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The Case of Lightning Protection Solutions for Electric Power Facilities

Each year a multitude of electric power facilities are knocked off-line due to lightning. However, this is probably common knowledge, because we have all suffered the consequences. What is less known is that on a bright and sunshiny day when there is no lightning in sight and the power goes out and/or operations shut down that it can also be due to lightning -- more accurately the repercussions of previous lightning strikes which occurred months earlier.

Sure, the general population at large accepts the occasional bolt and clap of thunder, then power goes off. But why would a lightning strike from a few weeks or even years back have anything to do with loss of power on a sunny day? There are even times when the electric power companies themselves are left scratching their heads and have no idea what went wrong. People do not realize that not only are there

primary effects of a lightning strike (like fire) but secondary effects, such as transient surges and over-voltages, as well. Each time a bolt hits, the electrical current is carried through to ground, the ground potential rise (GPR) and electromagnetic pulse (EMP) can be coupled or transferred through the wires and into the equipment and sensitive electronics of the facility. If not immediately destroyed, every time this happens, degradation occurs and the life of that item is shortened. The same is true at your home. Did you ever wonder why that flat screen television you thought would last 10 years just stopped working? Well, it could be that lightning strike from last summer or two weeks earlier. So why would you want to collect a strike into the ground by using a Franklin Rod?

This occurrence degrades/reduces what is called mean-time-between-failure (MTBF) and it can be extremely costly to electric power providing companies as well as their customers. Therefore it is important for these entities to have lightning protection, and to create a thorough and comprehensive solution which combines lightning protection, with grounding engineering, as well as appropriate surge solutions.

In order to do this properly, electric power companies should not only install lightning protection systems but implement a full and extensive lightning risk mitigation plan, which begins with assessment, perhaps testing, in addition to a customized design unique to the facility, followed by proper installation, and continual maintenance and inspection. This approach can save companies and customers millions of dollars in the long run.

Electric Power and Lightning

Lightning protection performs an important and imperative function in the energy and electric power sectors helping companies avoid the downtime and restoration costs that come with outages. A single outage lasting 1 hour can cost upward of $1 Million not only to the company, but also to its customers depending on the users that are serviced. But sometimes, the initial choice of a lightning protection solution can become the problem when outside or unknown influences are factored in. Weather, particularly lightning is one of the biggest threats to facilities of this type all over the world. Several companies have found that traditional lightning protection tends to create more issues than solutions and have opted to implement a solution based on charge transfer technology.

Whether it is a nuclear power facility such as Browns Ferry or substations, much like those operated at EPB, or a cooperative, such as Tri-State Generation and Transmission Association, the usual protection, like lightning rods and overhead grounding/shield wires, do not do the job. They need assurances and have found that a customized approach, tailored to meet their unique set of circumstances, is more preferable than the standard approach. When utilities or power generation facilities experience adverse operational events and are subsequently knocked offline the cost can be devastating, resulting in the ultimate consequence of death, and/or substantial losses (some of which are outlined in a DOE report on page 3) which can have an impact on customers ranging from thousands of dollars to millions, depending on location and the customers who are impacted.

The Risk of a Lightning Strike to Electric Power Providers:

According to the DOE one report references the following:

Cost to the end-user for momentary outages (costs are per customer) to be as follows:

•Residential – $1.82

•Commercial – $574

•Industrial – $1895

Therefore, for a load serving station that serves 20 MW of load (or 2800 to 4000 residential customers/meters), the cost impact to end-users of losing service is in the range of $5096 to $7280.

This is a momentary outage and does not take into account a specialized industrial process that would be impacted. One statement from a high tech manufacturing group mentioned $1,000,000 an outage.

The Lightning Protection Solution

The direct opposite of shield wires and/or lightning rods, the Dissipation Array® System (DAS®) uses a different, innovative method of operation compared to both. While shield wires are meant to re-direct an incoming lightning strike's energy to the ground, away from equipment, the damaging secondary effects of the strike are still experienced. A lightning rod collects the strike and carries the current into the ground as well, creating the same effect. DAS uses "charge transfer" technology, which prevents the termination of lightning within the area of desired protection altogether. The technology is so effective, the DAS has over a 99% success rate and is the only lightning protection product to offer a full no-strike warranty.

