Meeting NERC Requirements for Oscillography and Disturbance Monitoring by Collecting Data from Relays

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***Abstract*—The North American Electric Reliability Corporation (NERC) and the region reliability councils have mandated electric utilities to monitor their power systems at critical locations throughout their system. The monitoring systems are to be phased into service by 2010. American Electric Power (AEP) and Tarigma Corporation with assistance from Schweitzer Engineering Laboratories, Inc. (SEL) have developed a disturbance monitoring system to provide an alternative to traditional monitoring equipment to meet these monitoring requirements. This paper will discuss the collection of event and synchrophasor data from relays to satisfy the NERC requirements for disturbance monitoring. Event data from relays on the AEP system is currently retrieved, stored locally and then moved to several server sites on the AEP system. This same approach will be taken with synchrophasors and allow AEP to use this data to meet the disturbance requirements mandated by NERC.**

Combining these two approaches provides the means for AEP to save millions of dollars by not having to purchase conventional recording equipment for their system in order to meet the NERC requirements. This approach provides a very cost-effective means of capturing event and disturbance data in stations that could typically justify the need for conventional recording equipment. Since this approach is a fraction of the cost of traditional disturbance monitoring equipment, monitoring can be justified in smaller stations.

This paper addresses the challenges of retrieving the data from relays in a way that meets the NERC requirements. The economics of the traditional approach of collecting data versus using data captured by relays will be contrasted. Techniques for storing the data locally and moving the data efficiently and securely to corporate servers for engineering access will also be examined.

I. Introduction

AEP was faced with the costly challenge of meeting the mandated NERC requirements by 2010. If they took the traditional approach, they would have to add many new conventional recording devices and rewire many of their existing recording devices to meet the NERC requirements. Additionally, only fault data is collected using the conventional approach. Since the AEP power system is large, the estimated cost to comply was staggering at over $75 million. AEP investigated other alternatives and found they could retrieve data from digital relays to meet the NERC requirements at a fraction of the cost.

As a result of these initial investigations, the AEP Grid Enterprise Manager (AEP-GEM) system was conceived. It is designed to automatically collect data from substation assets such as protective relays, lines, transformers, circuit breakers, and carrier tone equipment. This system is able to collect not only traditional disturbance data but also transient, sequence-of-event, fault reports/summaries, and dynamic disturbance data. It also trends data from monitoring station devices such as lines, transformers, circuit breakers, protection carrier equipment, etc. The data collected is saved locally at the station and then forwarded to central corporate servers. Prior to the development of this system, this data was generally available only to engineers with intimate knowledge of the station protection and metering systems. With AEP-GEM, the data is now available to corporate users who previously did not have direct access to this information. The system is designed to be flexible, configurable and scalable. It is also designed to integrate with and enhance AEP's existing systems including supervisory control and data acquisition (SCADA), Asset Management, and Map systems.

The following are the three primary components:

- Station panels
- Data collection and transport component
- Visualization and analysis tools

The main goal for the development of AEP-GEM was to meet NERC requirements for disturbance recording at a fraction of the cost of conventional recorder equipment. Once the system was put in place, there was a wealth of additional information that could be integrated into the system. Within this system, the data is collected from the protection relays and stored on a hardened station computer known as a Station Data Repository (SDR). The SDR server is required only at higher voltage stations that require full disturbance recording functionality. Other types of stations, typically subtransmission and distribution, will typically not require the SDR server and will be accessed directly from a central AEP-GEM server. Since the SDR replaces the traditional "stand-alone" monitoring equipment, no recording equipment is required.

Data is recorded in multiple devices within the substation, linked together via an Ethernet LAN to a central station server. The components of the system include:

- Protective relays and meters
- SCADA RTU
- SDR server
- Substation Ethernet LAN
- AEP-GEM data collection servers (located on the SCADA network)
- AEP-GEM data server (located on the corporate network)

AEP service areas lie within multiple reliability council regions, including Reliability First (RFC), Southwest Power Pool (SPP), and Electric Reliability Council of Texas (ERCOT). The design of the system had to meet the requirements of these three regions. For this reason, the AEP-GEM system has two primary configuration options. Option #1 is for sites requiring the SDR server where disturbance recording is required. This includes all stations 200 kV and above and critical 100 kV to 200 kV as defined by NERC and the regional reliability council requirements. Option #2 is for sites that do not require the SDR server.

A typical station configuration is shown in Fig. 1 below.

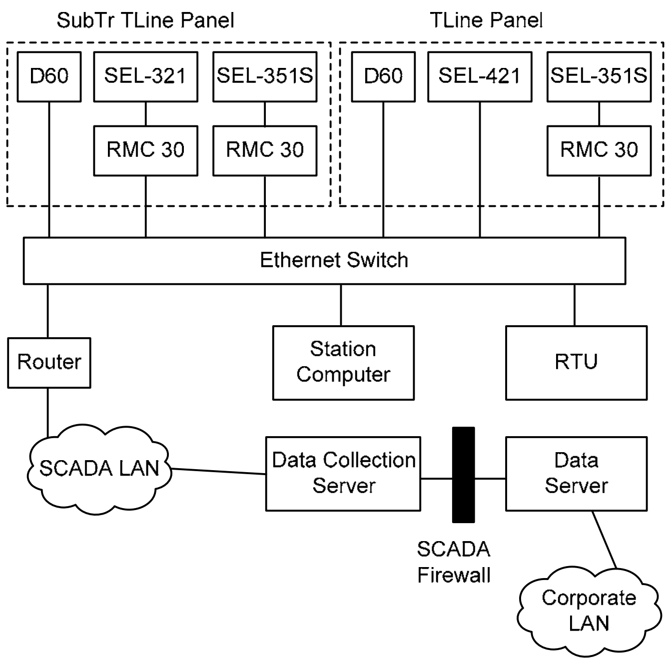

Fig. 1. Typical station configuration

II. Substation Protection System Design

Beginning around the year 2000, AEP began developing new protection systems based on the SEL and General Electric product lines. These protective relays have been applied in the AEP typical panel designs: transmission line, transformer, bus, reactor, capacitor bank, and breaker control. In developing these standard designs, these devices were looked at as not just a protective relay, but as a multifunctional device. The functionality defined for these devices were:

