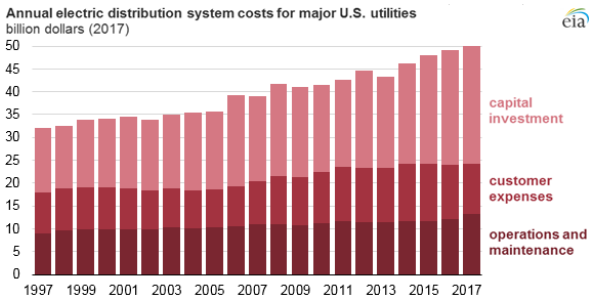
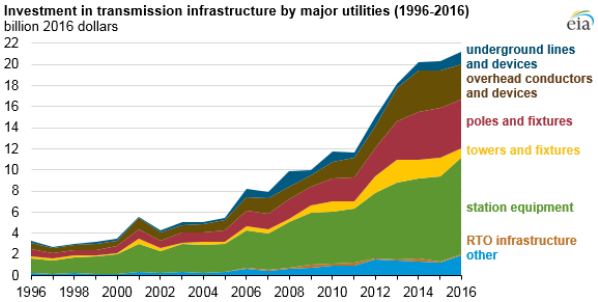
Modernization and Upgrading of Protection Relays in Generating Stations

There are many driving factors that prompt the decision to modernize a protective relay system. One of the major factors is age of equipment. Many U.S. utilities and associated generation stations are currently faced with the issue of an aging electrical infrastructure. According to a 2015 U.S. Department of Energy report: 70% of power transformers are 25 years of age or older, 60% of circuit breakers are 30 years or older, and 70% of transmission lines are 25 years or older. Many of the associated protective relays in these systems fall into the same age range as their associated electrical distribution equipment counterparts. Aging equipment, in many cases, brings with it increased maintenance cost and reduced reliability. Additionally, availability of replacement parts and equipment obsolescence is also becoming a growing problem.

To offset these issues, many utilities are allocating an increasing amount of funds each year to performing modernization and upgrades to their existing protective relay systems.





Choosing to modernize and upgrade a protective relay system can bring with it many advantages. The past few decades have brought several advancements and improvements in the field of protective relaying. The progression of technology has yielded many improvements to both protective relay hardware and software. Modern microprocessor-based protective relays offer many advantages when compared to their predecessors in the field of electrical power system protection. Some of these advancements include robust data collection, improved communication capabilities, and the ability to implement programmable logic. Generation stations and generation plants are one segment of the electrical power system that stands to benefit greatly from this evolution in protective relay technology.

Once the decision to upgrade a protective relay has been made, there are several project phases that need to be considered and carefully managed. These phases are crucial to the ultimate success of the project, and a vigilant approach to adhere to these project phases should be followed.

These project phases can be summarized as follows:

- Documentation and Planning,
- Implementation and Installation,
- Testing and Commissioning, and
- Close out.

Project Documentation and Planning:

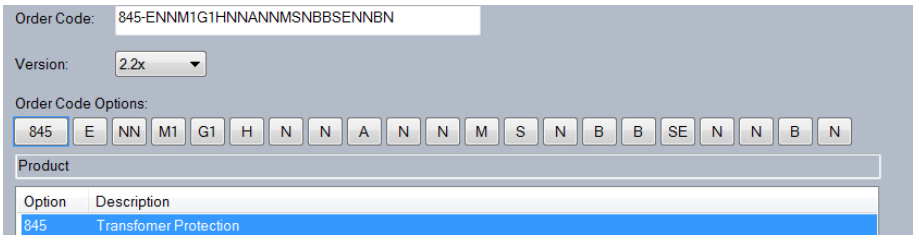
Documentation of the existing system should be one of the first steps performed when upgrading a protective relay system. The first piece of information that needs to be documented are the existing electrical drawings. The applicable one-line, three-line, control drawings, and wiring diagrams need to be obtained. For ease of modification, it is preferred to obtain these drawings in an electronic format that can be upgraded. Depending on the site's document control and record keeping system, obtaining all these drawings and ensuring they are the most up to date revision can sometimes be a daunting task. Whenever there is doubt about the accuracy of a drawing, field verification of wiring, terminals, and point nomenclature should be performed. The second piece of information that needs to be obtained is the 'as found' protective relay settings. Depending on protective relay type, settings can be in electronic or paper format. Verification of these settings is also recommended to ensure accuracy. Other items that should be documented, if applicable, are photographs and measurements of existing equipment, relay panels, wiring.