It is important to first assess the situation, and then design the right solution for each facility. A cookie cutter approach will not work because each facility is unique. Once the proper lightning protection system is in place including proper grounding and surge protection, maintenance and inspection are integral to protecting your facility and keeping it protected.

Lightning Eliminators has provided critical solutions for numerous electric power facilities over the past 40 plus years. The response has resulted in statements such as this made by Dave Fatkin, Plant Engineer at the City of Tallahassee, Hopkins Generating Station (case study included in this document), "I want to again thank you for a job well done. I know you guys put in some extra effort during the on-site data acquisition phase and based on the report with it also. If you have a need for a reference, please feel free to pass my contact information along." which we frequently do upon request.

Planning Starts with Accurate Testing, Assessment and Design

The Smart Ground Audit

Smart Ground is a relatively new technology and service offering by LEC. The technology employs state-of-the-art grounding system design and modeling software (WinIGS) and an advanced ground system multi-meter to deliver ground test and analysis capabilities far beyond that of the standard test meter and methodology.

Smart Ground analyzes the in-situ grounding environment and compares actual measurements to an electro-geometric computer model of the system being tested. The results are highly-accurate measurements and practical recommendations to help you make informed decisions.

1. The standard Smart Ground audit *typically* consists of three tests and an analysis: Point-to-Point measurements, Soil Resistivity measurements, a Ground System Impedance test and a Ground System Safety Evaluation.
2. If the standard audit is not desired, audits can be tailored to meet the needs of the customer.
3. All audits require a virtual (computer aided) electro-geometric, 3-D, model of the plant grounding system and power network.
4. Field measurements are compared to the validated model's computed values. Discrepancies are noted.
5. Recommendations are based on the findings of the test and analysis, as well as the initial reason for the audit. If necessary, a simplified bill-of-material will be included along with a rerun of the analysis to quantify their effects, assuming the recommendations are implemented.
6. Smart Ground mitigates many of the problems associated with standard ground system testing devices and is a featured test method in IEEE Std. 81 – 2012.

Additional Options for Lightning Protection Success:

The Technical Review: Is a basic review conducted remotely by a technical representative and is based on photos, drawings and building plans provided by the client. Solution specialists examine the data and provide basic recommendations which will enable an initial understanding of what your facility should plan for.

Site Evaluation: Is a more substantial review typically done on-site by a solution specialist. It can range from a one day, to a comprehensive multi-day event for large sites with complex electrical systems. The overall cost is based on the complexity of the site and will generate a 'Scope of Work' which will allow a facility to better understand the dangers and analyze the risk their site faces from lightning's direct and secondary effects.

Design Study: Is DAS specific and is facilitated by an engineering team member visiting the site. It provides a more detailed and scientific evaluation of the site's exposure and options for protection. You receive a formal report with findings and recommendations which may contain site specific drawings of recommended designs, and/or a risk assessment as per IEC; a "Strike Probability Analysis" and possibly a "Transient Analysis" depending on the scope of work.

Site Survey: Is conducted after a purchase is made and before installation, and requires an engineer. It is the final stage in designing a solution tailored to your protection requirements and includes all aspects of risk analysis and design to produce detailed engineering drawings and system specifications, in addition to providing a hands-on approach in the installation process.

What does a Solution Look Like?

Below are a collection of terminologies and case studies providing examples of what a complete lightning protection solution might consist of:

