Automated Event Retrieval Reduces Operating Costs

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Published in
SEL *Journal of Reliable Power*, Volume 1, Number 2, October 2010

Previously presented at the
35th Annual Western Protective Relay Conference, October 2008,
and 10th Annual Western Power Delivery Automation Conference, April 2008

Previous revised edition released December 2008

Originally presented at the
61st Annual Conference for Protective Relay Engineers, April 2008

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***Abstract*—In August 2007, Oncor Electric Delivery began installing a centralized automatic relay event retrieval and indexing system. With over 400 transmission substations and 3,600 relays capable of recording critical event data, Oncor wanted to improve their existing process of dispatching a technician to a substation each time a critical event occurred that needed further review. Beyond the obvious operating cost savings associated with retrieving critical event data, Oncor had additional ideas for using the data.**

Analyzing every event file where the relay sensed a fault condition and the breaker cleared it is an opportunity to gauge the health of the protection and control system. Relays that generate power system event reports ranging from a few cycles to a few seconds provide the opportunity to see fault inception, relay response, and breaker operation. To analyze every event file, Oncor developed a process to retrieve event records from their protective relays.

It is often assumed that automatic event collection systems require installation of new and potentially costly communications equipment for high-speed data transfer. Additionally, proposed North American Electric Reliability Cooperation (NERC) Critical Infrastructure Protection (CIP) reliability standards are often interpreted as mandates to apply potentially expensive and complex firewalls or software security to associated communications channels. Considering the high costs of applying this equipment or software across 400 transmission substations, Oncor engineers immediately recognized that they could obtain significant cost savings if the recommended security guidelines and event collection requirements could be satisfied using existing installed communications equipment. Oncor met this goal with minimal hardware installations. This paper highlights the installed system and provides a summary of installation and operational benefits.

I. Background

Oncor Electric Delivery (Oncor) is an electric distribution and transmission business that provides power to more than three million homes and businesses throughout east, west, and north central Texas. Oncor has more than 115,000 miles of transmission and distribution lines and 900 substations throughout the state.

In the 1990s, Oncor began deploying digital fault recorders (DFRs) in their substations. In January 1997, due to the amount of information coming from the DFRs and in order to address the need to efficiently analyze, categorize, and prioritize DFR records, Oncor finalized a software development contract with Texas A&M University. The project included the development of automated DFR event classification logic and universal viewing software. Reference [1] highlights Oncor's initial system.

Over the last 10 years, the DFR program has grown from 80 to over 230 data acquisition units with automatic DFR event retrieval. Fig. 1 shows the present system. Initially, the system monitored between 32 and 64 analog channels and 64 to 128 digital channels at each location. Today, Oncor has nearly doubled the analog and digital data channels at each site. Of the 235 DFRs, over 30 are dual purpose and provide Oncor with transient and long-term recording capabilities.

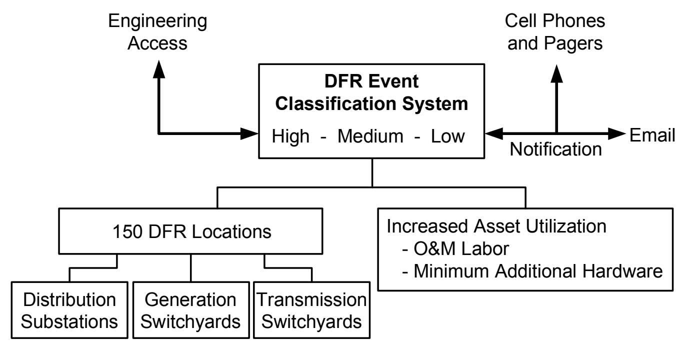


Fig. 1. Oncor Electric Delivery Classification System

While Oncor continues to make software improvements to the event classification software, the overall event priority criteria remain the same.

- High priority: undesirable operations
- Medium priority: events from correct operations or reclose failure
- Low priority: manually triggered, switching operations, or remote fault events

See Fig. 2 for additional details on event classification [1].

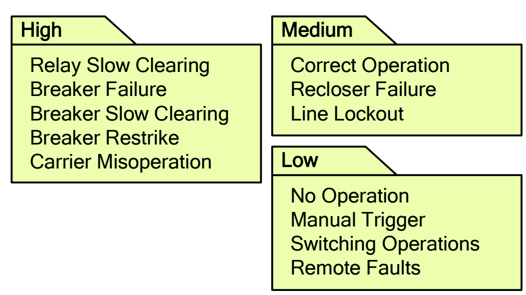
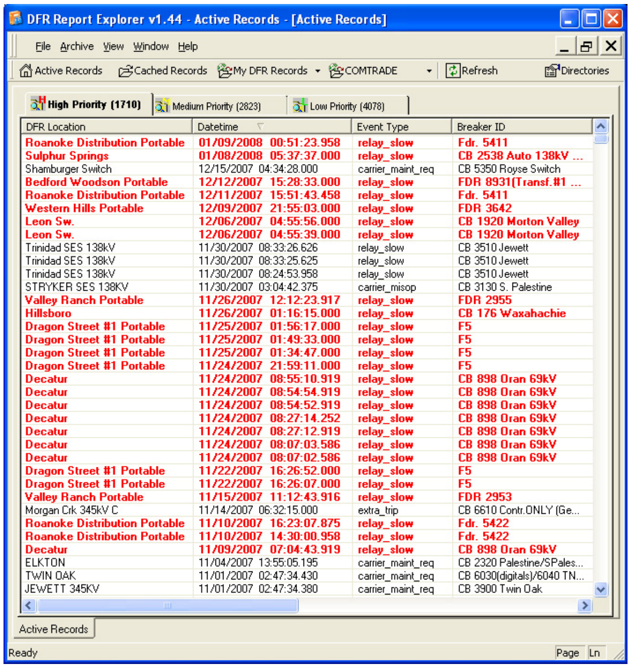


Fig. 2. Event Priority Classification

Oncor uses the DFR report data to help schedule maintenance or review relay settings. Fig. 3 shows three months of high-priority DFR records that alerted Oncor personnel to issues that resulted in an unexpected operation, such as delayed relay trip time or required carrier maintenance.



