GR-14-05 PV Inverter Control to Sustain High Quality of Service

Y. Chen, M. Strothers, B. Luckey, J. Wigmore, A. Benigni

**Introduction**

The purpose of this project is to:
- Investigate the optimal strategies for planning, controlling, and coordination of PV generations into the conventional power grid.
- Develop a two-stage hierarchical control structure where:
  - A top-level day-ahead control optimizes energy losses and voltage deviations.
  - A fast on-line control compensates for PV generation and load variability.

**Day-ahead Optimal Scheduling**

- The proposed method uses the PV inverters, OLTCs, and SCs to minimize the node voltage deviation and power losses.
- Methodology
  - Decision variables: $x = [Q_{PV}^t, Tap^t, SC^t], t = 1, 2, ..., T$
  - Objective function:
    $$F = \sum_{i=1}^{n} (w_1 \times \sum_{i=1}^{n} P_{PV}^t)^2 + w_2 \times \sum_{i=1}^{n} P_{PV}^t$$
  - Constraints:
    - Distribution power balance equations:
      $$P_k = \sum_{i=1}^{n} V_{kn} V_{n} \cos(\delta_k - \delta_n - \theta_{kn})$$
      $$Q_k = \sum_{i=1}^{n} V_{kn} V_{n} \sin(\delta_k - \delta_n - \theta_{kn})$$
    - Reactive power limit of PV generation:
      $$\sqrt{S_{PV}^2 - (P_{PV}^t)^2} \leq Q_{PV}^t \leq \sqrt{S_{PV}^2 - (P_{PV}^t)^2}$$
    - Limit of bus voltage magnitude:
      $$|V_i| \leq |V|^U \leq |V|^L$$
    - Limit of tap position:
      $$Tap^t \leq Tap^t \leq Tap^U$$
    - Limit of the tap operations within a day:
      $$TT0 \leq TT0^max$$
    - Limit of the shunt capacitor operations within a day:
      $$TSC \leq TSC^max$$

**Real-time Test Facility**

- The day-ahead optimal scheduling is implemented in the real-time digital simulator. The model is developed using MATLAB/Simulink.
- The real-time PV inverter reactive power control algorithm is executed on a host computer.
- Hardware in the Loop (HIL) capability
  - OPAL-RT (OP5607) for power system simulation and signal generation.
  - 6 ODROID-U3 computers with 1.7GHz Quad-core processors for data acquisition and communication.
  - Host computer for real-time optimization.

**On-line Var Optimization**

**Simulation Results**

- Scenario 1: Qpv, OLTCs and SCs calculated from the day-ahead optimal scheduling with load coefficients and Ppv values as predicted.
- Scenario 2: Qpv, OLTCs and SCs calculated from the day-ahead optimal scheduling. The load coefficients and Ppv are the next-day actual values (different from predicted).
- Scenario 3: OLTCs and SCs calculated from the day-ahead optimal scheduling. The reactive power of the PV inverter is corrected in real time with actual load coefficients and Ppv values.

**References**