Protection relay settings management in the modern world

Settings

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1 Abstract Summary

Modern digital protection relays are continually evolving to take advantage of the increasing speed and memory capabilities of digital signal processors and computer hardware. Consequently, the complexity and number of settings available in each relay is increasing - it is not uncommon for a modern feeder management relay to include distance protection, directional over-current and earth fault, under-voltage, under-frequency, negative phase sequence and many other functions. In addition, there are settings for relay communication and software configuration. Protection relays are also associated with ever more complex records from sequence of event recorders (SER), disturbance recorders (DR), measurement functions and power quality monitoring. All these settings, recorded data and events history must be managed by power systems engineers. This can be a formidable task for companies with large systems containing many different relays.

This paper discusses the philosophy and requirements for a manufacturer independent relay settings database software to actively manage all relays in a power or industrial network. The challenges for such a system include developing communication methods for importing and storing proprietary settings information from third party manufacturers, flexible user rights management, flexible organisational hierarchies and settings status tracking. Ideally, it will be web-based to enable remote offices, contractors and consultants to have easy access to the system. It is envisaged that such a relay management system could have a huge benefit for an electricity network utility or large industrial company, creating significant cost and time savings and ensuring a more reliable electrical system.

2 Introduction

This paper is divided into three sections. The first section will provide some historical context on the functional evolution of protection relays and increasing power of these devices. Section two will explain how utilities typically manage the relay protection setting process of their relays and some of the typical problems they encounter. The final section will discuss a 'wish list' for a protection settings management system (PSMS) that can overcome many of these problems.

3 Historical Context

The first protection relays for power systems were electromechanical analog devices. Electromechanical relays have been in use for almost 100 years and most typical utilities still have several throughout their power system. They work on the principle of a mechanical force causing the operation of the relay contact in response to a stimulus. The stimulus is usually a current flow through windings on a magnetic core. Hence the origin of the term electromechanical relay. A typical electromechanical relay will have less than 10 settings that are set with plugs and switches, so often it is practical to store the settings information on paper on relay settings sheets.

Over the last 30 years electromechanical relays have been progressively superseded, firstly by static analogue relays then by digital/numerical relays. A numerical relay implements protection functions using a digital signal processor (DSP) and on-board software. A trip decision is made by interpreting the input currents and voltages using a discrete Fourier transform (DFT) on the DSP and assessing the result using internal logic. The functionality and trip conditions are configured with settings files uploaded to the relay.

The development of numerical relays has lowered cost and provided greater functionality within each relay. Some examples of additional features now commonly available on relays are Sequence of Event Recorders (SER), Disturbance Recorders (DR), measurement functions and power quality monitoring. A numerical relay can also provide network load-flow and switching information to SCADA systems. Numerical relays also use sophisticated communication for signalling other remote relays. Most relays also have user programmable logic to alter the operation of the relay and even add custom functionality. However, the trade off for all these advantages is complexity.

Most numerical relays contain multiple settings groups each often with tens to hundreds of settings. These settings must be configured by power system engineers using manufacturer specific software and then stored in a manufacturer specific settings file. Each settings file must be archived so that if a relay fails, a replacement relay can be quickly commissioned with equivalent settings. Settings files are also required for analysis tools to analyse relay operation (or mal-operation) and testing the functionality of the relay. Most utilities will also use a settings process that requires additional settings files such as issued, returned and emergency settings and will maintain an archive of older applied settings. Therefore, for each numerical relay, there could be ten or more associated settings files. In a typical utility with a thousand or more relays, a settings file storage repository is required to keep track of many thousands of relay settings files.

4 The Existing Process

Most utilities have a combination of the following for relay settings management:

- A paper based system of settings sheets and records, principally used for electromechanical relays;
- Spreadsheets for recording relay information and simple settings;
- Databases and file repositories for storing and organising relay settings files;

A paper based system is only practical for electromechanical relays as these have only a few settings. Even here though if a company has more than a few dozen relays, then the management overhead of such a system quickly becomes impractical. This then leads to a computer based management system such as a spreadsheet that can record a significant amount of information about each relay such as make, manufacturer, location, protected circuit/s and some basic settings.

A spreadsheet based system is limited only by imagination and is inherently flexible. However, this also leads to its downfall. Because a spreadsheet by default has no internal consistency checking of records, then users are mostly free to enter data as they choose. This typically results in data that is inconsistent and could lead to settings errors. Additionally, there is no accountability and checks to confirm existing settings are applied in the field. An incorrect relay setting can cause a protection mal-operation, or even worse a failure to operate that ultimately risks lives and can lead to criminal prosecution.

Many utilities have a combination spreadsheet/database system. For example, a spreadsheet keeps track of typical relay attributes such as manufacturer, model, functions, substation protected circuit/s, voltage level and others. For numerical relays, the spreadsheet also holds a reference to the settings files that are stored on a file server or database. Such a system can work well but it requires significant administration to keep the data updated and maintain the appropriate links. A higher administration overhead requires more manual entering of data by engineers that often leads to inconsistencies in the data. For example, for a common relay function such as instantaneous over-current the IEC and ANSI abbreviations are I>> and 50 respectively. Engineers use these two terms but also refer to this function as OC, O/C, over-current etc. So a spreadsheet that has such an over-current function field unless it has built in error checking, can have several different representations of the same information. This can lead to confusion and requires the engineer to check the settings file to confirm the relay functions. This wastes time and is an inefficient use of resources.

