Application and Integration of Automation-Based Tools for Efficient and Accurate Modeling of Transmission System Protection

Daixi Li, Tim Chang, Saman Alaeddini, Guanhua Wen, and Xinyang Dong, *Quanta Technology, LLC.*
Chris Bolton and Ahsan Mirza, *San Diego Gas & Electric®*
Aaron Feathers and Robbie James, *Pacific Gas & Electric*
Andrew Reindel and Michael T. Miller Jr., *PECO Energy*
Jacob Tucker and Jessie Bauer, *Commonwealth Edison*

***Abstract*— The protection simulation capabilities of short-circuit software platforms can offer significant efficiency benefits for utilities facing increased responsibilities due to emerging compliance requirements. However, the challenges of modeling an entire system of protection as well as the need to keep it updated have limited the practical utilization of these simulation capabilities. Automation-based tools offer a solution to these modeling challenges, enabling efficient and accurate creation of protection representation on these short-circuit platforms. This paper presents the experiences and technical considerations of four utilities that have employed these automation-based protection modeling methodologies. First, implementation and deployment considerations are discussed, in order to meet the specific needs and conventions of an organization in engineering, data, and logistical aspects. Next, actual utilization of the tools and their impact on protection activities are explored. Third, strategies for long-term governance are considered, covering the utility processes necessary to maintain the tools. Finally, general experiences and thoughts are provided by the four utilities, as well as potential avenues for expansion of this engineering automation concept, and to further assist Protection and Control departments in meeting the challenges of the modern power systems industry.**

Keywords—modeling, engineering automation, short circuit model, simulations, protection studies

I. Introduction

Industry-standard short-circuit software platforms are essential tools to Protection and Control Departments, providing representation of the primary system for key applications such as protection settings development and event analyses. The most widely utilized software platforms have long offered advanced simulation capabilities in addition to their core short-circuit analysis functions, enabling engineers to observe relay responses to system events. However, the significant effort required to model protection representation on a system-wide scale, as well as the need to keep the representation up to date on an ongoing basis, have historically limited the practical adoption of these simulation capabilities among major utilities. Recently, increasing demand on engineering resources brought on by emerging technological and regulatory requirements, such as the NERC PRC-027 reliability standard, has motivated utilities to reconsider how these simulation capabilities may be practically implemented and the modeling challenges overcome [1].

Engineering automation concepts such as automation-based tools are one solution to these modeling difficulties, offering the capability to create simulation-ready protection quickly, efficiently, and accurately. Although automation-based tools can provide crucial advantages to utility Protection and Control departments in general, their long-term success requires consideration of how they are to be utilized and how they may fit into existing utility practices [2].

This paper discusses the application and integration considerations of automation-based protection methodologies as well as considerations for their utilization within utilities' existing data infrastructure and processes. These considerations draw upon the experiences of four organizations who have employed automated protection modeling tools to further the capability of their engineering teams. These utilities represent a varied range of different protection and data conventions, existing processes, and software application implementations, and are geographically located across the entire United States. Both technical and logistical aspects are discussed, as well as overall experiences and potential avenues for expansion of this engineering automation concept.

II. Automation-Based Modeling Methodology

The actual implemented form of automation-based modeling tools can vary, depending on the philosophy, conventions, and needs of the application and users. However, the basic functionalities required for any implementation can be described as the following:

- Obtain relay settings
- Interpret relay settings and translate data into the form required by the short-circuit software
- Identify which location in the short-circuit model the protection relay data corresponds to
- Create the protection representation in the short-circuit model using the obtained and interpreted settings data

All four utilities discussed in this paper implemented their automation-based modeling tools to function as a bridge between their relay settings repository and short-circuit platform. Although the actual platforms for both repository and short-circuit simulation software differed between the four organizations, the general structure of the automation-based modeling methodologies consisted of three main components:

- Interface to relay settings repository to obtain settings and location information
- Logic engine to interpret relay settings in the form required by the short-circuit software and to match location information to a specific terminal
- Interface to short-circuit software to create protection relay models with the required settings data

This three-stage process, as shown in Fig. 1, enables the seamless transition of settings data from file records to a simulation-ready representation.

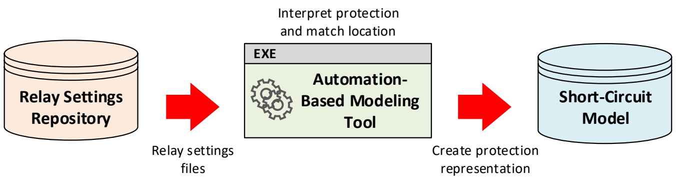


Fig. 1. Three-stage process of the automated-based modeling methodology

The technical requirements for each interface in this structure must be considered with respect to specific utility conventions and preferences. As with most automation-based solutions, data consistency is crucial for reliable operation of automation-based protection modeling methodologies. In the implementation for all four utilities, the aspects of customization, data preparation, existing and new processes, and strategies for long-term governance were key considerations for the successful deployment, utilization, and maintenance of these modeling tools.

