An Application for Automatic Checking of Relay Settings in a Database

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***Abstract*— Achieving high productivity while retaining high quality of relay settings represent a significant challenge for utility protection engineers. With the advent of microprocessor relays and their evolution into multi-functional integrated devices the door was opened for new opportunities, but also increased work load. Protection engineers place a high importance on quality yet, setting errors do occur and sometimes have a negative impact on customer reliability indices.**

This paper describes the development and implementation of an automated tool to efficiently sweep a relay database for "out of normal bounds" settings and abnormal logic. The benefits and limitations of the application are discussed. The Relay Setting Checker (RSC) development reflects PG&E System Protection efforts to equip its engineers with tools for efficiently meeting the requirements of modern power system.

I. Introduction

Although protection engineers place a high importance on quality, setting errors do occur and sometimes have a negative effect on customer reliability indices such as MAIFI, SAIFI and CAIDI. The importance of producing secure and dependable settings on compressed time schedule became obvious during the extensive PG&E work on infrastructure replacement and upgrades for the last decade. PG&E deployed a program of installing Modular Protection and Control (MPAC) buildings to upgrade all the aging devices at a substation. This approach has many benefits but significantly increased the work load for protection engineers, as there were many new microprocessor relays which required settings. Meanwhile, sacrificing quality in order to meet required operational dates is not an option.

Protection engineers have the challenge of applying thousands of settings on a variety of microprocessor based relays. Many of these relay settings have a direct affect on dependability and security of the electrical power system. The Relay Setting Checker (RSC) application reduces existing and future errors by sweeping the database for "out of normal bounds" settings before they cause problem.

The RSC allows a protection engineer to select one or many protective relays in a utility relay database and check those devices against various selectable setting rules. Rules are designed to review settings and logic per utility standards. The application generates a report listing the possible setting errors and warnings specific to each relay setting.

II. The Need For an Automated Tool

The onset of microprocessor relays created a dramatic increase in the number of settings compared to prior technologies, from the typical one or two pages for discrete relays to over a hundred sheets for integrated multifunctional devices. An integrated multifunction relay may have multitude of critical and non-critical settings. The critical settings are integral in sensing power system conditions and initiating the proper response. Non-critical settings are used for a variety of tasks such as labeling, status points, non-critical analogue monitoring and recording parameters. Checking of such a large number of settings results in time and resource challenges coupled with a greater risk of human error, thus an automated computer program for checking was considered as an appropriate tool for this task.

Errors in settings, though a relatively small component of the causes of all outages, can be further reduced using an automated tool. PG&E system protection group uses a variety of tools including training, peer review, protection guidelines, settings templates and checklists to help reduce setting errors. The RSC application is additional strategy aimed at improvement of the quality and consistency of relay settings over an enterprise.

The ability of an automated Relay Setting Checking application to provide valuable results partly depends on the level of standardization; increased standardization, significantly increases effectiveness of automated tools. For example; the implementation of the RSC application will be easier for utilities that have standardized relays for particular applications and standard settings. Other utilities in the industry are increasing standardization and employing software tools to reduce the risk of human errors [8].

III. Application Design Considerations

The following development requirements were formulated for RSC:

Targeted Users:

- Protection engineers

Interface:

- Friendly and clear graphical user interface
- Intuitive feel for users
- Well documented relay setting warnings and error messages in report

Application:

- Ability to check single relay prior to relay installation
- Provide the ability to check many relays or all relays across the enterprise in "sweep mode"
- Application is structured in a way that new relays can be added
- Rules for checking the relays can be updated or expanded
- Software development tools should be available on the market and relatively widespread
- Program should be well structured and properly documented to assure accurate and consistent knowledge transfer of application development
- Interface built with integration of other protection software tools in mind for future development
- Application uses relay database information so quality of the data in the relay database is important
- Current application version does not recommend protective relay settings to the engineer, but this functionality may be added later
- Minimal training will be required to run the application

The RSC is designed as a stand-alone software application, rather than a series of scripts in an existing program, in order to reduce the dependency on other programs and to provide an easy to use graphical user interface that would require little or no training for use by a protection engineer.

In order to increase the ease of growth in scope and type of relays to be checked, the application is developed in a modular per relay methodology. The application is expandable so that new rules for each relay can be added as well as new relay models.

The Relay Setting Checker (RSC) is an easy to use and effective tool for performing relay setting checks of settings in a relay database. The application can be used to check electromechanical, static or microprocessor based relays, although there will be increased benefits when using the RSC with modern microprocessor relays for a couple reasons. First, microprocessor relays often have multitude of settings which make an automated tool more attractive to use. In addition, the transfer of microprocessor settings to a database is automated, so the format of the settings is consistent and predictable. Electromechanical relay settings, on the other hand, are manually typed into the database, which results in inconsistent data that is not easily checked using an automated tool.

