The Green Age, Smart Grid and Fourth Generation Protection

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For the last several years, the reality of aging, overburdened electrical grids has been realized by the world-wide engineering and utility community. Identifying and addressing the issues has been a challenge and the challenge is being met, in part, by the development of the Smart Grid concept. In conjunction with this alternative energy sources are an integral component in the Smart Grid. Their use goes hand-in-hand with significantly reducing the environmental impact of the whole electricity supply system.

Although seldom realized, lightning and surge protection play a critical role in reducing the impact of industrial waste in commercial and industrial operations and this in turn helps reduce any negative impact on the environment. This is accomplished, in part, by decreasing the amount of printed circuit board cards, office machinery, computers, lighting and other equipment that must be discarded due to damage caused by internally or externally generated surges.

The successful implementation of 21st century technology demands attention in the arena of electrical systems and technology, much of which has seen little change since the 1970's. The field of electrical power quality and more specifically lightning and transient surge protection holds the key to obtaining full benefit of the electronic equipment that companies today invest in that are designed to make them more profitable. Yesterday's designs are insufficient to protect today's electronics. A fresh approach that zero's in the true needs of 21st century electronics is what this paper will explore.

The underlying purpose of the presentation is to reinforce the fact that surge protection, the Fourth generation type, is not an option; it is the foundation for all we do in the 21st century. A faulty foundation of antiquated technology will not provide the stability necessary to revolutionize the economies of Africa.

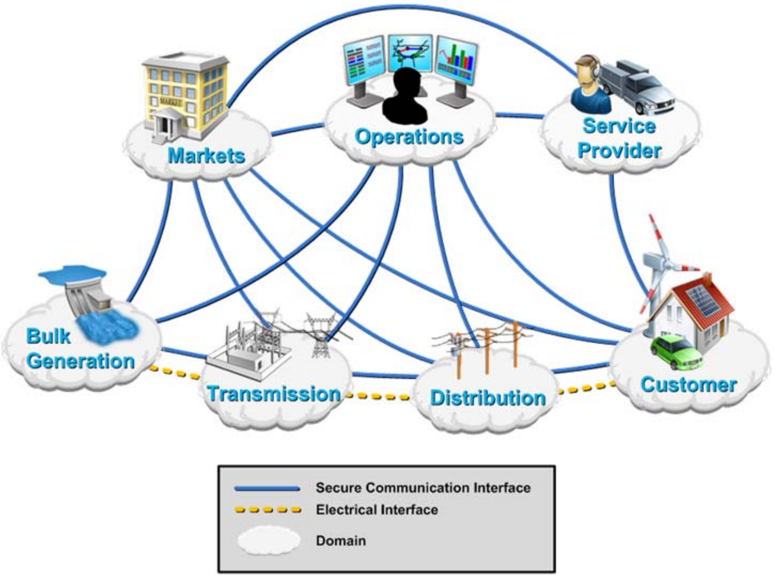
What is Smart Grid?

According to their basic statements, Wikipedia, and the European Technology Platform, Smart Grids are electrical systems that can intelligently integrate the behavior and actions of all users connected to it – electricity company power generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimizing the operation of the system;
- Provide consumers with greater information and options for choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;

- Maintain or even improve the existing high levels of system reliability, quality and security of supply;

The picture to the right, courtesy of NIST Smart Grid Framework 1.0 January 2010, helps to illustrate the Smart Grid as defined herein.



The IEC has defined the smart grid as an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimizing the operation of the system;
- provide consumers with greater information and choice of supply;
- significantly reduce the environmental impact of the whole electricity supply system;
- deliver enhanced levels of reliability and security of supply.

It is clear that the smart grid project is not a simple one; but rather involves significant inter-disciplinary communication and cooperation in the standards and application arena. The good news is that looking at the basic “definitions” and structure as shown in the NIST diagram are all relatively consistent.

Another key factor in dealing with the smart grid is “interoperability”. As indicated by the IEC, There is a lot of confusion regarding interoperability. The task ahead is to define the boundaries and needs of interoperability. In the end it is about making certain that each "box" can connect with all the others and that those "boxes" are interchangeable. The proprietary content of each "box" doesn't necessarily have to be defined in detail to accomplish this goal.

It is believed by some that generally speaking, the interoperability factor although challenging, can be achieved as long as the proprietary rights of company equipment is not challenged. Secondarily, in a rush to premature implementation of the myriad of technologies and programs there has been a neglect of proper testing. As commented by Jessie Berst in Smart Grid

News.com – “In God we Trust – all else we test”. We are pleased to see the launching of SmartGrid Labs by Enernex to begin to fill that need for “field” trials and testing.