A. *Relay Settings Repository*

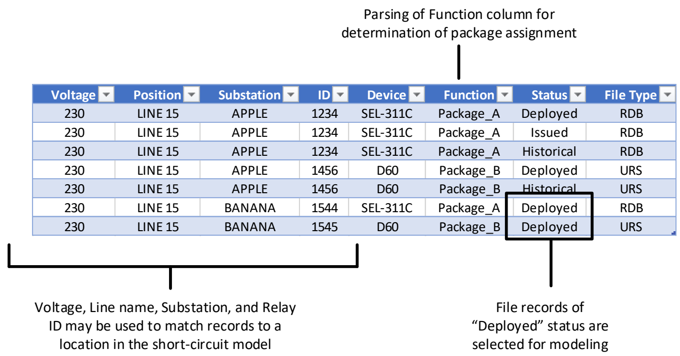
In the implemented solutions deployed across the four utilities, the relay settings repository served as the source of data for relay settings as well as locational and status identifiers. The utilization of the relay settings repository minimized risk of transcription or data error in the settings, since protection data would come directly from the actual field-deployed settings files. Furthermore, the repository was an existing database that was already utilized by the Protection and Control departments, minimizing the need for new support infrastructure.

The automation-based tools connect to the relay settings repository through an interfacing component that performs the following functions:

- Identify unique device records in the settings database
- Obtain locational and functional identifiers for each unique device record
- For records with multiple revisions, select the appropriate file using pre-defined logic for status
- Extract the settings data from the select relay settings file

Proper operation of the above functions requires consideration of the data schemes and structures of the relay settings repository, as well as utility conventions for record status, device functional and protection package assignment, and locational organization.

Although software packages typically use comparable data schemes, some fields, such as those used for package assignment, may vary greatly between organizations. Similarly, the concept of setting status is typically used in the same manner across organizations, although the actual implemented terminology (and selection criteria) can differ according to individual utility conventions. Fig. 2 shows an example of how these identifiers for each unique relay record may be utilized for location matching, file selection, and package assignment in automation-based protection modeling.



Voltage	Position	Substation	ID	Device	Function	Status	File Type
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Deployed	RDB
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Issued	RDB
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Historical	RDB
230	LINE 15	APPLE	1456	D60	Package_B	Deployed	URS
230	LINE 15	APPLE	1456	D60	Package_B	Historical	URS
230	LINE 15	BANANA	1544	SEL-311C	Package_A	Deployed	RDB
230	LINE 15	BANANA	1545	D60	Package_B	Deployed	URS

Fig. 2. Record identifiers from the relay settings repository

B. *Translation and Logic*

In all implemented solutions, a bridge layer was situated in between the interfaces to the relay settings repository and short-circuit software. This layer represented the logic engine that translated the settings and identifier data from one database to the form required by another through the following functionalities:

- Determine where in the short-circuit model the protection should be created according to location identifiers from the repository
- Obtain settings data from specific fields in the settings files and interpret the protection functionality in terms of tripping elements, directionality, and special logic schemes
- Translate the interpreted settings into the form required by the short-circuit software to create simulation-ready models

Proper operation of the above functions requires consideration of the naming conventions and consistency utilized in both repository and short-circuit data sources, as well as the specific protection conventions for settings in the relay files.

Location determination is typically based on matching of key identifiers between the repository and short-circuit model. Automation methodologies may be employed to achieve this if strict naming conventions are used, or a user-defined Translation Table may be necessary if naming between the two data sources are too dissimilar for reliable automated matching. Fig. 3 shows how locations may be defined differently in the two sources, requiring user-defined input to match the two.

Protection interpretation of industry-standard microprocessor-based relays is typically straightforward, as common elements and functions are defined and are required to be set in a consistent manner. The use of custom logic or electromechanical devices may require customization to accommodate specific utility conventions, particularly in defining interaction with communication-based protection schemes.