Although there are additional challenges associated with using the RSC tool with electromechanical and static relays, it may be worth pursuing in some cases. If there are a large number of electromechanical relays to be checked and the settings have been entered into the relay database in a consistent format, it may be worth the effort to design rules for the relays in question.

IV. Description Of The Application

The protection group at PG&E first developed a relay setting checker for distribution transformer relays in late 2008. The original application had some success with users, but lacked flexibility required for easy updating. In addition, the expandability of the original program was limited because it dealt with the specific manufacturer file format for reading settings rather than retrieving settings from the relay database. In order to increase the ease of expandability of the application and allow users to review many settings in an efficient way, the next version of the application was developed which connected to the relay database and used a standard class library defined for each relay used in the application.

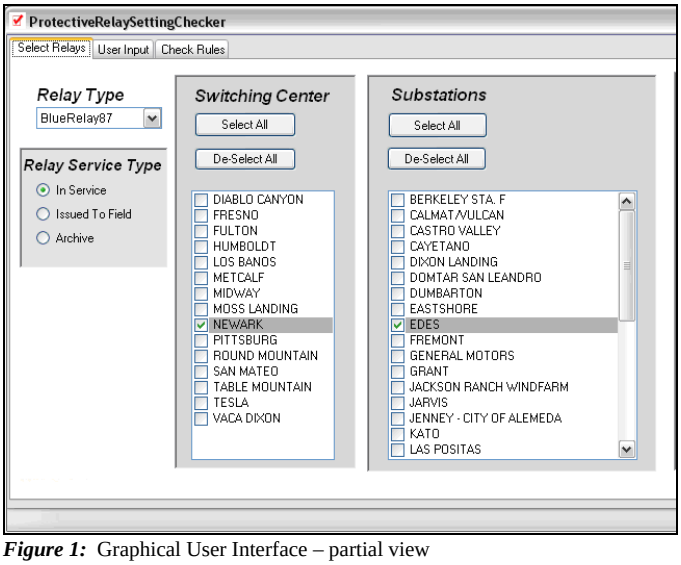

Figure 1: Graphical User Interface – partial view

The Relay Setting Checker (RSC) is a stand-alone application used to check the existing or proposed settings stored in the relay database. As a stand-alone application, the RSC is decoupled from the normal relay setting process which allows for a more independent verification. The protection

engineer typically uses specific relay manufacturer software to create a relay setting file. The relay setting file is uploaded to the relay database for documentation and storing purposes.

The RSC connects to the relay database and retrieves relay settings as required for the relay setting checks. The application has options to select either an "In-Service" setting or a relay setting designated as "Issued-to-Field", which has not been placed into service.

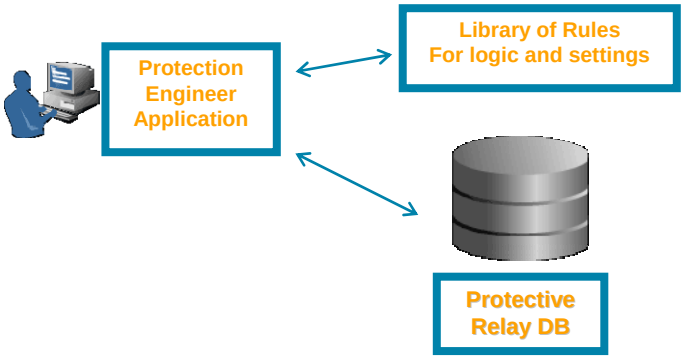

Figure 2: Application Diagram

The RSC employs a rule-based approached to review settings. The rule class is designed to be able to be easily expanded or modified as needed for future developments. An example of a rule incorporated in the RSC, is a logic check for a tripping equation. With any particular type of relay, if there is standard utility trip logic, the setting checker can be used to check that the trip logic of the relay in question is logically identical to standard setting.

Protection setting criteria have been changing over time. The utility practices for protection settings are influenced by NERC and other regulations. Recently, there has been a trend towards additional scrutiny of protection dependability. Using the rule-based approach, new rules can be easily added or changed as required. It also provides flexibility for the user to select or deselect individual rules to be applied.

The RSC is designed to accommodate a variety of rules associated with each standardized relay which is added to the RSC class library. The RSC can be run in the single relay mode or the "Sweeping Mode" (multi-relay selection).

In the single relay check mode, a protection engineer is prompted to input additional information about the device being protected and the system the relay is being applied. The additional information will allow for a more detailed check of the specific relay. The single relay mode is intended as a review of protection settings to be done prior to settings going into service.

When using the RSC in the single relay mode, the application relies on fault data that is entered into the application by the protection engineer. This data is based on fault duty information obtained by the protection engineer. The data is checked for quality to make sure it is within a known range. If engineer accidently enters incorrect data, it is likely that the application would come up with an error message.

