Automatic Multi-Vendor IED Fault Data Collection and Analysis Solution

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***Abstract*—** Smart automation technologies aim to improve efficiency and productivity in several areas. Specifically for power system disturbances, automation can greatly reduce capital and labor costs by not only reducing travel time to substations to collect event data but streamline event response processes. A key concept in fully achieving this type of automation involves solutions that not only support automated fault data collection from IEDs, but automated fault data analysis as well.

The fault data collection was a challenging feat for a utility from the Dominican Republic where their power system consisted of a breadth of multi-vendor devices such as SEL, GE, ABB, Siemens, ERLPhase, EMAX, APP, and Qualitrol. This presentation details the integration of three multi-vendor solutions that provided the utility with a complete vendor agnostic system to achieve the following benefits:

- A centralized IED management solution that supports automatic multi-vendor event data retrieval
- Email notification, version control and archival of collected records
- Secure authentication to a web-based interface to access and conduct in-depth post-event analysis
- Automatic conversion of proprietary event record formats to open standards such as COMTRADE
- Automatic event record analysis that summarizes disturbances and calculates Takagi, Modified Takagi, and Novosel fault location
- Ability to integrate with other business intelligence systems such as Enterprise Resource Planning systems like SAP to historians from OSIsoft, Schneider Wonderware eDNA, and Automsoft that can be utilized for breaker analytics and trending

During this integration, several fault analysis applications ranging for open source, vendor-specific, and third-party applications such as EPRI openXDA, SEL microwave, GE Enervista, Siemens SIGRA, and Wavewin were all integrated into the complete solution. This was done to support in-depth fault analysis for any fault data format when automatic conversion to an open standard was not supported. A need for device vendors to adopt open standard fault data formats and fault data transfer protocols would greatly improve interoperability moving forward. For existing power systems that face the same challenges as above, a vendor-agnostic solution that supports collection and analysis of fault data from essentially any grid device is available.

Analyzing power system disturbances is a critically important task for any electrical utility, especially for this main transmission utility in the Dominican Republic. When a power system event occurs, such as an outage, the utility needs to identify the source of the event to take corrective action.

Intelligent Electronic Devices have been deployed by power utilities to protect the power system. Protective IED's usually contain SCADA data, non-SCADA data (useful real-time data not collected by SCADA system) and fault files which capture detailed information about power system disturbance and assist utilities in determining the cause of the disturbance.

This collection is time-consuming and prevents the utility's ability to respond promptly to system events. Collecting this data is further complicated by the many different relay vendors and product models.

As a result, the utility has deployed a solution that not only collects and centralize non-SCADA data but also faults file data to be analyzed. The centralized location contains event viewing tools for authenticated users to analyze the fault files. Additionally, the system extrapolates the key time series data from the fault files, performs calculations (for example; breaker analytics) and sends all data (extrapolated and calculated) to the data historian for further historical analysis.

Historical analysis on both the fault data and non-SCADA data allows the utility to perform predictive maintenance, event analysis, load contingency studies, reliability improvement studies, substation transformer life studies, power quality studies and much more. Overall, the company envisioned results from this project are to prioritize investments better, prioritize labor resources and improve system reliability.

The paper outlines the process for automated fault file collection focusing on the importance and benefits that a company can receive by archiving both fault file data and non-SCADA data in a data historian.

I. Nomenclature

IED – Intelligent Electronic Device. Applies to various substation devices that collect analog or digital substation data using electronic (as opposed to electromechanical) means.

II. Introduction

THE power industry has been immersed in a new era of substation communication and operations. Today, utilities generate mountains of data that could be useful, but that instead lie untapped, locked away in hundreds of devices communicating over different proprietary protocols. On the other hand, the data that is being used is shunted through a web of conflicting priorities, its usefulness diluted by the lack of a standardized platform for secure information transfer, dissemination, and analysis. In their efforts to build a more efficient and responsive power transmission system, utilities often find themselves struggling to maintain the illusion of managed chaos simply. Developing a solution to such a complex problem is not easy; with this approach, the transmission company in the Dominican Republic and SUBNET Solutions Inc. are laying the foundations for an intelligent substation network for more effective power management.

III. Background

Over the past several years, utilities have seen tremendous growth in the number of smart relays and other smart substation devices. There have also been significant advancements in communications to these field devices. The devices include microprocessor-based relays, fault and event recorders, meters, transformer dissolved gas analysis (DGA) monitors, battery monitors, transformer temperature monitors bushing monitors, breaker monitors. While some of these devices provide traditional supervisory control and data acquisition (SCADA) data, they also offer data that can be used by various departments to improve the planning, operations, and maintenance of power system assets.