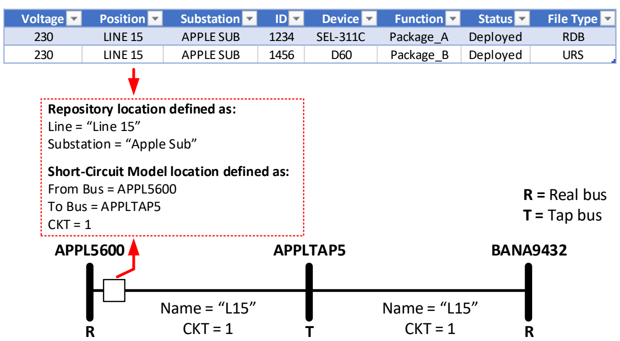


Fig. 3. Different naming conventions for the same location

C. Short-Circuit Software

The third and final interface of automation-based modeling tools is with the short-circuit platform. This interface is concerned with the creation of simulation-ready protection representation through the following functionalities:

- Identify location where protection is to be created
- Create logical protection group, relay instance, and if applicable, supporting elements, at the required location
- Push specific field data to the relay instance and supporting elements, and if applicable, set up connections between modeled components
- Configure supporting logic to enable proper simulation operation
- Write additional tag data to support supplemental and record-keeping functionalities

The main considerations for this interface are the requirements to create simulation-ready protection representation in the specific short-circuit software, which may vary greatly based on the modeling philosophy of the platform. For example, industry-standard software platforms may take either a device-representative approach, where relay devices and instrument transformers are modeled as separate elements, or a function-representative approach, where devices are split into separate components by function with embedded instrument transformers.

In addition to creating the protection representation and pushing settings field data, proper operation of the protection during simulations requires configuration of logic to indicate tripping elements and to accommodate custom logic schemes. Useful supplemental data, such as date of modeling and specific repository identifiers, may be included in the protection model to enable easy identification from which record this data was obtained [3]-[4]. Finally, utility-specific requirements and preferences must be addressed by this interface, including naming conventions, modeling approaches, and scope of modeling with respect to both system and protection functionality.

III. Implementation

The aspects of implementation involve the technical preparatory considerations required for automation-based modeling tools to function in a specific utility environment. As conventions differ between organizations, automation-based tool interfaces and logic engines need customization to accommodate the varied data structures, naming conventions, protection approaches, and modeling methodologies in use across the organizations. These considerations cover a wide range of functionalities across all components of automation-based modeling tools.

Customization considerations were primarily focused on utility-specific conventions covering repository data structures, protection approaches, and modeling methodologies. These considerations supported key functionalities such as location matching, repository file selection, protection interpretation, and were crucial for proper operation of the modeling tools.

A. Location Matching

For location matching of repository records to a specific location in the short-circuit model, all four organizations utilized user-defined Translation Tables to connect repository identifiers to short-circuit model identifiers. Some organizations used the minimum number of data identifiers required to enable this matching as a consideration for easing the burden of future Translation Table maintenance. Others opted for matching schemes that required a greater number of identifiers to allow for future potential integration with the settings repository, including processes to quickly identify which relays had updated settings that needed to be modeled.

B. Repository Data

The data structure conventions of the relay settings repository were important considerations for the selection of the appropriate file to model if multiple revisions were present, and for the determination of protection groupings (or packages). All four utilities defined a ranked hierarchy of setting statuses to identify the suitable file to model (all corresponding to the utility-specific status that denoted “field-deployed”). File upload dates or revision designations were utilized as further criteria if multiple records under the same status were encountered. Although not adopted by all the utilities, some specific additional filters were applied in some cases to limit the scope of records to those relevant to BES-level protection.

Determination of groupings or packages of complete redundant protection sets was made through different criteria across the four utilities. For several organizations, parsing of specific identifiers in key function data fields specified the package. For other organizations, packages were assigned according to a defined hierarchy based on the combination of relay devices present at a terminal.

C. *Protection Interpretation*

For protection interpretation of settings and tripping elements, the typical functions of distance, overcurrent, and differential elements were common to most organizations. Although most relay trip expressions were set in similar manners across the four organizations, one highly customizable device family employed different methods and terminology in defining tripping functions which required extensive pre-defined logic to properly parse. Some utility-specific implementations required additional customization of these functions, such as the use of non-standard fault detectors or relay logic schemes. An example for one of these protection function customizations is shown in Fig. 4, covering the steps the tools go through to address non-standard fault detectors.

