[AGM] Robust Real-Time Control, Monitoring, and Protection of Large-Scale Power Grids in Response to Extreme Events

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Timeline: FY2020 – FY2022

Challenge:

The protection and emergency control system for the US transmission grid is one of the most crucial national security points. Increased variability in the system state due to a higher level of renewables and frequent extreme weather events leads to greater demand and diversity in the required control actions than traditional schemes. The project has designed a new generation of controls that integrates with existing automated and manual protection and operational processes while also allowing these processes to continue operating. The new emergency controls include fully automated, real-time corrective actions to ensure voltage and transient stability following a significant disturbance. The controls take the system from a post-disturbance emergency state to a stable restored state so that the system operator may confidently resume normal, economically optimized operations. The emergency control actions are computed in real-time, making them adaptive to the current system state and the imposed disturbance.

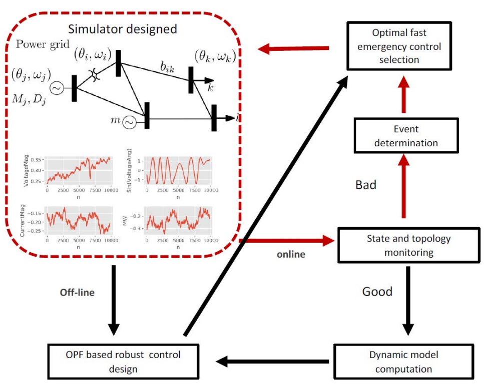

Figure 5-2: Emergency control operation pattern in a power grid. The project contributes both real-time detection and mitigation of an extreme event.

Technical Approach:

By designing novel numerical optimization and statistical tools to address non-convex problems, Los Alamos was able to reformulate AC power flow in a computationally efficient form to enable real-time computations of control actions. Our steady-state algorithms outperform more traditional undervoltage load shedding schemes in providing stabilizing control actions and accurate predictions of the post-contingency operating point. We further adapted the methods to ensure dynamic stability of the system using frequency regulation, HVDC power injections, SVC reactive power injections, and load shedding as controls. The proposed methodology has recently been extended to efficiently model cascading processes by constructing a proxy for the impact of cascading events and further incorporating it to the emergency control optimization problem to optimize over both the preemptive and corrective response to large disturbances. The algorithms were published in multiple IEEE Transactions on Power Systems papers and are partially implemented in DOE supported software DCAT and GridDyn.

Impact:

The project's primary impact is robust real-time emergency control and detection methods that incorporate AC power flow physics and non-linear dynamics to protect a grid under large disturbances, such as a significant contingency or an extreme weather event. It is now possible to rapidly detect an extreme event and identify proper corrective actions in a similarly short time-frame to mitigate the associated risk, which leads to revisiting traditional RAS/SPS based control response. Our team member, Prof. Wachter, was awarded the second prize at the DOE Grid Optimization Competition for the contribution to security-constrained grid optimization.