2015 Georgia Tech Annual
Fault & Disturbance Analysis Conference
April 27-28, 2015 Atlanta, GA

Automated Disturbance Analytics and System-wide Dashboard Insights Using Open Source Software

Fred L. Elmendorf
Grid Protection Alliance
Chattanooga, TN USA
felmendorf@gridprotectionalliance.org

Abstract— Power companies have invested huge sums of money in building out their substation infrastructure with current technology devices and the supporting communications systems to integrate and operate new devices and data gathering systems. The challenge created by an increasing number of intelligent electronic devices (IEDs) producing data, and the resulting increased volume of data to be managed and analyzed makes it impossible for a human fully understand the operational health of the fleet of reporting devices, or to extract all the value from the data that is being recorded. Economic pressures are reducing the available staff to analyze data, and customers are demanding better performance and power quality (PQ). With greater volumes of data and decreased staff, automated disturbance analytic systems are becoming ever more critical. An open source software (OSS) approach maximizes investments and facilitates industry wide collaboration to meet the challenge.

Existing desktop tools are not designed for dynamic, real-time, system-wide reporting, and typically, analysis engineers and staff are so overwhelmed with data that only the most critical events can be explored in any detail. Employing state of the art technologies to aggregate data from the entire fleet of reporting devices, and positioning that data in a highly optimized database allows new value to be extracted from the existing data. An open source 'dashboard' presentation of information related to the entire population of reporting devices, regardless of the type of device or manufacturer, can quickly identify and alert on significant events or conditions.

This paper will provide a brief update on the growth and benefits of OSS for the electric power industry, and a follow-up to last year's paper 'The BIG Picture – A Look at Automated Systems for Disturbance Analytics using Open Source Software'. Fleet-wide techniques will be explored that can move disturbance data analysis from reactive 'firefighting' to a near-real-time understanding that facilitates proactive decisions. Specific data management, aggregation, and positioning techniques that make up an effective data layer to support a responsive and scalable dashboard solution will be presented, and system-wide insights facilitated by this approach will be discussed. Whether you choose to use OSS in facing the automated disturbance analysis challenge or not, this paper will give you a better understanding of the complexity of the challenge, and prepare you to make more informed solution decisions. The paper will conclude with a case study of an Electric Power Research Institute (EPRI) sponsored open source power quality (PQ) dashboard funded by a number of major utilities. The Open PQ Dashboard is currently in beta testing, and has being deployed at the Tennessee Valley Authority (TVA), Dominion Virginia Power, and Georgia Transmission Corporation for further evaluation, testing and extension.

Keywords—power quality, dashboard, open source software, disturbance analytics

I. Growth and Benefits of OSS

OSS has received a lot of attention already this year as Microsoft continues with new contributions and provides blog posts and online "how to" training videos. Microsoft is just one example of a major, historically proprietary IT company that has embraced OSS in a huge way. 2015 also marks the ninth year that Black Duck Software has conducted a comprehensive cross-industry survey to assess the future of open source, and in a recent webcast they included these three points:

- OSS is becoming a more important part of the software ecosystem
- The use of OSS is critical strategy for commercial companies
- The OSS business model has been validated

There is no longer a question regarding OSS as a possible solution. It should be evaluated on an equal basis with proprietary offerings. All software should be evaluated on quality, security, and features whether OSS or proprietary, but visibility of the source code, and community involvement give OSS potential advantages in these areas. A recent EPRI white paper provides a fresh perspective on OSS, lists some of their important OSS projects, and presents the results of an electric

utility specific OSS survey conducted in late 2014. The initial survey results support the observation that OSS is still not well understood within U.S. electric power companies.

Additional benefits of OSS that are particularly valuable in the relatively small electric utility industry include:

- Lower total cost of ownership
- Reduced time to deployment
- Stimulates innovation
- Encourages and facilitates collaboration

Results from the 2015 Future of Open Source Survey conducted by Black Duck Software were presented in a webinar on April 16, 2015[i]. Figure 1 below shows examples of a few recent OSS related presentations and activities.

Figure 1. OSS Collage

II. FOLLOW-UP: "THE BIG PICTURE - …"

Leveraging the benefits of OSS and continuing to encourage the use of industry standards over the past year has yielded many improvements in automated disturbance analytic systems. Following is an update on the gaps identified in "The Big Picture – A Comprehensive Look at Automated Systems for Disturbance Analytics using Open Source Software"[ii].

