



Setting-less Protection: Centralized Substation Protection

Final Project Report

T-55G

Power Systems Engineering Research Center

*Empowering Minds to Engineer
the Future Electric Energy System*



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Executive Summary

In recent years, there has been substantial technological progress of protective relays in substations. With the introduction of merging units and standards such as the IEC 61850, it is possible to formulate effective, reliable and self-healing centralized substation protection schemes. Such schemes utilize real-time measurements from various data acquisition equipment via standard communication protocols. These schemes perform single protective tasks (protection zone functions) and also supervise the health of the individual components of the protection system including instrumentation channel integrity, data integrity and software integrity. We refer to these schemes as centralized substation protection. Centralized substation protection can also enable condition based maintenance of protection and control systems.

Setting-less protection based on dynamic state estimation is a promising technology to fulfill the objectives of centralized substation protection. The setting-less protection method was inspired from the fact that differential protection is one of the most secure protection schemes, which does not require coordination with other protection function. Differential protection simply monitors the validity of Kirchhoff's current law in a device, i.e., the weighted sum of the currents going into a device must be equal to zero. This concept can be generalized into monitoring the validity of all other physical laws that the device must satisfy, such as Kirchhoff's voltage law and Faraday's law. This monitoring can be done in a systematic way by use of dynamic state estimation. Dynamic state estimation (DSE) measures the consistency between measurements in the protection zone and its physical model. The method operates on measured sampled values. Accordingly, if the measurements do not fit the protection zone model, the relay detects a fault or abnormality. The DSE obtains the zone measurements in sampled value format via the process bus. The relay processes these measurements to perform dynamic state estimation in the time domain. This process determines how well the data fit the dynamic model by performing the chi-square test.

Hidden failures in the instrumentation channels result in inaccurate measurements that will not fit the model of the zone under protection, even if no fault occurs in the system. Such failures could affect the scheme's performance and cause relay mis-operation. Thus, a mechanism to detect such failures is essential for a reliable protection system. It should be noted that hidden failures affect the performance of any relaying scheme, not only setting-less relays.

In prior research, numerical experiments and laboratory test based on the setting-less protection approach were performed on a number of protection problems, specifically, transmission line protection, capacitor bank protection, transformer protection, reactor protection, induction motor protection and distribution line protection. The research demonstrated that the dynamic state estimation approach provides a secure and dependable protection scheme, and does not require coordination with other devices or protection schemes while, at the same time, addresses many protection gaps.

Following the above positive results previous study, the method has been extended to centralized substation protection. This report introduces a new dynamic state estimation-based centralized protection scheme (ebCSP) at the substation level. This system supplements dynamic state estimation-based protection for individual zones known as "setting-less relays" to secure their operation against hidden failures. The ebCSP communicates with the setting-less relays via the

station bus and obtains essential information from each protection zone, such as phasor quantities, breakers, and disconnect status. This information is processed by the ebCSP to extract the substation topology and states. Specifically, the ebCSP performs dynamic state estimations in the quasi-dynamic domain once per cycle to detect any sort of abnormality within the substation. Upon detecting abnormalities, the ebCSP performs hypothesis testing to distinguish between faults and hidden failures. The ebCSP detects and locates hidden failures within the substation through hypothesis testing. Then, the ebCSP streams the estimated measurements that correspond to the detected bad measurements to the setting-less relay to replace the compromised measurement. Its capability to detect hidden failures and replace the compromised measurements in real time secure setting-less relays from mis-operation and ensure high dependability even with the presence of hidden failures. Such capability bridges a critical gap in protection systems. The integration of the proposed scheme and the individual zone protection form a resilient protection system that is self-immunized against hidden failures. The ebCSP concept has been tested with five numerical experiments:

- PT fuse blown
- CT saturation
- CT short circuit
- CT reverse polarity
- wrong CT ratio setting

The results show that setting-less protection is a viable approach to centralized substation protection.

Project Publications:

None

Student Thesis:

- [1] Albinali Hussain. *State Estimation-Based Centralized Substation Protection Scheme*. Ph.D Dissertation, Georgia Institute of Technology, Atlanta GA, 2017.