Electric Power Distribution and System Operations

By: Chris Caballes and Varsha Balusa
Distribution

- What is distribution of electricity?
- Primary systems vs Secondary systems
Distribution system components

- Transformers
- Voltage regulators
- Switch breakers
- Automatic reclosers
- Monitoring systems
- Service drops
- Customer meters
Distribution is monitored using SCADA

- Monitor loads
- Status of the circuit breakers
- Voltage and VARs
- Best if constructed initially
- Can be monitored and controlled remotely
Type of distribution loads

- Radial Feed
- Loop Feed
- Network System
Radial Feed

Diagram of a Radial Feed system:
- Primary Distribution
- Step-down transformer
- Circuit breaker
- Secondary Distribution
- Customer
Loop Feed

Diagram showing the components of a Loop Feed network, including Primary Distribution, Step-down transformer, Switch, Secondary Distribution, Circuit breaker, and Customers.
Network System
Roles of dispatch centers

- Daily maintenance of the distribution systems
- Look at flow values
- Maintenance of the activity
- Response to outages
- Restore normal operations
Types of Distribution Utilities

- Investor Owned Utilities
- Municipal
- Rural Electric Co-ops
What are Smart Grids

- What are smart grids?
- What are the benefits?
- Where are they now?
Electric System Operations
Operational Characteristics of Power Systems

Operating is a complex task due to the following characteristics:

- Electricity cannot be stored economically
- Supply and demand must always be in balance
- Path of electric flow is difficult to control
- Disturbances travel quickly
- Voltages and frequencies outside of limits damage equipment
- Momentary outages not acceptable
System Operations

Duties of the system operator:

- Forecast demand in the day ahead
- Schedule:
  - Generation
  - Reserves and other ancillary services
  - Use of transmission systems
- Communicate schedules to neighboring operators
- Manage the system in real time
- Correct any system disturbances
- Restore power should an outage occur
System Operations - Who Handles Them?

- Four regional grids between the U.S. and Canada
  - Eastern, Western, Texan, and Quebec Interconnects
- Control areas operated by:
  - Vertically integrated utilities, munis, federal power agencies, power pools, or ISOs
  - Smaller utilities often contract service with a neighboring larger utility
- North American Electric Reliability Corporation (NERC)
  - Ensure electrical transmission grid in North America is reliable, adequate, and secure
System Operators in the U.S. and Canada

(photo: Understanding Today's Electricity Business)
Forecasting & Scheduling

- Optimize schedule to:
  - Meet reliability standards
  - Minimize overall supply costs

- Demand Forecasting
  - Hour-by-hour day-ahead demand forecast is created using models developed from historical demand given forecasted weather patterns and business activity

- Generation Scheduling
  - Scheduled on an hour-by-hour basis to match load and reserve requirements

(photo: Understanding Today’s Electricity Business)
Ancillary Services

Services required by system operators to ensure safe and secure operation of the grid

- **Automatic Generation Control (AGC)**
  - Ramped up or down to manage minute-by-minute fluctuations in system loads
  - Sources of AGC: hydro power, gas combustion turbines, gas or coal steam turbines

- **Load-following Resources**
  - Manage fluctuations over a longer period of time than AGC, typically five minute periods
  - Sources: hydro power, gas combustion turbines, gas combined-cycle turbines, gas or coal steam turbines
Ancillary Services

● Spinning Reserves
  ○ Units that are synchronized to the frequency of the system that don’t put energy into the system until needed
  ○ Sources: hydro power, gas combustion turbines, gas combined-cycle turbines, gas or coal steam turbines that are using a portion of their capacity but have an additional unused capacity

● Non-spinning reserves
  ○ Units that are not synchronized to the frequency of the system but can be available within 10 minutes
  ○ Sources: similar to that of spinning reserves

● Supplemental Reserves
  ○ Units that are available with a lead time of 30 minutes
  ○ Sources: coal and gas steam turbine units with already warm boilers
Ancillary Services

- Voltage Support
  - Provided by specially equipped units that have the capability to provide VARs (volt-amp reactive) to the system

- Black Start
  - Units that can start independently without electricity from the grid
Real-time Supply & Demand Balance

- AGC and load-following units are ramped up and down in response to changes in load
- If loads are higher than forecasted, spinning reserves are used, and then ramped down once non-spinning reserves are ramped up
- High voltages and frequencies are managed by reducing supply
- Low voltages and frequencies are managed by increasing supply
- Rolling blackout
References

