SAND2013-8875C

Unit Commitment Model

Cesar A. Silva Monroy, Ph.D. – Sandia National Labs

Bogota, Colombia

Oct. 15, 2013

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U.S. DEPARTMENT OF ENERGY

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Power System Operations

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- Decision making in power systems looks at processes ranging from very large time constants to near real-time:
  - **Years, Seasons, Months, Weeks**: Forward capacity and reserve markets, hydro planning, hydro-thermal coordination.
  - **Days**: Day-ahead (DA) energy and reserve markets, Unit Commitment (UC), reliability UC.
  - **Hours**: look-ahead processes, dynamic economic dispatch.
  - **Minutes**: Economic Dispatch (ED).
  - **Seconds**: Automatic Generation Control (AGC).

Unit Commitment

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- Schedule on/off states of generating units for the next operating day
- Minimize total production cost based on load and non-dispatchable generation forecasts
- Subject to operational and economical constraints.
- Objectives and constraints present subtle differences from one power systems to the next
- Usually formulated from a vertically integrated utility (VIU) perspective
- Security constrained: include transmission system

UC vs. DA market

- Same results: commitment schedules of market participants
- Maximize economic surplus (benefit - cost) based on market participants offers and bids – **There are no forecasts!**
- Subject to operational and economical constraints
- Subtle differences between deregulated regions:
  - "Co-optimized" energy and reserves (i.e., ancillary services)
  - Types of ancillary services included (regulation, regulation up/down, spinning, non-spinning, replacement, etc.)
- **Financially binding**: money changes hands based on results.

Where's the uncertainty?

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- Demand Forecasts
- Wind/Solar Forecasts
- Generator outages
- Intra-hour variations (reserve margins)

- Daily operations can use Stochastic Programming in
  - VIU:
    - Stochastic UC
    - Stochastic look-ahead processes
  - Deregulated regions:
    - Stochastic RUC
    - Stochastic look-ahead processes

Reliability Unit Commitment (RUC)

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- ISO-NE term that refers to the centralized process of modifying commitment schedules for reliability purposes:
  - Ensure there are enough units available for energy and reserves
- DA market closes at 8 pm, RUC starts:
  - Market participants are allowed to modify their offers.
  - ISO replaces demand bids with demand and non-dispatchable generation forecasts.
  - ISO-NE does not include regulation reserves, but RUC is subject to ten-minute operating and thirty-minute operating reserves.
  - Performed after day-ahead market but before operating day.
  - It updates the current operating plan (COP).
  - Not financially binding (ISO-NE).

RUC Objective function

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- Minimize total production cost:
  - Production costs:
    - Fuel costs in VIU or energy offers related to variable costs in markets
    - Expressed as a quadratic function or piecewise linear function
  - Startup costs:
    - Cost of starting up a unit
    - Piecewise step function
  - Shutdown costs:
    - Cost associated with shutting down units'
    - Usually lumped with startup costs
  - Reserve costs:
    - Opportunity costs of reserving capacity to provide balancing or replacement ancillary services
  - Penalties (Value of lost load) associated with power balance slack variables.
  - Subject to…

Transmission Constraints

- Name because of the relationship between angles and power flows

- DC Power Flow:
  - Nominal voltages (i.e., 1 p.u.).
  - Line resistance is negligible.
  - Difference between bus angles is small (> 30 degrees).
  - $P_{kj} >> Q_{kj}$ … "VArs don't travel"
- Find the real power generation and angles at each bus
- Missing reactive power and bus voltages
- Computational gain by linearizing the power flow problem

Transmission Constraints

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- Modeling every bus might not be necessary
  - If there is no congestion within a Zone it is possible to model zones with transmission paths within them
  - Modeling regularly congested lines only
    - Equivalent transmission capacity
    - Equivalent reactance
- Simplified transmission model results in computational gain
- DC OPF Solutions must be checked in the AC world for
  - Feasibility/Stability
  - Contingency analysis

Power Balance Constraints

- Power generation + power flowing into at a bus/zone must match demand + power flowing out of bus/zone
- For solution feasibility a slack variable that represent the power mismatch is introduced for each bus/zone
- Non-dispatchable power can be treated as must-take resource (today) or dispatchable in the down direction (future).