Engineering access to smart substation devices is defined as the ability to remotely connect to substation devices and perform various functions, including data or file collection, troubleshooting, and updates. This network connection is the conduit to collect the additional data from the smart substation devices.

With its substation network connectivity solution underway, the utility embarked on an effort to identify technology solutions that could support the collection and storage of large volumes of data, as well as provide tools for visualization and analysis of the data. One prerequisite was to not burden the utility energy management system (EMS) or transmission control centers with data that was not needed for real-time operations.

While there is an increasing number of breakers, transformers, coupling capacitor voltage transformers (CCVTs) and other power system equipment, the funds to maintain this infrastructure remain flat with pressures to decrease costs. This leads the substation maintenance organization to implement more condition-based maintenance programs, which require equipment data. And, there are a growing number of departments that need access to substation device data. Additionally, the difficulty and inefficiency of individuals performing ad-hoc data extraction from these devices is becoming worse because of increased security around access to substation devices.

Further, there is an overriding desire in all departments to minimize both customer outages and avoid costly repairs and site cleanup from catastrophic failures. This increases the pressure on operations and maintenance organizations to predict power system equipment problems and remove equipment from service before a failure occurs.

Reducing the time it takes to retrieve and analyze digital fault recorder and protective relay event files reduces the time it takes to locate, isolate and restore electric service, which would contribute to improving reliability metrics and customer satisfaction. Lastly, having an easy-to-use central repository for power system data and event files, and providing more flexible tools for visualization and data analysis, will improve the results of short- and long-term power system studies.

The proposed solution integrated local automatic fault file collection and centralized platform that also integrated the OpenXDA Disturbance Analytics application developed by Grid Protection Alliance (GPA).

GPA is a non-profit organization formed to facilitate and support the development and deployment of comprehensive electric energy system-wide solutions and enhancements to electric sector security through integrated, adaptable, collaborative and rapidly-evolving programs of threat identification and analysis and infrastructure research, development, demonstration and technology transfer.

OpenXDA is an extensible application for processing event and trending records from disturbance monitoring equipment such as digital fault recorders, protective relays, power quality meters, and another power system intelligent electronic devices. It includes a parser for COMTRADE and PQDIF formatted records, and demonstrations have been conducted using .eve files. OpenXDA can be used as a data integration platform and can facilitate the development of automated analytic systems. OpenXDA has been deployed in many US utilities to perform automated fault distance calculations based on disturbance waveform data combined with line parameters. OpenXDA determines the fault presence and fault type, and uses six different single-ended fault distance calculation methods to determine the line-distance to the fault.

The utility selected a combination solution from two vendors: GPA OpenXDA Disturbance Analysis software and SUBNET Solutions Inc. PowerSYSTEM Center software.
OpenXDA Analytics include:

- 4 Line-Ground Fault Cases
- 5 Line-Line Fault Cases
- 3 Line-Line-Ground Fault Cases
- 8 Three-Phase Fault Cases
- As well as waveform visualization

PowerSYSTEM Center would be retrieving fault files from devices and trigger an automatic analysis of the fault files.

OpenXDA can produce automated fault recognition, type determination, and distance to fault calculations to be included in notifications, emails, or an event database. Systems built on the OpenXDA platform can produce analytic results as quickly as files can be retrieved from the remote devices.