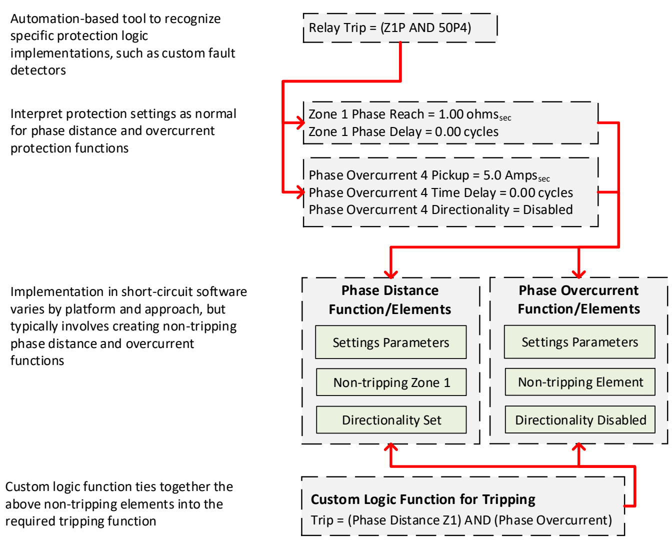


Fig. 4. Custom logic for addressing non-standard fault detectors

Communications-based protection schemes, including transfer trips, were considered for two of the organizations, and required review of external drawings to determine scheme configuration. In addition, one organization opted for the inclusion of transformer protection schemes.

D. *Short-Circuit Platform Modeling*

Modeling considerations were primarily governed by the short-circuit software platform and its approach to protection representation. The structures for protection model representations are shown in Fig. 5 for the most widely utilized short-circuit platforms, indicating the aspects that would need to be populated from the same interpreted data from the relay settings repository.

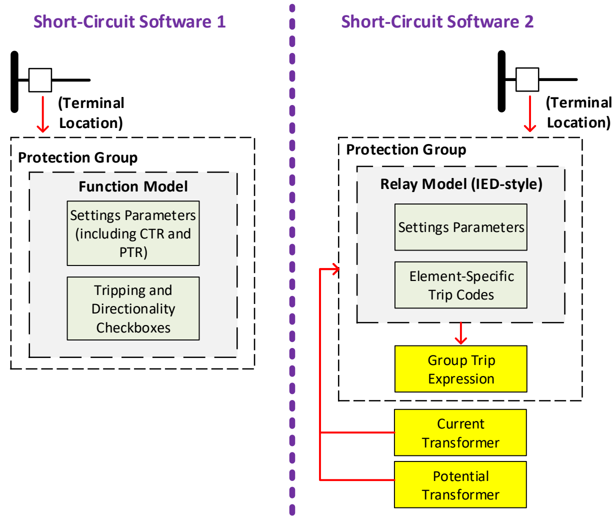


Fig. 5. Protection representation on different short-circuit software platforms

In particular, the representation approach would determine how devices or functions, measurement transformers, settings data, and tripping logic would be created, pushed, or configured in the short-circuit model. Utility conventions such as naming and preferred supplemental data also played a role although overall modeling approach for like software platforms did not differ greatly across organizations.

IV. Deployment

The aspects of deployment involve the logistical considerations required for the tools to connect to external data sources such as the relay settings repository and short-circuit model. These considerations are primarily focused on data source preparation and data security aspects that proved to be crucial to the successful deployment of the tools.

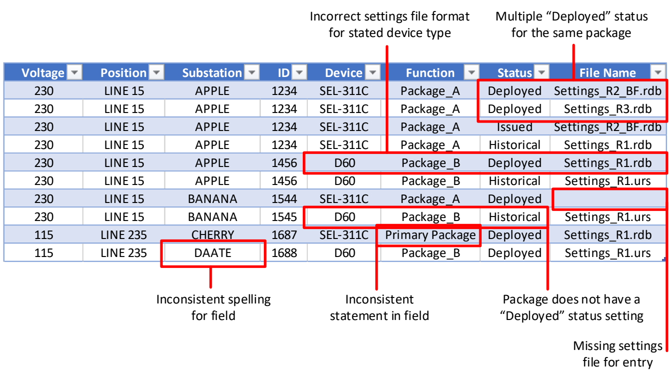
A. *Repository Data Integrity*

Considerations for the status of the relay settings repository were focused on the ability for automation-based tools to reliably identify and obtain the data needed for location matching, file selection, and package assignment. As with all automation-based methodologies, data consistency was an essential consideration for proper tool operation. Although strategies to mitigate potential variations such as limiting allowable entries to data fields were employed by all four organizations, the presence of legacy data drove concerns of data quality and usability.

Several of the utilities had undertaken repository data quality investigation efforts prior to the implementation of automation-based modeling tools, while others required this “repository health check” in parallel with tool customization efforts. For all organizations, data considerations that may cause issues for reliable tool operation, including questionable statuses, inconsistent naming, or missing data, were identified and flagged for correction prior to tool deployment.

