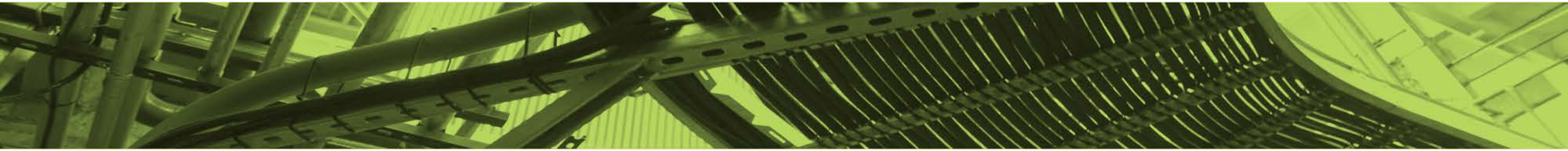
Microgrids: Distributed Controls Perspective

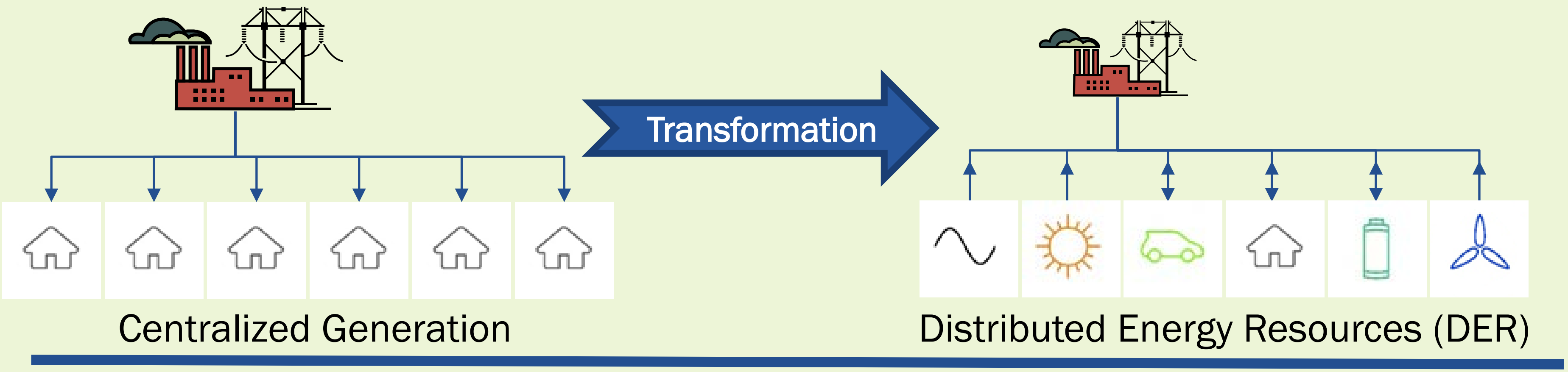


QER Public Outreach Workshop

Andrew Merton, Ph.D. | February 2016

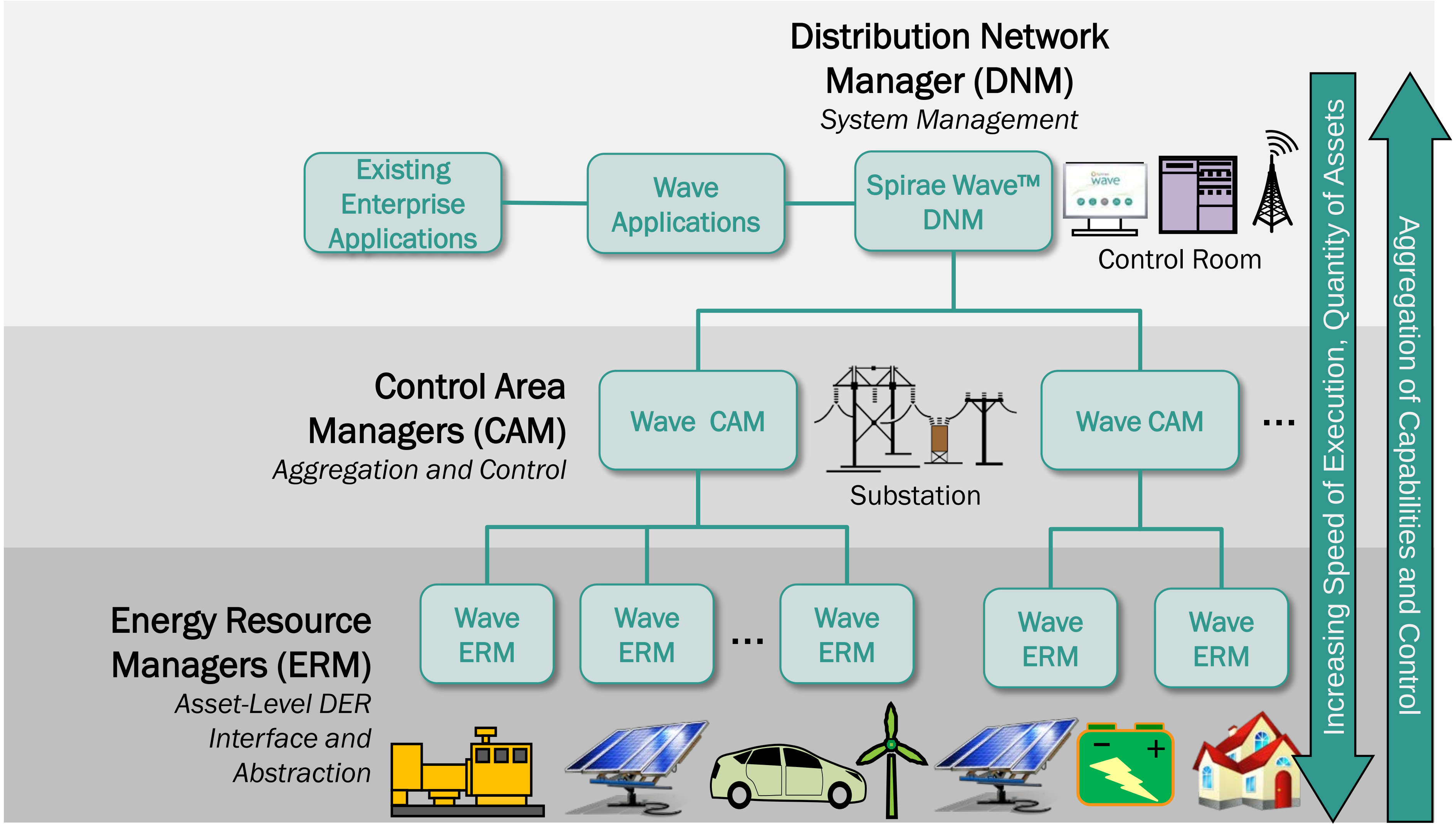
Spirae: Who We Are

Spirae supports the transformation of the grid from centralized to distributed, enabling the integration of renewable resources, enhancing energy resilience, engaging prosumers, and stimulating flexible business models.



Spirae's Wave™ control platform provides a scalable architecture for integrating and managing high levels of renewable and distributed energy resources (DER) at the edge of the grid.

Spirae's Wave™ Control Concept



Case Study 1: Necker Island

- Objective: Maximize renewable penetration to reduce diesel consumption by at least 75%
- System Summary
  - Remote island resort (BVI); 1995 MWh annual demand; 350 kW peak
  - Assets
    - (3×) 400 kVA Caterpillar Generator Sets
    - 320 kW PV Solar Plant
    - 900 kW Wind Turbine
    - 1000 kWh Battery Energy Storage System
    - Demand Response/Load Shed: pool heating, reverse-osmosis plant
  - Operational Constraints
    - Support complete suite of microgrid operations: black start, RE curtailment, etc.
    - Enforce genset minimum loading and run times/cool down periods
    - Recharge BESS with RE resources

