Implement a Relay Replacement Program to Enhance System Performance and Flexibility and Reduce Costs

Peter Allen

Introduction

Generation, transmission, distribution, and their regulation continuously evolve. The equipment monitoring and protecting the power system needs to be flexible to meet these changes. For example, several U.S. states have pledged to convert to 100 percent renewable energy in the coming decades, which would remove the inertia-based generation that has long stabilized system frequencies, and replace it with variable sources that require more intelligent monitoring devices. Intelligent and automated decision-making is becoming more important than ever for utilities to maintain operating costs, safety, and power reliability. Digital relays, such as those from SEL, adapt to power flow changes and other changes in system conditions with flexible settings, custom logic, and multiple settings groups.

Additionally, the fault location information provided by digital relays minimizes outages and reduces the time field technicians spend searching for issues. Improving how the power system is monitored and controlled can provide operations and maintenance benefits that exceed the initial capital investment. This paper examines both the financial and nonmonetary benefits provided by relay replacement programs.

Benefits of Digital Relays

Multifunction digital relays require less wiring than electromechanical alternatives. They also save technicians' time by making intelligent decisions and implementing remote controls, enabling rapid and automatic system operations [1] [2]. Digital relays can be reset via SCADA, which reduces the number of visits to substations to reset electromechanical relay flags [2].

Digital relays also provide load and fault data that can assist with system performance, and they provide telemetry data that can increase critical asset longevity. Short-circuit and power flow modeling using these data allows for model accuracy verification and improvement, reducing the need for safety margins and extended trip times. Asset maintenance prioritization and condition-based monitoring programs can be implemented using the data and recording capabilities of digital relays (such as breaker wear data recording), which come standard in SEL relays.

Other data captured by digital relays include breaker open and close timing (a simple calculation in SEL Real-Time Automation Controllers [RTACs] using Sequential Events Recorder data), through-fault current on a transformer, transformer temperature monitoring to calculate insulation life, and transformer and load tap changer temperature monitoring to predict incipient failures [1]. Digital relays can be connected to an RTAC in a standard panel to collect data from asset monitoring devices and provide real-time telemetry, alarms, and notifications to ensure that operators can be confident in the automated decisions of the system. The communications capabilities of digital relays reduce the amount of required equipment for SCADA and operations.

Critical assets monitored and controlled by digital relays require less periodic inspection and testing. NERC regulations state that digital relays should be tested for proper operation every 12 years, compared to every 6 years for electromechanical relays [3]. However, if comprehensive commissioning tests are performed, self-test alarm contacts are monitored by SCADA, continuous checks are implemented (e.g., of metering by comparing telemetry CT/PT data of one relay to another), event reports are analyzed for accuracy of relay operation, and service bulletins are acted upon, then no periodic relay testing is required [4].

Protection and control technicians with knowledge of the intricate maintenance, calibration, and troubleshooting details of electromechanical relays are decreasing in number [5]. Aging electromechanical relays can be hard to find spare parts for and may require costly refurbishment that increases downtime following relay failures. Finally, electromechanical relay periodic panel testing and maintenance is complicated and time-consuming because the logic is performed using wiring and ancillary devices instead of settings.

Standardized Panels

There are many benefits to using standardized panels when embarking upon a relay replacement program. Standardized panels and settings templates decrease long-term costs for engineers and field technicians by providing consistent and complete documentation and consistent system equipment and designs. Standard panels also provide the following benefits:

- Reduced manufacturing and delivery time.
- Reduced engineering and design costs.
- Reduced installation time and costs.
- Fewer human performance errors.
- Increased quality.

Standard panels provide consistent installation and maintenance procedures throughout the substation. This reduction in variability reduces all of the following:

- The cost of technician training.
- The time it takes field technicians to locate and troubleshoot problems.
- The time engineers spend reviewing drawings, creating settings, and answering calls from field technicians.
- The commissioning costs associated with panel testing.

Cybersecurity

To reap the full benefits of a digital relay replacement program, proper cybersecurity measures must be implemented at the time of installation. These measures include password change requirements, intrusion monitoring, and logging. Also, cybersecurity best known methods, including software-defined networking, can be implemented in standard panels for NERC CIP-005 compliance. One digital relay can provide the same functionality as several electromechanical relays. This smaller equipment footprint leaves room for integration and cybersecurity equipment in the panels. Cybersecurity measures allow for remote collection of data and reports while meeting compliance requirements.