DFR Location	Datetime	Event Type	Breaker ID
Roanoke Distribution Portable	01/09/2008 00:51:23.958	relay_slow	Fdr. 5411
Sulphur Springs	01/08/2008 05:37:37.000	relay_slow	CB 2538 Auto 138kV ...
Shamburger Switch	12/15/2007 04:34:28.000	carrier_maint_req	CB 5350 Royse Switch
Bedford Woodson Portable	12/12/2007 15:28:33.000	relay_slow	FDR 8931(Transf.#1 ...
Roanoke Distribution Portable	12/11/2007 15:51:43.458	relay_slow	Fdr. 5411
Western Hills Portable	12/09/2007 21:55:03.000	relay_slow	FDR 3642
Leon Sw.	12/06/2007 04:55:56.000	relay_slow	CB 1920 Morton Valley
Leon Sw.	12/06/2007 04:55:39.000	relay_slow	CB 1920 Morton Valley
Trinidad SES 138kV	11/30/2007 08:33:26.626	relay_slow	CB 3510 Jewett
Trinidad SES 138kV	11/30/2007 08:33:25.625	relay_slow	CB 3510 Jewett
Trinidad SES 138kV	11/30/2007 08:24:53.958	relay_slow	CB 3510 Jewett
STRYKER SES 138KV	11/30/2007 03:04:42.375	carrier_misop	CB 3130 S. Palestine
Valley Ranch Portable	11/26/2007 12:12:23.917	relay_slow	FDR 2955
Hillsboro	11/26/2007 01:16:15.000	relay_slow	CB 176 Waxahachie
Dragon Street #1 Portable	11/25/2007 01:56:17.000	relay_slow	F5
Dragon Street #1 Portable	11/25/2007 01:49:33.000	relay_slow	F5
Dragon Street #1 Portable	11/25/2007 01:34:47.000	relay_slow	F5
Dragon Street #1 Portable	11/24/2007 21:59:11.000	relay_slow	F5
Decatur	11/24/2007 08:55:10.919	relay_slow	CB 898 Oran 69kV
Decatur	11/24/2007 08:54:54.919	relay_slow	CB 898 Oran 69kV
Decatur	11/24/2007 08:54:52.919	relay_slow	CB 898 Oran 69kV
Decatur	11/24/2007 08:27:14.252	relay_slow	CB 898 Oran 69kV
Decatur	11/24/2007 08:27:12.919	relay_slow	CB 898 Oran 69kV
Decatur	11/24/2007 08:07:03.586	relay_slow	CB 898 Oran 69kV
Decatur	11/24/2007 08:07:02.586	relay_slow	CB 898 Oran 69kV
Dragon Street #1 Portable	11/22/2007 16:26:52.000	relay_slow	F5
Dragon Street #1 Portable	11/22/2007 16:26:07.000	relay_slow	F5
Valley Ranch Portable	11/15/2007 11:12:43.916	relay_slow	FDR 2953
Morgan Crk 345kV C	11/14/2007 06:32:15.000	extra_trip	CB 6610 Contr.ONLY (Ge...
Roanoke Distribution Portable	11/10/2007 16:23:07.875	relay_slow	Fdr. 5422
Roanoke Distribution Portable	11/10/2007 14:30:00.958	relay_slow	Fdr. 5422
Decatur	11/09/2007 07:04:43.919	relay_slow	CB 898 Oran 69kV
ELKTON	11/04/2007 13:55:05.195	carrier_maint_req	CB 2320 Palestine/SPales...
TWIN OAK	11/01/2007 02:47:34.430	carrier_maint_req	CB 6030(digitals)/6040 TN...
JEWETT 345KV	11/01/2007 02:47:34.380	carrier_maint_req	CB 3900 Twin Oak

Fig. 3. High-Priority Event Records

Looking at the details of each specific event, Oncor engineers are able to determine the root cause and make appropriate changes to improve future operation. The event report in Fig. 4 resulted from a high-priority event classification (Relay Slow Clearing due to carrier delay). Engineers were able to schedule carrier maintenance to ensure the problem would not occur again.

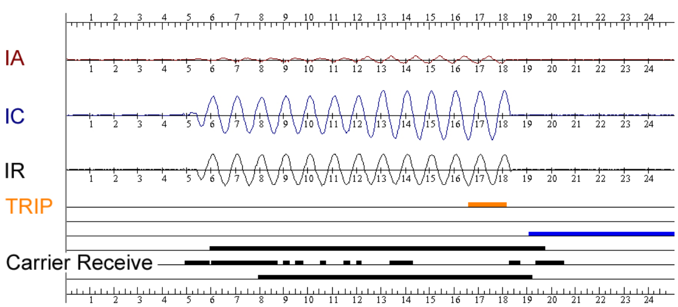


Fig. 4. High-Priority Event Record

Annually, the system automatically retrieves and analyzes over 12,000 events. The system automatically diagnoses the following:

- Fault location
- Power grid impact
- Event root cause
- Breaker problems
- CT and PT instrumentation issues

With over 10 years of success with the DFR automatic file collection and classification, Oncor decided to extend this capability to protective relays (see Fig. 5). Oncor has over 400 transmission substations with more than 3,600 protective relays in operation that are capable of storing event reports.