Case Study 1: Necker Island—MicroGrid Use Cases

- Service load using 100% renewable resources
  - Pre-position BESS SoC and set mode to frequency and voltage master
  - Wind turbine able to provide volt/VAR support
  - Redirect extra-RE generation to BESS; curtail if necessary
- Service load with mix of conventional and RE resources
  - Maintain minimum load on generator sets (~100 kVA)
  - Prioritize direct consumption of RE resources: Wind and PV
- Black start and power system transitions
  - Leverage BESS when appropriate to energize system, transfer frequency and voltage control

Case Study 2: Flathead Electric Cooperative (FEC)

- Objective: Minimize *monthly* peak demand
- System Summary
  - Libby to Kalispell, MT; 65,000+ meters; ~240 MW winter peak (06:00-08:00)
  - Assets
    - Fleet of 600+ in-home electric water heaters distributed (non-uniformly) across 25 substations; FEC's goal is to recruit 5000 units over the next few years
    - Future: Expand program to include heat pumps (or other)
  - Operational Constraints
    - Single dispatch per household per workday; holidays and weekends excluded
    - Individual water heater engagement not to exceed 3 hours per day

Case Study 2: FEC—Solution Strategy

- Demand Response (DR) Application
  - Monitor the load forecast and, if conditions warrant, create and execute a dispatch plan to reduce the peak demand
  - Load forecast, updated at regular intervals, calibrated using realized (observed) power system, weather, and calendar data
  - Assets are grouped (e.g., by substation) and dispatched to maximize the expected demand reduction subject to minimizing the “snapback” i.e., stagger (feather) the start and end times
    - Dispatch schedule = {start time, duration, active power setpoint (if available)}
    - Note: Do not need to restore communications with individual assets to “release” from event

Case Study Comparison

- Necker Island
  - Microgrid solution
  - High speed communication requirements
    - Modbus/DNP3
  - Automated mode and setpoint control of all assets
  - 24/7 operations
  - On-site Operator interacts with the system

- FEC
  - DERMS solution
  - "Slow motion" process
    - Power line communications (Aclara)
  - Scalable to accommodate 100s to 1000s of end-user assets
    - Subscription manager to add/remove assets and to integrate with new asset classes
  - Opportunistic dispatch strategy
  - Hosted solution
    - Precursor to cloud implementation

Recommendations

- Align power system objective(s) with asset and communication capabilities
  - E.g., Webservice API *may* limit solution space
    - Working with Green Mountain Power to develop and integrate control of Tesla Power Walls (3.3 kW/ 7.0 kWh) into DR App to work in concert with Rainforest water heater control for peak load management (both are webservice implementations)
    - May *not* be able to perform volt/VAR (available modes, aggregation, etc.)
- Explore/advocate methods to reduce cost to implement
  - E.g., Capital to upgrade infrastructure or acquire new assets can be expensive
    - Seneca Nation interested in microgrid solution to separate from National Grid by combining in-situ (diesel) generation with planned 300 kW PV and 150 kW/600 kWh BESS
    - Solution strategy: Drive energy import/export to (near) zero at the boundary; no need to separate and re-sync

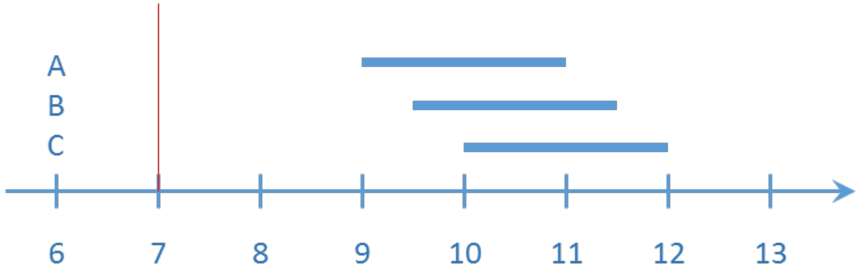
Support Slides

- The subsequent slides are provided to further illustrate application specific design principles and concepts.