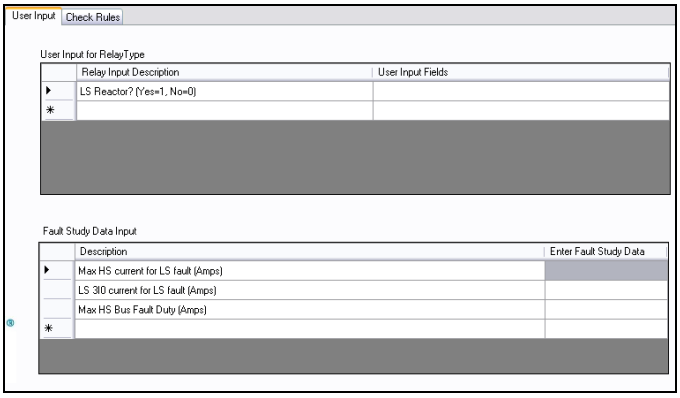

Figure 3: Additional User Input field for single relay mode

In the Sweeping mode (or multi-relay check mode), the user can select many relays to check at the same time. For example a protection engineer may select all relays within his or her area of responsibility to be checked. The engineer can use the RSC to quickly run a report which provides a review of settings based on the user selectable rules for that relay.

The sweep mode is used to check the settings on a large group of relays that are already in-service. The in-service relays can be reviewed for setting errors which may not have been caught during the original installation. Also, if the utility has a change in protection philosophy, the RSC can be used to see how many in-service relays need to be updated to conform to the new philosophy.

The relay settings database allows flexibility to store settings from simple electromechanical relays to the complex modern numerical relays. Before checking the relay settings using the RSC, it is necessary to import them in the database. This is a normal practice at PG&E. The relays are organized according to substations and switching centers in the database to facilitate the region based approach of management of protection settings.

RSC provides an easy interface to select specific relays that need to be checked from the relay database. The Protection engineer selects the applicable rules for the relays to be checked. The Protection engineer can selectively enable and/or disable individual rules by selecting or de-selecting each one. RSC application then checks each rule from an internal rule-base and generates a report indicating the check as pass or fail. The design of each rule is based on the protection guidelines and practices at PG&E and is designed for expansion based on the feedback of protection engineers.

RSC is designed to provide useful information about setting problems that may exist among the protective devices in a model. However, a successful run indicating no errors in the settings is not a guarantee of error free settings. The analysis is limited to evaluations based on the rules created and cannot account for conditions in the power system that may be unique. The report provided by the analysis is valuable and

can be used in conjunction with the protection engineer's knowledge of the particular application in the power system. It has been recognized that setting a protective relay is complex and in most cases requires human judgment. The analysis of RSC results coupled with protection engineer's knowledge of the system can reduce setting errors.

The automated RSC application can be used to proactively and quickly identify "out of normal bounds" relay setting mistakes. It is clear that an automatic program will not find all errors that are present in the system, but the RSC application will identify and highlight a variety of possible errors. It will be up to the protection engineer to use good engineering judgment regarding whether the possible errors identified are significant and then make the appropriate corrections. Our goal is to apply relays and settings consistently across the enterprise; however, the differences in the substation configurations will require differences in relay settings. Some of the inconsistencies identified by this program will be appropriate for the application. These differences are a source for possible error and this application will help identify differences and provide added focus and scrutiny to these settings.

By using both single relay checking and sweeping methodology, the application is capable of checking settings that are newly developed by engineers as well as checking the existing settings in the database. The RSC is able to review settings for the relays used in the PG&E integrated standards. The type of checks done by the application is based on using PG&E standard data and other settings in the relay to identify possible errors in the settings. The application does not perform any changes, instead it suggests to the engineer to review certain aspects of the settings file.

V. Implementation Of the Tool

It is expected that new tests will be suggested by Protection Engineers and these would be incorporated in subsequent versions of the application.

Protection engineers will download and install the Setting Checker Application on their PC. It is assumed that protection engineer already has installed a database client since it is required to upload, download, and review settings in the database. Implementation of the application for use in the protection group will be done by deploying the installation executable on the shared drive.

PG&E has a very large geographic area and System Protection is organized in 3 areas (Northern, Central Coast, and Southern). In order to provide some guidance and support to people in each office, one or two local experts will have additional training and background information regarding how to install and use the application. Although the application will be very simple from the user's perspective, some individuals may have questions or concerns, especially for the installation stage. In addition, this local expert will also serve as the local advocate to promote use of the application in all locations.

VI. Evaluation of Application Performance

The feedback of protection engineers using the application will be used to improve the application and to provide data on the effectiveness of the tool. The application has been tested by select protection engineers in the local offices of PG&E and the feedback has been positive. When the application is rolled out to all the protection engineers, various feedback sessions with key stakeholders will be held to facilitate application improvement.

VII. Conclusion

RSC development is one of the steps in PG&E System Protection plan to improve both quality and productivity of protection engineer's work. It is just one of the elements of the overall effort directed at process improvement, automation of engineering tasks, schedule compression, etc. It should be noted that these efforts are not intended to reduce protection engineer's participation in the development of technical decisions or replace good engineering practices or judgment, but rather to reduce time and efforts required for routine work.

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