(FRS) FUTURE RESILIENT SYSTEMS

MASTER'S THESIS PROJECT PROPOSAL

Title: Enabling Fast Frequency Response with Virtual Power Plants
Start: ASAP
Deliverable(s): Master Thesis Report, Midterm and Final Presentation
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BACKGROUND

Amidst the global transition away from fossil fuels, the power grid faces a critical shift in dynamics. As inertia decreases, disturbances can trigger more severe frequency nadirs, increasing the risk of automatic load shedding or tripping. Fast Frequency Response (FFR) emerges as a new ancillary service to stabilize the grid by either injecting power or shedding load in time frames less than a second. With renewable energy sources driving decentralized power generation, Distributed Energy Resources (DERs) play a pivotal role and include renewable energy sources, storage devices, and controllable loads. However, to harness their potential for FFR, effective coordination is realized through the concept of Virtual Power Plants (VPPs) that allow for centralized orchestrating of DERs. This master thesis project delves into the communication requirements within VPPs, aiming to optimize activation times for fast frequency response, thus ensuring grid stability in a rapidly evolving energy landscape.

PROBLEM STATEMENT

In traditional power systems, the control of generators and the collection of measurements are handled via physically separated process control networks and SCADA networks, offering reliable communication guarantees. However, in VPPs, DERs often communicate over the open public internet, lacking the same hard quality of service (QoS) assurances. Compounded by the geo-spatial distribution of a VPP's DERs and different Internet Service Providers connecting DERs, activation times for Fast Frequency Response (FFR) become disparate, exacerbating the frequency nadir. Further, the Border Gateway Protocol (BGP) in the prevalent internet can cause significant disruptions due to re-routing. This project seeks to understand the vulnerability of FFR provided by the current BGP based internet architecture and to propose a new paradigm to ensure reliable ancillary services. Specifically, we aim to assess the efficacy of the SCION internet architecture in mitigating these challenges by ensuring robust communication guarantees compared to the current public internet architecture that relies on the Border Gateway Protocol.

GOAL

The goal of this project is to formulate a cyber-physical model for FFR services and to study the communication requirements for VPPs under a set of future inertia scenarios. Further, it should be determined whether the current BGP based internet architecture can fulfill those requirements and by how much the application of the SCION architecture can improve the FFR performance. Based on shortcomings identified from each architecture, further discussion shall be carried out on what requirements shall be imposed on VPPs to cope with future development of both power grid and communication networks.

METHODOLOGY

The methodology for this study entails a simulation approach to analyze the dynamics of Fast Frequency Response (FFR) within Virtual Power Plants (VPPs) across various scenarios. Detailed work packages (WPs) are described as follows:

WP1: The first step will be to construct a frequency dynamic model, incorporating communication modules to simulate the cyber-physical nature of providing FFR services. A proposed resulting block diagram of the simulation model is shown in Figure 1. On this basis, various deterministic scenarios are simulated on the frequency dynamic model to investigate the impact of latency and packet loss on the performance of FFR services.

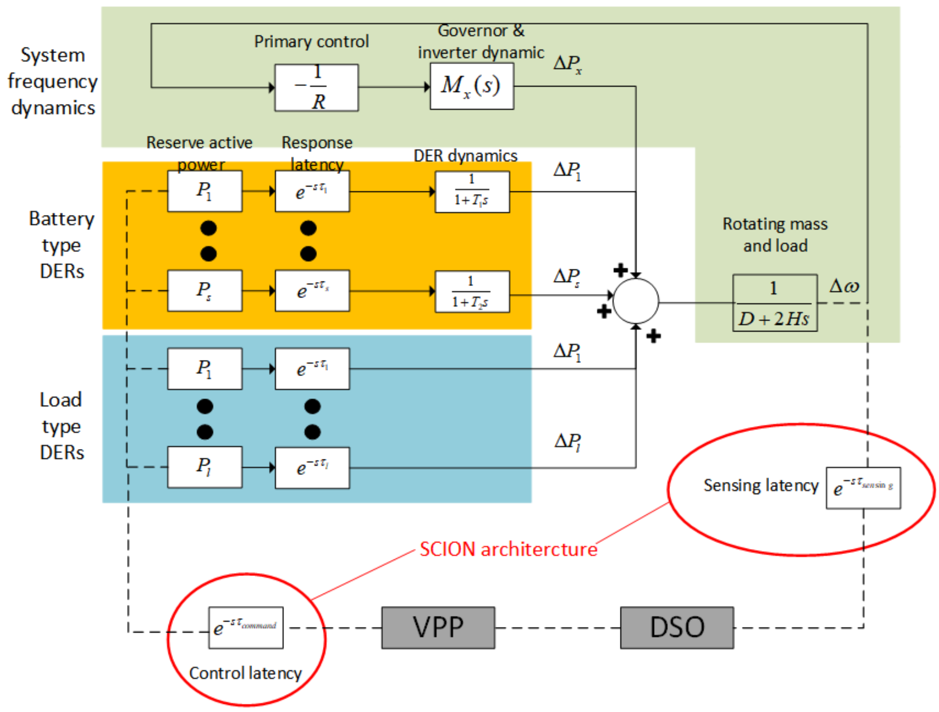

Figure 1 Block diagram of the VPP simulation model.

WP2: A stochastic communication model considering both latency and packet loss shall be developed. The stochastic model can be characterized by statistical distributions of latency and packet loss obtained from the internet models built upon the Border Gateway Protocol (BGP) and the SCION architecture. Specifically, a stochastic model for delays caused by re-routing will be developed for both architectures.

WP3: Finally, various test cases shall be carried out based on a set of future projections of European power grids and communication networks based on various scenarios of renewable energy penetration, power system inertia and potential implementation of new communication technologies for better QoS (e.g. 5G). Simulations shall assess mean and median performance as well as tail risk metrics. Performance metrics such as Rate of Change of Frequency (ROCOF) and frequency nadir will be derived from the simulation results, providing insights into the robustness of different configurations and communication architectures in ensuring grid stability under diverse conditions.

WP4: A generalized cyber-physical management strategy should be proposed based on the findings of WP3 that optimizes FFR performance while satisfying the constraints imposed by both cyber and physical layers.

ADMINISTRATION

This project will be supervised by a PhD researcher & a Post-doc researcher affiliated with the Future Resilient Systems programme (Singapore-ETH Centre) and will be supported by the Power Systems Laboratory (ETH D-ITET), the Reliability and Risk Engineering (ETH D-MAVT) and the Network Security Group (ETH D-INFK). Supervision can be arranged as in Zurich (remotely) or in Singapore (in-person) at the interest of master students. This project can be also chosen as a semester project with a reduced scope.