Flexibility

Renewable energy sources (e.g., wind and solar) can connect to the grid from anywhere and provide variable generation. The mixing of generation sources changes the operating characteristics of the system, requiring flexibility in protection and monitoring equipment. An intelligent and programmable system based on digital relays can provide this flexibility.

Multiple settings groups can be implemented in digital relays to adjust protection during changing system conditions. Digital relays provide remote digital I/O to implement remedial action schemes and microgrids to support the evolving transmission network and distributed energy resource management systems [6]. There are also changing requirements resulting from an increase in charging stations for electric vehicles and new or expanding electric mass transit systems.

Digital relays can help utilities adapt to NERC generation retirement scenario recommendations, which aim to address reliability problems that can occur when traditional generation is retired without enough replacement generation [7]. NERC suggests that transmission planning studies be performed to assess the impacts of generator retirement. Reliability problems can occur if these retirements occur faster than the system can respond. SEL Engineering Services has transmission planning and Real Time Digital Simulator (RTDS) expertise to assist in analyzing these impacts.

Safety and Reliability

Digital relays can help improve safety, reliability metrics, and event reporting by providing the following:

- Reduced panel wiring.
- Arc-flash protection.
- Broken conductor detection with synchrophasors.
- Faster tripping to decrease the risk of fires and other hazards.
- Instantaneous tripping, when workers are present, via settings group changes [8].

Data show that 30 to 35 percent of power system misoperations can be attributed to the incorrect operation of aging electromechanical relays [5]. Digital relays provide a more reliable system, as shown by mean time between failures (MTBF), mean time between returns for repair (MTBR), initial quality (IQ), and maintenance indicator (MI) data [9]. Digital relays synchronized with GPS clocks allow utilities to use event reports to determine the root causes of outages across small and wide-area networks, as required by NERC EOP-004-4 Event Reporting. Automating event retrieval allows engineers quicker and easier access to these reports.

New Digital Relay Technology

Digital relays that use traveling-wave technology, such as the SEL-T400L Time-Domain Line Protection, provide many advantages for transmission protection and can increase the life of critical assets. Time-domain and traveling-wave technology results in secure tripping in as little as 1 millisecond, thereby reducing stress on power system assets. The line monitoring feature in the SEL-T400L can be used to log low-energy events, investigate faults, and possibly prevent future faults. The SEL technical paper "Mystery Solved: Five Surprises Discovered With Megahertz Sampling and Traveling-Wave Data Analysis," provides event records with a 1 MHz sampling rate, providing an increased level of detail and resulting in new insights into the power system. It also demonstrates how RTDS system studies ensure accuracy, reliability, and quality before installation [10]. Traveling-wave technology can provide accurate fault locations, typically to within one tower span, to reduce outage times and personnel hours spent looking for faults.

Case Studies

American Transmission Company

In 2011, American Transmission Company (ATC) completed a report proposing additions and expansions to ensure transmission system reliability with an objective "to ensure assets perform the required function in a sustainable manner at the lowest whole life cost," [11]. In this report, ATC stated that digital relays are the cornerstone of a reliable transmission system and should meet compliance requirements, improve reliability, minimize inadvertent operation (i.e., improve performance), and provide additional information to operations personnel to improve restoration times when outages occur. ATC plans to improve line and equipment capabilities with digital relays by eliminating overreaching misoperations and increasing capacity load limits. The improved performance of the digital relays will allow ATC to address stability issues and increase system reliability and security with the use of carrier and fiber-optic communications systems. The digital relays will also provide the benefits of better factory and technical support, improved spare part availability, and software upgrades. Additionally, fault location information will be used with a geographic lightning detection network to correlate lightning strikes with line outages, enabling ATC to historically track the performance of specific line sections and to prioritize transmission line asset renewal. ATC plans to spend approximately $121 million for relay renewal in the 10-year horizon. This equates to about 50 relay panels per year [11].

Oncor

Oncor Electric Delivery Company, headquartered in Dallas, Texas, was able to replace 170 panels (transmission line terminals) in less than 6 months by creating standard panels as part of their relay replacement program [5].

