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The Big Picture

A Comprehensive Look at Automated Systems for Disturbance Analytics using Open Source Software

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***Abstract*— As the grid continues to experience an ever increasing rate of change in response to pressures from the many players involved in modernization, it is critical to have a comprehensive strategy for the rapid development and deployment of flexible disturbance analytics systems. This paper will briefly review the value of open source software (OSS) for the electric utility industry, then describe existing OSS components that can be used in developing a customized strategy to accomplish specific disturbance analytics goals of each power company. It will also describe the gaps that remain where new OSS components could be developed to provide complete end-to-end solutions.**

From the time a disturbance occurs on the power system until information about the disturbance is available for the appropriate resources to initiate action, the data associated with that disturbance must move through many different hardware devices, data management systems, and analytics processes. Traditionally, many of the steps along the way have required human interaction. This paper will describe new data systems that can be created using OSS to eliminate or greatly reduce the need for human intervention in the vast majority of disturbances, allowing engineers and analysts to focus on the most important and unusual disturbances.

Keywords—open source software; oss; disturbance analytics; fault location, grid modernization

I. VALUE OF OSS FOR ELECTRIC UTILITIES

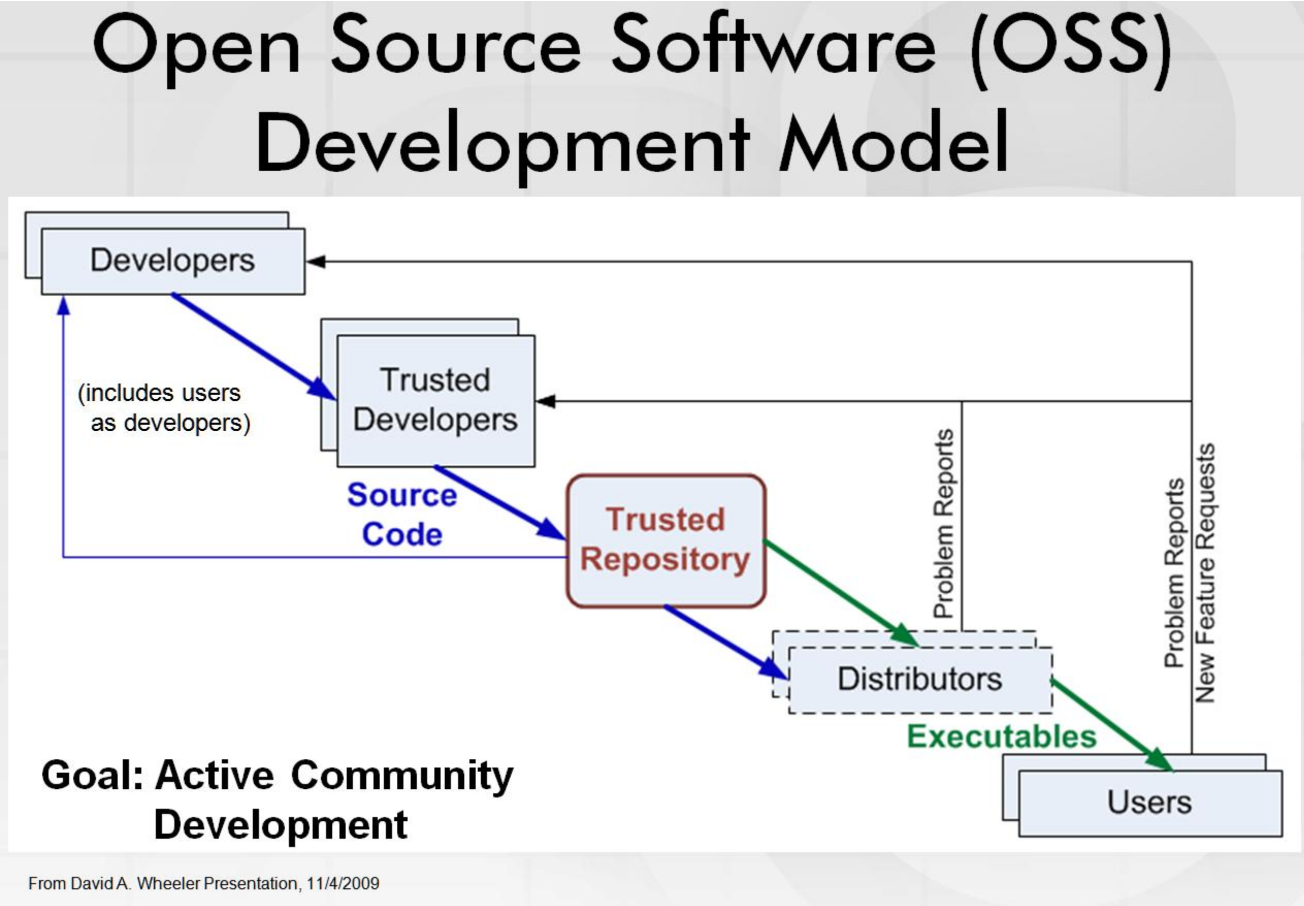
Market and business pressures force utilities to continually strive to do more with less, which translates into decreased work force and other resources. Proprietary data systems and solutions may be backed by large companies, and have long histories to draw on but they also carry large annual fees and require significant in-house staff for support and configuration. A rapidly growing body of current literature describes many advantages of OSS, and those advantages apply to electric power system applications just as they do in other industry segments. However, the size of the total electric utility community is relatively small, which makes the collaborative benefits of OSS even more significant here than in many other industries.