Generators

- Generators have physical/economical limits
  - Minimum (economic) power
  - Maximum (economic) power
- They also have limitations on how quickly their output can change:
  - Ramp rate up/down limit
  - Start-up/shut-down ramp rate limit
- Certain generators have long time constants once they are turned off (e.g., nuclear plants, large coal plants)
  - Minimum up/down times

Ancillary Services - Regulation

- Regulation reserves are deployed to follow intra hour variations.
- Generators that are on Automatic Generation Control (AGC) have response rate to AGC signals (Automatic Response Rate in MW/min)
- Generators reserve for regulation also have different minimum and maximum (economic) power limits.
- Generators seek compensation for their opportunity cost: missing revenue from not providing energy in the day-ahead/real-time.

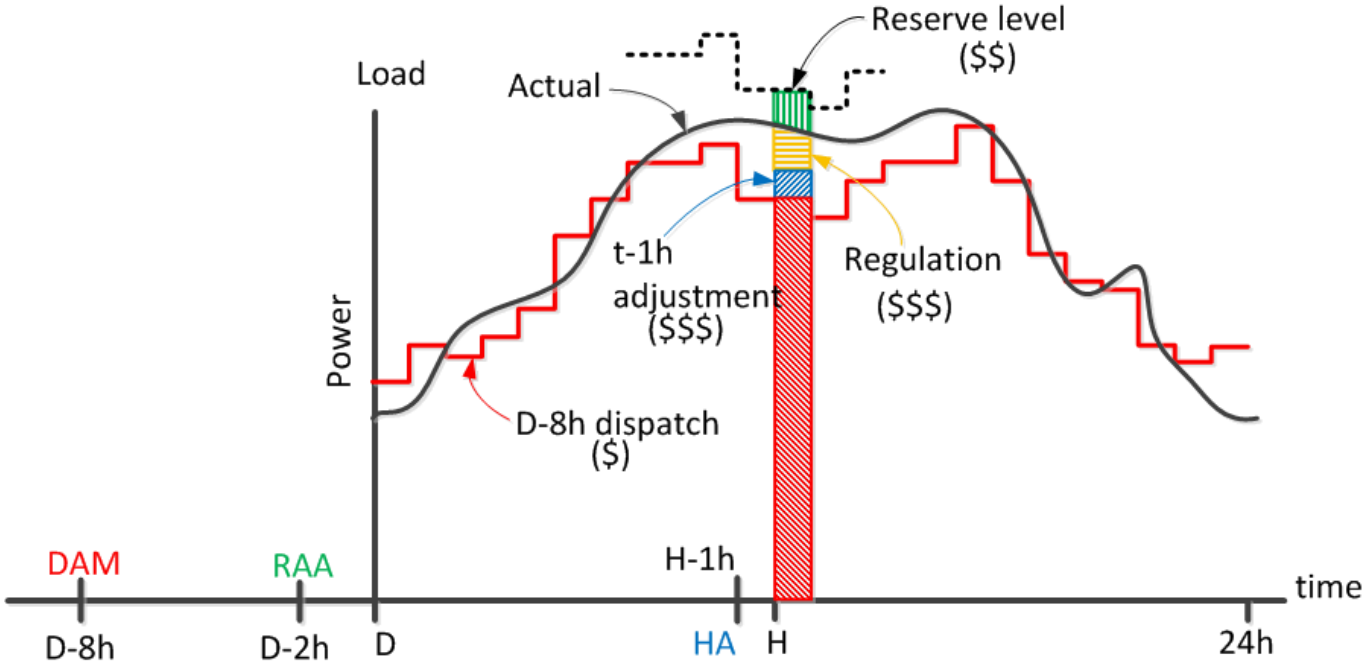
Ancillary Service - TMOR

- Deployed when a contingency occurs
- Ten-minute operating reserve (TMOR)
  - At least X% must be spinning reserve (i.e., online generators).
  - Spinning reserve: headroom of online generators.
  - Non-spinning reserve: 10-minute capacity from offline state.
- There could be zonal and system requirements on
  - Spinning reserve
  - TMOR
- In deregulated zones there are offers from generators to provide these services.

Ancillary Services – TMR

- Thirty-minute Reserves (TMR) are deployed when a second contingency occurs.
- Thirty minute capacity from offline resources.
- Zonal and system requirements might also be enforced.
- In deregulated zones there are offers from generators to provide this services.

Markets and Adjustments



- At D-8h DAEM is cleared using UC. Generator schedules (on, off), dispatch levels (MW) and DA LMPs are produced for the next 24h.
- At D-2h the RUC results are posted to meet the reserve requirement.
- At t-2h adjustments to dispatch levels are made (SCED2). Adjustments are paid according to RTEM offers.

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QUESTIONS