- Protection
- Alarm annunciation
- SCADA
- Disturbance recording

Taking advantage of this multifunctional capability allowed AEP to reduce costs by eliminating the need for stand-alone alarm annunciator devices, typical SCADA data devices such as metering transducers and conventional recording equipment. Cost savings from this design not only included the elimination of these devices, but also the labor-intensive wiring of signals to these devices.

Another key feature applied to these design standards was the substation Ethernet local area network. Many of the devices chosen for the standard panels came equipped with direct Ethernet connectivity. For devices chosen without direct Ethernet but with only serial communication connectivity, AEP used serial-to-Ethernet device servers. The result is that all devices used in AEP's standard designs have Ethernet communication ability.

III. Disturbance Recording Using Protective Relays

The foundation of the AEP-GEM system is the ability of standard protective relays to record disturbance data at resolutions typically found in conventional monitoring equipment.

These data consist of the following four components:

- Fault reports
- Transient
- Sequence of events
- Dynamic

These data are recorded in the individual relays. Each of the standard panel designs consist of two independent systems; i.e., two protective relays. For example, a typical line-protection panel consists of one SEL-421 relay and one GE UR D60 relay. The other standard panels follow the same design pattern, one SEL and one GE relay.

All of the relays are time-synchronized to a substation GPS clock. The standard time setting for the GPS clocks across the AEP system is Greenwich Mean Time (GMT). It is essential to have all relays time-synchronized to one standard time for purposes of post-fault analysis. In addition, synchronized time-stamping is required by NERC and the regional reliability councils.

IV. Fault Reports

Each relay will record a fault report when the relay issues a trip. This report is an ASCII text file providing information regarding the fault as seen by the relay. Typical information included in this type of report is trip time, targets, distance to fault, pre-fault current and voltage quantities, and post-fault current and voltage quantities.

A typical fault report is as shown.

```
Line/Relay Name                 Date: 03/08/2007  Time: 10:39:34.919
Station Name                    Serial Number: xxxxxxxxxx

Event: TRIP        Location: $$$$.$$           Time Source: HIRIG
Event Number: 10107     Shot 1P: 0  Shot 3P: 0     Freq: 60.00    Group: 1
Targets: GIOC SOFTE B_PHASE C_PHASE GROUND CCTRIP
Breaker 1: OPEN        Trip Time: 10:39:34.919
Breaker 2: NA
```

PreFault:	IA	IB	IC	IG	3I2	VA	VB	VC	V1mem
MAG(A/kV)	0	0	0	0	1	0.007	0.007	0.012	0.000
ANG(DEG)	-167.1	-3.5	3.8	-16.0	-167.1	60.9	103.4	-131.0	-53.0

Fault:									
MAG(A/kV)	3639	1	2	3641	3641	0.023	0.005	0.060	0.001
ANG(DEG)	0.0	146.3	10.1	0.0	0.0	-132.2	154.5	77.6	-60.4

V. Transient Disturbance Monitoring

Transient records are recorded inside the relay for system disturbances.

The transient records are sampled at typical rates of 32 or 64 samples per cycle. *This sample rate may be dictated by the regional reliability council*. The data record lengths are configured to allow for a minimum of 5 cycles pre-fault and 60 cycles post-fault. *These types of relays will be considered as Tier 1 recording devices*. Within each zone of protection, there must be at least one Tier 1 recording device in order to meet the NERC and Regional Reliability Council data requirements.

There are a few relays used that can only record at rates less than 32 samples per cycle or cannot meet the required record length duration. *These types of relays will be considered as Tier 2 recording devices*. Data from these devices are included in the SDR system as well.

Traditional monitoring equipment provides for both analog and digital triggering. Therefore, the relays must have this same triggering capability. Analog waveform triggers applied in the relays include three phase-to-neutral undervoltage, three phase-to-neutral overvoltage (765 kV applications only), line neutral overcurrent, relay polarizing overcurrent, under/overfrequency, and df/dt. In the transformer applications, additional analog triggers consist of 2^{nd} and 5^{th} harmonics. Digital event triggers include trip, DTT receive, breaker open, and breaker close.

For line applications, the recorded analog traces include three phase currents, three phase voltages, neutral current, MW, MVar, and frequency. For transformers, the recorded analog traces include all current inputs, the differential operating current in each phase, the differential restraint current in each phase, the 2^{nd} harmonic current in each phase, and the 5^{th} harmonic current in each phase. For bus applications, the recorded analog traces include all current inputs, the differential operating current in each phase, the differential restraint current in each phase and bus voltages (if applicable). Analog data are displayed in primary units.

Digital information recorded from each relay includes all inputs and outputs, internal programmed logic, and internal protection logic.

VI. Sequence of Events

Sequence-of-event (SOE) data, also known as a sequential event records (SERs) are recorded inside each relay. This file is an ASCII text file providing time-stamped sequence-of-event information. Only one file resides in each relay. Once the end of the file is reached, then old data are dropped from the file. Most of the relays can record at 1 millisecond resolution, and there will be at least one in a protection zone.