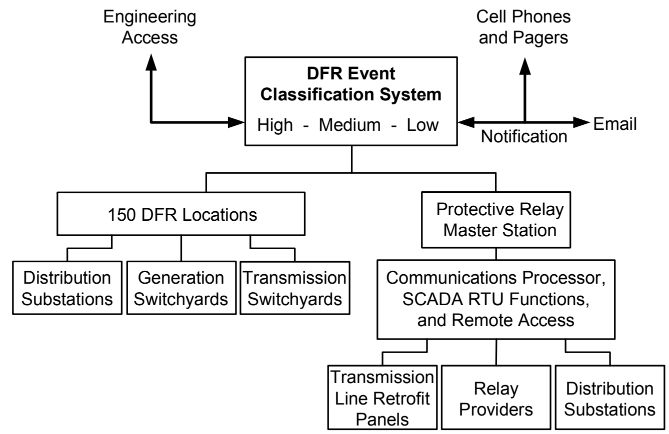


Fig. 5. System Modified for Protective Relay Automatic Event Retrieval

II. Proposed System

Oncor's substation protection schemes generally require primary and backup relays using communications-assisted protection schemes. The associated permissive trip or blocking signal comes from a carrier device wired to the relay's contact I/O. In addition, a serial cable connects the relay to a communications processor where data from up to 15 relays are gathered and passed on to a DNP or Modbus® master (see Fig. 6). Via either protocol, the operation center collects target and meter data for monitoring and control.

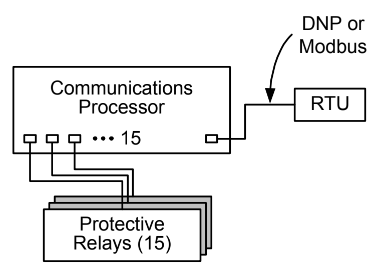


Fig. 6. Traditional SCADA Connection

With a system already in place to communicate to each of the relays, Oncor wanted to mirror the success of the DFR automatic event retrieval system and add dial-up modem communications to the communications processor. Due to the DFR program, most of Oncor's substations already had dial-up access. With the 16 ports available on the communications processor, the modem access port would take the place of one protective relay and could coexist with the DNP or Modbus server port (see Fig. 7). While this approach is definitely the least costly method of obtaining relay event reports, Oncor engineers looked for alternatives to improve the security.

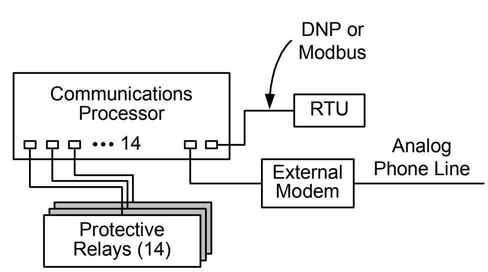


Fig. 7. Proposed Event Retrieval With Analog Phone Line

Oncor is underway to expand Ethernet communications to their substations. The first two test sites went online in October 2007, and Oncor wanted to make sure this proposed system could adapt to Ethernet communications. Using the communications processor, they could either communicate by adding a direct Ethernet connection or by using a serial-to-Ethernet transceiver (see Fig. 8). Oncor chose the transceiver. In addition to being more economical than adding an Ethernet port, the serial-to-Ethernet transceiver would later provide security consistent with the dial-up application and simplify settings management.

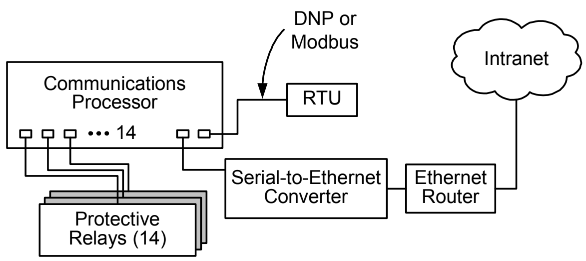


Fig. 8. Proposed Event Retrieval With Ethernet Connection

On the master station side, Oncor used a configuration similar to the DFR system. External modems connect the master station computer to the remote locations. The master station uses a static IP address so the communications processors that are connected via serial-to-Ethernet transceivers know through which port to send the data. The automatic event classification and archiving software communicates to the master station. Once the master station retrieves the events, the classification program, similar to the program already in place for DFR records, assigns priority to the events (see Fig. 9). Oncor met their goal of integrating 20 substations in 2007 and will complete the remaining substation installations in 2008.

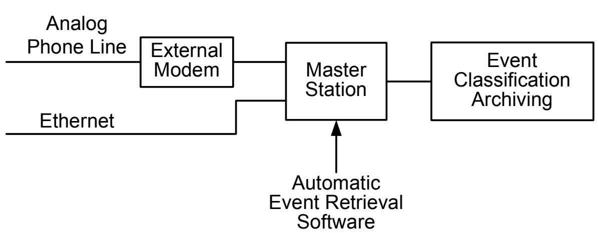


Fig. 9. Master Station Connections

While this system mimics the proven communications system of the DFR program, Oncor knew NERC/CIP Reliability Standards specified requirements for the electronic security perimeter associated with dial-up and Ethernet access to critical cyber assets.