Current Grid Challenges and Smart Grid Benefits

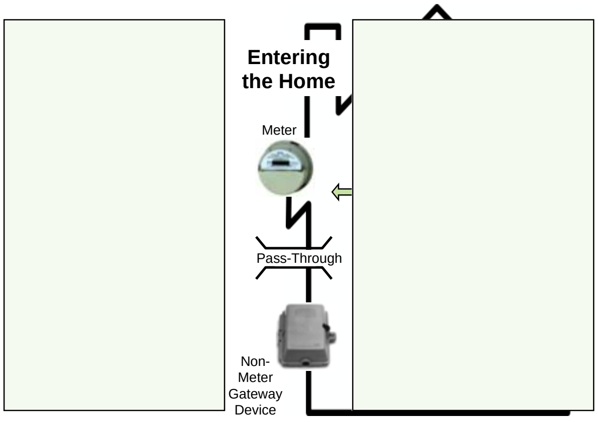
All parts of the electric network have organically grown over many years, even decades; figuring out where intelligence needs to be added is very complex. Further, communication between networks is limited at best and the sustainability and security of our current systems is, in some cases, fragile.

As so aptly stated by Reid Detchon of the Energy Future Coalition, ***“Running today’s digital society through yesterday’s grid is like running the Internet through an old telephone switchboard.”***

Beyond the de facto functions shown above, the basic concept of Smart Grid includes the addition of equipment to add monitoring, analysis, control, communication capabilities and improve sustainability to the electrical delivery system to maximize the throughput of the system while reducing the energy consumption.

The Smart Grid will allow utilities to move electricity around the system as efficiently and effectively as possible. It will also allow the homeowner as well as commercial operations from the small business to large facility operations to use electricity as economically and efficiently as possible.

Surging New Challenges for a New Grid



While the successful deployment of a smart grid system will allow the benefits above to be realized, some of the elements of the new system create their own issues.

Case-in-point is the residential graphic shown on the left. The addition of the gateway devices, energy management devices and the communications between them all require surge protection as well.

In order to have a perspective of the potential impact, a solid understanding of power quality basics and common power quality anomalies that occur whether or not a Smart Grid/Modern Grid is helpful. Regardless of the presence of a Smart Grid/Modern Grid system the goal of power quality remains the same -- to ensure that a system operates without interruption and protects electric/electronic devices from unplanned outages or other anomalies that negatively impact operations. In short, the intent is to have systems that function without unplanned interruptions.

Some of the anomalies that can cause disruption to the systems include:

- Under voltage conditions – Sags
- Over voltage conditions – Swells and sustained over-voltages
- Transient /Surge Events
- Harmonic Distortions

Because of the sensitive nature of much of the Smart Grid equipment, the installation of such Grid systems only increases the opportunity for these anomalies to occur

Even without a detailed understanding of the interoperability of all of the systems involved in the Smart Grid, increased susceptibility to transients and surges is a reasonable expectation that must be addressed. It is for this reason that intelligent installation of what is termed "4th Gen" surge protective devices within these systems is a critical need.

And the Green?

Throughout the Smart Grid Systems, monitors will be used to capture energy usage data and to hopefully reduce that usage whenever possible. Having an efficient, effective power quality system that includes this equipment as well as effective surge protection can reduce the waste of electronic equipment, including such things as printed circuit boards in automotive robotics as well as other equipment. While surge protective devices are not designed for the purpose of reducing kilowatt-hours, they certainly do increase productivity and reduce waste. This factor is often overlooked; however the use of surge protective devices within a power quality system definitely has a positive environmental impact.

In short, modernizing the electrical grid to meet the needs of a 21st century digital world requires the deployment of a truly Smart Grid that incorporates surge protective devices throughout both the grid system and the alternative energy sources providing electricity to the system.

The failure to give ample consideration to proper surge protection implementation is to open the door wide to equipment failures and frustrations. A potential unintended consequence would be a general lack of securing the benefits of the global smart grid strategies currently being discussed in the various forum's in this conference and various others around the world.

New Technology – Old Methodology

Given the global trend to digitalization of all things electrical and its continued incursion in to the electric utility industry and the currently evolving Smart Grid arena; it is of paramount importance that significant attention be directed towards the electrical environment and preservation of the systems upon which the grid is being built.