Example: Dispatch Plan Evolution(1 of 2)

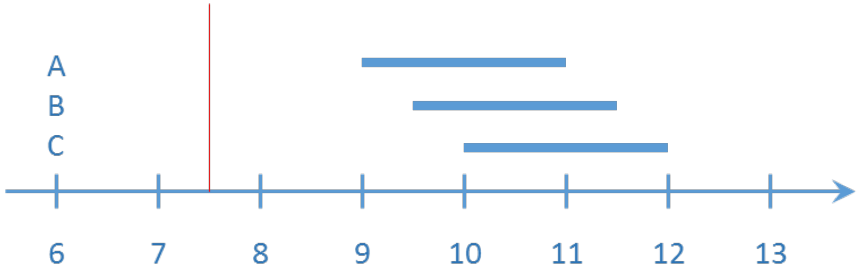
Start Condition

- Load forecast updated every hour
- Plan updated every 30 minutes starting at 7:00
- Three assets {A, B, and C} are scheduled per plan
- Lead time to commit = 30 minutes



Time = 7:00

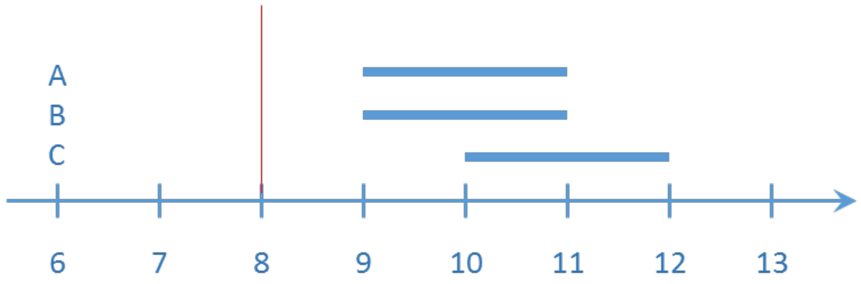
- Plan generated using 7:00 load forecast
- Plan contains 3 asset schedules; earliest dispatch scheduled for 9:00
- Lead time to first dispatch = 120 minutes; do not commit plan



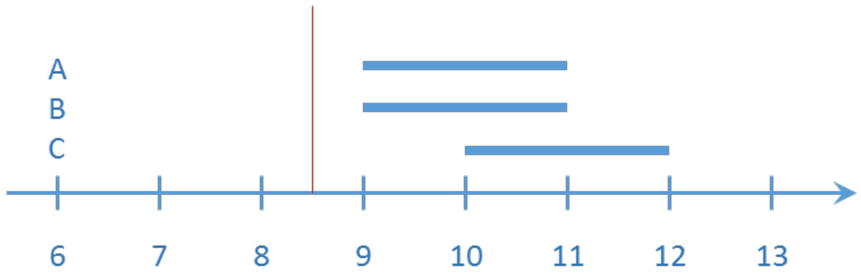
Time = 7:30

- Plan (re-)generated using 7:00 load forecast; no change
- Earliest dispatch scheduled for 9:00
- Lead time to first dispatch = 90 minutes; do not commit plan

Example: Dispatch Plan Evolution (2 of 2)



Time = 8:00
- Plan (re-)generated using **8:00** load forecast
  - Schedule for asset B moved up to start at 9:00
- Earliest dispatch scheduled for 9:00
- Lead time to first dispatch = 60 minutes; do not commit plan



