placid electrical environment of the research facility and then thrust into the tumultuous world of electrical interaction suddenly finds itself grossly unprepared to function according to its designed specifications.

With these developments, a global industry has emerged and is growing at double digit rates. Unknowledgeable and naïve, facility managers, technicians and engineers have acquired and installed SPD’s like ornaments on a tree and believing for the miraculous, only to be disappointed with the lack of results. Many of the same individuals now are hesitant to consider any surge suppression.

Electronic equipment has evolved and so also has the technology of surge protection devices. A renewed consideration should be given to this emerging topology of frequency attenuating type devices. Dramatic results have been documented from around the world from the utilization of this design.

Case Studies

Site: North American Healthcare Facilities

Problem: Excessive downtime of MRI, CT, Xray (even with maintenance contracts)

Solution: Against the wishes and will of the service contract provider, the Healthcare management company chose 5 hospitals where they had monitored the emergency service calls and the downtime hours. At the close of the 12 month period they installed the frequency attenuating devices in a cascaded fashion at 5 different facilities.

Results: Pre-install Emergency Service Calls: 441

Post-install Emergency Service Calls: 188

Pre-install Downtime Hours: 806

Post-install Downtime Hours: 267

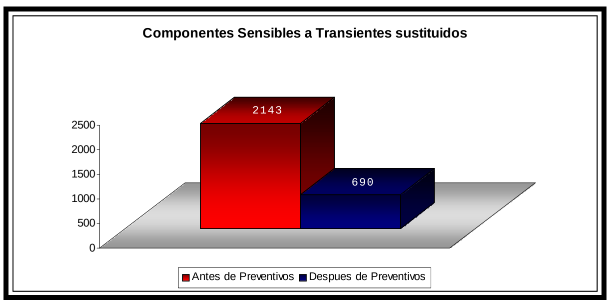
Benefits: $3,000,000 value of downtime reduction.

Site: South American Oil field – Drilling operations

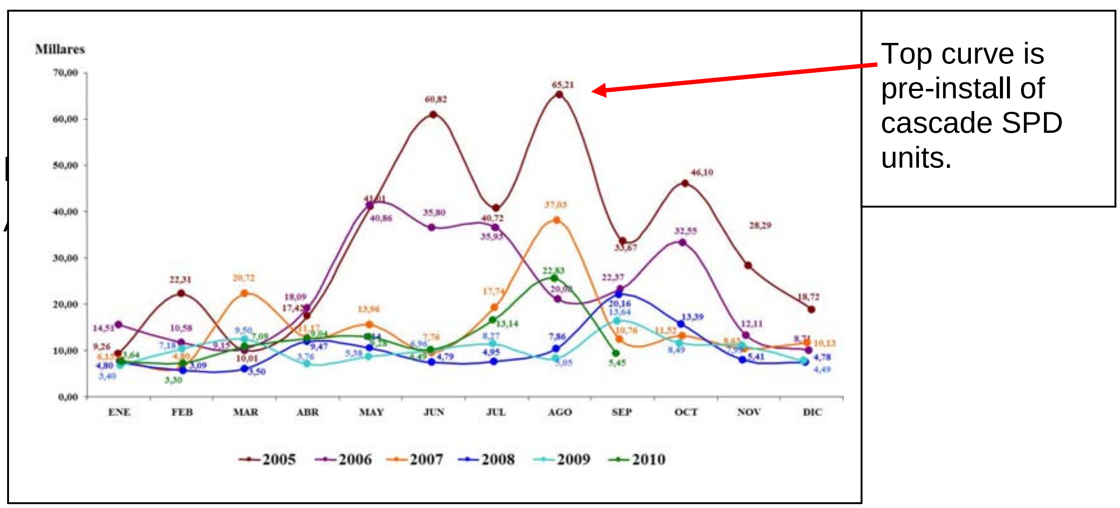
Problem: Excessive losses in electronic components and oil production. Inspections revealed primary surge protective devices installed.

Solution: Evaluated the scenario and recommended cascade protection for the VFD at the well site. Conducted testing to validate the concept and proposed to the oil company. Installed threshold clamping high energy device at main and frequency attenuating devices at 2 lower levels.

Results: Over a 4 year span of time, replacement of electronic sub-components decreased by over 67%.



Downtime decreased radically – resulting in less lost production. On average over the same 4 year span of time an additional $32,000,000 of oil was produced and sold. An average of 136,000 barrels per year additional was able to be pumped due to increased uptime of the well.



Site: Casino – Iquique Chile

Problem: Weekly failures of slot machine monitors at an average cost of USD$ 750.00 each, resulting in lost revenue and unhappy clientele.

Solution: Step one was installation of first level protection at casino electrical service entrance.

Benefits: Noticeable, but minimal.

Solution- Step 2: Recommended and install second level frequency attenuating suppressor technology.

Benefits: 80% of downtime disappeared. Return on investment was three months. Fewer spare parts in inventory, more profitability, better allocation of Casino staffing.

Conclusion

The implementation of cascaded frequency-attenuating technology suppressors produces identifiable, verifiable and profitable results. These surge protective devices are not ornaments in the electrical room; they are profitability enhancers from the date of installation.

References

ANSI C62.41.1-2002

ANSI C62.41.2-2002

ANSI C62.72-2007

IEC 61643-1 2005

IEEE 1100-2005

IEEE 100 A-Z Guide

Cramming More Components onto Integrated Circuits by Gordon E. Moore