The SDR server is configured to automatically copy the file from the relay periodically. The periodic time is programmable. In addition, if the relay is detected to have issued a trip based on the availability of a fault report file, then the SDR server will automatically copy the sequence-of-event file as it retrieves the fault report and transient file.

A typical sequence-of-event file is as shown.

```
Mountaineer/421U1U                                 Date: 06/28/2008  Time:
Amos 765KV                                         Serial Number: 200416700

FID=SEL-421-R108-V0-Z002003-D20021216

#     DATE        TIME          ELEMENT            STATE
1000 06/22/2008  16:33:52.472  RF_OUT             ON
999  06/22/2008  16:33:52.474  CC_LVL_DETECT      ON
998  06/22/2008  16:33:52.913  CC_RCV             OFF
997  06/22/2008  16:33:52.944  CC_RCV             ON
996  06/22/2008  16:33:52.963  CC_RCV             OFF
995  06/22/2008  16:33:52.977  CC_RCV             ON
994  06/22/2008  16:33:53.013  CC_RCV             OFF
993  06/22/2008  16:33:53.027  CC_RCV             ON
992  06/22/2008  16:33:53.046  CC_RCV             OFF
991  06/22/2008  16:33:53.061  CC_RCV             ON
990  06/22/2008  16:33:53.129  CC_RCV             OFF
989  06/22/2008  16:33:53.144  CC_RCV             Auto-Removed
988  06/22/2008  16:33:53.200  CC_LVL_DETECT      OFF
987  06/22/2008  16:33:53.219  CC_LVL_DETECT      ON
986  06/22/2008  16:33:53.433  CC_LVL_DETECT      OFF
985  06/22/2008  16:33:53.504  RF_OUT             OFF
984  06/22/2008  16:33:53.513  RF_OUT             ON
983  06/22/2008  16:33:53.519  CC_LVL_DETECT      ON
982  06/22/2008  16:33:54.052  CC_LVL_DETECT      OFF
981  06/22/2008  16:33:54.068  CC_LVL_DETECT      ON
980  06/22/2008  16:33:54.339  RF_OUT             OFF
979  06/22/2008  16:33:54.959  CC_LVL_DETECT      OFF
978  06/22/2008  16:33:54.989  CC_LVL_DETECT      ON
977  06/22/2008  16:33:55.126  CC_LVL_DETECT      OFF
976  06/22/2008  16:33:55.172  CC_LVL_DETECT      ON
975  06/22/2008  16:33:55.203  CC_LOOPBK          OFF
974  06/22/2008  16:33:55.226  CC_LVL_DETECT      OFF
973  06/22/2008  16:33:55.236  CC_LVL_DETECT      ON
972  06/22/2008  16:33:55.343  CC_LVL_DETECT      OFF
971  06/22/2008  16:33:55.455  CC_LVL_DETECT      ON
970  06/22/2008  16:33:55.559  CC_LVL_DETECT      Auto-Removed
969  06/22/2008  16:34:47.971  CC_RCV             Auto-Reinstate
968  06/22/2008  16:34:53.972  CC_LVL_DETECT      Auto-Reinstate
967  06/22/2008  17:53:39.187  CC_RCV             ON
966  06/22/2008  17:53:39.189  CC_RCV             OFF
965  06/22/2008  17:53:39.196  CC_LVL_DETECT      ON
964  06/22/2008  17:53:39.221  CC_LVL_DETECT      OFF
963  06/22/2008  19:34:10.919  IO OSC TRIGGER     ON
962  06/22/2008  19:34:10.921  OSC_TRIGR          ON
961  06/22/2008  19:34:10.969  IO OSC TRIGGER     OFF
```

VII. Dynamic Disturbance

Starting in 2007, the AEP standard system for dynamic disturbance recording requirements is the Phasor Monitoring Units (PMU) system, which is also known as synchrophasor technology. Dynamic disturbance data are recorded using synchrophasor data supplied by some relays. For example, synchrophasor data can be acquired from all contemporary SEL utility relays including the SEL-421 line protection relay as well as the GE D60, L90, or N60 relays.

The data are polled in real time by the SEL-5077 SYNCHROWAVE® Electric Power System Wide-Area Visualization Software application running on the substation SDR server. These data are recorded continuously in COMTRADE data files. The files are broken up into one-hour intervals to allow for ease of transferring the desired data back to a remote location. The recording is set to overwrite old data files based on NERC and regional reliability council requirements.

At a minimum, the data will be polled at a rate of 30 samples per second. The regional reliability council may require that the data be polled at 60 samples per second.

The data recorded include positive-sequence voltage magnitude and angle, positive-sequence current magnitude and angle, MW, MVar, three-phase voltages, three-phase currents and frequency.

Another feature of the SEL-5077 application is to select data from the station synchrophasor data pool for remote real-time data applications. An example of this data is found in the State Estimation application.

VIII. Substation SDR Server

The function of the SDR server is to automatically collect disturbance data recorded in the protective relays and organize that data for shipment to the remote data servers. Due to limited memory storage in the relays, these records are automatically copied to the SDR server. The server continuously monitors the relays watching for new data records. Upon detection, these data files are transferred to the server. As files are copied from the relays, they are renamed per the IEEE C37.232 standard. An example transient filename viewed at the SDR Server is as shown.

