Automated Analysis & Reporting from Relay Setting Database

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***Abstract*—Protection engineers often verify relay settings stored in a database. The conventional way to view settings is to open the setting files with software released by the respective manufacturer. Often times, the most commonly used settings are stored in a report for quick access by protection and other departments within the same utility. Depending on the size of the network, creating and updating such reports can be time consuming. This paper proposes a process to automatically create customized reports based on setting files stored in a database. Logics are programmed to read relay settings and intelligently convey tripping information to the relay engineer. The connection to the settings database is facilitated by using an Open Database Connectivity (ODBC) link. Custom queries are utilized to retrieve relay settings by a predefined search pattern. The relay engineer can generate reports based on a specific settings file, relay, position, or substation.**

Keywords—Automation; Compliance; Database; Relay Settings; Analysis; PRC

I. Introduction

Relay protection is becoming increasingly complicated, requiring more resources for analysis and maintenance. The variety and complexity of numerical relays are also increasing. Tracking settings values has become more difficult between relays from different manufacturers. Power system topology is constantly evolving, and documentation needs to be up-to-date and communicated effectively across the utility. NERC and local ISOs have stricter compliance expectations and require readily available data to prove compliance. Ever since the Northeast blackout of 2003 in the U.S., an increasing number of compliance requirements have been placed upon utilities. This has put tremendous pressure on relay engineers to prepare audit-ready reports in addition to their regular responsibilities. Accommodating these requirements have made staff shortages a common problem. By developing processes that favor automation, the labor effort of compliance reporting can be greatly reduced [1]. Over time, utilities need to maintain or upgrade the grid to meet increasing demand. New transmission lines are built, electro-mechanical relays are replaced with numerical relays, new generation is added, and line loading limits are frequently changing. When designing protection settings, it is important for relay engineers to have the most up-to-date information in order to make the best decisions.

Tracking and handling of protection information can be greatly simplified for the relay engineer with the use of computer automation and upfront investment (time and resources) in setting up proper processes and databases. The use of databases in the industry is not a new concept – some utilities have already migrated most of their relay settings files into a database management system. Theoretically, any information related to a power system can be digitized and centralized in a database. By having all of the relevant information available, decisions can be made more accurately and efficiently. Additionally, compliance reporting for NERC CIP and NERC PRC [2]-[3] can be analyzed and made readily available. Topology changes, once tracked, can be reported with ease. Relay settings that have been modified can be compiled into a report for the engineer on demand.

Automation of information has been successful in the other areas of the electric power industry. By consolidating and analyzing relay settings data, new insights can be provided to the relay engineer. By combining automation with the right processes and staff that support it, compliance and reporting can be streamlined and automated. The setting of relays to meet upcoming compliance standards is proving difficult for utilities' existing processes. However, software can be developed to read and analyze settings based upon these written rules. For example, software can be written to parse a string of text that identifies itself as the primary protection relay for a specific transmission line. This paper proposes a process and tool to automatically create customized reports based on setting files stored in a database. Logics are programmed to read relay settings and intelligently convey tripping information to the relay engineer. The connection to the settings database is facilitated by using an Open Database Connectivity (ODBC) link. Custom queries are utilized to retrieve relay settings by a predefined search pattern. The process incorporates a combination of lookup tables containing relay styles, enabling the tool to navigate the many relay styles used for settings files. Support for new/future relay models can also be added to the relay mapping catalogue. The relay engineer can generate reports based on a specific settings file, relay, position, or substation.

The rest of paper is organized as follows: In Section II, different use cases for automation approaches in power system protection are summarized. Section III discusses the existing roadblocks in utilizing automated tools. In Section IV, the automated process of creating relay setting summary reports is elaborated. Section V concludes the paper.

II. AUTOMATION USE CASES

Once all the necessary pieces of information are easily accessible by the relay engineer, data can be analyzed in many different ways and organized into a report for the following use cases:

Reporting – Summary reports automatically generated with carefully preselected relay settings can prove to be useful for certain departments in a utility. For example, grid operations may find value in having the most limiting settings for each circuit in the system. Section IV of this paper focuses more on the reporting possibilities resulting from automation.

Compliance – Audit reports can be generated yearly in preparation for audits by NERC. Certain CIP compliance reports can be easily automated. For example, CIP-005-related relays can be flagged in the database. Any changes to applicable relays can alert the relay engineer to evaluate [4]. PRC-023 compliance can be met with automated reports of relays that violate line loadability with line thermal limit inputs from planning group.

