White Paper

A Guide for Calculating Step Distance Relay Settings

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On June 7, 2018, FERC approved the NERC Reliability Standard PRC-027-1: Coordination of Protection System Performance During Faults. This standard mandates that generator, transmission, and distribution owners *establish a process for developing new and revised protection settings* and properly coordinate their systems with interconnected utilities as part of Requirement 1. This requirement must be completed by October 1, 2020.

The relay setting development process should include a series of steps that guides the settings engineer to achieve reliable and properly coordinated relay settings. First, each utility must develop a solid protection philosophy that establishes the guidelines for setting the functionality of protective relays. When developing a protection philosophy, clear indication should be given for special cases where the normal procedures are not most suitable for certain applications. Next, a set of calculation sheet templates embedded in a spreadsheet or automation program should be implemented in order to maintain consistency and uniformity throughout the company. In this way, multiple engineers or consulting parties can follow the same standard procedures, preventing an inconsistent set of settings and formats from being created.

This white paper provides a basic structure for calculating Step Distance Relay settings which utilities can follow to implement their own protection philosophy and achieve compliance. It also provides the reader information on software solutions for building and storing an entire protection philosophy to maintain uniformity and consistency.

In an increasingly automated industry, it is important to preserve the knowledge behind the automation, empowering engineers to enhance their relay setting experience by understanding the work going on "behind the scenes." SynchroGrid is committed to providing helpful resources to the power engineering community to help ensure that this critical information is not lost.

Step Distance Relaying

Step Distance Relaying is a setting philosophy that utilizes zones of protection and tripping time intervals to determine when a relay operates. This protection scheme is used for both phase and ground faults, but it uses separate relays for each. Distance relaying is directional and typically utilizes four zones of protection, each of which reaches a fixed distance and operates in a set amount of time. Below is a step-by-step guide which outlines how to set the reaches and timers for each of the zones correctly.

Zone 1 Relay

A. Reach

1. For a two-terminal line, set the relay to reach up to but no more than 85% of the total line impedance. For ground elements, take any parallel line elements out of service and check to see if the relay is overreaching. Set the relay so that the apparent impedance does not overreach 85%.
2. For a three-terminal line, set the relay to reach up to but no more than 85% of the total line impedance to the nearest terminal, without infeed. For ground elements, take any parallel line elements out of service and check to see if the relay is overreaching. Set the relay so that the apparent impedance does not overreach 85% of the nearest terminal.

B. Time

1. The zone 1 relay will trip instantaneously.

Zone 2 Relay

A. Reach

1. For two-terminal lines, set the relay to reach at least 125% of the protected line with infeed.
    a. Check to see if this setting overreaches by more than 80% of the Zone 1 relay reach on the other lines away from the remote terminal of the protected line with the maximum infeed off.
    b. If the setting does overreach, set the Zone 2 timer 0.3 seconds above the Zone 2 timer at the remote terminal.
2. For three-terminal lines, set the relay to reach at least 125% of the protected line with infeed.
    a. Check to see if this setting overreaches more than 80% of the Zone 1 relay reach on the other lines away from the remote terminals of the protected line with either the protected line infeed or the largest bus infeed off.
    b. If the setting does overreach, set the Zone 2 timer to 0.3 seconds above the Zone 2 timer at the remote terminal.

B. Time

1. Set the Zone 2 timer as follows:
    a. If the equipment fed from the remote terminal(s) is protected by instantaneous relays, set the Zone 2 timer to 24 cycles (0.4 seconds).
    b. Coordinate 24 cycles (0.4 seconds) behind any type of time delay relay used to protect any piece of equipment at the remote terminal(s) of the protected line for faults which can also be seen by the Zone 2 relay.

Zone 3 Forward Relay

A. Reach

If in the following settings, the relay overreaches the Zone 2 of any of the remote lines, then the relay must be time coordinated 18 cycles (0.3 seconds) behind the remote Zone 3 relay time.

1. For two-terminal lines where the remote station is a ring bus or breaker-and-one-half scheme with breaker failure protection, set the relay to reach 110% of the sum of the protected line impedance and the impedance of the longest adjacent line.
    a. Do not take infeed into account.
    b. Check that the relay does not overreach Zone 2 of any of the remote lines with the maximum infeed off.

2. For two-terminal lines where the remote station is a ring bus or breaker-and-one-half scheme including breaker failure protection, set the relay to reach 110% of the sum of the protected line impedance and the remote line impedance, with infeed, if any.
    a. Check that the relay does not overreach Zone 2 of the remote line when there is no infeed.

3. For three-terminal lines where the remote station is a ring bus or a breaker-and-one-half scheme with breaker-failure protection, set the relay to reach 110% of the sum of the protected line impedance with infeed and the longest adjacent line impedance without the effect of the bus infeed or the third terminal infeed of the adjacent line if the line is three-terminal.
    a. Check that the relay does not overreach Zone 2 of any of the remote lines when either the three-terminal infeed or the maximum bus infeed is off.

