



System Protection Schemes: Limitations, Risks, and Management

Final Project Report

Power Systems Engineering Research Center

*Empowering Minds to Engineer
the Future Electric Energy System*



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Power Systems Engineering Research Center

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Executive Summary

Special protection schemes (SPS), known also as remedial action schemes, are designed to detect abnormal system conditions and take predetermined, corrective action (other than the isolation of faulted elements) to preserve system integrity and provide acceptable system performance. Today, in many parts of the world, SPS represents a viable planning alternative to extending transmission system capability. Although SPS deployment usually represents a less costly alternative than building new infrastructure, it carries with it unique operational elements among which are: (1) risks of failure on demand and of inadvertent activation; (2) risk of interacting with other SPS in unintended ways; (3) increased management, maintenance, coordination requirements, and analysis complexity. Additionally, there is a dearth of simulation and assessment tools for performing reliability studies of SPS and enable planners to evaluate the operational complexity that SPS brings into the system along with its various economic and operational advantages.

So the objective of the proposed work is to provide a structured framework for identifying limitations of SPS deployment within a system, and assessing SPS risks and develop proper standards and practices for maintaining SPS reliability over its lifetime.

One of the highlights of the report is the unique assessment framework proposed based on both a *process view* and a *systems view* to identify risks and associated consequences for SPS. The process view based framework will view SPS in terms of a *process* which considers all the building blocks starting with the actuating signals, the equipment and logic used to operate on those signals, communication equipments and so on till the final action. The system view framework will view SPS in terms of its position in and impact on the power *system* in which it exists. This framework proposed is one of the significant contributions of this report, as even though a particular SPS design may appear quite reliable from the process view, it may not be so from system view due to the prospect of failures from interactions among many SPS in the system. So the system view risk assessment framework addresses such critical issues, which otherwise could cause cascading and catastrophic system consequences.

Some of the contributions from this project are:

1. A document with concentrated information pertaining to:

- Background: Summary of relevant literatures on SPS, their operational and maintenance strategies from IEEE transaction papers, CIGRE documents, NERC standards, NERC sub-regions, and individual RTOs, ISOs, and companies.
- Technology or knowledge transfer: An overview of standards and methods from industries such as process control, nuclear and power system, in order to leverage interesting ideas from these mature industries that could be applicable to reliability and maintenance studies related to SPS. Safety instrument systems (SIS) of process control industry lend themselves very well in this regard.

2. SPS failure mode identification: The project provides SPS failure mode taxonomy from both process and system point of view, and proposes approaches to identify and evaluate such SPS failures.
3. Software design for system view risk assessment: Design of a simulation capability to test various SPS logics, with flexibility to vary the SPS logic and intelligence to vary operating conditions and events over a wide range.

Several reliability models and architectures for SPS and PMU-aided SPS have been developed to facilitate system view reliability studies, which would enable capturing impacts of SPS on system level phenomena.

4. Operational complexity metric: The operational and maintenance complexity due to the proliferation of SPS in power system is quantitatively captured by a proposed metric. System planning studies must incorporate such operational complexity metric in their overall formulation to estimate the limit of SPS growth for economical and reliable system operation.

The report identifies the importance of including such metric in power system planning framework, and therefore illustrates a transmission expansion planning study for SPS aided power systems.

In further investigations, the conceptual designs developed in this report will be applied on real time utility systems.