Ontario Power Generation

Ontario Power Generation Inc. was forced to consider a digital relay replacement program when their equipment surpassed its expected service life and spare parts became limited. They analyzed the cost of not upgrading relays in maintenance dollars versus the capital investment for upgrading and concluded that the capital cost was justified based on the following:

- A projected reduction in operations and maintenance costs.
- Plant safety.
- Equipment reliability.
- Improved plant protection.
- Diagnostic information [12].

Conclusion

Digital relays are the cornerstone of a reliable transmission system, and a relay replacement program provides safety, reliability, and cost benefits. The initial capital investment in standard panels and settings templates reduces long-term operations and maintenance costs. Digital relays enhance system performance and provide the flexibility needed for the power system changes projected for the future. Digital relays provide operators and engineers access to fault location data, which reduces personnel time spent in the field searching for problems. Improved monitoring results in better maintenance scheduling, increased reliability, and improved lifecycles for critical assets. This increases safety not just for personnel but also for the community. Cybersecurity regulations and compliance are also easier to achieve with digital relays.

References

[1] R. Wernsing, "Reliability & Resiliency in New Jersey: Making New Jersey Energy Strong," IEEE Power & Energy Society, July 2014. Available: https://www.ieee-pes.org.

[2] Commonwealth of Kentucky, "In the Matter of: Electronic Application of Louisville Gas and Electric Company for an Adjustment of Its Electric and Gas Rates," Testimony of Paul W. Thompson, President, Chairman, and Chief Executive Officer Kentucky Utilities Company and Louisville Gas and Electric Company, September 2018. Available: lge-ku.com.

[3] NERC Standard PRC-005-2 – Protection System Maintenance. Available: nerc.com.

[4] K. Zimmerman, "SEL Recommendations on Periodic Maintenance Testing of Protective Relays," March 2014. Available: selinc.com.

[5] A. Jezak and R. Garcia, "Aggressive Electromechanical Relay Panel Replacement Project at TXU Electric Delivery," proceedings of the 58th Annual Conference for Protective Relay Engineers, College Station, TX, April 2005.

[6] IEEE P2030.11, Distributed Energy Resources Management Systems (DERMS) Functional Specification.

[7] North American Electric Reliability Corporation, "Generation Retirement Scenario: Special Reliability Assessment," December 2018. Available: nerc.com.

[8] Schweitzer Engineering Laboratories, Inc., "Improve Distribution Feeder Safety and Reliability (Distribution Safety Tips)," January 2019. Available: selinc.com.

[9] R. D. Kirby and R. A. Schwartz, "Microprocessor-Based Protective Relays Deliver More Information and Superior Reliability With Lower Maintenance Costs," proceedings of the 42nd Annual Industrial & Commercial Power Systems Technical Conference, Detroit, MI, April 2006.

[10] E. O. Schweitzer, III, V. Skendzic, A. Guzmán, M. V. Mynam, J. L. Eternod, and Y. Gong, "Mystery Solved: Five Surprises Discovered With Megahertz Sampling and Traveling-Wave Data Analysis," proceedings of the 72nd Annual Conference for Protective Relay Engineers, College Station, TX, March 2019.

[11] American Transmission Company, "10-Year Assessment," September 2011. Available: atc10yearplan.com.

[12] K. Craig and A. Sinclair, "Motor Protection Retrofit: A Business Case," proceedings of the 64th Annual Conference for Protective Relay Engineers, College Station, TX, April 2011.

Additional Reading

D. Costello, "Fly Safe and Level: Customer Examples in Implementing Dual Primary Protection Systems," June 2007. Available: selinc.com.

A. Guzmán, "Improving Power System Reliability Using Multifunction Protective Relays," September 2003. Available: selinc.com.

D. Stewart, R. Jenkins, and D. Dolezilek, "Case Study in Improving Protection System Reliability With Automatic NERC PRC-005 Inspection, Testing, Reporting, and Auditing," proceedings of the 66th Annual Conference for Protective Relay Engineers, College Station, TX, April 2013.

Biography

Peter Allen earned his B.S. in electrical engineering from the University of North Carolina at Charlotte. In 2006, he was an instructor at Central Piedmont Community College in the Engineering Technology department. In 2007, he joined Schweitzer Engineering Laboratories, Inc. as an intern and is currently a regional director in Engineering Services.