070308,221756694180,-0t,
HyattSwitch,345KVMarysvilleD60,AEP,OSCCTB.cfg
070308,221756694180,-0t,
HyattSwitch,345KVMarysvilleD60,AEP,OSCCTB.dat

Field Definitions

Date: Year, Month, Day

Time: Hour,Minute,Second,Millisecond

Time Zone: 0 = GMT, t = time is the trigger time

Station Name: Station name

IED Name: Voltage, line/transformer/etc name, relay type

The transient and dynamic data files are stored in COMTRADE format. The sequence of events and fault report files are in ASCII text format. A useful feature added to this system is to modify the COMTRADE file channel names after the data are extracted from the relays, replacing the generic channel names recorded in the relay with more meaningful names. For example, in the SEL-421, the generic channel name in the oscillography COMTRADE file for the phase A current is IAW. The SDR application changes this name to, for example, Mountaineer 421 765KV Ia.

The data files on the SDR are organized with the following directory structure as illustrated in Fig. 2.

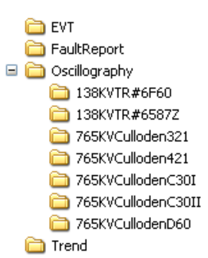

Fig. 2. Data file structure

A secondary function of the SDR system is to collect equipment trend data from the station lines, transformers, circuit breakers, and relay protection carrier tone equipment. Data typically monitored include three-phase real and reactive power, current, voltage, transformer temperature, and combustible gas. With respect to carrier tone equipment monitoring, a loopback test is periodically triggered and the maximum signal level is recorded. All other data are recorded using an average value over a defined time period.

The SDR server used by AEP is the SEL-1102. It is equipped with the following hardware and software:

Hardware: SEL-1102 computer
Monitor
Keyboard/Mouse

Software: Wonderware InTouch
Wonderware OPCLink
Wonderware Modbus I/O Server
AXS4MMS IEC61850/UCA I/O Server
Tarigma FrameWorx SDR Collector
SEL-5040
SEL-5077

Wonderware InTouch features are used to provide the GUI interface to the user, scripting routines to perform the FTP file collection and data organization and scripting routines to provide equipment trend recording. The SEL-5040 is used to collect data from SEL relays that do not support FTP.

The SDR application uses I/O server applications to communicate with the station relays. The protocol used is IEC 61850 or UCA. The I/O server used for this protocol is AXS4MMS from SISCO. The AXS4MMS I/O server communicates with the relays using IEC 61850/UCA protocol and presents the data to the Wonderware InTouch application via its OPC Server. The Modbus I/O server is only used in the application for Wonderware InTouch to communicate with the station RTU to gather data for trending. The Tarigma FrameWorx SDR Collector securely transfers the collected data to central corporate servers.

Fig. 3–Fig. 5 present some typical screen shots from the SDR application.

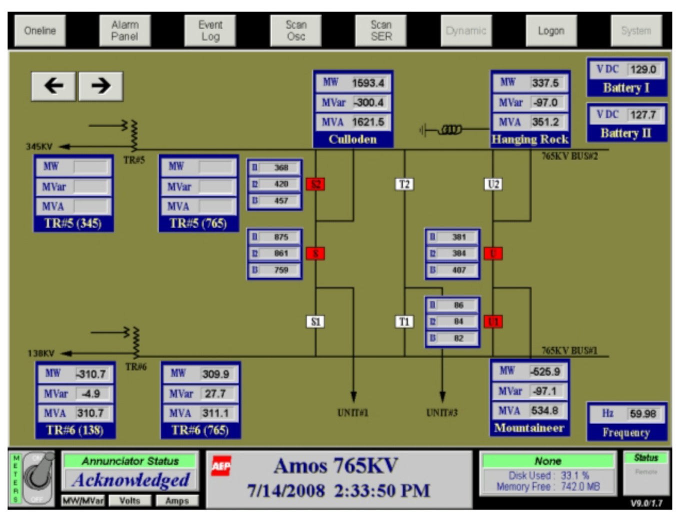

Fig. 3. Station one-line

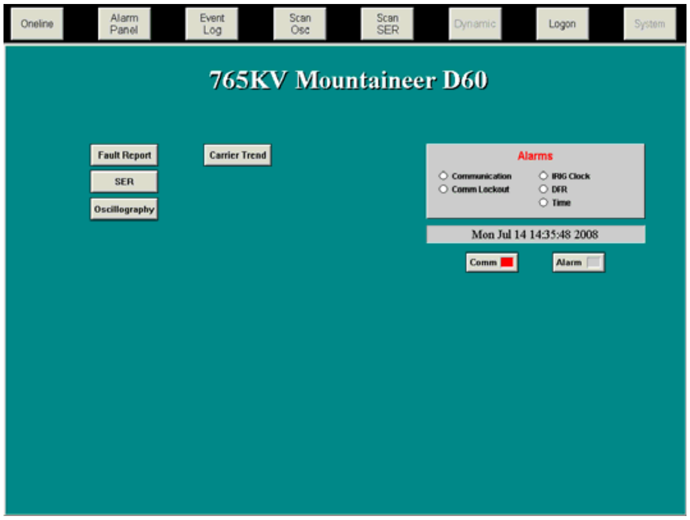

Fig. 4. Typical relay screen

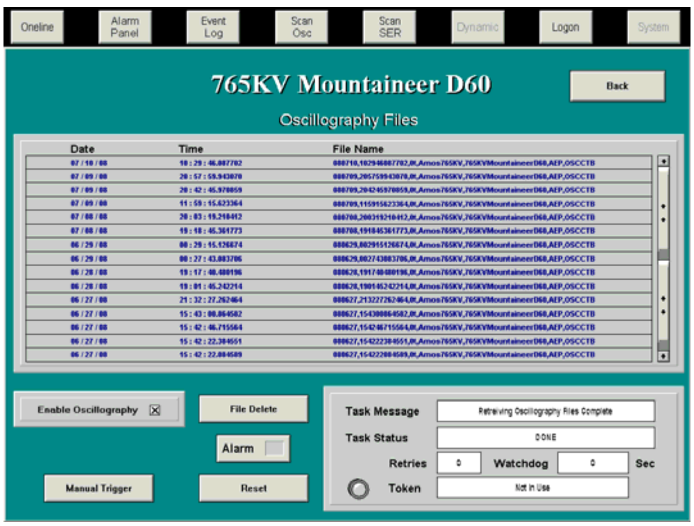

Fig. 5. Typical oscillography screen

IX. Data Collection and Transfer

Tarigma Corporation's FrameWorx is the underlying communication infrastructure responsible for collecting, framing and securely transporting the data from the station to the corporate servers. Each geographical area/region within AEP has one GEM server operating on the SCADA network. FrameWorx is a system integration package that facilitates data collection and sharing between heterogeneous devices and transport of data across wide-area network connections.

