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Closing the Gap – Using Open Source Software to Make the Connection Between Lightning and Power System Data

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Abstract— Tremendous strides have been made since the early days of the National Lightning Detection Network (NLDN), both in sensor technology, and in the analytic processes used to produce the invaluable information provided by today's North American Lightning Detection Network (NALDN). Considering the extremely accurate time stamp, along with stroke location accuracy of 150 m to 200 m and stroke detection efficiency of 76%, it could easily be concluded that this is "good enough". Unfortunately in the electric power business, that level of information truly isn't good enough. For lightning data to be "good enough" to facilitate the optimal operation and maintenance of an electric power system, the reports should look somewhat like these:

18 March 2014 UTC:03:46:27.187635
Lat: 35.04569298015 **Lon:** 85.26725297677 **kA:** 38.4
System Impact: This stroke attached to a 62 ft. oak tree 2.4 miles from the nearest power system asset. Interaction with the power system did not exceed effective operating limits and initiated no associated fault.

18 Mar 2014 UTC:03:46:27213267
Lat:35.04568076326 **Lon:**85.26725483724 **kA:**7.9
System Impact: This stroke attached to the A-phase conductor mid-span between structures #264 and #265. A cracked insulator at structure #267 allowed a flashover to the insulator attachment causing a momentary A-phase to ground fault.

Foreseeable evolution in lightning sensor technology will not yield those needed detailed reports. However, the appropriate combination of available power system data together with lightning data produced by the latest sensors and analytics could, in many cases. This paper proposes that Open Source Software (OSS) is a community building approach that can leverage existing infrastructure and technologies to rapidly develop and evolve new software tools for more effective use of lightning data to meet power system needs. It will explore a brief history of OSS, touch on existing OSS power system tools, and suggest new opportunities for data integration.

Keywords—lightning; open source software; OSS;

I. OSS – A BRIEF HISTORY

In the early days of computing, developers viewed writing software as a form of personal expression, and programming was a functional art form. Early developers were happy to share with others in the community, and this open sharing facilitated rapid advances in software tools. Computer companies generated most of their income from the hardware sales, not the applications that ran on their machines. However, by the mid to late 1970s a shift in focus occurred, and computer manufactures began to introduce proprietary software to increase differentiation, protect their personal interests, and develop a new income stream.

As computing resources became available for power system engineers and operators, virtually all of their tools were developed collaboratively. User groups were formed to coordinate activities, and a spirit of community encouraged engagement. A few of these early endeavors resulted in applications and systems that have survived through the years, but over time a large majority have migrated to proprietary systems. The concept of de-regulation increased the construction of walls between companies, and the spirit of community was pushed back. As restricted proprietary software began to dominate the application landscape, some development communities insisted that software development should not be constrained, and promoted the idea that software creation was an expression of freedom. However, the term "free software" that emerged could be confusing since to some it meant "free – as in freedom of speech and expression"[i] while to others it meant "free – as in free beer". In 1998, The Open Source Initiative (OSI) coined the term 'open source' as part of a marketing campaign to remove ambiguity and convey a more positive message.

In spite of the fact that a majority of end user applications migrated to proprietary software, a huge portion of the back-office computing infrastructure has remained in open source. Some well-known examples are network and communications software, web server software, and more recently 'big data' repositories.

II. Existing OSS Power System Tools

Driven by many converging forces, such as the need for quality, agility, efficiency, and security, a new emphasis has been placed on developing open source tools. A 2003 study showed that open source software was already being widely used in the Department of Defense, and since then a number of more specific policy statements have been issued requiring that OSS be considered equal to or even preferentially over equivalent proprietary solutions.

The overview section of the website *Open Source Software for Electricity Market Research, Teaching, and Training* (iastade.edu)has this to say: "lack of open-source access prevents users from gaining a complete and accurate understanding of what has been implemented, restricts the ability of users to experiment with new software features, and hinders users from tailoring software to specific needs. In addition, these packages can be cumbersome to use for research, teaching, and training purposes requiring intensive experimentation and sensitivity analyses". The US Department of Energy feels so strongly about the necessity of open source software (OSS) that it has established the following policy:

"POLICY:

The U.S. Department of Energy (DOE) Office of Science/Office of Advanced Scientific Computing Research (OASCR) and the Office of Defense Programs/Office of Advanced Simulation and Computing (historically known as ASCI) are establishing the following policy:

1) All publicly released DOE Laboratory software, which is developed using funding from OASCR and/or ASCI, shall be either:
   a. designated and distributed to the public as Open Source Software (OSS); or
   b. designated as an unrestricted releasable software to the public by delivering the software to DOE's Energy Science and Technology Software Center (ESTSC) for sole distribution using DOE standard software licenses.
2) HQ Program approval will be required for software to be restrictively licensed when:
   a. Laboratory successfully demonstrates that extraordinary circumstances exist such that commercialization of software through restrictive licensing is necessary; or
   b. the software is subject to export control, classification or contractual requirements.
3) The DOE Laboratories will ensure that subcontracts to contractors working directly for Laboratory code development will include provisions consistent with this policy."

The background for this policy specifically sites the following benefits:

- OSS provides HPC sites the opportunity to identify and fix bugs quickly;
- The OSS model yields important contributions to the global state of the art, thus providing significant leverage of Government investments;
- The OSS model provides a hedge against "change in support" status for software required to execute the missions of these Programs. This yields protection for the investments made in the software
- Access to source code of OSS can enhance cyber security by facilitating rapid identification and repair of security vulnerabilities.

