# Secure Partitioning of Large Power Systems

PI: Eduardo Cotilla-Sanchez, Assistant Professor
3023 Kelley Engineering Center, Corvallis OR 97331-5501
Email: ecs@eecs.oregonstate.edu, Phone: (541) 737-8926
School of Electrical Engineering & Computer Science
Oregon State University

The statistics of large blackouts are not good. On August 14th 2003, a sequence of events originated in Ohio ended up disconnecting over 50 million customers from the power grid. Eight years later, another cascading outage initiated by a misoperated 500 kilovolts line in Arizona disconnected about 3 million customers across the Southwestern United States. These large cascading outages accentuate the continuing need for new approaches to increase situational awareness in regards to the security of power systems. And while the integration of renewable energy sources and smart grid technologies into our electrical infrastructure are fundamental paths to sustainable energy demand, the new conditions are unmanageable by traditional power system protection schemes.

Naturally, extreme events may expose the limitations of an otherwise carefully designed protection scheme and subsequently develop into cascading failures. In particular, the smart grid paradigm contemplates the islanding of power system into microgrids in order to alleviate severe scenarios, however, the real-time interaction of this solution with more traditional protection schemes is not well understood [1]. Computationally, it is also essential to break down a stressed network into microgrids to ameliorate the tractability of protection problems. *Can we design a computational framework that leverages real-time input sources and informs remedial action schemes with secure power system partitioning solutions in order to avert cascading outages?*

The PI will advance modern power system protection by developing two synergistic research thrusts: 1) Synthesis of power system networks, and 2) Real-time system islanding algorithms.

**Research Thrust 1: Synthesis of power system networks**

It is difficult to obtain real data to model electricity networks. Those datasets are generally defined as Critical Energy Infrastructure Information (CEII) and researchers have to carefully consider the tradeoff between improving power system simulations and national security. The goal of this research thrust is to synthesize realistic power system networks using random graph models to build large-scale datasets and provide deeper insights about the structure and dynamics of power grids.

Efficient modeling of electric power transmission networks is an important activity for electrical and computer engineering investigative teams. Graph-theoretic approaches have been used extensively for this purpose due to their favorable scalability characteristics. An unweighted, undirected graph $G = (V, E)$ is a pair of vertex set $V$ representing unique entities and edge set $E$ representing binary relations on $V$. A fundamental limitation of this representation is the need to have vertices and edges represent entities in a consistent manner while carefully reproducing network statistics that stem from real power systems [2].

The PI proposes a *dual-division* approach to improve these models. The first one is a *vertical* division. By leveraging the partitioning algorithm described in Research Thrust 2, we will be able to generate and interconnect the building blocks that compose real power systems. This division captures real power system properties such as geographical and demographic distributions. The second one is a *horizontal* division. By constraining the generating algorithm to different network voltage levels one can capture, for example, the disparate costs of building transmission level lines versus distribution level feeders.

**Research Thrust 2: Real-time system islanding algorithms**

The process of partitioning a power system into different islands or microgrids as a protection scheme is related to many other power system problems that consider sub-divisions of the network: resource adequacy assessments, zonal pricing, zone-based voltage control, Area Control Error (ACE) calculations, et cetera.

Research work by the PI and colleagues [3] propose an alternative approach, which defines zones within a power system as collections of buses such that buses within a zone are *electrically close* and buses between zones are *electrically far*. This electrical distance measure relates network topology to active-power sensitivities, and is primarily based on information found in the system admittance ($Y_{BUS}$) matrix, thus avoiding the need for extensive use of simulation data.

The PI proposes the development of an efficient, real-time system islanding framework that is based upon electrical distance metrics. This thrust is organized around the following subtasks: a) Assessment and validation of fast partitioning solutions with respect to simulation-based solutions for very large power systems. b) Annotation of simplified graphs (as described in the previous research thrust) to input constraint scenarios to the algorithm (for example, abnormal demand levels or severe contingencies) and reshape objectives in real time (see Figure 1). c) Investigate simultaneous solution visualizations that enhance system operators' situational awareness and minimize the risk of erroneous actions.

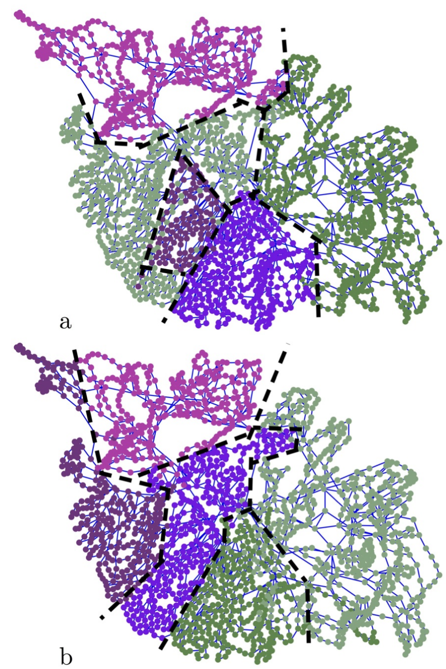


Figure 1: Example partitions of the power grid in Poland [3]. While using the same electrical distance metric, Solution *b* improves the balance of cluster sizes with respect to Solution *a*.

## References

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[2] E. Cotilla-Sanchez, P. Hines, C. Barrows, and S. Blumsack, "Comparing the topological and electrical structure of the north american electric power infrastructure," *IEEE Systems Journal*, vol. 6, no. 4, pp. 616–626, 2012.

[3] E. Cotilla-Sanchez, P. Hines, C. Barrows, S. Blumsack, and M. Patel, "Multi-attribute partitioning of power networks based on electrical distance," *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 4978–4987, 2013.