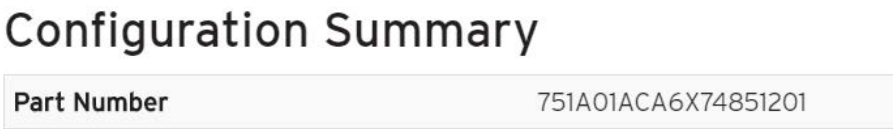
Planning and the subsequent development of a project schedule is also one of the initial steps that needs to be performed. The project schedule should include milestones such as material lead time, electrical outage start and end dates, and any other key dates that are critical to the project. The electrical outage duration, the time the generation unit will be allowed to be out of service to perform the work, is a key point to identify in the project schedule. Manpower requirements should be made, accordingly, to ensure the new protective relays get installed, tested, and commissioned within this outage window. Additionally, any potential time constraints or schedule impacts should be identified and plans to mitigate enacted. The overall goal of the planning task is to ensure that the design intent and schedule expectations of the project are being met within the required timeframe.

Project Implementation and Installation:

Once the required information has been documented and a plan is enacted, project implementation and installation can commence. One of the first steps in this phase is specifying and ordering material. Most modern microprocessor-based protective relays have detailed and complex part numbers or order codes consisting of several characters and digits. Each character and digit corresponds to a specific feature in the new protective relay. Care should be utilized to ensure that the correct protective relay part number or order code is selected for the application. Focus should be made on ensuring that the new protective relay has the correct power supply range, I/O arrangement, communication capability, and ANSI protective elements for the application. Any other electrical devices that are being replaced during the project such as lockout relays, indication lights, wiring, and terminal blocks should also be specified at this time. Once all material has engineering approval, equipment can be ordered.

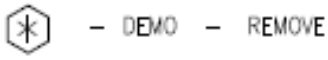
Examples of Modern Microprocessor-Based Protective Relay Part Numbers and Order Codes:

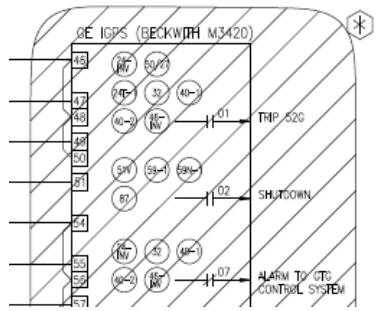


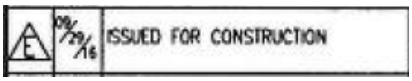


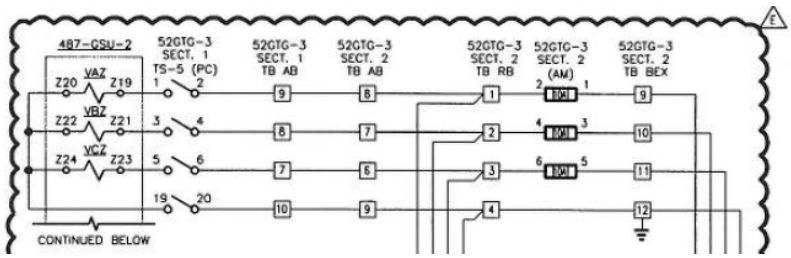
Based on the electrical drawings obtained during the documentation stage, two new sets of electrical drawings need to be created. The first set of drawings are the Demo drawings. Demo drawings show the wiring and equipment that is 'to be removed or demoed' during the protective relay upgrade project. Wiring and equipment that is 'to be removed' is typically annotated with strikethrough lines and a drawing note to the original drawings. The second set of drawings that need to be created are the Construction drawings. Construction drawings show the wiring and equipment that is 'to be added' during the protective relay upgrade project. The wiring and equipment that is 'to be added' is typically annotated with a cloud or bubble and a drawing note to the original drawings.

Examples of typical Demo and Construction Drawings:









Based on the existing 'as found' protective relay settings and the new construction drawings, new protective settings need to be created. The new protective relay settings need to incorporate the following items from the previous installation. The first item to be translated into the new device are the protective elements and setpoints. These items can vary greatly based on the previous install and manufacturer. For example, going from an electromechanical to a microprocessor-based relay would require interpreting physical tap or time dial settings (either physically on the existing protective relay or

on a coordination study) to the modern microprocessor-based software setpoints. Another example would be changing between different microprocessor-based relay manufacturers. This would entail properly interpreting, translating, and implementing the variances in the nomenclature between the two relay manufacturers. The second item to be translated into the new device is the device I/O (inputs and outputs). Care should be utilized to ensure that the specified inputs and outputs are correctly programmed in the new device and that they correlate with the new construction drawing wiring. The third item to be translated into the new device are the communication settings. Items that could potentially need to be converted over to the new protective relay would be custom MODBUS or DNP maps, baud rate settings and slave addresses for serial communication, IP addresses, etc. When all translation has been completed, the new protective relay settings generated and approved by engineering are labeled 'as specified' protective relay settings.