Common repository data integrity issues are shown in Fig. 6, including:

- Multiple entries with highest priority status for the same package and location; mitigating logic may utilize file date as tiebreaker
- Stored relay settings file is incorrect format for stated device type
- Missing settings file for a selectable entry
- Missing entry with highest priority status for a specific location
- Incorrect spelling or inconsistent form of data in a field



Voltage	Position	Substation	ID	Device	Function	Status	File Name
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Deployed	Settings_R2_BF.rdb
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Deployed	Settings_R3.rdb
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Issued	Settings_R2_BF.rdb
230	LINE 15	APPLE	1234	SEL-311C	Package_A	Historical	Settings_R1.rdb
230	LINE 15	APPLE	1456	D60	Package_B	Deployed	Settings_R1.rdb
230	LINE 15	APPLE	1456	D60	Package_B	Historical	Settings_R1.urs
230	LINE 15	BANANA	1544	SEL-311C	Package_A	Deployed	
230	LINE 15	BANANA	1545	D60	Package_B	Historical	Settings_R1.urs
115	LINE 235	CHERRY	1687	SEL-311C	Primary Package	Deployed	Settings_R1.rdb
115	LINE 235	DAATE	1688	D60	Package_B	Deployed	Settings_R1.urs

Fig. 6. Common data integrity issues from the data settings repository

A final consideration for the repository was related to alignment of data with external sources, such as asset management software. Since asset data, including naming references, was pushed from these external sources for several of the utilities, some restrictions were imposed on the length and format of the data. Further, these asset management databases were outside the control of the Protection and Control department for some organizations, requiring collaboration with other departments if modifications were needed.

Protection settings data for third-party entities was stored in different manners across the four organizations. These could range from being included in the repository with specific identifiers indicating their belonging to neighboring utilities, to not being stored in the repository at all, to something in between. Each utility accommodated protection modeling on interconnection lines according to their own data availability.

B. Short-Circuit Primary Model

Short-circuit primary model considerations were focused on representation of primary system elements such as lines and buses which define the terminals at which protection models are created. As with the settings repository, automation-based modeling tools rely on consistent conventions in the primary model to enable correct operation. In particular, proper classification of buses (differentiating substation “real” buses and tap buses) was the single most important aspect for short-circuit model consideration. All four of the utilities required some degree of primary model check to ensure successful identification of terminal locations, which ranged from minor corrections for some organizations to a major review of all lines for others.

Short-circuit model conventions could provide other benefits to automation-based modeling tools. Several of the utilities utilized a short-circuit model that contained extensive representation for neighboring entities. In these cases, data fields specifying the bus owner limit the scope of lines and elements considered by modeling tools to only those that involve these organizations.

As with the relay settings repository, the naming and data conventions used within the short-circuit model were dependent on external sources in some cases, limiting the ability to align repository and short-circuit data.

C. IT and Data Security

Security considerations are becoming more prevalent at utilities, particularly with data involving the BES system. Some of the organizations who deployed automation-based modeling tools implemented additional accommodations to meet IT and data security considerations.

First, database security practices did not allow external tools to connect directly to production databases in use for day-to-day relay settings efforts. In these cases, the production settings repository was replicated into an Electronic Data Warehouse (EDW) that was updated periodically from the production version. Considerations for the utility included the frequency of these updates and what tables would need to be included in the replicated database to minimize duplication, but still enable the tools to operate. The interactions of this EDW with respect to the automation-based modeling methodology process is shown in Fig. 7.

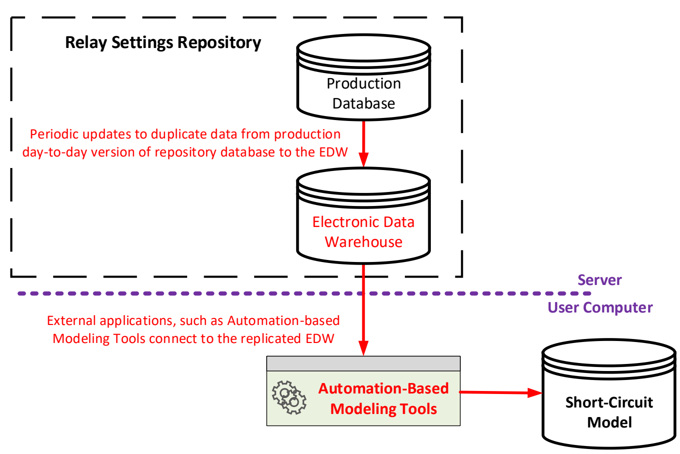


Fig. 7. Interactions of EDW in automation-based modeling process

Second, with increasing focus on cybersecurity and NERC CIP requirements, settings repositories or even individual settings files may have been subject to heightened security considerations. These requirements had implications on how the automation-based modeling tools addressed user access and data handling, particularly in encryption requirements for data-at-rest. For some of the four organizations, the tools were managed by IT departments, while for others, the Protection and Control departments retained direct control.