III. How NERC/CIP Could Impact This Automatic Event Retrieval Process

On January 16, 2006, NERC proposed the following CIP Reliability Standards [2]:

CIP-002–Critical Cyber Asset Identification

CIP-003–Security Management Controls

CIP-004–Personnel and Training

CIP-005–Electronic Security Perimeters

CIP-006–Physical Security

CIP-007–Systems Security Management

CIP-008–Incident Reporting and Response Planning

CIP-009–Recovery Plans for Critical Cyber Assets

CIP standards 002, 003, 005, and 007 directly impact the implementation of dial-up modem and Ethernet access to protective relays. Oncor expects to use collected event data to aid in compliance with future NERC relay maintenance standards. Oncor has implemented and documented a plan to protect critical cyber assets in order to comply with CIP-003, Requirement 4. This plan is confidential; however, we will discuss one element of the plan for improving security.

A. *CIP-002–Critical Cyber Asset Identification*

CIP-002 provides definitions for critical assets, cyber assets, and critical cyber assets. In a system with dial-up access, the communications processor could be subject to CIP-002, while the relays are not. Although the relays have routable protocols, they were not required for this application where all communications use nonroutable protocols. Distance relays commonly use communications-aided protection schemes; however, by definition, due to communications between discrete electronic security perimeters, they are exempt from CIP-002. To provide "defense in depth" [3] to their protective relays, utilities take additional steps as outlined in [4]. In contrast, the DFRs may not be affected by these NERC/CIP standards—depending on how your company views the DFR data.

B. *CIP-003–Security Management Controls*

CIP-003, Requirements 4 and 5 apply to automatic event retrieval from protective relays. Requirement 4, Information Protection, requires implementing and documenting a program to identify, classify, and protect information associated with critical cyber assets. Requirement 5 addresses access control. This requirement addresses the need for a program to document and manage access to critical cyber assets. Because Oncor needed dial-up and Ethernet communications in their substations, they looked for an innovative and economical way to limit access to the communications processor (see Section IV), thus meeting the intent of CIP-005, Requirement 2.1.

C. *CIP-005–Electronic Security Perimeter*

CIP-005 details the requirements that define the electronic security perimeter, monitoring of electronic access, and cyber vulnerability assessment. Clearly, if the communications processor is a critical cyber asset, it needs an electronic security perimeter and additional security to meet these requirements. Oncor chose to incorporate existing technology rather than invest in new technology that would add to the overall project cost and complexity.

D. *CIP-007–Systems Security Management*

CIP-007 defines the methods, processes, and procedures for securing critical cyber assets and other cyber assets within the electronic security perimeter.

IV. Adding Defense in Depth

Oncor improved control access security using the NOCONN (no connections permitted) function in the communications processor. NOCONN terminates existing connections and blocks requested communications on each individual port. The NOCONN function meets the security standard by aborting transmissions in progress, terminating the receipt of characters, and blocking connections. This communications termination appears the same as a port time out to other connective devices.

Each port in the communications processor contains the NOCONN function. Users enter either a setting to permanently enable or disable the port or a control equation to specify the condition in which NOCONN is used.

Oncor uses the NOCONN solution as one of several defense mechanisms. In the normal state, NOCONN remains on until an event occurs. Once the relay has a new available event, the communications processor turns off NOCONN and allows the modem to dial out or the Ethernet port to connect to the master station. Once the communications processor transfers the event to the master station, the communications processor turns on NOCONN and blocks any external communications. During the outgoing transmission, the communications line is in use and blocks other communications attempts. Users define the specific dial-out number for modem applications or the specific static IP address of the master station for Ethernet applications as part of the communications processor's set file.

As an additional benefit to this secure system, Oncor engineers have remote engineering access to the protective relays. Oncor accomplished this by modifying the NOCONN logic to accept known remote access to the communications processor. To comply with NERC/CIP reliability standards, Oncor will have to develop strong procedural or technical controls to authorize and log temporary remote access. As with automatic event transmission, other communication is blocked during temporary access.

V. System Operation

The master station contains automatic event retrieval software. Similar to other relay setting programs, Oncor created a connection directory for each protective relay (Fig. 10). The connection directory includes connection information (modem or Ethernet) for the communications processor and the appropriate port to which the relay is connected.

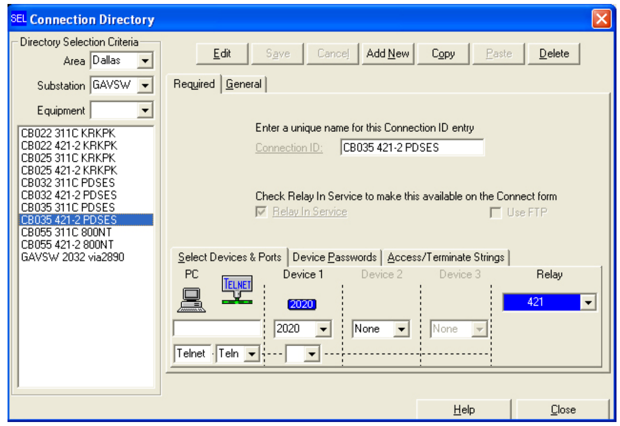


Fig. 10. Configuring Connection Directory

Once Oncor configures the connection directory, they define the specific event reports that the software extracts from the relay (Fig. 11). Options include standard ASCII-based event reports, compressed event reports, or raw COMTRADE files.