In the context of AEP-GEM, it is used to collect and transport data stored on each Station SDR server across the company network. On each RTU-DMZ machine, there is a process for each station, which initiates the connection. FrameWorx then transports data from the SDR server to the corporate web server. On the station end, there is another process (see Fig. 6), which transports the data to the RTU-DMZ server, which in turn transports data to the database and the web server.

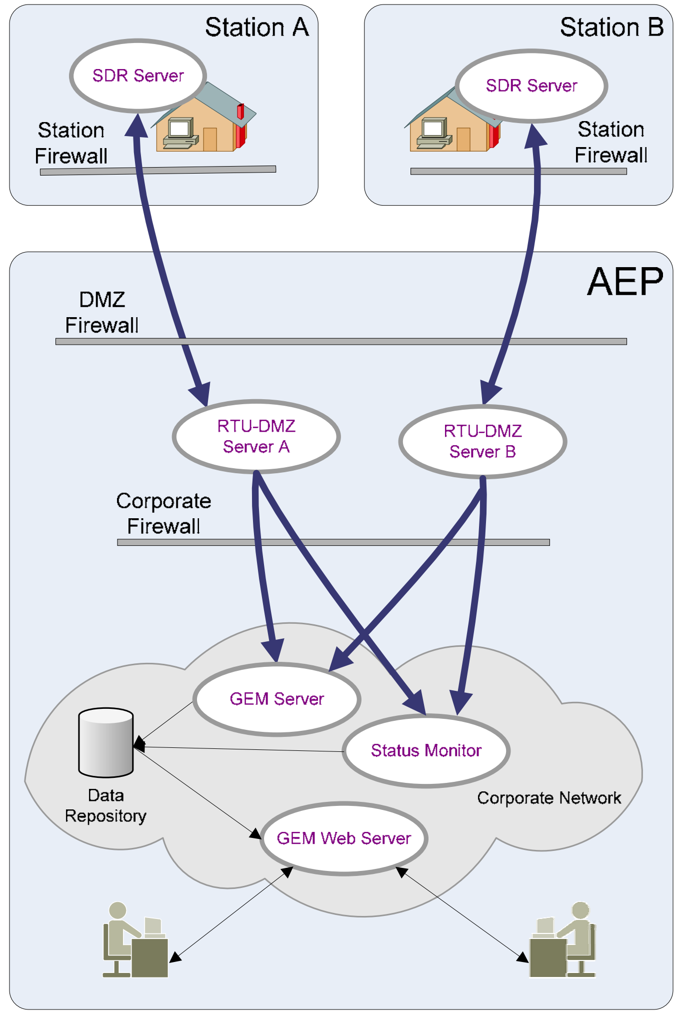

Fig. 6. AEP-GEM station devices to corporate server data flow

All FrameWorx processes share data among themselves (running on the same machine or different machines) using a publication/subscription model. This means that each process that has data to share makes that data available to other processes by registering that data with the publication sub-system, which is present in each process. Other processes (or objects within the same process) can subscribe to data by name. All behavior for a given process is controlled via configuration. All inter- and intra-process data sharing is handled by the publication/subscription subsystem.

FrameWorx is designed so that all processes use the same executable, yet each of these processes is able to do different tasks depending on the role it is assigned to do. This is accomplished by using configuration files and dynamic link libraries (DLLs). At startup, a process reads a configuration file. This file can be thought of as the "operating instructions" for the process. It tells the executable which modules to load, what data points to publish, and which data points to subscribe to in the process. Thus, each FrameWorx process obtains its runtime behavioral characteristics from its configuration file and the behavior embodied in the various DLLs loaded. The various processes running on the different computers use these instructions to act together and transport the station data over the network to the corporate server. Each process has the capability to log warnings, errors or informational messages to a standardized log file to provide information on how the system is performing.

X. Reliability

Another function of the Station SDR FrameWorx process is to ensure end-to-end communications integrity by monitoring the status of the station processes and the connection between the station and corporate servers. Status information from the station is published periodically and displayed by the corporate web application. Notifications can be sent to interested parties when problems are detected. The FxStatusMonitorDevice (Status Monitor) process (Fig. 6) receives the status messages from the station on a periodic basis. If the status information indicates that the station SDR server has an error, the status monitor updates the database on the corporate server to show one of the station SDR servers has an error condition. If the status monitor process does not receive any status messages from a station SDR server within a configured time span, the database will be updated to indicate a failure of the communications link or the station SDR.

FrameWorx processes ensure data transmission reliability on two levels, both at the TCP/IP stack and at the application data transmission layer. Processes communicate at the application layer using an end-to-end protocol with acknowledgement. All process-to-process communications are handled by the publication/subscription engine. Data are transported in a normalized fashion via discrete data points. Points are delivered to subscribing clients and held in an in-memory database for access within the process. Several subscription models are supported (change of value, time-based etc.).

