Technology Session 3: Control and Protection

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Control and Protection: Where We're Coming From…

Long-Standing Practice

disclaimer–oversimplified view, but helpful to set context…

- Moderate numbers of centralized, large synchronous generators primary actors in active power & frequency control.

- Voltage/Var control more distributed, but still large role for synchronous generators and large capacitor banks, Static Var Compensators, tap-changing transformers.

Control and Protection: Where We're Coming From…

- Measurement & control hierarchy, based on time-scale and geographic "reach."
- On time scales of electromechanical dynamics (secs), fast measurement and control action almost exclusively local.
- On quasi-static time scale (10's of secs-to-hours), slower measurements, wider coordination primarily via periodic setpoint updates.

Control and Protection: Where We're Coming From…

- Most protection and relaying focused on local equipment, not system level (possible exception–under frequency load shed).

- Given local focus, little ability to anticipate conditions that might require relay action – purely reactive.

- Little consideration of impact of relaying as action to steer system state.

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Control and Protection: Where We're Coming From…

- Little co-design between protection & control. Protection set boundaries of acceptable operation, within which control is to function

- Relaying uses its own dedicated measurement & data, largely unshared with outside world.

Control and Protection: Characteristics of Challenges Today

MANY challenges with growing penetration of renewable and distributed generation.

- Large component of stochastically varying power injections, with volatile characteristics very different from historic load variation.

- Even when such sources participate in control, much larger number of distributed control actors, with narrow range of control.

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Control and Protection: Characteristics of Challenges Today

Emerging trends for new avenues of control carry some common challenges…

…larger number of distributed elements contributing to grid control, while simultaneously serving multiple objectives (e.g., consider responsive load and vehicle-to-grid storage technologies as contributors to grid regulation).

Control and Protection: Characteristics of Challenges Today

Similar trends yield challenges in protection:

- Abrupt changes in generation patterns
- Extensive switching of power system configuration
- High penetration of distributed generation (DG)

Control and Protection: Characteristics of Challenges Today

Result is far wider range of operating conditions over which relays must be expected to protect, ***while not endangering system response.***

- Under volatile operating conditions, performance of conventional relays that rely on predefined settings may deteriorate. Possibility for protection itself to contribute to system-wide disturbances and blackouts.

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Control and Protection: Characteristics of Challenges Today

Relaying of future grid needs to accommodate:

- Bi-directional power flows
- New power-electronic-based generator controls that can alter active/reactive power supply and limit/increase the fault currents
- Highly variable output & characteristics of energy resources in the case of renewables

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Control and Protection: Frameworks for Future

Key enabling technologies: improvement in measurement and communication.

- Synchrophasors and other high bandwidth measurements key. We now have "eyes and ears" into system dynamics measurements.

- From analytic control perspective, previously hard to observe dynamic modes become much more observable.

Control and Protection: Frameworks for Future

Premise 1: Local controller can have much more intelligence, allowing it to “look out” to and control dynamics of neighboring states.

- In terms of control methods, allows ***dynamic*** state observation to be much more widely utilized. Opens door to powerful array of modern, state-feedback based control design, previously impractical in power grid.

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Control and Protection: Frameworks for Future

Premise 2: Greater high-speed “reach down” from more centralized intelligence.

- Low latency, secure communication will allow use more cost-effective use of wide area information in control. “Hierarchically-coordinated” architecture coordinate more rapidly from regional control to local actuators.

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Control and Protection: Frameworks for Future

Premise 3: “Predictive Protection”

- Vulnerability analysis deployed at the control center level, with alert to substations when threats show need monitor relays at vulnerable components (“beyond relay blocking”).

- Prediction of potential for protection mis-operation, as early warning of routes to failure evolving contingencies.

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Control and Protection: Frameworks for Future

Premise 4: “Inherently Adaptive Protection”

- Relay operation based on feature recognition in full range waveform measurements.
- Seek to move beyond simple threshold or fixed settings – use advanced tools of statistical signal processing in decision to operate.

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Control and Protection: Frameworks for Future

Premise 5: “Corrective Protection”

- Intelligence of protection should not “quit” after relay operates.
- For example, upon transmission line tripping, fault location algorithm seeks to validate correctness – in case of unconfirmed fault condition, system component (transmission line) can be quickly restored.

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Control and Protection: Frameworks for Future

Summary Premise of Hierarchically-Coordinated Communication/Control/Protection:

Control Informs Protection and Protection Informs Control

- Predictive protection key example of control informing protection.
- Protection informs control through high speed communication of critical topology status updates, “sharing” of relay measurements.