Once all material is received and all drawings and protective relay settings have been approved, installation can commence per the project schedule. When preparing for installation, care should be taken to ensure that site and company Lock-Out-Tag-Out (LOTO) procedures are maintained. Isolation of AC/DC control power circuits, test switches, along with main power conductors need to be performed. Additionally, if any generation units are still online during the installation phase, care should be taken to ensure no potential back feeds or inadvertent trips of the online units occur. Installation is per the demo and construction drawings generated. All 'to be removed' and 'to be added' equipment and wiring should be addressed at this point. Any wiring discrepancies identified with the construction drawings during install should be noted and documented, and should be discussed further in the close out phase.

Project Testing and Commissioning:

Any new equipment installed, or changes performed to system wiring should be tested and verified prior to re-energization of the associated power system. The newly installed protective relays should be powered on and the new 'as specified' setting files should be uploaded. 'Bench Testing' of the new protective relay can then be performed, consisting of verifying the new microprocessor-based relay's metering and specified protective element operation. Secondary current and voltage injection, utilizing a 3-phase relay test set, is utilized for this task. Once the new protective relays have been successfully tested, 'as left' setting files need to be downloaded and saved. These 'as left' files will serve as project documentation, discussed further in the close out phase. Functional testing of the associated protective relay I/O should also be performed. Each protective relay input should be verified along with each protective relay output. It may be necessary to engage the site's DCS or PLC representative during this portion of testing. Protective relay outputs that are wired to PLC inputs often need modification during an upgrade project. Modification is often required for annunciation points of alarms and trips on the site's HMI system. For example, an existing alarm coming into the control room for the previous system might display on the HMI system as 'Beckwith 3425 Common Alarm'; consequently, if the new protective relay being installed is a SEL-700G, the HMI text would need to be adjusted accordingly. Additionally, any system wiring that was disturbed during the demo and construction phase should be point-to-point verified for functionality. Instrument transformer secondary circuits, modified during the install phase, should also be loop checked for accuracy. Loop checking is typically performed by injecting secondary current and voltage on their respective CT and PT loops. Loop check signals are verified for accuracy on their respective protective relay metering screen. Documentation of these loop and point-to-point checks are typically performed by highlighting the associated construction drawing circuit portions.

Once all testing is complete, the system should be returned to a normal state. In preparation for re-energization of the power system, all LOTO items need to be cleared and all test switches and isolation points restored. During energization and initial power system loading, the new protective relay metering and annunciation targets should be monitored. Items to note during startup are current and voltage magnitudes and phasors, differential and restraint current magnitudes, system phase rotation, and any other applicable metering value. Additionally, all of the protective relay I/O should be verified to be in the normal and expected states. In the case that an inadvertent trip occurs during energization or loading, preparation should be made to retrieve any applicable event records for use in troubleshooting root causes.

Project Close Out:

Once the power system has been successfully re-energized and is back on-line, the project close out phase can commence. The stage consists of compiling the following documents for project record purpose. Any field markups, from the install phase, to the construction drawings are incorporated into a final set of 'as built' drawings for submission as project record. These drawings should accurately reflect the updated system and incorporate all work performed during the protective relay modernization project. The 'as left' protective relay settings, downloaded during the install phase, are also documented and submitted as project record. Additionally, any test results produced during the testing phase should be submitted as project record.

One additional item of importance that should be addressed during the close out phase is equipment operator training. With the upgrade and modernization of the system comes new technology and protective relay software. Operators need to be adequately trained on the new system. This owner's training should cover the capabilities, hardware connections, software, and navigation of the new protective relay system.

Summary:
Modernization of existing antiquated electrical protective relay systems provides a solution to an ageing electrical infrastructure while also adding the benefit and advantages of improvements in protective relay technology. Although a protective relay upgrade project may seem like a dauting task, it can be achieved by following a detailed and thorough procedure. When performed properly, it can greatly extend the life and reliability of the associated electrical power system.

"U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems - Today in Energy - U.S. Energy Information Administration (EIA)*, www.eia.gov/todayinenergy/detail.php?id=36675.

"U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *Utilities Continue to Increase Spending on Transmission Infrastructure - Today in Energy - U.S. Energy Information Administration (EIA)*, www.eia.gov/todayinenergy/detail.php?id=34892.

"*Quadrennial Technology Review 2015 Chapter 3: Enabling Modernization of the Electric Power System Technology Assessments." Energy.gov, www.energy.gov/sites/prod/files/2015/09/f26/QTR2015-3F-Transmission-and-Distribution_1.pdf.*