If communications are lost between subscriber and publisher, the subscribing process will enter a reconnection state until communication is reestablished. Data are "spooled" (saved) by the publishing process on behalf of a subscribing client in the event of a communications loss, thus ensuring no data loss due to communications failure.

XI. Data Compression/Throttling

Because connections to many stations are over leased lines with limited bandwidth, FrameWorx provides a means to compress the data between the station and corporate servers when needed.

Although data compression can reduce the total bandwidth required bandwidth is a perishable resource, if not used it is wasted. Data compression alone does not solve the problem of needing instant access to a station. The GEM solution needs to share station bandwidth with AEP's SCADA group, which requires on-demand data access to the station, it is imperative that the process running on each station SDR server not take up all of the bandwidth at any given time. The FrameWorx service running on the station SDR server has a feature that allows data throttling over the communication link. This feature limits the data transmissions to a certain percentage of the available bandwidth, thus ensuring that the SCADA processes can complete their time-critical tasks. Data throttling is configured similar to other behaviors using the station SDR server configuration file.

XII. Corporate Server Components

Data are stored in both an SQL server database and to a file system structure that mirrors the storage on the station SDR server. All data are available for viewing by end-users via a web-based application. End-users may also register with the application for notification of certain events that can be delivered via email.

XIII. Visualization

Grid Enterprise Manager has a web-based visualization application, customized to AEP's specifications, that transforms the collected data into information that can be more easily interpreted and accessed by all associates with the proper access. A few of the pages available are discussed below.

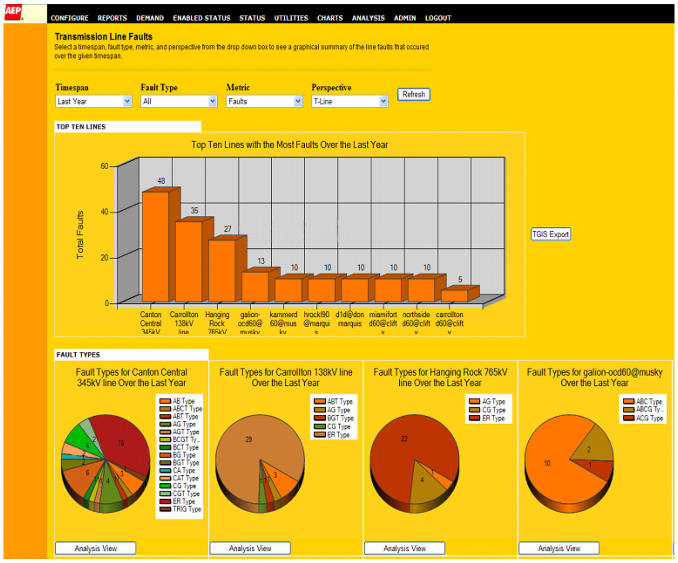

Fig. 7. Faults/Event Dashboard

The Faults/Event Dashboard gives users a quick view of the 10 areas with the highest occurrence of faults or events. The top section of the display shows a summary of the fault or event occurrence in decreasing order. The lower section of the display shows details of each station's faults or events. This information allows engineers and maintenance personnel to quickly identify areas that are or may adversely affect system performance. In many cases this can drastically improve the overall system reliability and allow allocation of improvements and upgrade resources to those areas in need rather than based solely on a scheduled maintenance and upgrade plan, thus also providing overall cost improvements.

The dashboard allows various filtering capabilities such as:

- Timespan :== View faults for the previous day, week, month, quarter, or year
- Fault Type :== Filter the results to specific faults or all fault types

- Metric :== Select either faults or events
- Perspective :== Select between transmission lines or stations

If more details are desired the Analysis button can be selected to view the actual data for the line or station of interest.

In Fig. 7, 3 stations have a relatively high number of faults. Engineering and maintenance personnel can then investigate these stations to determine if proactive maintenance or upgrades are necessary to reduce faults occurrences.

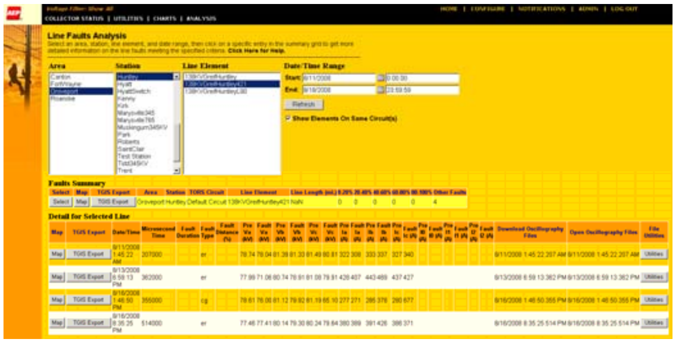

Fig. 8. Faults/Events Dashboard—Analysis (Details)

The Faults/Events Dashboard—Analysis display shows the details, actual data, of a station. This display presents the collected data in a tabular manner. This display page also allows one to navigate to any other station.