Modeling – The simulation model for short circuit software as well as the protection system can be built up using the stored as parameters and information in the database. Automation can facilitate the importation of protection setting and network topology from other data sources. Once the initial setup is complete, maintaining the short-circuit model can be done with minimal effort.

Analysis and Studies – Once all of the protection settings are consolidated, subsets of settings can be easily extracted via SQL queries. For example, overcurrent protection can be extracted for all 12-kV feeders to be compared to damage curves of safety equipment. This can provide a good sanity test of the purchased safety equipment. Another recommendation that can be automatically suggested is results of a sensitivity study. Distance elements can be extracted and evaluated to see if they are operating within the intended parameters.

III. AUTOMATION ROADBLOCKS

The storage medium used to maintain information for different equipment, relay settings, line ratings, etc., is becoming ever important. Often, a storage medium is chosen without much foresight, overlooking the eventual need to integrate all the information. To perform and automate a study on a large scale, data needs to be organized and readily available to computer software running SQL queries. Depending on how a utility has operated in the past, a major effort may be required to cleanup and consolidate data. Using relay settings as an example, they might be housed in any number of ways/locations within a utility:

- Main relay settings database
- Legacy relay settings database
- Folder structure for prior legacy relays
- Physical reports stored in a filing cabinet

Data inconsistency is a major roadblock in automated reporting. Whether it is the result of each relay manufacturer having their own proprietary approach to relay logic or utilities using several types of short-circuit software, significant effort can be required to prepare such data for automated software analysis.

A. Consolidation of Relay Settings

Relay settings need to be made available prior to automating report generation. Electro-mechanical relays and numerical relays often have settings stored in the following ways:

- Physical copies of relay settings (scanned reports)
- Manufacturer-specific file formats
- Settings saved in spreadsheets and documents

Due to multiple sources of relay settings, it is necessary to consolidate all relay settings into a main repository so that every active relay in the system is readily available (Fig. 1).

B. Standardization of Naming Conventions

Implementing a well-thought-out naming convention for relay settings files is required. A naming convention should include information regarding the location, voltage, relay model, and revision. The filename should include enough details for the setting to be mapped to the database. For example:

Substation_Circuit_Relay_RevNumber.rdb

The information contained within the naming convention should allow software to automatically sort a large amount of settings files and populate a database. One possible approach to organizing relay settings can be found in Fig. 2.

IV. RELAY SETTINGS SUMMARY REPORT

As the size and complexity of the grid grows, information needs to be seamlessly communicated to key stakeholders. One of the many use cases of automation is to generate relay setting summary reports on a relay-by-relay basis. These reports can be automatically generated based on relay setting files stored in a relay setting repository.