Data Retrieval – The ever increasing demand for more information on the health and operation of the power system is driving continuous growth in the communications infrastructure. While the rate of change varies widely from one company to another, overall it is improving. With regard to automated near-real-time disturbance analytics, having this data highway available is the first step. Managing the traffic on the data highway is the next critical step in the process and at this point it is still a patchwork of proprietary vendor supplied systems. An OSS solution to isolate the analytic processes from the proprietary uniqueness of reporting devices offers potential value to all of the players. The OSS approach is good for vendors because data from their device becomes more valuable if there are fewer barriers to its use and it is more readily incorporated into new applications with new audiences. It's also good for power companies because they can extract more value from their installed devices, and have more flexibility in choosing new hardware solutions. Many vendors and utilities have expressed interest in an OSS solution, but at this time it has not been accomplished.

Data Quality – OSS projects are underway to address a number of data quality and availability issues. In one application a large historical data set is analyzed to determine the normal operating range for any trended value. Once the normal operating range is established, each new data point is compared to the range and appropriate alarms and notifications are generated when the range is exceeded. New work for this year will address missing data, latched values, engineering reasonableness, and possibly others.

Analytics - Automated fault distance calculations continue to be enhanced. Ongoing work funded through Dominion Virginia Power, EPRI, Georgia Transmission Corporation, and TVA, has added a sixth single-ended distance calculation method and a native E-Max DFR format parser, and additional work this year will add double-ended fault distance calculation and breaker timing analysis and reporting. Additional analytics under consideration are capacitor bank and other substation equipment health, and cataloging and reporting on transient events. The existing OSS data layer is capable of automatically performing any analytics appropriate for disturbance or trending data recorded in PQDIF, COMTRADE, or native E-Max DFR formats.

Applications – Automated fault distance calculation and notification systems have been deployed at Dominion Virginia Power, Georgia Transmission Corporation, and TVA. Features and analytic methods are being enhanced in projects this year as noted above. An exciting new use for the OSS data layer is to position data for visualization in an OSS dashboard. The initial development of the dashboard is to provide a fleet view of PQ related information. An independent web based OSS system event explorer[iii] has been developed to provide interactive review and comparisons of waveform data associated with an event. A screenshot of the system event explorer is shown below in Figure 2. The data layer is also being extended this year to integrate PQ data with a proprietary EPRI PQ investigation tool.

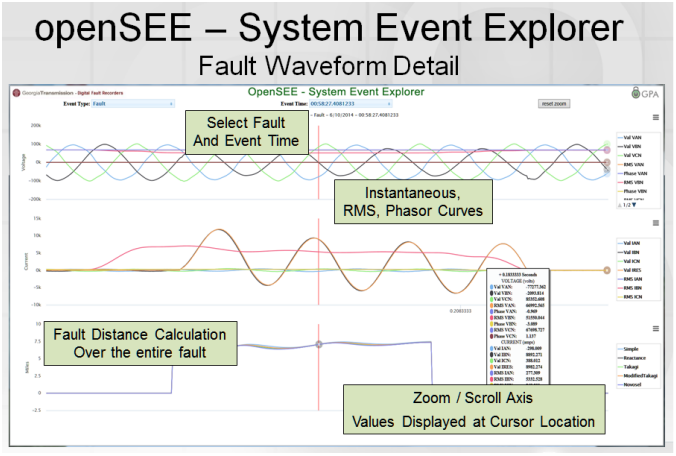

Figure 2. System Event Explorer

III. REAL-TIME INFORMATION FOR PROACTIVE DECISIONS

Historically, PQ and event related information have been recorded and archived to support largely manual processes for event investigation, and manually initiated batch processing to

produce reports of trending data. Typically this data has only been reviewed to produce periodic reports or to investigate events that are known to have caused system or customer issues. Automated real-time processes are capable of analyzing and categorizing information from every event record or trending file. In this context, real-time means as soon as the data is available. Data retrieval processes dictate the 'real-time' periodicity and lag time. Data from network connected devices can be analyzed to produce reports and notifications within seconds from the time of the event.

IV. Effective Data Layer

PQ and disturbance data is available from many different types of devices and different manufacturers. As mentioned previously, this presents a challenge in retrieving the data from field devices, and it also presents a challenge in analyzing the data. Through the extension of a 2012 EPRI OSS project to prove the concept of automated fault location at the enterprise level, an open source data layer[iv] has been developed to address these challenges.

The data layer consists of:

- An automated back office service (Windows OS)
- Input parsers for event and trending data
  - PQDIF
  - IEEE COMTRADE
  - EMAX native file format
- Output: database, emails, etc.
- Data sources:
  - Power quality (PQ) monitors
  - Digital fault recorders (DFRs)
  - Other information systems

A logical overview of the automation platform is shown below in Figure 3.

