North American Transmission FORUM

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Relay Performance During Stable Power Swings (PRC-026-1) Evaluation Tools Reference Document

Version 1.1
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Versioning and Acknowledgments

Version History

Date	Version	Notes
02/08/2019	1.0	Original issue (Restricted Distribution)
03/11/2019	1.1	Revised to change marking to Open Distribution. No changes to content.

Review and Update Requirements

- Review: every 3 years
- Update: as necessary

Contents

1. Purpose

NERC Reliability Standard PRC-026-1, "Relay Performance During Stable Power Swings" [1] requires utilities to evaluate the performance of various load-responsive protective relays in response to stable power swings during non-fault conditions. Impedance-based relays are evaluated against a power swing region defined by the standard. This evaluation is unlike any analysis currently performed when setting most impedance-based relays. Thus, new power swing analysis functions are needed within commercial protection system analysis tools, or utilities must develop custom calculators using general-purpose spreadsheet or engineering calculation software.

This document lists functional attributes for either type of tool. Tool developers may reference this list when developing software requirements specifications.

2. Scope

This document provides attributes for software tools to evaluate impedance-based, load-responsive relays in accordance with PRC-026-1, Attachment B, Criterion A. The attributes are written with transmission line protection in mind; however, many of the attributes are useful for generator protection analysis.

Software tools for evaluating overcurrent relays in accordance with Criterion B are not addressed, nor are transient analysis tools used to perform analyses that may be necessary to comply with PRC-026-1, R1.

It is possible to perform the Criterion A evaluation without software tools, and software tools lacking some or many of the attributes listed herein may also be used. Therefore, this document does not provide a basis to judge the adequacy or accuracy of any evaluation performed to demonstrate compliance with PRC-026-1.

This document is not a procedure for performing the evaluations and record keeping necessary for PRC-026-1 compliance. Templates for a procedure and record keeping spreadsheets are under development.

This document is not a complete software requirements specification, as it specifies neither the details of the user interface nor the calculations required. Those requirements depend on the underlying software platform for the tool and are therefore outside the scope of this document.

3. Attributes for Power Swing Analysis Tools

While graphical analysis is not explicitly required by PRC-026-1 R2, the evaluation lends itself to graphical comparisons of impedance-based relays and the PRC-026-1, Attachment B, Criterion A unstable power swing region. This requires special functions within commercial protection system analysis tools or the development of custom calculators using general-purpose spreadsheet or engineering calculation software. Such tools either do not exist or have been released in early versions that lack some attributes needed for efficient analysis.

The following is a list of attributes for either type of tool. In this list, "shall" indicates a minimum attribute necessary for efficient use of a software-based, graphical analysis tool. "Should" indicates a desirable attribute that may make the analysis easier to perform but that may be more difficult to implement. These desirable attributes may not be provided by every tool.

Individual utilities, in consultation with software providers, may specify any of these attributes as minimum requirements.

Explanatory text shown in this format is not part of the attribute.

Relay Characteristic Plots

The calculation tool:

1. Shall plot the unstable power swing region at a given Element terminal in the R-X plane as defined by PRC-026-1, Attachment B, Criterion A.
2. Shall plot impedance-based relays located at that terminal, including mho and quadrilateral phase distance protection, out-of-step tripping relays, and loss-of-field relays.
3. Should plot impedance-based relays based on the characteristics of existing device models, if the underlying protection system analysis software supports device models. If the software does not support device models the tool may use a generic model of the protection function. When a generic model is used, the documentation provided with the tool shall specify the equation(s) used.

   Custom tools built using general-purpose software will most likely use generic models or a single relay model based upon the utility's installed protection equipment.

4. Should allow the user to select which impedance-based relays to plot based on relays available in the existing device models, if the underlying protection system analysis software supports device models.
5. Should allow multiple relay characteristics to be included in a single plot.