The White House developers (whitehouse.gov)make this statement regarding Open Source on their web site:

"The communities of programmers that grow up around successful open source projects often produce tools that are more secure, flexible, and cost-effective than those produced by a team working in isolation."

Within the electric utility community we find the IEEE Task Force on OSS for Power Systems (OSSTF)with this chronological list of free and open source software for power system analysis:

- UWPFLOW (1996) - a research tool that has been designed to calculate local bifurcations related to system limits or singularities in the system Jacobian.
- TEFTS (1996) - a simple transient stability program
- MATPOWER (1997) - a package of Matlab M-files
- PSAT (2002) - The Power System Analysis Toolbox
- InterPSS (2006) - The Internet Technology-based Open-source Power System Simulation
- AMES (2007) - The AMES Market Package, developed entirely in Java
- DCOPFJ (2007) - a free open-source stand-alone power flow solver
- OpenDSS (2009) - EPRI Distribution System Simulator
- MatDyn - a free Matlab based open source program to perform dynamic analysis of electric power systems.

III. New Opportunities for Data Integration

The present computing landscape includes a significant and growing open source community as evidenced by the results of Black Duck Software's annual Future of Open Source Software survey (BlackDuck). The number one reason for using OSS according to their 2013 survey was Quality!

This growing community and freely available tools that also boast security, flexibility, and extensibility, are providing opportunities that did not previously exist. An environment that promotes unrestricted collaboration sets the stage for development and deployment of new solutions.

The online publication **Tech Crunch** included an article by Peter Levine (Levine) on *The Economics of Open Source*, in their February 13, 2014 edition. The following quote was taken from that article:

"Many of today's most successful new companies rely on an ecosystem of standardized open source components that are generally re-used and updated by the industry at-large. Companies who use these open source building blocks are more than happy to contribute to their ongoing success. These open source building blocks are the foundation of all modern cloud and SaaS offerings, and they are being monetized beautifully in many cases".

A February 4, 2014 article in Forbes (Finger) states that *"…businesses and consumers world-wide will ultimately benefit from the proliferation of "open source" in the form of lower prices for a plethora of products across many spectrums".* In a subsequent comment to that article, Jilles Gurp says *"Very few companies inside or outside the software industry can afford to do business without depending (heavily) on open source".*

When considering the task of bringing lightning and power system data together to create more robust tools, the rapid development and open collaboration that can be accomplished through an OSS approach allows data considerations and strategies that would not be possible or even practical in a proprietary environment.

IV. CLOSING THE GAP

The abstract for this paper acknowledges great strides and continuous improvement that have taken place over the past two decades in lightning detection, analysis and reporting systems. From a global perspective, it's amazing to consider how far the lightning industry has come in such a short time. Business and physical constraints exist that dictate the direction and scale of future refinements. Every business has to consider their total customer base, and the electric power sector is a relatively small portion of the total population of lightning data consumers. From a technology perspective, managing a lightning detection system to provide maximum national, continental, or global value may limit that same system's ability to provide stroke location accuracy with sub-meter resolution which would benefit electric power systems.

The other part of the equation, for the purposes of this paper, is power system data. The electric power grid is an extremely complicated and dynamic 'machine' with many vulnerabilities that can be impacted by lightning and other weather phenomena. On a path somewhat parallel to the dramatic improvements of lightning and weather data systems, power system data monitoring, retrieval, and analysis has also made great strides. Continuously improving technologies in sensors, communications, and analytics provide much better data granularity and provide more actionable information in near real time, than has been previously possible.

The gap being discussed here is the distance between these two types of data, and the systems that produce and manage each type. With very few exceptions, the only interaction between these two systems occurs at the edge. Each system produces valuable data or information within the context of its own business drivers, and the results of each system can be combined through the expertise of an engineer that is familiar with both systems, or through automated correlations using spatial and temporal proximity. In today's implementations of these systems, they continue to operate independently of each other and neither can take advantage of data available in the other to improve the results that they produce.

An open source software approach could facilitate extensible solutions where many knowledgeable and interested participants could come together to explore new ways to get better answers. The use of open source has many benefits as described earlier and in related reference material, and some very important advantages in this context would come from facilitating innovation that does not have to be cost justified by the respective vendors as a new business venture or product. Building a collaborative open source community dedicated to the development of new tools leveraging both sources of 'raw data' to produce better and more expedient information for the operation of electric power systems could facilitate a step change in innovation.

There are as many opportunities for innovation as there are smart people who would be willing to participate in this proposed new community, but one specific example could be the use power system data to reduce the workload of the lightning processing system. In a manner similar to the manual investigation of missed events that occasionally occur now, power system data that provides a timestamp and general location of a known disturbance could be used to subset raw lightning data such that only relevant data would need to be processed to provide an answer for that specific power system event. In many cases a simple answer, provided within a few seconds, that stated with 99% confidence no lightning was involved in the event, could be very valuable information. Conversely, in the same scenario if an answer could be provided within a few seconds to indicate there was a 75% confidence that lightning was involved in the event, that would also be very valuable.

The example lightning reports shown in the abstract are not intended to be comprehensive or even optimal, but rather to provide food for thought to be used in considering new possibilities. Additional data sources and system knowledge will be needed to produce such reports, but they can serve as discussion points for considering what it would take to get these and even more robust answers.

The open source software development approach can facilitate rapid development and demonstration of new tools, and the community that supports the development can provide insight and direction to more rapidly close the gap between lightning and electric power system data. Improvement in the effectiveness of the tools to produce timely actionable information will increase the value of the underlying data systems, and improve the reliability and resiliency of the electric power grid.

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