Other limitations of a spreadsheet/database system include, lack of user management (limited auditing capability), difficulty configuring remote access and limited linking to analysis tools. In addition a spreadsheet will generally hold no data about the operation of complex relays. A spreadsheet system generally does not provide an intuitive user interface and may have a steep learning curve for engineers unfamiliar with a utilities' system.

5 The Modern Management System

This section discusses possible improvements to a PSMS with examples from a system developed by DIgSILENT.

The key requirements for a robust relay settings management system are:

- Storage of all relay settings in a manufacturer independent format;
- Remote access, ideally web based;
- Flexible user management and auditing;
- Representation of the protection settings 'lifecycle';
- Automatic storage and linking to relay manuals, settings calculation documents, test reports and historical records;
- Powerful reporting and search features for information; and
- Automatic linking to an analysis tool.

This paper will now discuss each of these features in detail.

5.1 Manufacturer independent storage format

Each different relay manufacturer uses a different data format to store the settings information for their particular digital relays. In many cases, a single manufacturer may have several different formats. For example, relay settings files for Schweitzer Engineering Laboratories (SEL) relays commonly use two formats, either the AcSELerator ASCII format or the SEL-5010 (MDB) format. Considering that many companies will use relays from several different relay manufacturers, it is not uncommon to have a dozen or more different data formats to manage. The end result is that elaborate and often overly complex management systems evolve to keep track of the relay settings process and storage of relay settings files. This is often a combination of old and new technology. For example, paper trails, spreadsheets and ad-hoc 'in-house' databases.

A modern PSMS should store all relay settings files in a single data format that enables easy transfer of settings to a power system analysis tool for testing. A common data format enables easy storage of relay settings files from multiple manufacturers in the same database and the settings from each relay can be presented to the user in a common format. Elaborate paper trials and spreadsheet management systems can be dismantled.

To use a common data format, requires that the manufacturer specific files are passed through a conversion tool that maps the manufacturer specific settings fields to appropriate 'universal' fields within the PSMS. This is the approach taken by most PSMS tools at present. However, the IEC standard, 61850, aims to produce a common format for relay data exchange. Once relay manufacturers fully embrace this standard there will no longer be a requirement for data conversion to and from a manufacturer specific format as the settings will be stored as native 61850 files both within the PSMS system and the relays.

5.2 Remote Access

It is common for a modern company to have several different work sites. This is especially true for power companies who may manage hundreds of substations across a vast geographic area. A PSMS tool that is hosted within a single building and can only be accessed internally is essentially worthless. A useful tool must be enabled for web-based access from any location with an internet connection. This then enables employees to have the database within easy access whether they are sitting in the head office or working at remote substation in the field.

Although internet coverage is continually becoming more widespread, there are still remote rural areas where internet access is unavailable. A robust PSMS will allow users to 'checkout' a portion of the database to use remotely where there is no internet connection. The relay settings within this checked out database can still be managed as if the system was connected to the main database and then later when internet access is available, the data can be resynchronised with the main system. For example, a technician can check out issued settings from a relay by accessing the PSMS database from the field office where an internet connection to the PSMS is available. The technician then travels to a remote site where she applies the settings to one or perhaps even a group of relays. Immediately she can update the PSMS database as if she were connected and later when she returns to the field office she can resynchronise with the main database. During the time the technician has the relay data checked out, other users will still be able to use the system. However, the data the technician checked out will remain locked until she has resynchronised and updated the database.

5.3 Flexible User Management and Auditing

In protection relay settings management, it is important to know at all times who has ownership of data and who is responsible for changes to and review of settings. A modern PSMS will allow flexible user management with the following requirements:

- Flexible user rights; read-only, write, administrative etc;
- Control user access and prevent unauthorised users from viewing or editing data they don't have access to;
- The ability to group users with similar privileges in 'common' groups to enable easy administration of user access rights.
- Keep track of who made changes to settings or relays (auditing functions);

5.4 Representation of the Protection Settings 'Lifecycle'

Most power engineering companies have a business process that describes the key stages in the management of protection relay settings. A simple business lifecycle process may look as shown in Figure 1. The process normally proceeds as follows:

- Settings designed and tested;

- Settings reviewed, amendments made, then issued;
- Settings applied in the field;