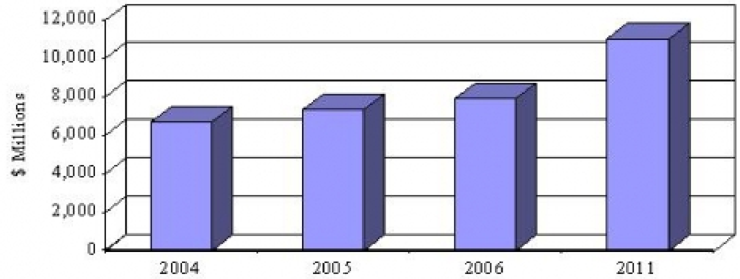
The successful implementation of 21st century technology demands attention in the area of surge and lightning protection, much of which has seen little change since the 1970's. This field holds the key to obtaining full benefit of the electronic equipment that we are currently implementing for Smart Grid. Yesterday's first or second generation surge protection designs are insufficient to protect today's electronics. A fresh 21st century approach that zeroes in on the true needs of 21st century electronics is what the remainder of the paper will discuss.

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 electrical environment is there and growing even more critical into the second decade of the 21st 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, free from pollution. 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.

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.

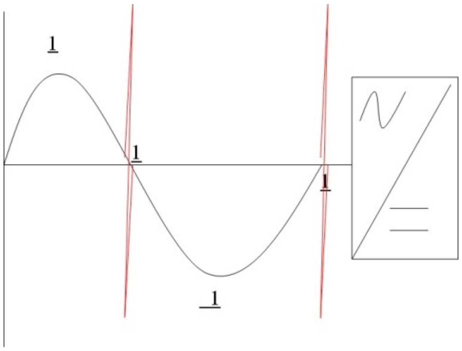
Events Defined and Expanded

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.

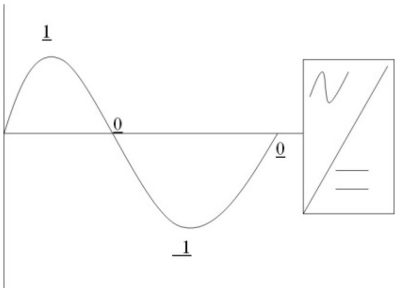
> a) *Lightning surges*. Lightning surges are the result of a direct flash to the power system, to the structure of interest and nearby structures, or to the soil. Distant lightning flashes can also induce voltage surges in the circuits of an installation.
> b) *Switching surges*. Switching surges are 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 available from the continually evolving microchip.

Surge Protective Devices

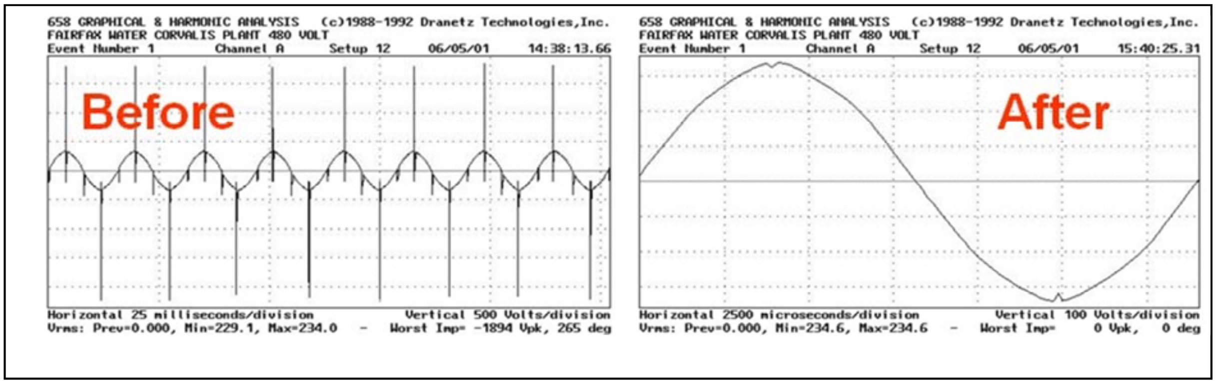
Over the last 25 years the evolution of the surge protective device (SPD) has been impressive. The SPD has evolved from a single component gas discharge tube, spark gap, or other nonlinear resistive type device as in an MOV (metal oxide-varistors) to a multi-component hybrid network of a variety of components, what has been called the 3rd generation design. 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.

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 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 topology, what we will term "Fourth Generation"; 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 Smart Meters, SCADA systems, Substation Reclosers, PhotoVoltaic invertors and all other high speed microprocessor based systems.

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.

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. 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.

Conclusion

In short, modernizing the electrical grid to meet the needs of a 21st century digital world requires the deployment of a truly Smart Grid that incorporates the deployment of cascaded frequency-attenuating technology surge protective devices throughout both the grid system and the alternative energy sources providing electricity to the system.

It is the implementation of 4th Generation surge protection technology that will produce identifiable, verifiable and profitable results. This is a measurable means of insuring a more rapid investment return on the global adoption of the Smart Grid concepts and technologies.

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