Definitions

- **Charge Transfer System:** A lightning protection technology that is based on the premise that production of positive space charge in the region around the protection ionizer (DAS) reduces the near-surface electric field strength. As a result of this lower near-surface field strength there is less likelihood of streamer formation near the protected equipment, and hence, less likelihood of a lightning leader-streamer connection; i.e. no lightning strike.
- **Ground Potential Rise (GPR):** The maximum electrical potential that a ground electrode, grid, or system might attain, due to an injection of electrical current from either a fault or lightning strike, relative to a distant grounding point assumed to be at the potential of remote earth/zero potential.[1]
- **Ground System Impedance Measurements:** A measure of the vector sum of resistance and reactance between a ground electrode, grid or system and remote earth.
- **Ground System Safety Evaluation:** An examination that characterizes the Ground Potential Rise and resultant Step and Touch potentials that will be present in the facility's grounding system during a worst-case fault. Analysis will determine if grounding system meets the safety requirements of IEEE Std. 80 or IEC 479-1.
- **Lightning Shielding Performance:** This analysis characterizes the likelihood of direct lightning strikes to electrical equipment, bus-work, buildings, etc. The results may reveal vulnerability to an unprotected facility or weaknesses in an existing LPS scheme.
- **Mean-Time- Between- Failure (MTBF):** The anticipated elapsed time between inherent failures of a system during operation and thus may be considered a measure of the reliability of a hardware product or component.
- **Point-to-Point Testing:** Analogous to unearthing and inspecting the cables and connections, without excavating, this test indicates the condition and integrity of the bonding, connections and cables of the buried system, and compliance to existing drawings of the grounding system.
- **Soil Resistivity Measurements:** A measure of how much a volume of soil will resist an electrical current. Usually expressed in ohm-meters.[1]
- **Step Voltage:** The difference is surface potential that could be experience by a person bridging a distance of 1 meter, with the feet, without contacting any grounded object.[1]
- **Touch Voltage:** The potential difference between the ground potential rise (GPR) of a grounding grid or system and the surface potential where a person could be standing while at the same time having a hand in contact with a grounded structure or object.[1]
- **Transient Analysis:** An examination that characterizes likely voltage potentials that electronic/electrical equipment will be exposed to, due to a strike, for a specific area in question.

Case Studies

Tennessee Valley Authority (TVA) – Browns Ferry Nuclear Power Plant

Facility Type: Browns Ferry Nuclear Power Plant – Athens, AL.

Problem:
Due to repeated lightning strikes to the off-gas stack and damage to critical equipment surrounding the base, the TVA was driven to find an alternative to the standard Franklin Rod system it originally used to protect the plant.

- Considerable equipment loss, repair and replacement
- Manual monitoring due to automation having been knocked off-line
- Downtime
- Increased workload
- Lost resources and revenue

Steps Taken:
In 1997 TVA solicited a comprehensive Site Survey and Design Study through Lightning Eliminators. In addition, TVA simultaneously conducted comprehensive testing 3 years before and 3 years after the lightning protection system was installed.

Solution:
To design a comprehensive protection scheme, LEC took into account factors such as the off-gas stack's location, size, shape, equipment, geography, and exposure to lightning activity. They then engineered, and deployed an integrated lightning prevention system for BFN which included DAS strike prevention. Spline Ball Terminals (SBTs), a form of hybrid preventer/collector, were used to augment the protection for the sensitive equipment around the off-gas stack's landings.

Additional Details:

1998 - LEC installs direct strike prevention system that utilizes Charge Transfer technology, on the off-gas stack and surrounding area consisting of:

- A Dissipation Array® System (DAS®)
- Multiple Spline Ball Ionizers (SBI®) and Spline Ball Terminals (SBT®)

2002- TVA conducts an internal test and review to gauge the success of the DAS.

Methodology:

Vaisala's lightning strike location data base (formerly the U.S. National Lightning Detection Network (NLDN) database.)

Time Line: 6 year Study 1996 – 2001-3 years before installation of DAS | 3 years after installation of DAS.

Testing Area: (Radii), off-gas stack at origin: 10 miles | 6 miles | 3 miles | 500 meters

Area of Protection: off-gas stack (600 ft. tall/6 ft. diameter on top) area around base of off-gas stack.

Findings Included:

- **1996 – 1998:** Cloud to Ground Lightning Strike Count (Top)
  500 meters: 40 | 3 miles: 2,630 | 6 miles: 11,277 | 10 miles: 33,685
- **1999 - 2001:** Cloud to Ground Lightning Strike Count (Bottom)
  500 meters: 13 | 3 miles: 4,327 | 6 miles: 18,688 | 10 miles: 55,199

80% reduced within 500m when normalized to strikes in 10 mile circle

Result:
There have been no reported lightning related issues at the Browns Ferry Nuclear Power Plant since implementation of the recommendations; 17 years. And the results of TVA's own testing proved substantial improvements.

