Voltage Regulation and Protection Assurance using DER Advanced Grid Functions

PROJECT OVERVIEW

This project is creating open-source components for a commercial platform to address the spectrum of distribution circuit and DER management, including: state estimation, voltage regulation, protection, economic optimization, communications and cybersecurity. This solution will safely allow PV penetrations of 50% or greater by providing real-time visibility into distribution circuits and optimizing the active and reactive power (P/Q) DER settings to meet voltage regulation, protection, and economic objectives in the presence of forecast uncertainty.

PROJECT OBJECTIVES

- Provide real-time feeder visibility/visualization
- Operate DERs to keep feeder voltages within ANSI C84.1-2006 limits
- Maintain protection with high penetrations of DER on distribution circuits
- Minimize economic costs using multi-objective optimization
- Create information exchange recommendations
- Generate cybersecurity recommended practices

TECHNOLOGY OVERVIEW

Georgia Tech and Sandia technologies will be released as open-source code or algorithms and incorporated into a commercial software product developed by BPL Global. The core technologies being developed are:

1. Distribution System Distributed Quasi-Dynamic State Estimator
   - Generates the voltage profile and power flow estimation with a scalable solution from feeder telemetry
   - Operates on partitioned distribution system solutions at up to 60 times/second

2. Estimation-Based Protection
   - Detects faults and protects the system by isolating the faulted section of circuit
   - Provides recloser, breaker, or other switching operations
   - Operates extremely fast after collecting state-estimation results (typically below 1 min)

3. Persistence forecasting
   - Uses historical data and clear sky index to generate PV power forecasts
   - 15-s forecast with a 10min horizon
   - Forecast uncertainty characterized by historical record to be used in the optimization

4. Robust optimization taking into account forecast uncertainty
   - Constraints on uncertainty set for the DER power injections
   - Define DER power injections in terms of \( u_i \) and \( \sigma_i \)

5. System level protection on series circuits
   - Provides protection on DERs, field devices

6. Password control
   - Ensures proper authentication and authorization

7. Power flow and voltage regulation
   - Provides accurate power flow and reactive power

8. System Modeling
   - Provides accurate modeling of system components

9. State Estimation
   - Provides accurate state estimation of system components

10. Dynamic Power Flow
    - Provides accurate dynamic power flow of system components

SYSTEM ARCHITECTURE AND OPERATIONS

Programmable Distribution Resource Open Management Optimization System (ProDROMOS)

(System is Greek for “forerunner” and the process word has slight connotations to secure “Glossary” used for naming purposes.)

1. Distribution System Distributed Quasi-Dynamic State Estimator (DS-QDSE) ingests feeder telemetry, DER and customer data, and generates the voltage profile and power flow estimation.

2. The Estimation-Based Protection (EBP) scheme detects faults and protects the system by isolating the faulted section of the distribution circuit by recloser/breaker/switching operations.

3. The forecasting component provides short-term (e.g., 10 minute) forecasts of PV power output and load using recent system states and statistical irradiance modeling in conjunction with PV performance models.

4. A dispatch optimization engine determines the necessary active and reactive (P/Q) power settings for groups of DERs to maintain voltage and distribution protection systems for the next time period (1-5 minutes) considering the economic impact of curtailment and non-power factor operations.

5. The communications system uses the SCADA and DER control network to update DER operations and get new data from the power system.

DER CYBER SECURITY

- The SunSpec/Sandia DER Cyber Security Working Group was initiated as part of this project and has already gathered hundreds of stakeholders to discuss DER cyber security.
- The working group covers security for DER devices, gateways, and other networking equipment, owned or operated by end users, aggregators, utilities, and grid operators.
- Primary Goal: Generate a collection of best practices that act as a basis for a national or international DER cyber security standard.
- Secondary Goal: Facilitate DER cybersecurity discussions between stakeholders to exchange perspectives and (hopefully) gain broad buy-in by the industry for the recommendations. [https://sunspec.org/sunspec/cybersecurity-working-group/]

DEMONSTRATION WITH POWER HARDWARE-IN-THE-LOOP

The ProDROMOS system will be demonstrated using a power hardware-in-the-loop system (PHIL) at the Distributed Energy Technologies Laboratory (DETL) at Sandia and in a field demonstration on a National Grid feeder with a utility-scale PV installation.