4. For three-terminal lines where the remote station has no breaker-failure protection, set the relay to reach 110% of the sum of the protected line impedance with infeed and the remote line impedance with the effect of the bus infeed, if any, but without the effect of the remote line infeed, if any.
    a. Check that the relay does not overreach Zone 2 of the remote line when either the three-terminal infeed or the bus infeed, if any, is off.

5. For two-terminal or three-terminal lines where the remote station has a single-circuit breaker with breaker failure protection, set the relay to reach 125% of the Zone 2 relay reach.
    a. Check that the relay does not overreach Zone 2 of the remote station without any infeed.

B. Time

1. Set the Zone 3 timer to 60 cycles (1 second).

Calculating & Storing Relay Setting Philosophy

Utilities can use a Word document or spreadsheets to document the step-by-step calculations of this philosophy, or they can now use a software application to store the protection philosophy, allowing them to consistently apply line relay settings across the utility. SynchroGrid has developed an efficient way to store relay setting philosophies in our software tool, SARA (Setting Automation Relay Assistant), which is demostrated by the figures below. In the screenshots, we show an example of equations we have constructed for a relay setting philosophy that have been saved in our user-friendly, customizable template. This template can be applied to any line in a system and integrates with ASPEN to calculate all fault values for each line.

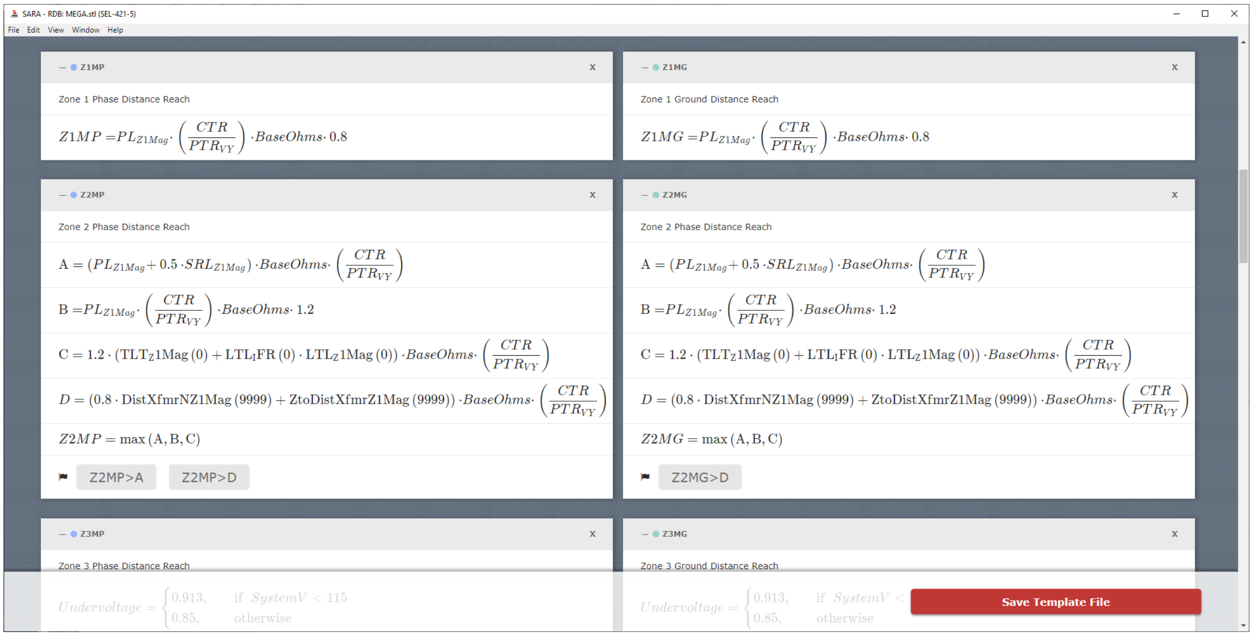

Figure 1: SynchroGrid Relay Setting Philosophy

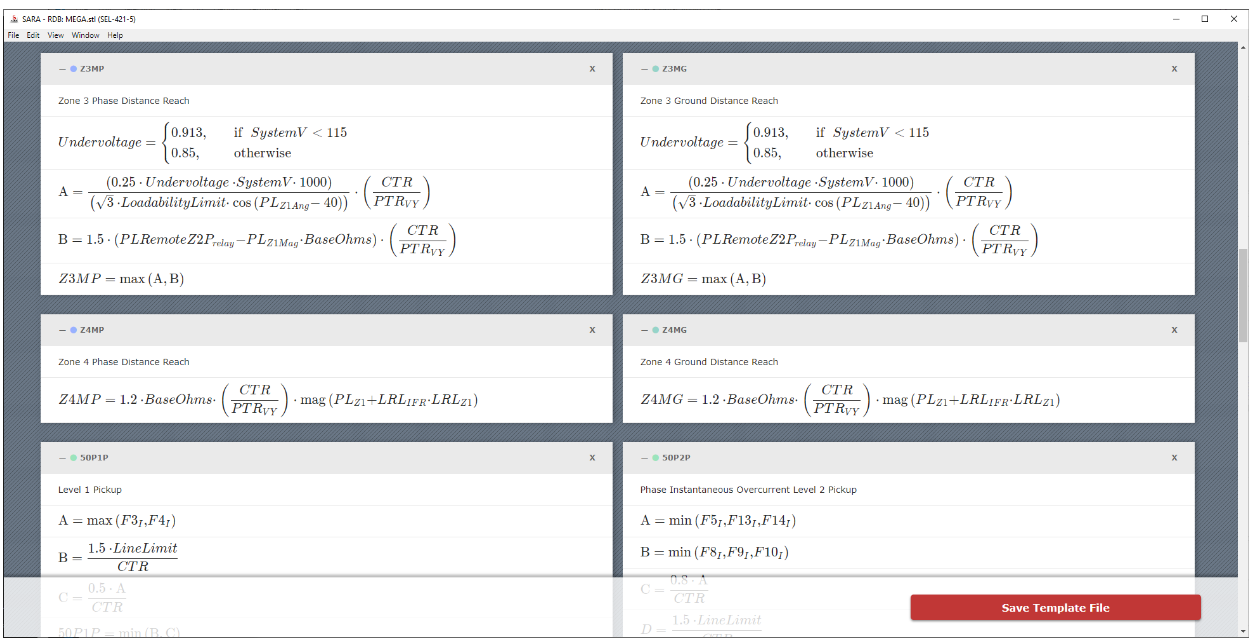

Figure 2: SynchroGrid Relay Setting Philosophy

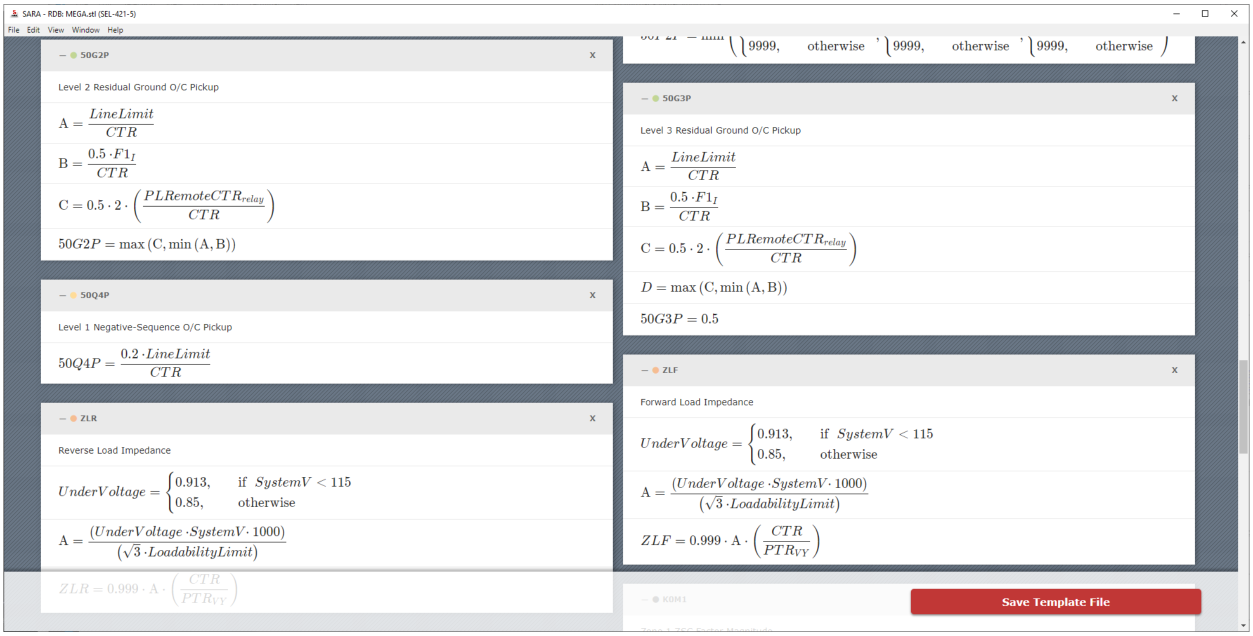

Figure 3: SynchroGrid Relay Setting Philosophy

SARA provides a centralized solution for utilities to store their protection philosophy, apply consistent settings, and, above all, calculate settings with no copy and paste error. While the application provides a powerful way to calculate relay settings, the review and overall quality of settings still relies on the protection engineer's experience for making necessary changes based on their knowledge of the application. Therefore, it is imperative that the engineer stays informed on the processes being performed by the software in order to use their industry knowledge to improve system operations.

References

[1] *Relay Setting Philosophy.* Texas Municipal Power Agency, Anderson, TX, USA, n.d., pp. 3-1-3-2.

[2] *The Art of Protective Relaying.* General Electric, Philadelphia, PA, USA, 1964, pp. 11-12.

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