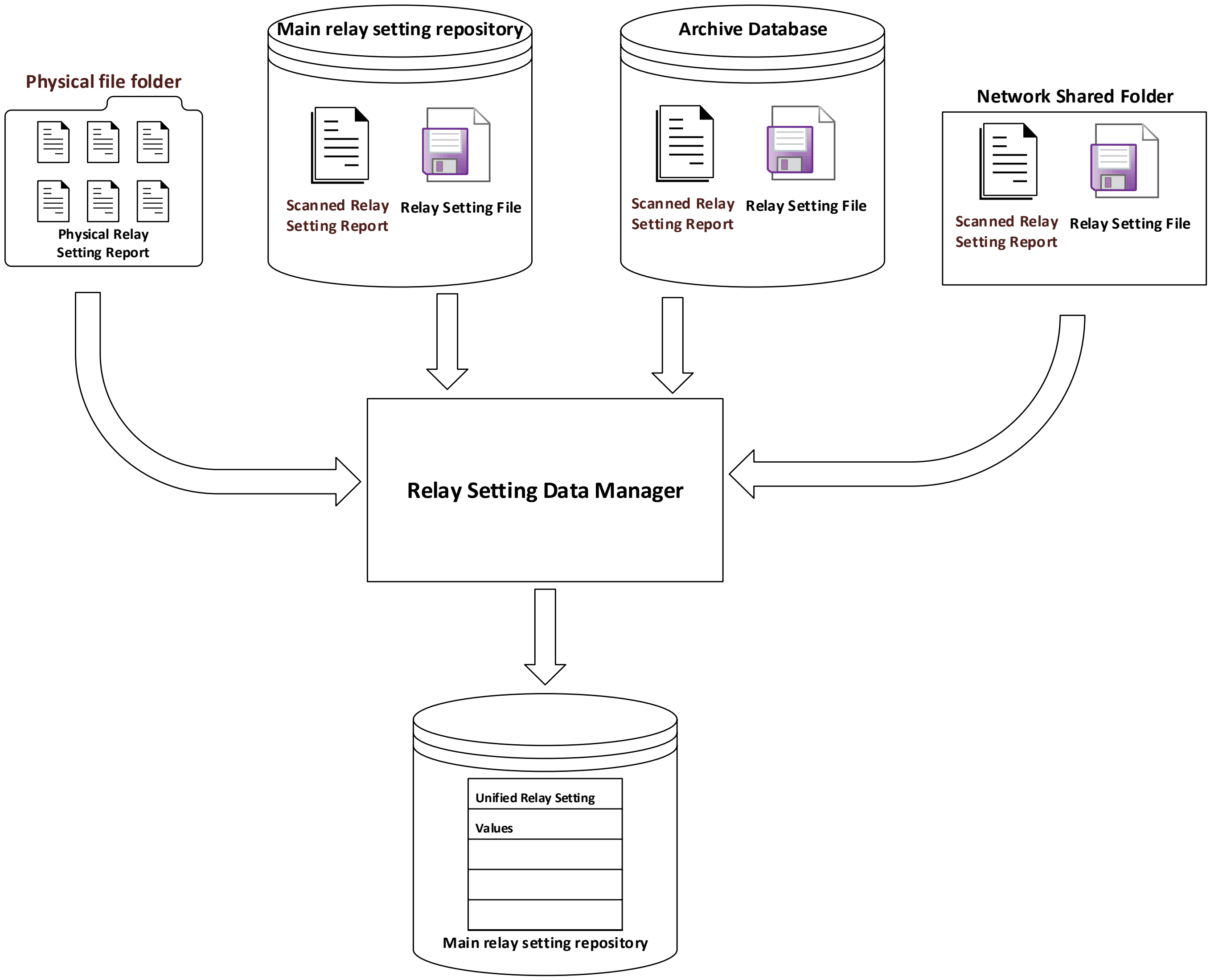

Fig. 1. Consolidating Sources Containing Relay Settings

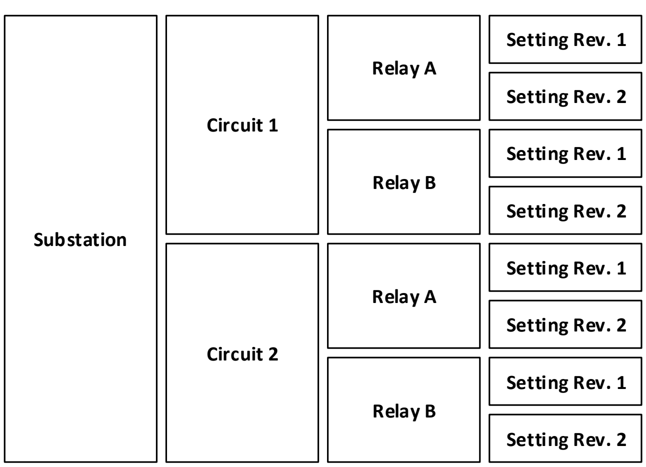

Fig. 2. Database Organization of Relay Settings Files

Once protection settings are easily readable via software, an executable program can be developed to translate the protection settings into a report-ready document (Fig. 3). The relay mapping catalog (Fig. 4) is a look up table that translates and deciphers relay settings from different manufacturers and prints them onto a report template customized for each utility.

A. Relay Mapping Catalog

The relay mapping catalog covers the functionalities of different relay models from individual manufacturers. Each manufacturer implements functionalities differently and allows the utility to set their own logic. The relay mapping catalog can be configured to look for utility-specific logic in every relay model and identify them from the relay settings. For example, 21 distance elements may be of interest to the operator. However, they do not need to know the exact make and model of the relay. The mapping will allow software to extract the overcurrent trip value and present it independent of the relay model to the operator.

