REAL-TIME CONTROL OF ACTIVE DISTRIBUTION NETWORKS
BY USING EXPPLICIT POWER SETPOINTS (COMMELEC)

The COMMELEC control framework

Main features
- **Abstract Framework**
  It applies to all electrical subsystems and specifies a simplified view of their internal state.
- **Composition of Subsystems**
  It is possible to aggregate a set of interconnected elements into a single entity.
- **Separation of Concerns**
  Grid agents manipulate only data expressed by means of the abstract framework and do not need to know the specific nature of the resources in their grid.

Architecture
- **Software agents** associated with:
  - Resources: load, generators, storage
  - Entire subsystems, including grids

Real-time control using explicit power setpoints

Grid Agent’s decision process

Leaders (LV grid agent, MV grid agent): compute and send explicit power setpoints $x = (P, Q)$ to their followers based on

- Estimated state of their grid,
- The advertisements from their followers and
- The requested power from the leader (as in case of LV grid agent in our case study).

The computed setpoints steer the electric state of the grid to:
- Minimize the cost of the followers
- Satisfy the leader’s request as much as possible
- Maintain the grid in a safe state of operation

$$C(u) = \sum_{k=1}^{n} \omega_k C_k(P_k, Q_k)$$

The cost of followers is considered as a weighted combination of the specific cost functions.

The belief functions are essential for the leader to compute safe setpoints: for each $(P, Q) \in BF(P_{req}, Q_{req})$, the QoS of the grid is acceptable (in terms of voltage magnitudes and congestions). Example of grid safe state in static conditions:

$$J(u) = \sum_{k} \beta_k (Q_k - V_{\text{nom}}^2) + \sum_{l} \left| I_l(u) \right|^2$$

Gradient-based approach: given the current (measured/estimated) setpoint $x = (P, Q)$, the computed next setpoint is given by $u = P(\hat{x} + \Delta u)$

$\Delta u$ is a vector in the direction opposed to the direction of the gradient of the overall objective function

$$P^T(\hat{x} + \Delta u) = P(\hat{x})$$

Simulations and Conclusions

- Comparison between Commelec vs standard droop control
- Scenario: overall overproduction in the grid from renewables (PV) with minimum load consumption
- Adapted to challenge both control methods to deal with a system characterized by a low margin of controllability.

Main conclusions
- Controls the reserve of the storage systems, thus maximizing the autonomy of the islanding operation
- Reduces the curtailment of renewables
- Identifies local power compensations
- Keeps the system in safe operation conditions preventing the collapse.
- All this is obtained in real-time with a simple and generic protocol
- It does not require the exchange of resources specific states

Advertisement Messages

Followers periodically advertise to the leader...

PQ Profile: Flexibility
- Region of feasible (P, Q) setpoints that this follower is willing to accept.

Virtual Cost: Preference
- Can represent how close the subsystem is to its operational constraints or operation preference

Belief function: Uncertainty
- Given a setpoint $(P_{req}, Q_{req})$, the belief $BF(P_{req}, Q_{req})$ is a region in $(P, Q)$ plane (set-valued function).
- This region represents all the possible values of $(P, Q)$ that the system may implement when it receives $(P_{req}, Q_{req})$.
- Takes into account the uncertainties in the resources (larger for partial and non-controllable ones).