CHANGING WHAT'S POSSIBLE

AC Optimal Power Flow with Preventive Security Constraints (PSCOPF) Phase 0 Formulation Explanatory Note

Disclaimer

This note is intended to explain the concepts contained in the competition problem formulation. It is not a complete description of the competition problem. The notation used here, including sets, parameters, variables, and equations, need not be self-consistent or consistent with the comprehensive formulation. The notation is chosen so as to communicate individual ideas as clearly as possible. For different ideas, different notation may be used. For fully consistent notation and complete description, the comprehensive formulation document should be consulted.

PSCOPF

- AC Optimal Power Flow with Preventive Security Constraints (PSCOPF):
  - Choose generator real power outputs for the near term, say the next 5 to 10 minutes, so that power flow constraints are satisfied, engineering bounds are observed, and in any realistic contingency, it is possible to recover by following certain rules of generator reaction behavior.
- Main problem features:
  - Electrical buses
  - Bus-connected elements: generators, shunts, loads, lines, transformers
  - Contingencies: loss of a line or a generator
  - Complex bus voltage and element current and power flows
  - AC power flow equations
  - Engineering bounds on voltages and flows
  - PV/PQ switching: Generator bus voltage variable in base case, set point in contingencies with reactive power output adjusting to maintain voltage
  - Generator real power output variable in base case. In a contingency, participating generators deviate according to prescribed factor. (Stylized AGC)
  - Minimize base case generation cost

AC Power Flow

- Given sets of electrical buses and bus-connected elements including loads, shunts, generators, lines, 2-winding transformers and 3-winding transformers.
- Determine values of bus voltages and current flows into each element at each connection bus satisfying physical laws. Relevant laws are Kirchoff's current law and Ohm's law.
- Voltages V and currents I are represented numerically by complex numbers, which may be expressed in rectangular or polar coordinates according to convenience:
  - Z = Z_real + sqrt(-1) * Z_imag
  - Z = Z_mag * exp(sqrt(-1) * Z_ang)
- Kirchoff's Current Law (current balance at a bus)
  - Sum_{elements j connected to bus i} I[i,j] = 0
- Ohm's law (current from one bus to another equals admittance times voltage drop)
  - I_orig = Y * (V_orig – V_dest)
- Current flows may be expressed as power flows, according to convenience. Power is represented as a complex number S:
  - S = V * conj(I)

Optimal Power Flow

- Determine a solution of the AC power flow equations satisfying prescribed engineering bounds on bus voltages and current flows
  - V_mag_min[i] <= V_mag[i] <= V_mag_max[i]
- Minimize a given cost function representing the total cost of generator real power. Real power is the real part of power S. I.e. in the rectangular representation S = P + sqrt(-1) * Q of power, P is real power and Q is reactive power.

Preventive Security Constraints

- Consider a given set of (n-1)-contingencies, each defined by the loss of a given connected component from the power system. Together with the base case k0, the set of security contingencies form a set K of cases.
- In a contingency case bus voltages and current flows are defined and must satisfy the power flow equations and engineering bounds as in the base case.
- Real power output of a generator active in a contingency case may differ from base case output, but the differences across all generators must be proportional to prescribed generator participation factors:
  - P_gen[g,k] = P_gen[g,k0] + Part_fact_gen[g] * P_delta[k] for all contingencies k and generators active in k
- Reactive power output of a generator g active in a contingency case k is determined by the need to maintain the voltage of its connection bus i at the level set in the base case, as much as possible:
  - Q_gen_min[g] <= Q_gen[g,k] <= Q_gen_max[g]
  - V_mag_min[i] <= V_mag[i,k] <= V_mag_max[i]
  - If V_mag[i,k] < V_mag[i,k0] then Q_gen[g,k] = Q_gen_max[g]
  - If V_mag[i,k] > V_mag[i,k0] then Q_gen[g,k] = Q_gen_min[g]