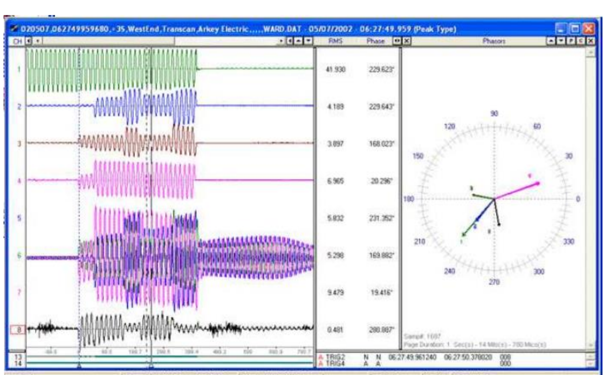
IV. Solution Design

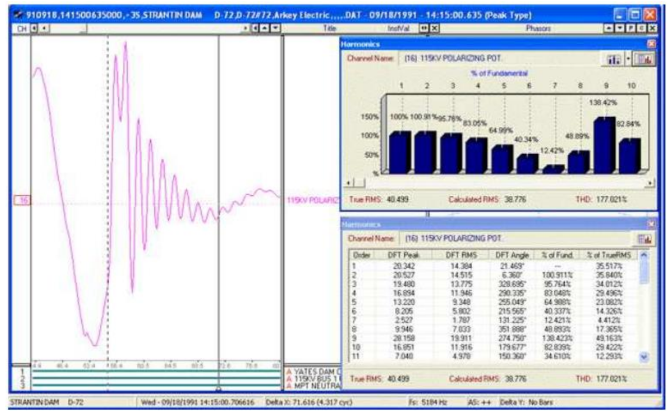
The proposed solution PowerSYSTEM Center allows users to create Fault File Analysis Workspaces to provide the collected fault and analysis files a centralized and organized system through the PowerSYSTEM Center's SharePoint. The Fault File Analysis Workspace allows users to:

- Create a document library within the Fault File Analysis Workspace.
- Bring one or more fault files into the workspace from any device within PowerSYSTEM Center.

The transmission utility takes a multi-layered approach to securing access to smart substation devices and access to the data available from these devices. Substations are located on a dedicated firewalled network with numerous regional firewalls to further segment substation access. Two-factor authentication is required to enter the centralized substation access control portal. The central access control portal provides detailed audit logs of all access and enforces an application air gap, which prevents users from having direct access to the substation network. Access to the historian data is restricted to approved users who have been included in a separate application access control list.

The following are examples of the analyses screens:





The project focused on the collection of data in the following areas:

- Breakers — the time to trip, continuous currents, fault magnitude, number of operation and the time since the last operation
- Transformers — three-phase megavolt amperes, continuous currents, and transformer gas data
- CCVTs — evaluating predictive failure indicators
- For single-phase CCVTs, comparing the sync-voltage to phase-voltage magnitudes and angles
- For three-phase CCVTs, comparing the phase- and sequence-voltage angle deviations from 120-degree separations and monitoring negative-voltage and zero- sequence-voltage magnitudes
- Automation of fault data event file collection from SEL relays and digital fault recorders

Within 10 minutes of a power system event, event files from SEL relays and digital fault recorders are transferred from the substation to a file collection server located on a secure corporate network. The MyFaults application allows operations personnel to view fault and event files easily. The Breaker Analytics portion automatically parses the line name, phase involvement, distance to fault, and duration of fault to make them readily available; this helps operators isolate the problem and restore service to customers. The application offers several ways to filter the information only to view the desired data.

Before the pilot project, substation maintenance personnel had to visit the substation in person to collect DGA monitor data. Now, for the seven DGA monitors included in the pilot project, the utility collects the DGA monitor data remotely every few minutes and stores the data in the historian solution. The transformer DGA history from the pilot project monitors is available online. The historian displays and trends can be laid out to the utility's preferences and can be easily changed as desires change. Other data sources can be queried and displayed on the historian displays. The utility wanted to display equipment asset information such as manufacturer, equipment rating, number of phases, date of manufacture and so forth. Users can query the existing asset management database and display asset data alongside near real-time information on the historian displays.

V. Future Applications

The utility is experimenting with finding an early-warning indicator for CCVT failures. The differences between the phase-voltage and sync-voltage magnitudes and angles are normally very small. Should either the magnitude or angle differences increase significantly, it could be an indicator of an impending CCVT failure. Likewise, data from early oil circuit breakers can be used to determine whether maintenance should be conducted or delayed.

The company wants to continue to integrate existing smart substation device types that will provide additional information. The utility also realizes that additional monitoring device types are needed to provide data not currently available on the system.

Shortly, the utility will do the following in preparation for a larger fault file collection system;

Develop standard data templates for each smart substation device type included in the system. During the project implementation, it was easier for the utility to gather all available data from the smart devices. It now has a better handle on what data elements are important.

Develop an architecture strategy to allow data to be collected and stored once between EMS and the fault file collection system. Traditional SCADA data will continue to be collected by EMS.

The result of this effort is the ability to collect more field data about system events and equipment performance and condition in real time. Use and analysis of this data into timely information translates into an improvement in the reliability of the power-delivery grid and improved prioritization of budgets and labor resources by optimizing the response to system events and the maintenance programs.

Systems Operators will have more data at their disposal during outages to determine the source and location of faults. This will allow more efficient outage restoration and more effective post-mortem analysis of system disturbances and outage events. Also, real-time and event monitoring of the performance of substation equipment create the ability to trend equipment performance for an enterprise-level shift toward performance-based asset management versus current time-based maintenance programs.

VI. Acknowledgments

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VII. References

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VIII. Biographies

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