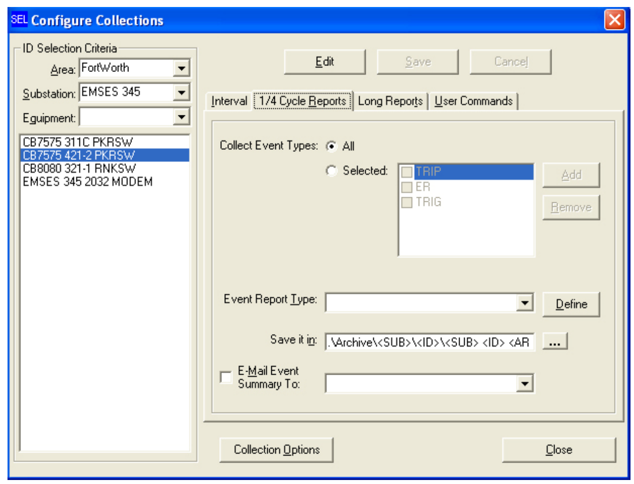


Fig. 11. Selecting Event Collection Options

When the software saves an event report or capture of a user command, it saves the data relative to the end user's file naming needs (see Fig. 12). This dynamic file naming ability conforms to the recently approved IEEE C37.232 standard [5].

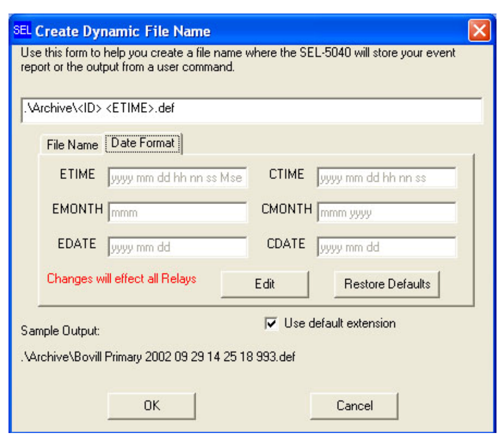


Fig. 12. Available Naming Conventions per C37.232

Depending on requirements, the software allows for two modes of operation: polling and listening.

- Polling allows the software to repeat a series of event collections based on time and date intervals.
- Listening places the software in a state to listen for incoming calls from a communications processor on a direct serial, modem, or Ethernet connection.

Due to the number of protective relays on their system, Oncor only enabled the listening mode. The software allows different parameters for serial modem and Ethernet (telnet) communications.

In listening mode, when an event becomes available in the protective relay, the NOCONN function is disabled and the communications processor dials out to the master station. Similarly, if the communications processor uses Ethernet to connect to the master station, the communications processor enables its serial port, allowing the serial-to-Ethernet transceiver to connect to the master station.

The software creates a database of all retrieved records (Fig. 13), and it provides a user interface for viewing each report. Oncor archives the event reports for long-term storage.

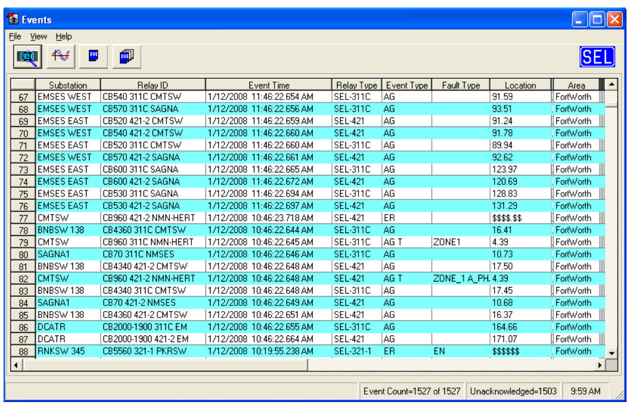


Fig. 13. Software Event Viewer

The software supports email notification of new events (Fig. 14). Oncor can set the software to email the event summary or the entire event to predefined individuals. The email contains information similar to the relay event summary, so it can quickly alert the operator of fault magnitudes and distances, allowing quicker power restoration.

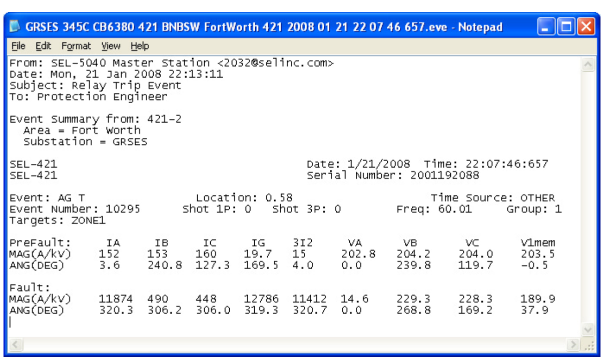


Fig. 14. Sample Email Notification

Reference [6] provides additional details on the protective relay, communications processor, and software configuration.

VI. Added Benefits

Beyond collecting event reports, the automatic event retrieval software also allows user-specified commands. Operators configure up to ten specific commands, and the software stores the relay's response to each command in a uniquely named text file. Fig. 15 shows the user command configuration dialog. With this configuration, the relay responds with breaker monitoring data (shown in Fig. 16). Once the relay transfers all available event reports to the master station, the software issues and records the response to all user-specified commands.