The 2013 Future of Open Source Survey[i] conducted by Black Duck Software[ii] shows that the 822 respondents ranked "Better Quality Software", "Freedom From Vendor Lock In", and "Flexibility Of/Access to Large Software Libraries" as the top three benefits of OSS. Additionally, from an internal decision making perspective the top four factors in favor of OSS were "Competitive Features", "Security", "Cost of Ownership", and "Internal Technical Skills". Security was seen as the second most important feature for deciding to use OSS, and is no longer a concern or seen as less robust than proprietary solutions. Sixty-two percent of the respondents believe that over half of all software purchased in five years will be OSS. All of these positive aspects of OSS apply to data systems and applications for electric utilities, and can be leveraged to facilitate more rapid grid modernization.

Some of the benefits of OSS gleaned from a variety of sources and experience are presented below in an unordered list.

- Better code and application quality
- Better environment for security
- Freedom from vendor lock in
- Flexibility of, and access to, large software libraries
- Lower acquisition and maintenance costs
- Lower total cost of ownership
- Encourages internal skill enhancement, but doesn't require it
- Facilitates innovation
- Perfect platform for collaboration
- Decreased time to deployment

The community approach of OSS provides a unique environment where all code is exposed for review, comment, correction, or enhancement. This sets the stage for a wealth of value to be realized that is not available in a proprietary environment. The OSS community and structure allows examination and input from anywhere, but the published code libraries are carefully tested and maintained by a responsible custodian. One benefit of this community is that the innovation, enhancements, and techniques used are not limited to a single company's knowledge and resources. The diagram below of the OSS development model is adapted from Dr. David A. Wheeler's work[iii],[iv], and shows the relationships of the community participants.



II. Existing OSS Components

The community nature of OSS tools and inherent flexibility and extensibility provide an opportunity for custom solutions to be developed to meet most any need. However, custom solutions may have a very small community and eventually become stagnant. It is highly recommended that industry standards be used wherever possible to ensure the broadest possible acceptance.

openFLE[v] - Initial work toward developing automated systems for disturbance analytics using OSS was pioneered by the Electric Power Research Institute (EPRI) in a project with the Tennessee Valley Authority (TVA) in 2012. That project was focused on automated distance to fault calculations and an analytic engine was developed to accomplish that task. The open source fault location engine (openFLE) accepts data in either of two IEEE standard formats, C37.111 COMTRADE or 1159.3 PQDIF. The openFLE is an OSS analytic component that uses waveform data to determine the presence of a fault, the fault type, and the distance to the fault.

PQDIF[vi] – Disturbance records in the standard PQDIF format can be read into openFLE using the GSF.PQDIF library contained in the OSS Grid Solutions Framework Codeplex project[vii]. GSF.PQDIF is an OSS data input component.

COMTRADE[viii] – Disturbance records in the standard COMTRADE format can be read into openFLE using the GSF.PQDIF library contained in the OSS Grid Solutions Framework Codeplex project. GSF.COMTRADE is an OSS data input component.

Schweitzer Engineering Labs (SEL) Event Records – SEL event records are used in many existing manual processes within utilities. While this is not an industry standard, it is a commonly used format and tools to parse these files could have a wide audience. GSF.SELEventParser is a proof of concept OSS data input component. Its applicability is limited to a specific subset of SEL event records used as a demonstration. While this component could be very useful in some utilities, more work is needed to make it a fully functional and generalized event record parser.

openXDA[ix] – a new framework that supports extensible disturbance analytics has been built around the openFLE. This new framework provides more powerful configuration tools, implements additional fault distance calculations, calculates unique fault distance curves, and is extensible to include any other analytics in the time or frequency domains appropriate for disturbance data. An example database is included with the framework to facilitate integration with downstream applications.

III. Gaps Remaining for End-to-End Solutions

Data Retrieval - The fundamental building block for any disturbance analysis is the event data recorded in the remote IEDs. The methods for retrieving that data range from someone physically going to the device and copying files onto some media to bring back to the office, to dial up modems, cellular and satellite modems, and physically connected high-speed networks. Regardless of the communications method that is used to retrieve the data, some unique software typically provided by the hardware manufacturer, is needed to obtain the files from the device. Getting the data from the remote device to the corporate data systems is still one of the most difficult aspects of the fault location process. Having OSS tools to accomplish this data retrieval process would greatly reduce the complexity of this process, but having some kind of near real time connectivity is required for timely automated disturbance analysis.