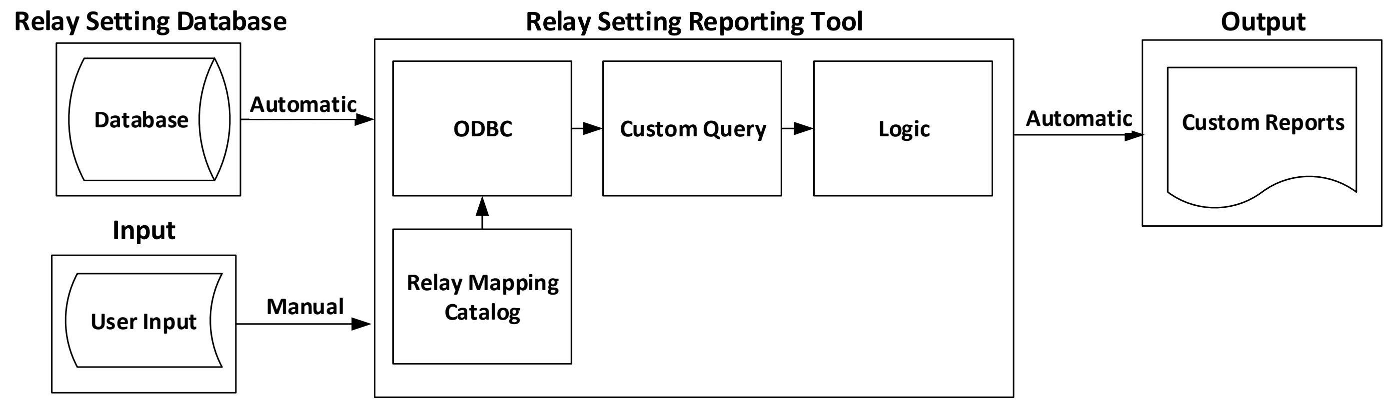

Fig. 3. Relay Setting Reporting Tool

For example, the instructions to find the ground distance element for a particular relay can be expressed as a logical equation. The software will parse through the relay settings file – first looking for the tap in group 1 “Z1GD” for ground distance enable – if the value found is not “OFF”, the next elements of “XG1” and “E21XG” will be stored into memory for reporting. “Cycles” will indicate to the software the units of element.

B. *Report Template*

Depending on the specific need of the end user, different templates can be created and populated with relevant protection data. For example, overcurrent trip value can be calculated to display in either primary or secondary amps. Minimum trip values can be evaluated based on the trip equation. An example is shown in Fig. 5.

C. *Comparing Multiple Setting Revisions*

Relay settings are constantly updated and changed. It is important to effectively communicate these changes to applicable users. There may be existing processes the relay engineer has to follow to inform others of these changes. With settings in a database, software can be used to highlight and notify others. There can be revision tracking for each element in a relay setting. Again this is independent of the relay make and model.

In the relay setting repository, multiple setting file revisions can be stored per relay. Software can be written to compare different versions of the settings file and highlight any changes on the relay summary report. The relay setting deployment process of a specific utility needs to be taken into account for this to work. Each relay setting file falls under a certain status throughout its life cycle.

Different departments are interested in relay settings of different statuses. For example, the relay engineer might be interested in a “Needs Review” setting for setting that was adjusted in the field and requires a second look. To quickly see what settings have changed from the field, the changed settings can be automatically highlighted in the summary report. This allows the relay engineer to quickly identify the difference between two relay settings. Fig. 6 illustrates the flow of information to compare relay settings.

D. *Logic to Calcualte the Most Limiting Factors and Determining Tripping Elements*

Logic can be programed to find the most limiting settings within a relay settings file. This can help the reader to quickly identify the most sensitive elements that can trip a relay. Some line-protection relay-limiting settings can be categorized as:

- General most limiting setting
- Loss of Potential (LOP) most limiting setting
- Switch onto Fault (SOTF) most limiting setting

The logic diagram of calculating most limiting settings is illustrated in Fig. 7. An executable program is able to parse the tripping and SOTF logic of a relay and analyze them to calculate the most limiting settings. It is assumed that the tripping logic is in “TR = A1 OR A2 OR A3 OR etc.” format where “Ai = Ai,1 AND Ai,2 AND Ai,3 AND etc." An example of calculating most limiting setting is shown in Fig. 7.

MEASUREMENT	IDENTIFIER	SEL_311C_0
Ground	Zone 1	1/Z1GD {(Z1GD <> OFF) & (XG1 <> OFF) & (E21XG >= 1)} [Cycles]
Ground	Zone 2	1/Z2GD {(Z2GD <> OFF) & (XG2 <> OFF) & (E21XG >= 2)} [Cycles]
Ground	Zone 3	1/Z3GD {(Z3GD <> OFF) & (XG3 <> OFF) & (E21XG >= 3)} [Cycles]
Ground	Zone 4	1/Z4GD {(Z4GD <> OFF) & (XG4 <> OFF) & (E21XG >= 4)} [Cycles]