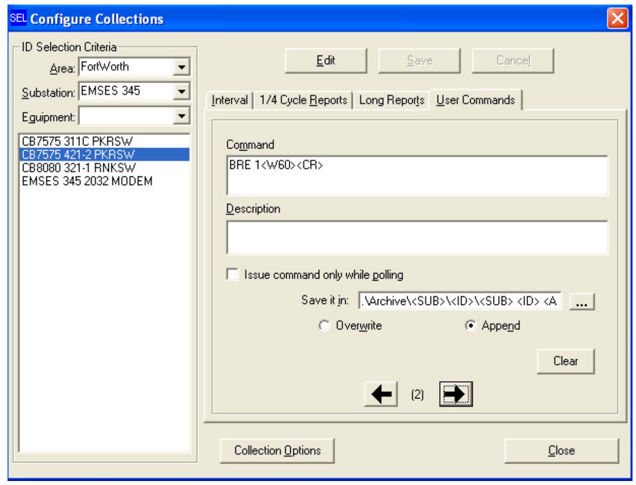


Fig. 15. Configuring User Commands (Breaker Monitor)

Fig. 16 shows the output for the breaker wear command. It includes information such as electrical and mechanical operating time, accumulated primary current interrupted, and maximum current interrupted.

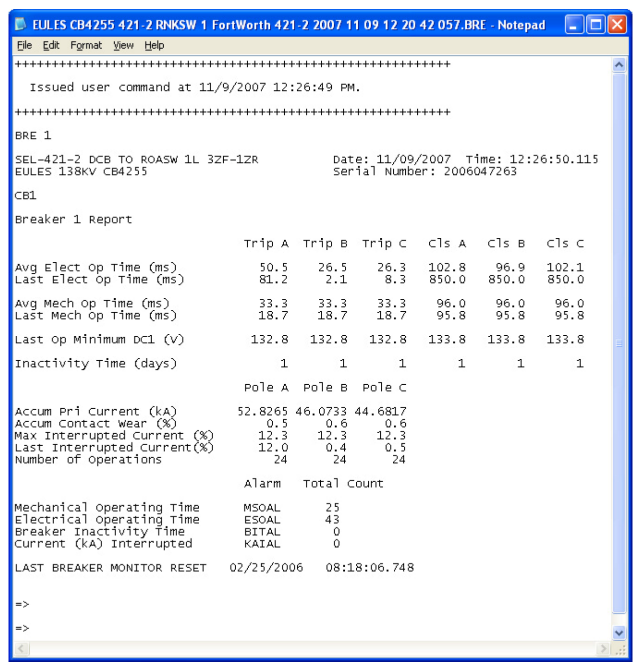
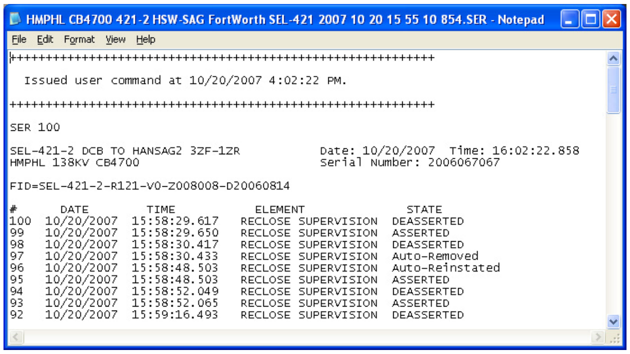


Fig. 16. Breaker Monitor Report

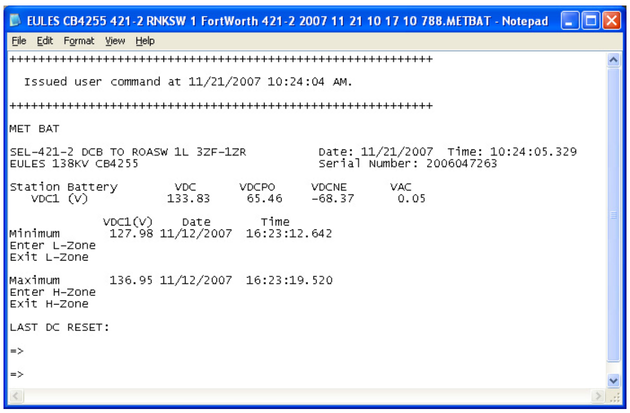
When analyzing event reports, it is helpful to have sequential events reports (SER). By entering a user-specified command, Oncor obtains SER data. In Fig. 17, Oncor used the **SER 100** command to obtain the latest 100 entries. Normally, SER records provide information relevant to reclose intervals and carrier issues. In this example, the SER records uncovered an unmonitored system issue, which could have negatively affected the outcome of a future event.



```
HMPHL CB4700 421-2 HSW-SAG FortWorth SEL-421 2007 10 20 15 55 10 854.SER - Notepad
File Edit Format View Help
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

  Issued user command at 10/20/2007 4:02:22 PM.

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

SER 100

SEL-421-2 DCB TO HANSAG2 3ZF-1ZR           Date: 10/20/2007  Time: 16:02:22.858
HMPHL 138KV CB4700                         Serial Number: 2006067067

FID=SEL-421-2-R121-V0-Z008008-D20060814

#      DATE        TIME          ELEMENT              STATE
100  10/20/2007  15:58:29.617  RECLOSE SUPERVISION  DEASSERTED
99   10/20/2007  15:58:29.650  RECLOSE SUPERVISION  ASSERTED
98   10/20/2007  15:58:30.417  RECLOSE SUPERVISION  DEASSERTED
97   10/20/2007  15:58:30.433  RECLOSE SUPERVISION  Auto-Removed
96   10/20/2007  15:58:48.503  RECLOSE SUPERVISION  Auto-Reinstated
95   10/20/2007  15:58:48.503  RECLOSE SUPERVISION  ASSERTED
94   10/20/2007  15:58:52.049  RECLOSE SUPERVISION  DEASSERTED
93   10/20/2007  15:58:52.065  RECLOSE SUPERVISION  ASSERTED
92   10/20/2007  15:59:16.493  RECLOSE SUPERVISION  DEASSERTED
```