V. Operational Utilization

The operational utilization aspect involves the considerations for day-to-day operation of the automation-based modeling tools in the utility environment. These considerations revolve around impact on existing processes, the approach for usage of the tools, and how short-circuit models are consequently managed.

A. Utilization Model

All four utilities adopted a two-tier approach for the utilization of these modeling tools:

- Use by a designated Subject Matter Expert (SME) to maintain updated protection representation in a reference base line case
- Use by individual protection engineers in location short-circuit case copies to assist with their own projects

This two-pronged approach enables a master copy to be kept as the department's reference case that represents the state of the protection deployed to the field. The designated SME or coordinator would run the tools in batch mode (modeling of multiple lines in one operation) on a monthly (or other periodic) basis to keep the reference case updated. Individual engineers would obtain this reference case and may push tentative or not-yet-deployed settings to their own local copies of the model to investigate protection performance in their projects.

Some of the organizations are also considering further integration with the relay settings repository in order to determine which specific devices need updating. Since modeling operations write a date tag to the protection representation in the short-circuit model, this date may be compared against record update dates in the repository.

B. Model Management

Following the two-tier approach to tool utilization, model management at the four organizations also sees a two-tier organization in the form of the master case, and engineers' individual copies for their various projects.

The reference case is stored at a shared location and is published on a periodic basis. Individual engineers may obtain a copy of this perpetually updated base line for their own local studies. One organization has utilized a check-in, check-out process for the master copy to enable updates.

C. Impact on Processes

Although some utilities did previously create limited protection models for some elements in their short-circuit cases, the inclusion of full protection representation for all BES lines was not a regular practice prior to the deployment of automation-based tools. At the organizations that have completed deployment of tools and the opportunity to integrate into their processes, engineers have more regularly utilized the simulation-based capabilities to assist in their work, including relay settings development efforts.

The timing of updates is one further consideration, as changes to relay settings files and system short-circuit representation may not always occur simultaneously. Most organizations have adopted a policy to model only devices that were confirmed to be field-deployed (controlled through status), ensuring that the master case would only represent current protection. Individual engineers, of course, would be free to model any future or tentative protection to assist in their own projects.

VI. Governance

The governance aspect involves the considerations to maintain the automation-based modeling tools as well as the required data sources. These considerations include strategies and processes to ensure continued data integrity of the repository and short-circuit model and updating of the Translation Table that connects the two.

A. Data Integrity

All four utilities have considered the data conventions required by the modeling tools and have adopted new processes to maintain these conventions. These processes may include periodic execution of repository data integrity investigations as well as regular utilization of the tools to help catch issues earlier. At one organization, where a handful of relay settings files could not be directly read from vendor-native format, new processes were put in place to upload a converted text format of the settings for use with the automation-based modeling tools.

For the short-circuit model, additional training was provided at some organizations on bus classification and naming conventions. Long-term plans to assist in maintaining the short-circuit case include the future development of data integrity "health report" investigation checks, in a manner comparable to those in use for the relay settings repository.

B. Location Matching

Since all four organizations utilize Translation Tables to match repository records to short-circuit model terminal locations, the maintenance of this table is crucial for long-term operation of the automation-based tools.

The organizations have designated administrators for the tools, whose responsibility would be to keep the Translation Table updated as relay and system changes occur. These admins communicate with the individual protection engineers and are informed of changes on both a scheduled periodic and ad hoc basis. Some organizations designate only a single admin, while others may have multiple individuals according to geographical operating centers.

As with the distribution of the short-circuit reference case, the updated Translation Table is kept at a central location and may be copied by individual engineers for their own projects.

Fig. 8 shows the update process for both the Translation Table as well as the short-circuit base case described in Section V.

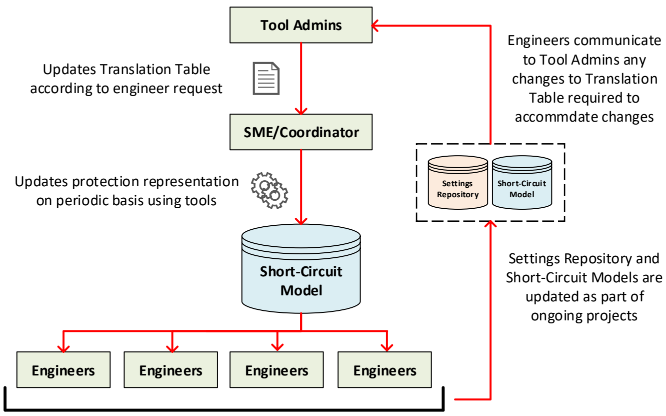


Fig. 8. Update process for protection represenation and Translation Table

C. *Tool Updates*

Updates to the automation-based modeling tools may be needed to accommodate new relay types, new protection logic schemes, or changes to defined convention in the relay settings repository or short-circuit model. For the initial implementation at all four utilities, the tools do not provide for user-accessible configuration of these conventions – updates would require the issuance of a new version of the tools. This was implemented as a deliberate design decision to minimize the risk of fragmented versions of the tools among different engineers.