Data Quality - While a method for retrieving data from the remote devices is critical to developing an end-to-end solution, another important consideration that directly impacts the effectiveness of the system is the quality of disturbance data. There are many factors that can negatively effect the quality and availability of data including hardware and communications failure, device configuration changes, and system maintenance and configuration changes to name a few. An OSS solution to address these issues will provide the flexibility and extensibility needed to address similar but different concerns across the utilities. Some of these issues are being addressed in current OSS projects, and broader utility involvement is needed to fill this gap.

Analytics – The openXDA and related work to date, has been focused on distance to fault calculations to support automated fault location, but the tools have been developed as a platform that can support unlimited extension. The industry has invested tremendous volumes of time and money to develop sophisticated algorithms for other types of analytics such as transient event analysis, and new opportunities are becoming apparent through the ability to automatically process every record as it is retrieved. Incorporating additional analytic algorithms into this OSS environment will make it much more powerful and valuable.

Applications – The OSS tools and platform developed for automated disturbance analytics so far, have been used to deploy systems for rapid notification to operators, to create email notification systems, and to build disturbance databases, but many opportunities for integration and new applications are waiting to be explored.

IV. Existing Data Flow and Human Interaction

While some utilities have robust communications infrastructures with all remote IEDs network connected, most still have a mix of manual or modem connected devices along with some that are networked. Data retrieval from remote IEDs, even those that are network connected, typically requires human interaction to initiate retrieval, or to verify that the retrieval processes are operating properly. Once the data has been retrieved and placed in the utility's repository, additional manual steps and processes are required to find the appropriate files and perform the analysis. The appropriate staff must then perform the analysis and incorporate the results into reports or use them to perform some kind of notification. The number of manual steps involved and the time required to work through the process typically results in a workflow that only analyzes the files associated with significant system events. The vast majority of the event related files are left in the repository and rarely if ever used. The files that contain data related to less significant events may actually contain very valuable data that can be aggregated or analyzed in an automated system.

V. Proposed Automated OSS Data System

Using the OSS tools described above that have been successfully deployed to accomplish automated distance to fault calculations as files are retrieved, and adding the suggested enhancements to fill existing gaps, will result in a dramatically different disturbance analytic landscape. Device interaction through OSS applications to verify configurations and retrieve data would greatly reduce the number of complex manual tasks and provide a single user interface for configuration and management, and allow automated data retrieval. Processing every IED record through an automated data system would facilitate the creation of data quality metrics that are not available in existing systems. Analyzing every record through automated analysis modules would not only facilitate rapid distance to fault calculations but would also pave the way for new histories and trends of device status and system parameters in addition to facilitating new analytics such as steady state alarming, transient event classification, and many others. To maximize the benefits of this approach, the new OSS applications, and integration with existing systems, should proactively disseminate pertinent information to targeted audiences according to the type of information available.

VI. Getting Started

To successfully develop and deploy an automated, centralized, disturbance analytics system, there is a short list of high level requirements that must be addressed.

- **Accurate device settings** – analytics can only be as good as the data used in the calculations, so the first step is to be sure that reporting devices are configured properly. Ideally, an automated process should be implemented that monitors and reports device configuration changes.
- **Access to accurate and up-to-date system parameters** – the improvement in accuracy of central fault distance calculations is directly related to the availability of accurate system parameters for use in the calculations. Ideally, system parameters will be obtained from a well maintained database that is used to support other business processes.
- **Efficient/rapid data retrieval** – the biggest time sink in the operation of a fully automated disturbance

analytic system is retrieving data from remote devices. Utilities where remote devices are connected through high-speed networks can see analytic results in near-real-time. Systems that require modems and phone lines, or manual processes for data retrieval will experience longer delays in obtaining results, but all other benefits can still be realized.

- **Effective presentation of resulting information** – there are many options for presentation of the results from an automated analytic system, and the choice should be determined by the requirements of business processes being supported by the information. Once the analysis has been completed, there is no practical limit to the possible ways that the information can be disseminated. Some of the techniques that have been used or are under development include email notifications, web page population, console alarm/notifications in environments such as SCADA, and population of an event centric relational database.

Once these requirements have been addressed, the stage is set to begin building the system. The foundation blocks for this proposed system are available, and the OSS environment provides the opportunity to rapidly extend and deploy the functions that are most valuable to each utility.

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[i] 2013 The Future of Open Source http://www.slideshare.net/blackducksoftware/the-2013-future-of-open-source-survey-results

[ii] Black Duck Software http://www.blackducksoftware.com/

[iii] David A. Wheeler http://www.dwheeler.com/

[iv] Dod-oss.ppt http://www.slideshare.net/Softwarecentral/dodossppt

[v] openFLE http://openfle.codeplex.com/

[vi] PQDIF http://grouper.ieee.org/groups/1159/3/

[vii] Grid Solutions Framework http://gsf.codeplex.com/

[viii] COMTRADE http://standards.ieee.org/findstds/standard/C37.111-1999.html

[ix] openXDA http://openxda.codeplex.com/