Highlights:

- Since installation of the DAS and peripheral equipment, the total number of strikes surrounding the stack in the 3 mile, 6 mile and 10 mile areas increased a uniform 65% +/- 1%.
- Based on the 65% increase, the number of strikes within the 500 meter radius would be expected to increase from 40 to 66, during 1999 to 2001.
- The actual number of strikes within the 500 meter radius, 1999 – 2001, decreased to a total of 13, with no strikes to the off-gas stack.

The LPS produced a savings of time, resources and money as well as increased reliability. "The result has been no known lightning strikes to the off-gas stack. Instead of using our resources to repair broken equipment and pay emergency overtime, we're preventing the problem in the first place." said Rick Brehm, TVA manager with oversight of electromagnetic interference and instrumentation and control systems. TVA continues to purchase products and services from Lightning Eliminators to this day.

Kellogg Brown & Root – International Paper

Facility Type: Paper Mill – Power Complex

Problem:
In early 2011 LEC was contacted by Kellogg Brown & Root in Birmingham, AL to discuss their client's (International Paper) issues they were having with a purchased power substation. The IP plant has its own power generation facilities, but one-third of the facilities power is purchased from a local utility that provides a substation. This purchased power is required to keep the plant operational, and this source had become unreliable during lightning events.

Steps Taken:
LEC was hired to perform a Site Evaluation of the facility: The objective of the on-site consultation was to visually survey the facility, provide photo documentation and to generate a comprehensive report. The report provided an overview of lightning, details of past lightning events, inspection of currently installed lightning protection elements (if any) and comment on their effectiveness, and to make recommendations as to the application of direct lightning protection equipment, protection from the secondary effects of lightning, earth grounding improvements and augmentation.

The areas of concern were the purchased power substation, the purchased power switchgear building, and the control interface between the purchased power switchgear building and the plant powerhouse control room (switchgear control and monitoring). The site evaluation found the following:

- The purchased power substation had Early Streamer Emitter LPS devices installed on masts in the substation that did not prevent lightning disruptions.
- The purchased power switchgear building had no direct lightning strike protection.
- The control interface between the purchased power switchgear building and the plant powerhouse control room is copper cabling and susceptible to surges and transients due to its length (over 2,200 feet).

The evaluation determined further testing was necessary. LEC recommended that a Smart Ground Test be performed in the areas of concern to verify grounding prior to any other remediation efforts. The Smart Ground Test was performed in January 2012 at the site. The on-site testing consisted of Point-to-Point measurements, Ground System Impedance Measurements and Soil Resistivity Measurements. The testing concluded the following:

- Point to Point testing confirmed that the measurements of the purchased power substation to the purchased power switchgear building (approximately 500 feet apart) contrasted with the measurements of the purchased power switchgear building to the plant powerhouse control room (approximately 2,200 feet apart), and that the purchased power substation needs to be directly bonded to the purchased power switchgear building.
- The soil resistivity was found to be acceptable.
- The Ground System Impedance test indicated that the agreement between measured and computed quantities was good with only a 20% error at 97% confidence.

Solution:
Recommendations included:

- Improving the performance of the earth grounding by bonding and adding ground rods between the purchased power substation and the purchased power switchgear building.
- Installing a charge transfer lightning protection system to the purchased power substation and the purchased power switchgear building.
- Installing surge protection to the control and monitoring circuits that are hardwired between the purchased power switchgear building and the plant powerhouse control room.

IP made the recommended grounding enhancements, and purchased DAS arrays for the purchased power substation and the purchased power switchgear building, and surge protection devices for the control and monitoring circuits between the purchased power switchgear building and the plant powerhouse control room. LEC provided a turnkey installation for all materials and equipment.

Results:
There have been no reports of lightning related losses in these areas since the recommendations were implemented.

Additional Details:
In late 2013, LEC was asked to provide Smart Ground Testing and a DAS lightning protection recommendation for the IP Power Complex and Recovery Boiler Areas of the same plant. In July 2014 LEC was awarded this additional contract.