VII. Experience and Expansion

This section highlights some of the major experiences stated by the four utilities in this implementation process as well as potential future applications for automation engineering concepts.

A. *Expectations*

The key takeaways from an expectation perspective stated by several of the utilities that employed these modeling tools was the unexpected significance of data integrity and the aspects of manual intervention that still require utility effort.

Data integrity concerns are primarily focused on the relay settings repository, both in terms of correcting existing data as well as the need to maintain the data for continued operation of the tools. In particular, cleanup efforts for the repository conducted prior to tool implementation required significantly more effort from the applicable organizations than initially expected.

Another major concern is the maintenance of the Translation Table to update matches between records in the settings repository to terminal locations in the short-circuit file. Less utility intervention would have been preferred in this aspect, which was necessitated by the incompatible state of data for reliable automated matching of identifiers.

Finally processes for the communications and coordination with other departments were reinforced to facilitate the update or modification of data for sources outside the direct control of the Protection and Control departments.

As a response to the above experiences, the utilities involved have initiated several actions to mitigate the effect of these challenges for both short and long-term outlooks. In the short-term, revised processes and greater emphasis on data quality can be supplemented through utilization of database "health reports" to identify potential issues. For more long-term solutions, more automation is under consideration, particularly for the Translation Table matching.

B. *Potential Expansion*

With the automation-based tools enabling the efficient and accurate modeling of widespread protection representation at the BES level, several of the organizations have looked to applying similar engineering automation and process integration concepts to other aspects of their responsibilities.

Since the need for automated protection modeling capability was initiated by the upcoming NERC PRC-027 compliance requirements, several utilities implemented the minimum required protection functions and disregarded differential elements and communications-based schemes. With the demonstrated effectiveness of automation-based modeling methodologies, these functions may be retrofitted to the modeled protection representation to provide a more complete view of relay performance. The inclusion of generator relay protection and additional elements such as voltage-based functions are also potential additions. In terms of modeling scope, the inclusion of distribution-level protection either on their own applicable software platforms or through platform conversion mechanisms may be considered as expansion to the automation-based modeling concept.

Within the discussion of potential improvements to the automation-based modeling process, the four organizations have cited greater automation and decrease in the need for utility intervention to be avenues to pursue. Of particular interest would be improvements to alignment of data sources to enable automatic matching of repository records to terminal locations, eliminating the need for a user-maintained Translation Table.

The concept of automation-based methodologies to create representation in short-circuit models may also potentially be applied the primary system components, including lines, generators, and transformers. Different data sources, likely related to asset management and equipment records, would be required, but the same general arrangement of data source to bridge to model would be retained. These applications of highly automated solutions that integrate with many different data sources across departments represent the logical conclusion of the engineering automation concept implemented in automation-based modeling methodologies.

VIII. Conclusion

Automation-based modeling tools can enable protection representation to be created or updated quickly and efficiently in short-circuit models. Serving as a bridge between the relay settings repository and the short-circuit case, these tools provide Protection engineers with the capability to feasibly leverage the robust simulation capabilities within short-circuit software packages for Protection System Coordination Studies.

This paper has discussed the practical considerations of implementing, deploying, utilizing, and maintaining these automation-based modeling tools, drawing from the experiences of four utilities across the United States. Although there were aspects that required customization for specific utilities based on their own conventions and practices, the general technical decisions and processes that were employed were largely analogous across all four organizations.

The outcome of these implementation efforts can be summarized in the comments of one of the utilities, who reiterated their skepticism that protection data could be successfully pushed to the short-circuit model in an automated manner. Following the successful deployment of these tools, they were able to identify some protection settings issues through the Wide-Area Protection Coordination studies that were made feasible by the widespread modeling of protection.

The engineering automation concept behind these modeling tools can potentially be expanded beyond protection to include primary system components of the short-circuit models. The logical conclusion of this concept are highly automated enterprise solutions that integrated many different data sources across departments that enable seamless flow of data from one application to the next. Ultimately, the end goal of any tool, including those represented by the engineering automation concept, is to assist engineers in their roles and responsibilities within the modern power systems industry.