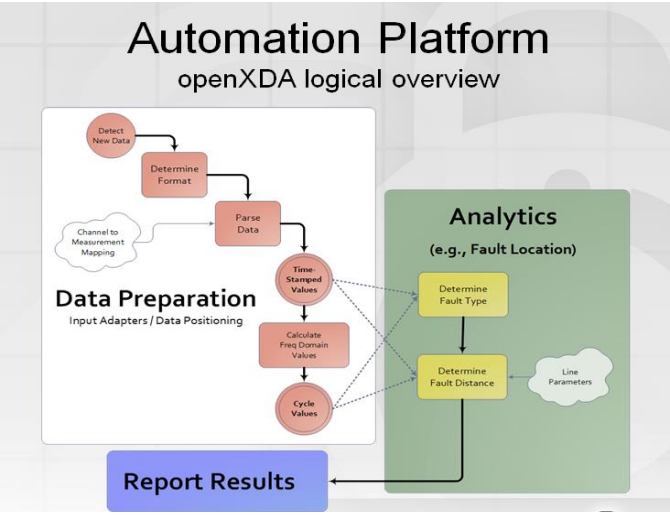

Figure 3. Logical Overview

A physical overview of the automation platform is shown below in Figure 4.

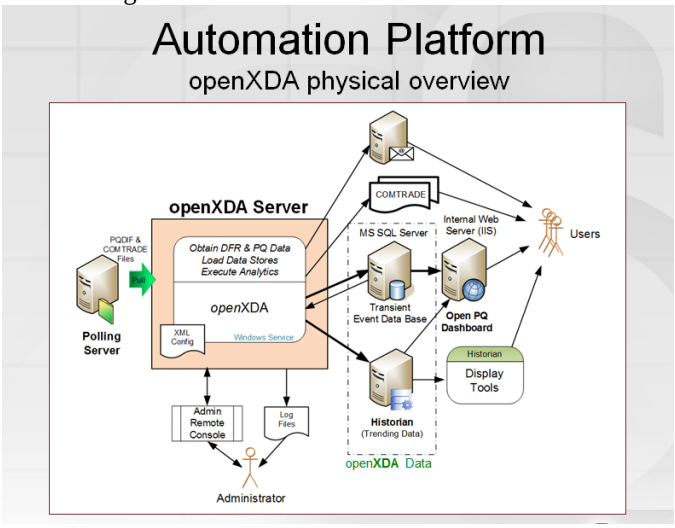

Figure 4. Physical Overview

V. System-wide Insights

Using the data layer and presentation tools that have been developed using OSS as previously described in this paper, it is now possible to draw data together from many disparate data sources, and present it in a system-wide context. The initial PQ Dashboard uses this technique to convey information through a combination of geographic, grid, histogram, and tabular visualization panels to present a 'one shot visual'. This 'one shot' approach assists the user in comprehending the information represented in very large volumes of data. Additional functionality is being added in current projects that will facilitate system wide visualization of any trended quantity overlaid with power system representations. For example, a heat map of system-wide minimum voltage could be displayed with a system single line.

VI. PQ Dashboard Case Study

In 2014 EPRI initiated a project to use the open source extensible disturbance analytics platform (openXDA) to provide the data layer for an OSS PQ Dashboard. The Open PQ Dashboard[v] is currently in beta status, and one of the tasks to be completed this year is to produce a stable, easily deployable, maintainable version 1.0. Additional tasks in the project will provide greatly enhanced geographic displays, add new data quality and availability alarming and reporting, and other features as budget and schedule allow. The Open PQ Dashboard has been deployed at two utilities with a third deployment scheduled in June, 2015. Because of the OSS nature of the Open PQ Dashboard and the openXDA, additional features and functions are being added through independent projects that all benefit the code base. Some of the features that have been added through other projects include much more flexible time controls and application navigation, the inclusion of new tabs for 'Faults' and 'Breaker Timing', and optimization of code for

responsiveness. An additional EPRI project is underway that uses the openXDA to integrate PQ data with EPRI's popular PQ Investigator tool, and displays the results through the PQ Dashboard.

An example of the EVENTS tab with the PQ Dashboard in the Map view is shown below in Figure 5.

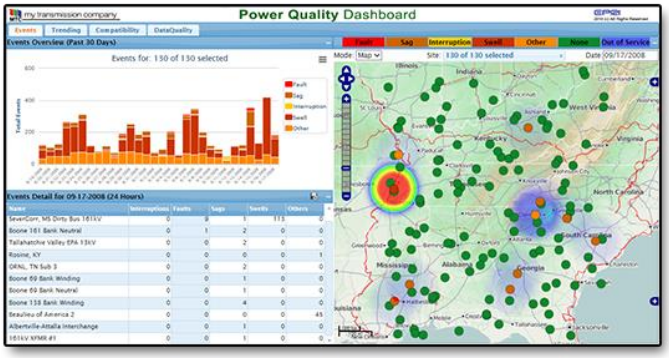

Figure 5. PQ Dashboard Events with Map

An example of the EVENTS tab with the PQ Dashboard in the Grid view is shown below in Figure 6.