A condensed Smart Ground Test was performed in December 2014 at the Power Complex and Recovery Boiler Areas. The on-site testing consisted of Point-to-Point measurements. The findings concluded the following:

- Point to Point testing confirmed that the tested grounds are bonded to the grounding system, and that the purchased power substation and purchased power switchgear building previously tested in 2011 are bonded together with the Power Complex and Recovery Boiler Areas.
- The installation of the LPS system for power boilers, bark boiler and two recovery boilers along with boiler, turbine, sync and distribution buildings are being implemented in four deployments through 2015. LEC is providing a turnkey installation of all materials and equipment.
- In August 2014, LEC was asked to provide Smart Ground Testing and a DAS lightning protection recommendation for the water treatment area of the same plant. In September of 2014 LEC was awarded the contract for Smart Ground Testing of this area.
- A condensed SGT test of the water treatment area of this facility was completed in December 2014. The findings included:
    - Bonding and grounding of the various test points to the utility neutral and ground conductors.
    - Bonding of instrument cabinets and equipment along with cameras to the same utility neutral and ground conductors.

LEC anticipates the contract to commence for the DAS LPS systems to be installed in the water treatment area. In addition, LEC has been contacted by IP corporate offices for opportunities to provide our expertise and services at other IP facilities, including a potential ground study at an IP facility in Russia.

A Power Utility in the Great Lakes Region

Facility Type: Power Plant

Problem:
The facility experienced a lightning strike to a transmission tower on plant property resulting in damage to two units and causing a shutdown in addition to necessitated repairs.

Steps Taken:
LEC was hired to perform a Smart Ground Audit (SGA) of the facility: The objective of the test and analysis was to evaluate the plant grounding system with respect to safety and lightning performance and if necessary, to recommend grounding design enhancements. The on-site testing consisted of:

- Point-to-Point measurements, Ground System Impedance Measurements and Soil Resistivity Measurements.
- Post-test analyses included a Ground System Safety Evaluation and a Lightning Shielding Performance Evaluation.

Smart Ground Findings:

- Point to Point testing confirmed that the vast majority of the tested equipment and structures were properly bonded to the plant grounding system. However, the majority of transmission line poles tested was found not to be bonded to the plant grounding system.
- The Lightning Shielding Performance indicated that the overall risk of shielding failure (i.e. direct strikes to phase conductors and sensitive electrical equipment) was relatively low. However there was a high risk of direct strikes on transmission line poles and shields (about 3 strikes per year). Some poles did not carry shield wires resulting in a very high ground resistance. A direct lightning strike at these locations would result in very high GPR and likely insulation flashover.
- The soil resistivity was found to be relatively high, contributing to the lightning related issues.
- The Ground System Impedance test indicated that the agreement between measured and computed quantities was very good with only a 4% error at 99% confidence.
- The Ground System Safety Evaluation determined that the grounding system met the safety requirements of IEEE Standard 80.

Solution:
Recommendations were made for improving the performance of the station grounding system, with respect to lightning strikes and their effects, to reduce the impact of the induced voltages and ground potential differences on the communication and control circuits and to minimize the possibility of back-flashover in the circuits.

- A design of the proposed changes and enhanced system was provided.
- A general bill of material for the proposed enhancements was provided.

Quantitative analyses of the recommendations were also provided, assuming their implementation.

- The lightning shielding analysis of the proposed enhancements indicated that the system would be effective in substantially reducing the probability of insulation flashovers due to lightning strikes.
- The safety analysis indicated that the enhanced grounding system would meet the IEEE Standard 80 safety requirements by a much wider margin than the existing system.

Furthermore, it showed that the proposed enhancements would substantially reduce the ground potential rise during faults. This is important since high GPR usually results in communication and control circuit damage.

Result:
The utility and the transmission towers' owner implemented the recommended changes. After completion, LEC was retained to verify changes to the system and compare to modeled system. No discrepancies were noted. There have been no reported lightning related issues at the facility since implementation of the recommendations. Lightning issues withstanding, the utility has been a repeat customer for Smart Ground testing services at other plants.

Exelon Generation (formerly Constellation Energy) - Hillabee Generating Station

Facility Type: Combined Cycle Natural Gas Power Plant (670 megawatt)

Problem:
In July 2011 the Hillabee Generating Station contacted Lightning Eliminators for a site consultation due to lightning caused reliability issues with plant operations. Subsequently a site evaluation of the facility was performed; the objective of the on-site consultation was to visually survey the facility, provide photo documentation and to generate a comprehensive report. The report provided an overview of lightning, details of past lightning events, inspection of currently installed lightning protection elements (if any) and commentary on the effectiveness of the findings. In addition the report was to include recommendations for protection from direct lightning strikes; the secondary effects of lightning; and earth grounding improvements and augmentation.