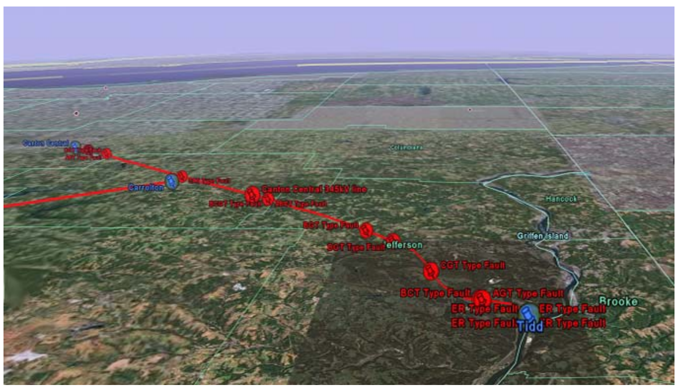

Fig. 9. Fault data overlay

In addition to allowing users to view trend and fault data, AEP GEM also allows users to view the physical locations of lines and faults rendered as an overlay using Google™ Earth (commercial license required). The overlay of geospatial data will display the transmission and distribution lines in the AEP GEM system highlighted in blue, except for the “top ten worst” lines, which will be highlighted in red (along with the associated station). Faults are displayed in the approximate geospatial location that they occurred. The same functionality, specific to a single transmission line and station, can also be viewed from the Faults/Events Dashboard—Analysis (Details) page.

XIV. Additional Analysis Tools

AEP has standardized using the Wavewin Universal analysis application from SoftStuf, Inc. This application provides many useful features with respect to the distributed design. These features include viewing multiple files simultaneously, being able to track the data cursors of all open windows with respect to time, and easily merging all files into one file if needed. It also provides a useful directory structure window, which allows for easy access to a mapped server drive to view the data.

Fig. 10–Fig. 13 provide typical Wavewin application views.

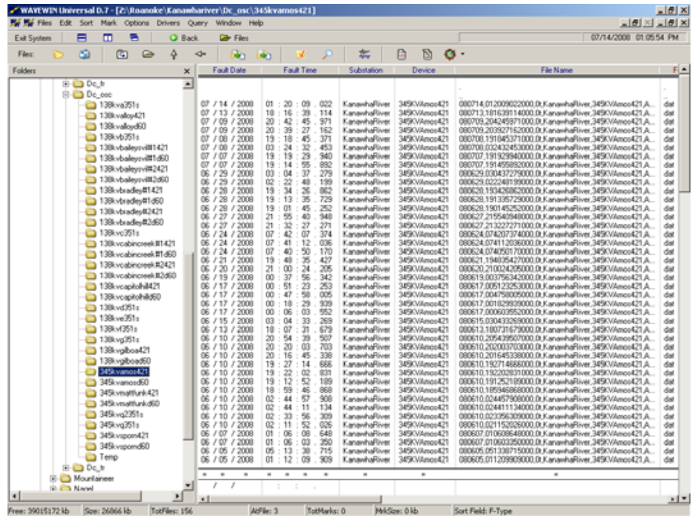

Fig. 10. Data server direction and file selection view

Fig. 10 illustrates the data server directory and file selection view. With this application, the user simply maps to the server drive where the fault data resides, allowing direct access to this data from Wavewin.

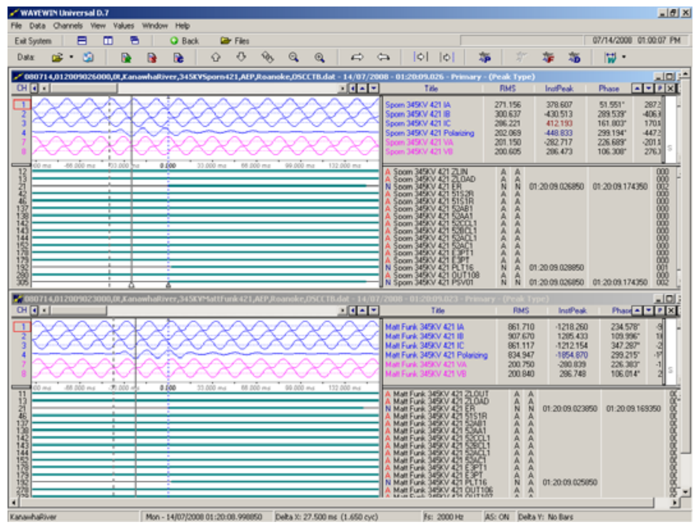

Fig. 11. Two relay files opened simultaneously

Fig. 11 shows two relay files opened simultaneously and with the data cursor time tracking feature enabled. Examining the traces from each file, you can see that the waveforms are in alignment by time. You can also observe from this figure where the analog and digital channel names were modified to more meaningful names.

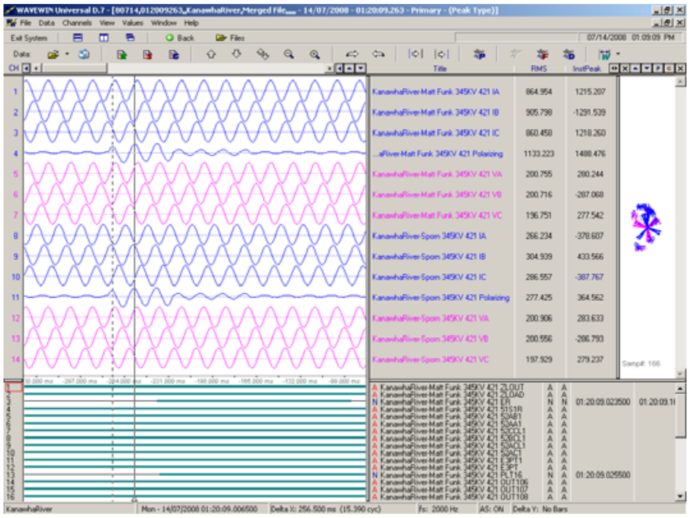

Fig. 12. Merging all open data windows

Using the traditional recording equipment approach, the analog and digital data are collect by a single device. Viewing the data collected is a matter of selecting the particular analog value or digital bit of interest. One of the concerns commonly expressed by engineers when presented with a distributed event collection system is that of how does one view the data in a single window when the data is from various sources?