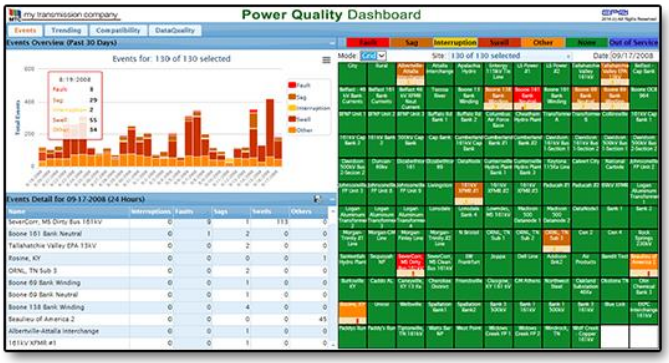

Figure 6. PQ Dashboard Events with Grid

An example of the TRENDING tab with the PQ Dashboard in the Map view is shown below in Figure 7.

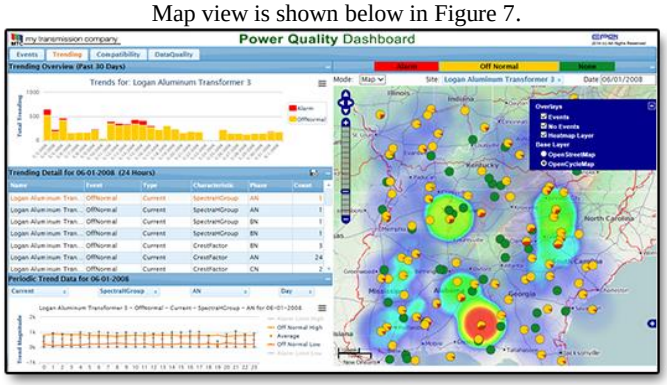

Figure 7. PQ Dashboard Trends with Map

An example of the TRENDING tab with the PQ Dashboard in the Grid view is shown below in Figure 8.

Figure 8. PQ Dashbaord Trends with Grid

VII. SPAWNING NEW TOOLS

The automated analytic functions provided through the openXDA and the fleet wide visualizations available through the PQ Dashboard allow the user to quickly understand events or changes on the system while positioning the relevant data for detailed analysis. As mentioned earlier, an OSS system event explorer (openSEE) has been developed to facilitate this detailed analysis. When openXDA is configured to produce automated email notifications for fault distance calculations, a link to openSEE can be imbedded in the email so that a user can instantly view the waveforms associated with the fault in an interactive web environment. Additionally, openSEE is directly available through the PQ Dashboard and allows the user seamlessly examine the associated waveforms. openSEE is one example of new analysis tools that can further leverage the power of the OSS tools described in this paper.

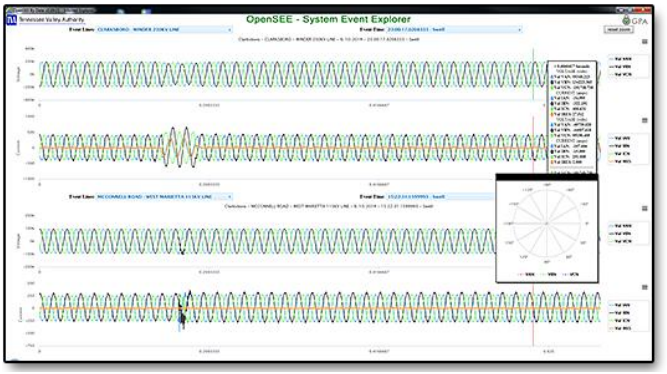

Figure 9. openSEE with Phasor chart

The frameworks are in place, and real-world experience demonstrates that it is now possible to develop robust, extensible software systems that can achieve automated disturbance analytics and system-wide dashboard insights using an OSS development strategy.

[i] 2015 Future of Open Source
https://www.blackducksoftware.com/future-of-open-source

[ii] The Big Picture
http://www.slideshare.net/FredElmendorf/2014-georgia-tech-fda-pres-asda-using-oss-37239423

[iii] openSEE-System Event Explorer
http://opensee.codeplex.com

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

[v] Open Power Quality Dashboard
http://sourceforge.net/projects/epriopenpqdashboard/