The site evaluation found that although the site had a UL-96A Master Label lightning protection system that was maintained and certified it did not alleviate the lightning related reliability issues. In addition, the earth grounding of the facility was questionable.

Steps Taken:
The site evaluation recommended that Smart Ground Test be performed of the entire facility prior to any other remediation efforts. In addition, a charge transfer type lightning protection system and specific surge protection devices be installed for critical structures and circuits.

- A Smart Ground Test was performed mid 2012 at the site.
  - On-site testing consisted of Point-to-Point measurements, Ground System Impedance Measurements and Soil Resistivity Measurements.

- Smart Ground findings:
  - Point to Point testing confirmed that the majority of tested connections were in good condition. However, the facility had discrepancies in its grounding and/or bonding to equipment at, and around, the water cooling tower (possibly due to excavation). This was the same area and equipment affected by lightning events.
  - The soil resistivity was found to be acceptable.
  - The Ground System Impedance test indicated that the agreement between measured and computed quantities was good with only a 32% error at 99% confidence.

Solution:
In addition to the lightning protection and surge solutions originally suggested, recommendations were made for improving the performance of the earth grounding system, verifying that all instrumentation were grounded properly, and that surge protection needed to be added to past affected circuits, specifically in the water treatment area and the DCS control cabinets monitoring these circuits. Per recommendations, Hillabee Generating Station purchased a charge transfer DAS array for lightning protection of the water cooling tower and surge protection devices for the water treatment area instruments and actuators.

In addition in mid-2014, the Hillabee Generating Station requested additional support. A condensed Smart Ground test was conducted to verify if previous recommendations were implemented completely, including a visual inspection of surge protection recommendations. The findings concluded:

- Not all of the previous recommendations had been completed therefore additional grounding and surge protection was implemented.

Hillabee Generating Station completed the recommended enhancements. Additional surge protection products were installed as needed.

Result:
There have been no reports of lightning related losses since the final implementation. The work with the Hillabee Generating Station has led to recommendations within Exelon Generation's Corporate Engineering Group, and work for LEC at additional Exelon generating facilities.

Bruce Power- Nuclear Power Plant

Facility Type: Nuclear Power Plant – Ontario, Canada

Problem:
Nearby lightning strikes were causing damage to low voltage instrumentation and control (I&C) circuits, nuisance tripping and security issues.

Steps Taken:
Lightning Eliminators performed a Smart Ground Audit of the facility along with a Surge Protection Survey.

The objective of this project fell into two categories: (i) to evaluate the grounding system integrity and lightning performance and, if necessary, to recommend grounding design enhancements; (ii) to perform a survey of critical I&C circuits and security circuits related to lightning surge damage and nuisance tripping, and to provide recommendations to mitigate future issues.

- On-site review of the plant's event history reports, the affected circuits and equipment, and their single line diagrams and specification sheets, was conducted. Interviews with key technical staff were also conducted.
- On-site testing consisted of Point-to-Point measurements, Ground System Impedance Measurements and Soil Resistivity Measurements.
- Post-test analyses included a Lightning Shielding Performance Evaluation and a Lightning Transient Analysis, concentrated on a specified area of the plant.

Findings Included:

- Point to Point testing confirmed that the tested equipment and structures were properly bonded to the plant grounding system.
- The soil resistivity was found to be consistent with the type of soil and geographic location.
- The Ground System Impedance test indicated that the agreement between measured and computed quantities was good with a 12% error at 99% confidence.
- The Lightning Shielding Performance indicated that the overall risk of lightning strikes to the facility was high at 2 -3 strikes per year. With a focus on just the Powerhouse Building and Vacuum Building, the expected strike rate was once per 2 years. It should be noted that the lightning protection system for the cited buildings is not the common lightning rod type system, but rather a Dissipation Array System (DAS) that prevents strikes to the protected structures. The DAS was installed in 1995; there have been no direct strikes to the Powerhouse or Vacuum Building since installation.
- A Lightning Transient Analysis was performed to determine the level of overvoltages (transient surges) that I&C and security systems would be exposed to, based on the point of entry and magnitude of a strike. Three specific lightning points of entry were considered: one each from the transmission system and switchyard and one within the lakeside/station fenced area. The initial magnitude was 10kA. The results indicated that the lightning overvoltages for surges from the transmission system and switchyard were moderate while the lightning overvoltages from lightning strikes within the lakeside/station fenced area were substantial. These transients were of a level that would likely cause problems to instrumentation.
- The Surge Protection Survey found a history of damages related to lightning – longer than what was first thought. Like a puzzle, the recorded history was pieced together to determine the vulnerable equipment and the scenarios leading to the damage.
    - Existing SPDs were found to be misapplied or ineffective due to improper bonding/grounding.
    - Since there were no strikes to the Powerhouse and Vacuum buildings, damage was entering the facility from outside the protected area.
    - The damage was not immediate, but cumulative, in a slow degradation of the circuits and equipment over time until a tipping point was reached and problems/issues became more prevalent and frequent.

Solution:

Recommendations for specific surge protection devices (SPD's) were made since improving the grounding system would result in only marginal improvements in reducing the impact of the induced voltages and ground potential differences on the communication and control circuits due to the lightning transients. Advanced bonding techniques were also recommended to reduce the amount of inductance and impedance to new SPD's and existing SPDs.

Direct strike protection for the Powerhouse and Vacuum building has been in place since 1995. With the completion of a grounding audit and surge protection survey, the criterion for a comprehensive lightning protection scheme was concluded.

Result:

There have been no strikes to the protected structures since 1995. There have been no reported lightning surge related issues at the Bruce B Nuclear Power Plant since implementation of the recommendations and implementations.

City of Tallahassee – Hopkins Generating Station

Facility Type: Natural Gas Powered Plant (504 megawatt)

Problem:
City of Tallahassee needed to meet test specifications and scope that was required by their insurance carrier for grounding.

Steps Taken:
In April 2012 Lightning Eliminators was awarded a contract by the City of Tallahassee (CoT) for the ground test work at Hopkins Generating Station. The work was based on a test specification and scope that was required for CoT insurance purposes.

A Smart Ground Testing was done in August of 2012.

- On-site testing consisted of Point-to-Point measurements, Ground System Impedance Measurements and Soil Resistivity Measurements.
- A safety assessment, modeling a worst case fault, was also conducted per IEEE Std. 80.

Findings Included:

- Point to Point testing found that that the majority of connections were in good condition, however, some areas needed grounding improvement including fences, water tower, and miscellaneous equipment near the power units.
- The Ground System Impedance test indicated that the agreement between measured and computed quantities was good with only a 24% error at 95% confidence.
- The soil resistivity was found to be acceptable.
- The safety assessment indicated that the maximum touch and step voltages exceeded the allowable touch and step voltages per IEEE Std. 80 for the worst fault conditions.

Solutions:
Specific recommendations for improvements were made and included a bill of material. The recommendations included a re-run of the safety assessment, assuming all recommendations were implemented. The re-un provided quantifiable results indicating that the improved system would meet the requirements of IEEE Std. 80 by a 35% margin of safety.

Result:
The scope of work was met to CoTs expectations, as well as the insurance companies, with a recommendation provided and reference available. In addition, CoT has implemented Lightning Eliminators' lightning protection systems and solutions at other CoT facilities including a hydro-electric plant and all new substations. Lightning Eliminators has also provided consultations at a combined cycle generating facility owned by CoT and continues to work with CoT on their lightning protection needs.

References:

1. IEEE Std. 81 – 2012 Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System.

Products of Interest:

Dissipation Array® System (DAS®)
Chem-Rod® - Chemical Grounding Electrode
Spline Ball Ionizer® (SBI®)
Spline Ball Terminal® (SBT®)
Facility Guard®
TLX 100®/TLX 50®
Consulting Services
Smart Ground Testing

Lightning Eliminators has been providing integrated lightning protection products, solutions and services utilizing charge transfer technology, grounding solutions and surge protection since 1971 throughout the electric power sector globally.

If you are interested in additional information regarding protection for electric power facility protection please contact us at **info@lecglobal.com** or call 303-447-2828. To read more about Lightning Eliminators & Consultants, Inc. and lightning protection visit **www.LightningProtection.com**

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