Fig. 4. Relay Mapping Catalog

GRID OPS - RELAY SETTINGS									
"Postion"						Relay Model		Most Limiting Setting	
PTR	CTR - 1	CTR - 2	CTR - 3	CTR - 4	CTR - 5	Term. ID		LOP - Limiting Setting	
						Relay ID		SOTF - Limiting Setting	

ELEMENT TYPE	PRI VALUE (A)		COMM	STATUS
	PHASE	GROUND		
Differential			1	
			2	

ELEMENT TYPE	PRI VALUE (A)	TIME DELAY (CYC)
Z1 Phase Distance		
Z2 Phase Distance		
Z3 Phase Distance		
Z1 Ground Distance		
Z2 Ground Distance		
Z3 Ground Distance		

ELEMENT TYPE		VALUE
Frequency	Under Frequency Setting	
	Under Frequency - Time Delay	
Reclosing	# of Shots	
	Time Delay - First Shot	
	Reset Time - First Shot	
	Master/Slave	
Synch Check	Max Angle 1 (degrees)	
	Low Volt Threshhold (kV)	
	High Volt Threshhold (kV)	
	Dead Bus (kV)	
Voltage	Under Voltage Setting	
	Under Voltage - Time Delay	
	Over Voltage Setting	
	Over Voltage - Time Delay	
Control Relay		

ELEMENT TYPE	PRI VALUE (A)	TIME DELAY (CYC)
Phase IOC 1		
Phase IOC 2		
Phase IOC 3		
Phase IOC 4		
Ground IOC 1		
Ground IOC 2		
Ground IOC 3		
Ground IOC 4		
Neg Seq IOC 1		
Neg Seq IOC 2		
Neg Seq IOC 3		
Neg Seq IOC 4		

ELEMENT TYPE	PRI VALUE (A)	TIME DIAL
Phase TOC 1		
Ground TOC 1		
Neg Seq TOC 1		

Notes:

Fig. 5. Relay Setting Report Template

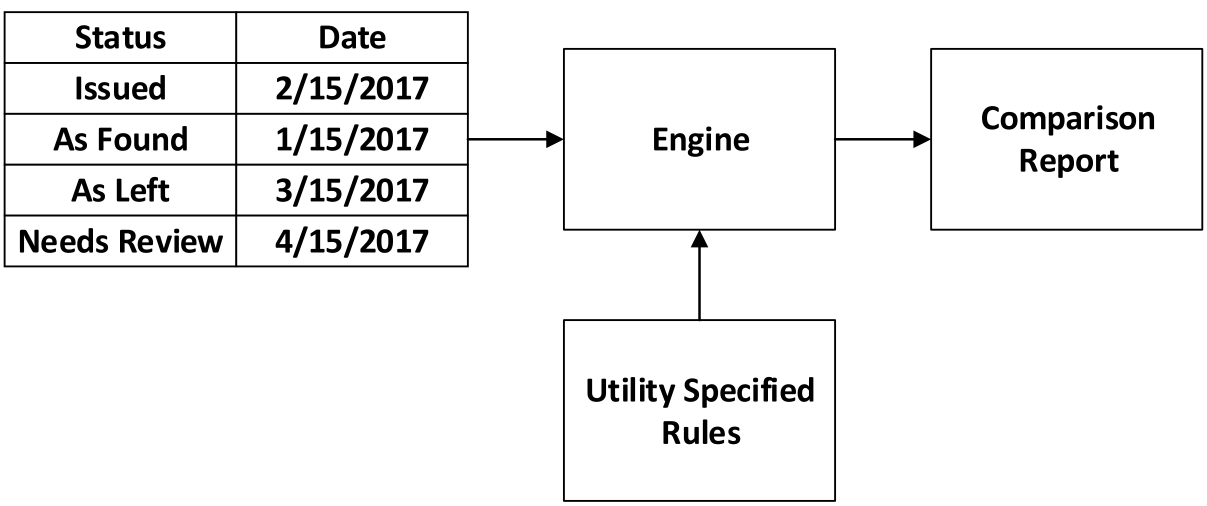

Fig. 6. Comparing Relay Setting Revisions Logic Diagram

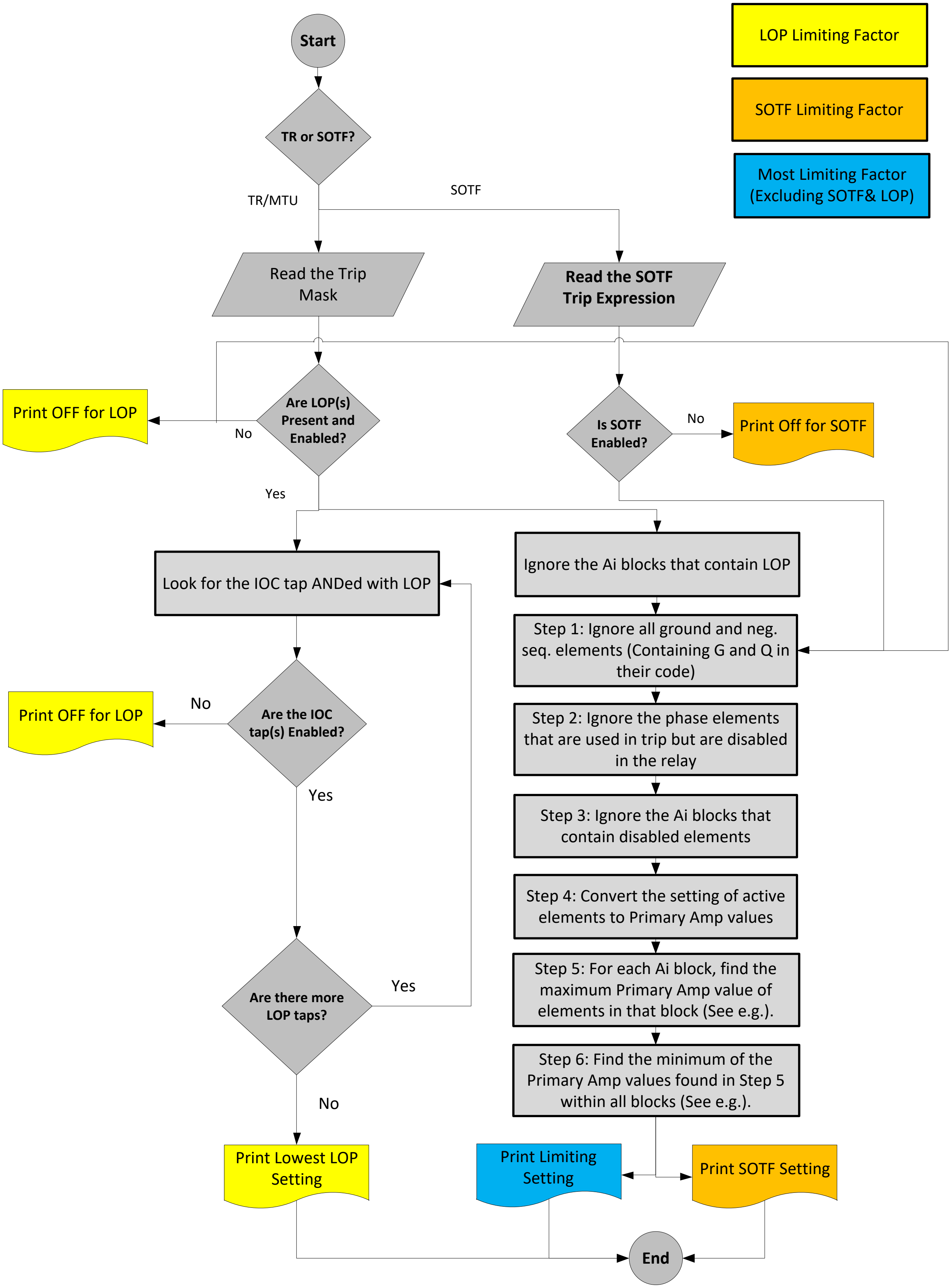

Fig. 7. Most Limiting Setting Logic Diagram

V. Conclusion

This paper proposed a process to automatically create customized reports based on setting files stored in a database. Logics were programmed to read relay settings and intelligently convey tripping information to the relay engineer. Consolidation of relay settings enables computer software to analyze and report information automatically to the relay engineer. This will greatly reduce the time and effort required for the relay engineer compared to manually creating these reports. Automation of report generation is not an easy process to implement, as it requires the proper staff and processes to support it. Utilities should carefully choose tasks and focus their resources on automating them to see the greatest benefit.

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Karl Iliev manages the System Protection & Control Engineering department at San Diego Gas & Electric. He began work in 1999 as an Engineering Intern at SDG&E and has held positions on both transmission and distribution sides ranging from planning to engineering to construction and operations. Karl graduated from California State University of Sacramento with a BS in Electrical Engineering and a minor in Physics. Karl is licensed as a Professional Engineer in the State of California.