Fig. 12 represents how, in just a matter of seconds, all open data windows can be merged into one data file. This example shows the merging of the two data files in Fig. 11. The merging feature is not limited to just two open files, but to all files open at the time. Using this approach, data from various sources can be viewed just as if it came from a single source.

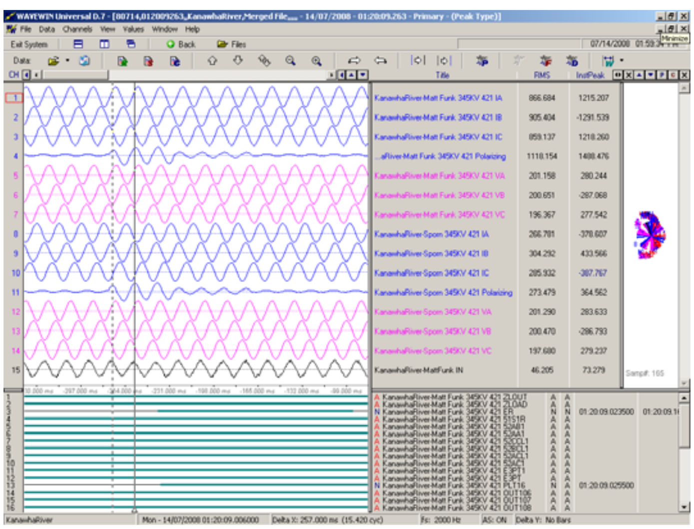

Fig. 13. Channel 15 added to provide a waveform

The AEP standard line panel provides for three-phase line current connections and one directional polarizing current source. The line neutral current is not directly connected to the relay. With Wavewin, software analog channels can be created. Fig. 13 shows where a software analog channel (15) has been added to provide a waveform for one of the line currents. This was programmed by writing an equation on the software analog channel configuration screen summing the associated three-phase currents.

XV. System Advantages

There are many advantages with this system when compared to traditional recording equipment.

A. Cost

This design takes advantage of the recording capabilities built into modern protective relays. Using the relays that are in place for protection to perform the recording provides significant savings in equipment and eliminates the labor-intensive wiring needed to provide the signals to the recording device. A typical AEP traditional recording device was a unit that included the recording equipment packaged in a pre-wired cabinet complete with isolating test switches for all signal inputs. The units were built for standard sizes of 32 analog/64 events, 48 analog/96 events, and 64 analog/128 events. In 2003, a typical 32 analog/64 event recorder installation cost around $250,000 (in 2008 dollars). This cost included material, labor, and company overheads. The cost to install the SDR system in a station is, at most, approximately $50,000. This is a savings of 80 percent when compared with a 32 analog recorder. With about 300 stations within the AEP system that require disturbance monitoring, this results in an overall savings of up to $60 million. The saving potential could likely be higher given the new NERC and regional reliability council requirements of monitoring all currents and all voltages on each circuit element in a station. Because of this requirement, many of the stations once covered by a 32 analog recorder would need to have the recorder increased in size.

B. Redundancy

This system provides redundancy typically not found in traditional recorder systems. The AEP standard panel design utilizes two redundant protection systems. Since data are continuously captured by both relay systems, AEP can tolerate the failure of one of those systems and not lose any critical data.

C. Distributed Design

Given the distributed nature of this design, one recording component failure will not take out the whole system. If one relay fails, there is a second relay for that zone of protection with the same ability to record the system data. If the station SDR Server should fail, then the relay's recording capability is still functional, though data retrieval falls back to a manual mode.

D. Reduction of a Catastrophic Failure Mode

The NERC requirements make it necessary to wire most if not all of the current and potential sources in the station into a monitoring cabinet when the traditional approach is taken. A single contingency of a fire in that cabinet will jeopardize the reliability of every one of those circuits for up to several weeks should a fire occur. Designing a monitoring system using relays that are distributed throughout the control house minimizes the possibility of a catastrophic single point of failure within the station. Furthermore, transporting the data out of the station to corporate servers provides data redundancy and centralization of the management of the data.

XVI. Biographies

Charles Jones received his BSEE in 1982 from West Virginia University. He works for the transmission company of American Electric Power in Gahanna, Ohio with 24 years of service. He is a Principal Engineer currently working in the Protection and Control Asset Engineering section developing the standard protection panels for transmission, station data networks, station automation and SCADA. Other work experience includes Columbia Gas Transmission Company where he designed control systems for natural gas compressor stations. He is currently pursuing a MEEE degree from the University of Idaho. He is a registered professional engineer in the state of West Virginia and Ohio and an IEEE member.

Declan Smith received his BSEE in 1981 from Kevin Street Technical Institute in Dublin, Ireland. He worked for AccuRay Corporation, Ireland, as a Test Engineer from 1981 to 1984. He was transferred to AccuRay's corporate headquarters in Columbus, Ohio, in 1984 where he worked as an Application Software Engineer. ABB acquired AccuRay in 1988. Declan continued to work as an Application Software Engineer for ABB until 1990. In 1990, Declan started SofPak, a software development company now known as Tarigma Corporation where he is currently President. Tarigma Corporation provides mission-critical software, running 24/7/365, to the steel, paper, and electrical utilities industries.

Jim Schnegg received a BSEE degree from Ohio State University in 1976. He worked for Goodyear Atomic for four years as Production Engineer at a Uranium enrichment plant in Ohio. In May of 1980, he began his career as a protection engineer with American Electric Power. At AEP, he held various positions in protection and control of stations and transmission systems. In May of 2000, he joined Schweitzer Engineering Laboratories, Inc. as an Application Engineer. He now serves as a Senior Application Engineer. He is a registered professional engineer in the state of Ohio and an IEEE member.

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