Fig. 17. Sequential Events Report

Oncor issues the **MET BAT** command to get station battery monitoring information, as shown in Fig. 18.



```
EULES CB4255 421-2 RNKSW 1 FortWorth 421-2 2007 11 21 10 17 10 788.METBAT - Notepad
File Edit Format View Help
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

  Issued user command at 11/21/2007 10:24:04 AM.

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

MET BAT

SEL-421-2 DCB TO ROASW 1L 3ZF-1ZR          Date: 11/21/2007  Time: 10:24:05.329
EULES 138KV CB4255                         Serial Number: 2006047263

Station Battery        VDC       VDCPO     VDCNE      VAC
   VDC1 (V)          133.83      65.46    -68.37      0.05

                 VDC1(V)    Date        Time
Minimum           127.98 11/12/2007  16:23:12.642
Enter L-Zone
Exit L-Zone

Maximum           136.95 11/12/2007  16:23:19.520
Enter H-Zone
Exit H-Zone

LAST DC RESET:

=>

=>
```

Fig. 18. Battery Summary Report

In addition to automatically prioritizing relay fault event records, Oncor expects to modify the classification software to review the available text files. This additional benefit provides more data points to allow Oncor to monitor the health of their power system including:

- Fault location
- Reclose intervals
- Carrier signal integrity
- Breaker failure
- Breaker operate time
- Battery alarms

VII. Results

From August 2007 to the end of the year, Oncor successfully commissioned over 20 substations with the automatic event retrieval software. This includes automatic event retrieval from over 150 protective relays using either dial-up or Ethernet connections.

On average, the master station receives the event within 5–10 minutes of the protective relay generating the event report. This time varies because the same event is recorded in multiple relays at each end of the line (for a transmission fault). To help illustrate the benefits Oncor has already realized, consider the following three examples.

A. Recurring Fault and Use of Two-Ended Fault Calculation Pinpoints Location

In November 2007, Oncor experienced two faults, one day apart, on their 345 kV system. They suspected the same fault location. With a line length of 78.9 miles, one relay calculated a single-end distance to fault of 51 miles, and based on the same reference point, the relay at the other end calculated 58.6 miles (see Fig. 19 and Fig. 20). Note that single-ended fault distance calculations require specific fault resistance assumptions.

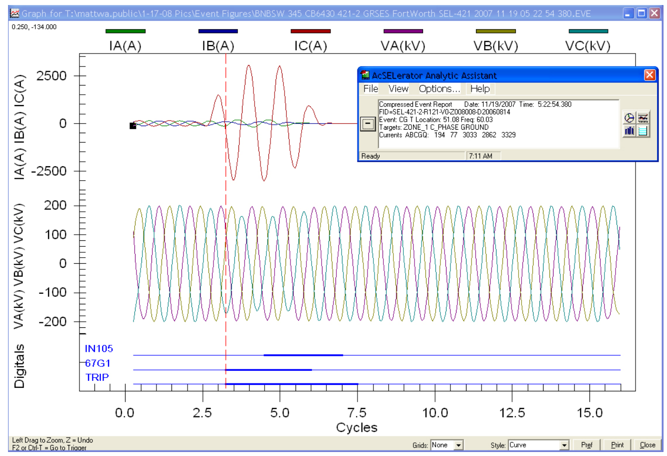


Fig. 19. Example I: Local Switchyard, 51 Miles

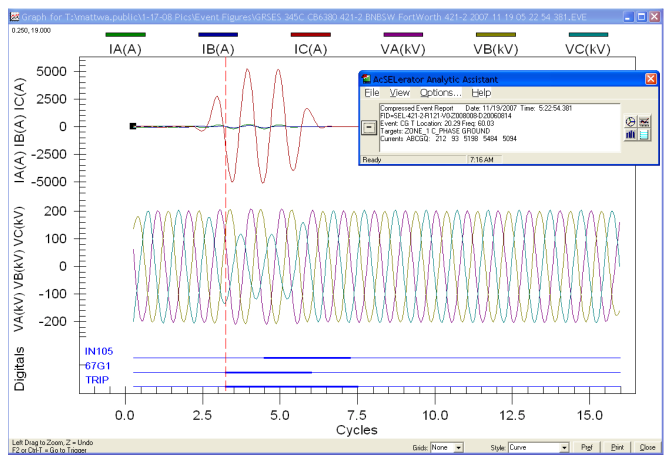


Fig. 20. Example I: Remote Switchyard, 20.3 Miles

Using a Mathcad® worksheet designed to take fault information from both ends of the line, Oncor calculated a distance of 54.4 miles. The local field employee found the fault and estimated the actual distance to be 54.25 miles. By having the event reports automatically transfer to the master station, Oncor was able to provide a more accurate distance-to-fault measurement and restore the line faster.