Total System Impedance Plots

The calculation tool:

6. Shall plot the total system impedance, including sending-end source impedance, receiving-end source impedance, and line impedance.
7. Shall allow the total system impedance to be plotted with or without the parallel transfer impedance, as selected by the user (See PRC-026-1, Figures 6 and 7.)
8. Should allow the user to readily distinguish between the different components of the total system impedance through the use of different colors, line type, or another distinguishing characteristic.
9. Should reduce multi-terminal lines to the two-terminal equivalent in accordance with PRC-026-1, Figures 15j and 15k.

   Tools built using general purpose software will most likely require the user to perform the reduction by other means.

While two and three terminal lines are most prevalent, some lines with more than three terminals are expected to meet the criteria of PRC-026-1 and will need to be evaluated.

System Separation Angle and Voltage Ratio Variation

The calculation tool:

10. Should allow the user to specify a system separation angle of less than 120 degrees. When the angle is adjustable as such, the angle shall default to 120 degrees. Angles other than 120 degrees shall be indicated through the use of colors, bold text, or other means to prominently show that an angle other than 120 degrees is being used.
11. Should allow the user to specify different voltage ratios (sending end to receiving end) for the lower and upper loss of synchronism circles, with the default values being 0.7pu for the lower circle and 1.43pu for the upper circle. Ratios other than default shall be indicated through the use of colors, bold text, or other means to prominently show that non-default ratios are being used.

Evaluation of Mitigation Methods

The calculation tool:

12. Should allow the user to plot load encroachment, based on the load encroachment functions provided in existing device models, if the underlying protection system analysis software supports device models, or based on a generic model for which the user specifies the settings in the calculation tool user interface.
13. Should allow the user to plot out-of-step (power swing) blocking functions, based on the functions provided in existing device models, if the underlying protection system analysis software supports device models.

Pass/Fail Analysis

The calculation tool:

14. Should allow the user to zoom-in to inspect the proximity of impedance-based protection elements to the unstable power swing characteristic.
15. Should allow the user to zoom-out to view the upper loss-of-synchronism circle, lower loss-of-synchronism circle, and the lens that connects the endpoints of the total system impedance, in their entirety.
16. Should produce a pass/fail decision based on a mathematical comparison of the relay characteristic, the plotted unstable power swing region, and mitigation methods specified by the user.

Output for Recordkeeping

The calculation tool:

17. Should produce a text output of the result, in tabular form, as follows:
    a. The mathematical pass/fail decision for each impedance-based relay at the terminal.
    b. The maximum reach setting(s) for the installed phase mho relay(s) that will allow the relay characteristic to be completely contained within the unstable power swing region. For relays that allow the adjustment of the maximum torque angle (MTA) or other parameters in addition to the reach, the values of these parameters specified in the existing settings may be used in this analysis.

> This attribute automatically determines the margin provided by existing settings without requiring the analyst to manually change the device settings. The analysis is simplified by holding constant all parameters other than the reach setting.
>
> This attribute is limited to mho elements. Automatic analysis of more complex relay characteristics that have multiple parameters, such as phase quadrilateral devices, is not required, but may be provided.

    c. A list of pertinent settings for each relay used in the analysis.
    d. The values of each of the components of the total system impedance used in the analysis.
    e. The value of the system separation angle used in the analysis.
18. Should allow the user to specify which terminals or Elements to include in the tabular output, so as to produce a single report that can be used to demonstrate pass/fail results for a specific part of the user's system.

4. References

[1] North American Electric Reliability Corporation, "PRC-026-1 — Relay Performance During Stable Power Swings," [Online]. Available: https://www.nerc.com/_layouts/15/PrintStandard.aspx?standardnumber=PRC-026-1&title=Relay%20Performance%20During%20Stable%20Power%20Swings&jurisdiction=United%20States.

[2] North American Electric Reliability Corporation, "Frequently Asked Questions Implementation Plan for PRC-026-1," 16 May 2018. [Online]. Available: https://www.nerc.com/pa/Stand/Project%202010133%20Phase%203%20of%20Relay%20Loadability%20St1/FAQ_Implementation_Plan_PRC_026_1_05172018.pdf. [Accessed 12 July 2018].