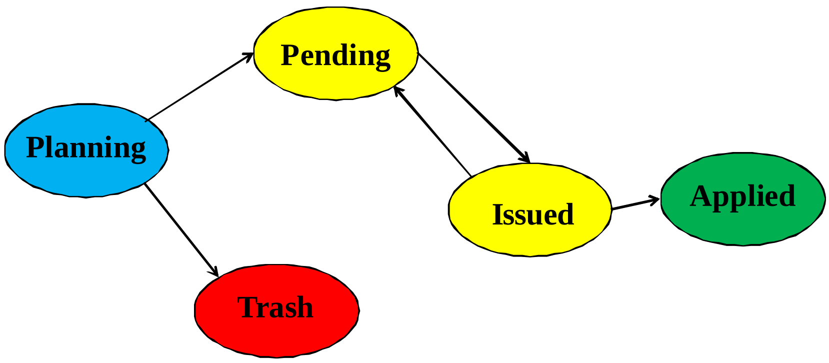

Figure 1 Example settings lifecycle

Once the settings are applied they become a permanent record of the relay settings and should be stored historically within the PSMS for review at any later date (even if new settings are applied). It is important for a modern PSMS to capture this process internally. This can be accomplished by assigning each relay settings file a 'lifecycle phase' and it then becomes the responsibility of the users of the system to transition a settings file between each phase after appropriate work. This accomplishes two things simultaneously - setting of all relays via a consistent process and providing user accountability/auditing for all transactions. As each company will have a different business process the management tool must have the flexibility to customise the lifecycle by changing the work-flow and adding or removing new phases and transitions.

5.5 Data Repository

A modern PSMS will provide a data repository for all information relevant to a particular device. This will include protection relay manuals, settings calculation sheets, test reports and other additional notes. The PSMS should also allow a utility to customise any additional material such as settings sheets according to its requirements.

It is important that the PSMS stores historical information regarding each device. For example, it is useful to have easy access to previous applied settings of the device for review and input into future settings calculations. In some cases it may be beneficial to store a record of 'review' type settings such as issued settings so that the engineer can later compare these with the applied settings on the device. An additional beneficial feature is automatic notification of settings changes via email.

5.6 Reporting and Searching

One benefit of a spreadsheet management system is that it can perform powerful and fast searches of data. The ideal PSMS must contain powerful tools that match the existing search and reporting requirements of utilities. Databases with strict data organisation usually outperform spreadsheets with equivalent searches.

Much searching can often be made redundant through the use of a meaningful database hierarchy. For example, Figure 2 shows an example hierarchy taken from DIgSILENT's Protection Settings

Management Tool, StationWare[2]. Shown is a default hierarchy Region -> Area -> Substation -> Feeder -> Device, that is intuitively familiar to users. A modern PSMS will allow a utility to customise the hierarchy according to their own requirements.

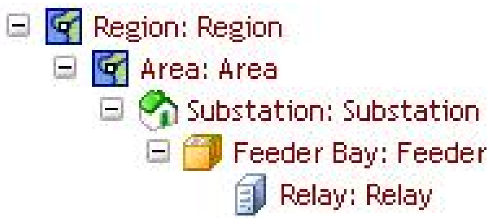

Figure 2 Example PSMS database hierarchy

5.7 Link to Analysis Tool

The analysis and design of protection relay settings is simpler when using a protection relay analysis tool such as DIgSILENT PowerFactory[1]. Such a tool can automatically create time over-current and R-X diagrams that aid settings calculation and can analyse protection relay operation. Using a power system network model the protection engineer can simulate various fault conditions and instantly know if a protection relay will trip. The power of a modern PSMS is the ability to automatically link with an analysis tool. Protection settings stored in the database can be directly uploaded to a relay model in the analysis tool and with a suitable model, the operation of the relay can be checked. Likewise, protection settings can be designed in the analysis tool then transferred to the PSMS for application to a relay in the field.

6 Conclusion

This paper has highlighted some of the typical issues utilities face in trying to manage a large number of modern numerical multi-function protection relays. Utilities use a wide variety of systems to manage their settings including hard copy settings sheets, spreadsheets and file servers. Such systems have tended to evolve with protection relays themselves but as the relays have continually increased in functionality these systems have started to reach severe limitations in terms of the administration overhead, potential for human error and data integrity. Additionally these systems do not allow utilities to fully utilise the powerful protection relay analysis functions available in power system analysis software. This paper discusses a modern approach to protection settings management using a web based management system that stores relay settings information in a common format, has in-built data auditing and business lifecycle representation and allows for automatic transfer to an analysis tool. Such a system has the potential to save a utility time, money and improve safety by ensuring accountability of settings actually applied to relays.

7 References

1. http://www.digsilent.de/Software/PowerFactory_Features
2. http://www.digsilent.de/Software/StationWare/

8 Biography

Brad Henderson, a power systems engineer originally from the South Island in New Zealand, graduated with a first class honours electrical engineering degree from the University of Canterbury in 2003. Brad subsequently worked for Transpower NZ, the New Zealand national electricity grid owner and operator, firstly as a graduate power systems engineer and later as a network planning engineer. Brad joined the DIgSILENT group in 2006 and has since developed expertise in power system stability, protection, and wind power engineering. DIgSILENT provides consultancy services using their power system analysis package, PowerFactory, for which Brad has successfully run a number of seminars and training courses throughout Australia, New Zealand and the Pacific Islands.

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