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Biographies

Daixi Li received her MASc from North Carolina State University and has been with Quanta Technology since 2016. At Quanta Technology, she has worked on wide-area coordination studies, feeder studies and relay coordination, protection system modeling and programmed tools to aid engineers managing substation points list reports. She is a licensed professional engineer in California.

Tim Chang received his MASc from the University of Toronto and has been with Quanta Technology since 2009. His experience at Quanta Technology has covered broad range of aspects from traditional transmission and distribution engineering applications to use of real-time simulators for advanced renewable impact studies. He has been a major contributor to the development of automated processes and applications for data management and engineering studies, including evaluation of NERC compliance standards, software modeling solutions, and wide-area protection coordination studies.

Saman Alaeddini received his MASc from Ryerson University and has been with Quanta Technology since 2009. He leads the engineering automation team at Quanta Technology that has developed many innovative software-based solutions for the power systems industry, particularly in the area of NERC compliance evaluation. Saman is a specialist in protection system modeling, database management and analysis, autonomous systems design, robotics, and industrial processes. He has been involved in wide-area protection projects for over 7000 transmission lines with 10 large electric utilities in North America and internationally.

Guanhua Wen received has BASc from the University of Waterloo and has been with Quanta Technology since 2016. His experience at Quanta Technology has included protection modeling, software design, and project management. He has developed, and has lead development of software to solve problems specifically for the power industry. His focus is to develop and grow a software team to bring modern software solutions to the power industry. Guanhua has worked on large-scale projects with major electric utilities in North America and internationally.

Xinyang Dong received her MASc degree from North Carolina State University and has been with Quanta Technology since 2016. During her time at Quanta Technology, she has contributed to wide-area coordination studies, line and transformer protection, feeder studies and relay coordination, fault location algorithms, and short circuit analysis using industry-standard short-circuit packages.

Chris Bolton is manager of system protection automation and control engineering at SDG&E, where he has worked since 2011. Bolton has held a variety of positions with the utility, including in substation engineering, capital projects, substation technical analysis and support, and system protection maintenance. Bolton graduated with a BSEE degree from California State Polytechnic University, Pomona and is a licensed professional engineer in California.

Ahsan Mirza is manager of system protection maintenance at SDG&E. He manages a team of relay technicians and supervisory control and data acquisition technicians responsible for the utility's T&D relay construction and maintenance. Prior to his current role, Mirza was a team lead in system protection automation and control engineering for five years. He joined SDG&E in 2009 after receiving his BSEE degree from University of Illinois in Urbana-Champaign. He is a registered professional engineer in California.

Aaron Feathers is a Principal Engineer in System Protection Engineering at Pacific Gas and Electric Company, where he has been employed since 1992. He has 29 years of experience in the application of protective relaying and control systems on transmission systems. Aaron's current job responsibilities include wide area RAS support, NERC PRC compliance, and relay asset management. He has a BSEE degree from California State Polytechnic University, San Luis Obispo and is a registered Professional Engineer in the State of California. He is also a member of IEEE and is on the Western Protective Relay Conference planning committee and participated on the NERC Protection System Maintenance Standard Drafting Team developing NERC Standard PRC-005-2 to PRC-005-6.

Robbie James received his BASc from University of California, Berkeley and MASc from California State University, Fresno. He started his career at PG&E in 2008 in distribution engineering and has held his current position as a transmission system protection engineer since 2010. He is a registered professional engineer in California.

Andrew Reindel, PE is the manager of Protection & Control Department for Transmission & Substations Engineering at PECO Energy. Drew has worked for PECO for over 30 years. He has worked in many departments and served in many roles over his time with PECO including Field Engineering, Project Engineering, Substation Standards, Regional Distribution Engineering and Maintenance Program Development.

Michael T. Miller Jr. is a Senior Engineer in the Protection & Control Department for Transmission & Substations Engineering at PECO Energy. Mike joined PECO in 2017. He has worked on several transmission and distribution replacement projects. He is the PECO SME for PRC-023, PRC-025 and PRC-027.

Jacob Tucker is a relay engineer in the Transmission and Substation Relay & Protection Group at Commonwealth Edison, where he has worked since 2014. Tucker's responsibilities include relay setting development, short-circuit model management, and compliance and reliability standards. He has been a major contributor to the department in the development of processes and tools to streamline setting development. Tucker received his BSEE from the South Dakota School of Mines and Technology and is a licensed professional engineer in Illinois.

Jessie Bauer received his BSECE degree from Illinois Institute of Technology and has been with Commonwealth Edison since 2011. He is currently the manager of Distribution Standards, and previously worked in Relay & Protection, and Regional Engineering.