B. Multiple PT Grounds Cause Undesired Relay Operations

In October, one of Oncor's 138 kV lines experienced a fault. One of the protective relays operated unexpectedly for a reverse fault (see Fig. 21). Comparing the time stamps in

Fig. 22 and Fig. 17, the master station received the event report within seven minutes. After review, Oncor engineers quickly noted incorrect prefault voltage measurements. As a result, the relay received improper information on which to base a directional decision and performed an undesired operation. Later, a review of the SER log obtained during the automatic event collection supported the suspicion of multiple PT grounds (see Fig. 17).

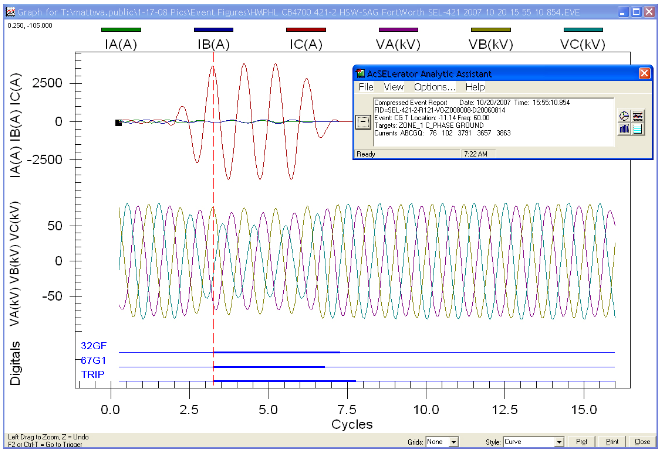


Fig. 21. Sample 138 kV Fault Record

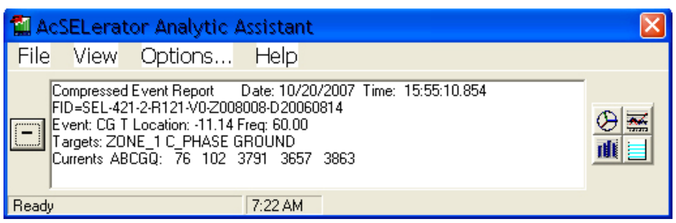


Fig. 22. Sample 138 kV Fault Record Summary Showing Time Stamp

C. *Periodic Event Trigger*

Oncor engineers wanted a method to automatically trigger relay event reports and automatically retrieve them using the master station software. In order to do this, they programmed the communications processor to periodically trigger an event report in the relay. Once the relay sends the event report summary to the communications processor, the communications processor begins the connection process as if the power system triggered the event in the relay.

VIII. Future Direction and Enhancements

Now that the master station has event data coming from the protective relays, Oncor can begin implementing the rules to interpret the data. This includes incorporating the event report and user data into the event classification software. In addition, Oncor wants to continue with the project and innovate even further.

A. *Automatic Two-Ended Fault Location*

While the master station is receiving event data from each end of the transmission line, Oncor would like an add-on module to calculate the two-ended fault location and email the summary to the local dispatcher.

B. *Actual Relay Settings Compared With the As-Set Database*

Each event report contains the active settings within the protective relay. This provides an opportunity for an auto-check with the settings located in the master relay settings database. Automatically checking the as-set settings with the actual settings provides another check to the overall management, such as technician training, and provides power system security.

C. *Automatic Emailing*

The automatic event retrieval software presently supports event summary or entire event emailing. After comparing the faults collected from the initial 20 substations, Oncor gained a high confidence in the single-ended fault location provided by the relay. Oncor plans to use this feature to help restore power faster.

D. *Needs-Based Maintenance*

Utilities commonly use periodic-based maintenance programs to schedule equipment service and repair. Now, with the available data, Oncor expects to schedule maintenance based on need. For example, the breaker user report provides information regarding contact wear, as well as electrical and mechanical system health. Operating times falling within a specific range could provide enough information to extend maintenance intervals.

IX. Conclusion

Based on realized cost savings, Oncor is continuing to implement this software in its present state to all its substations. Oncor hopes to use the future enhancements mentioned above to aid in compliance with future NERC relay maintenance standards. These future enhancements will add another layer of defense to an already secure power system.

X. References

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XI. Biographies

Todd Rosenberger received his BS from Rensselaer Polytechnic Institute in 1993 and his ME from Rensselaer Polytechnic Institute in 1994. Prior to joining Oncor Electric Delivery in 2001, he worked seven years for the National Grid as a substation engineer. He is a P.E. in the states of Texas and Massachusetts.

David Prestwich received his BS in Mathematics from the University of Idaho in 1999. He has been a Product Engineer for the PC Software group at Schweitzer Engineering Laboratories, Inc. for the past two years and has led several projects touching a wide variety of SEL products. Prior to joining SEL, he worked as an automation engineer implementing control systems around the world.

Matthew B. Watkins received his BS, Summa Cum Laude from Michigan Technological University in 1996 and an MBA from Cardinal Stritch University in 2003. Prior to joining Schweitzer Engineering Laboratories, Inc. in 2005, he worked for five years as a distribution protection engineer, responsible for the applications of reclosers throughout the distribution system. Presently, he is an SEL field application engineer in Dallas/Fort Worth, TX, and is a member of the IEEE.

Mark S. Weber received his AAS in Electronics Engineering Technology in 1985. Since 1986, he has been with Schweitzer Engineering Laboratories, Inc. His work includes product support, design, and training. Since 2006, he has been a supervisor in SEL's Automation and Integration Engineering group. During his time at SEL, he has authored and co-authored several technical papers and application guides.

Previously presented at the 2008 Texas A&M
Conference for Protective Relay Engineers.

20081216 • TP6311-01