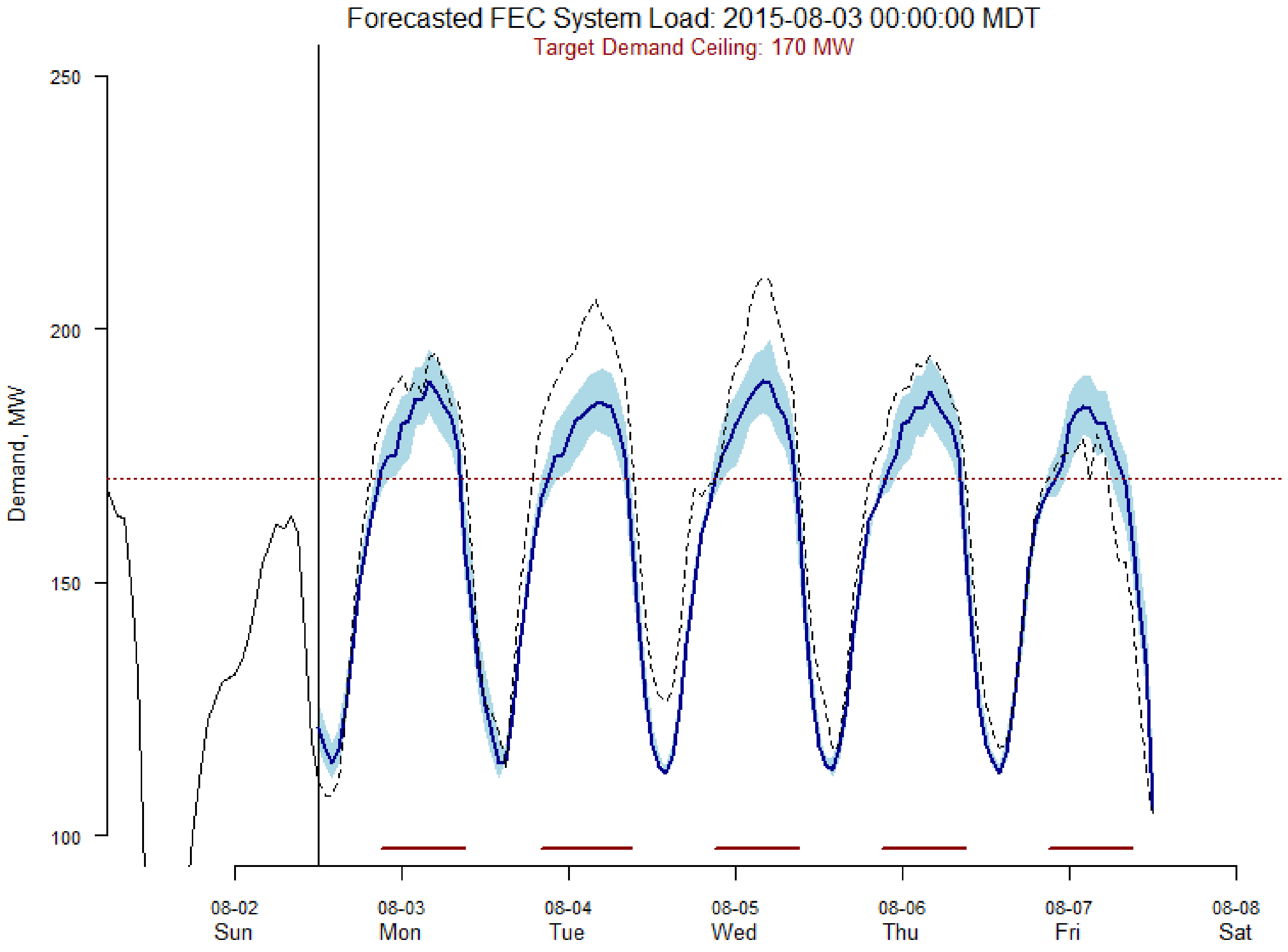
Time = 8:30
- Plan (re-)generated using 8:00 load forecast; plan unchanged from previous
- Earliest dispatch scheduled for 9:00
- Lead time to first dispatch = 30 minutes ⇒ **Commit plan**
- Suspend (re-)generation of plan

End Condition
- Plan committed to commence at 9:00
  - Dispatch assets A and B at 9:00
  - Dispatch asset C at 10:00

FEC Simulation: Forecast and Dispatch Plan Evolution

Note(s)

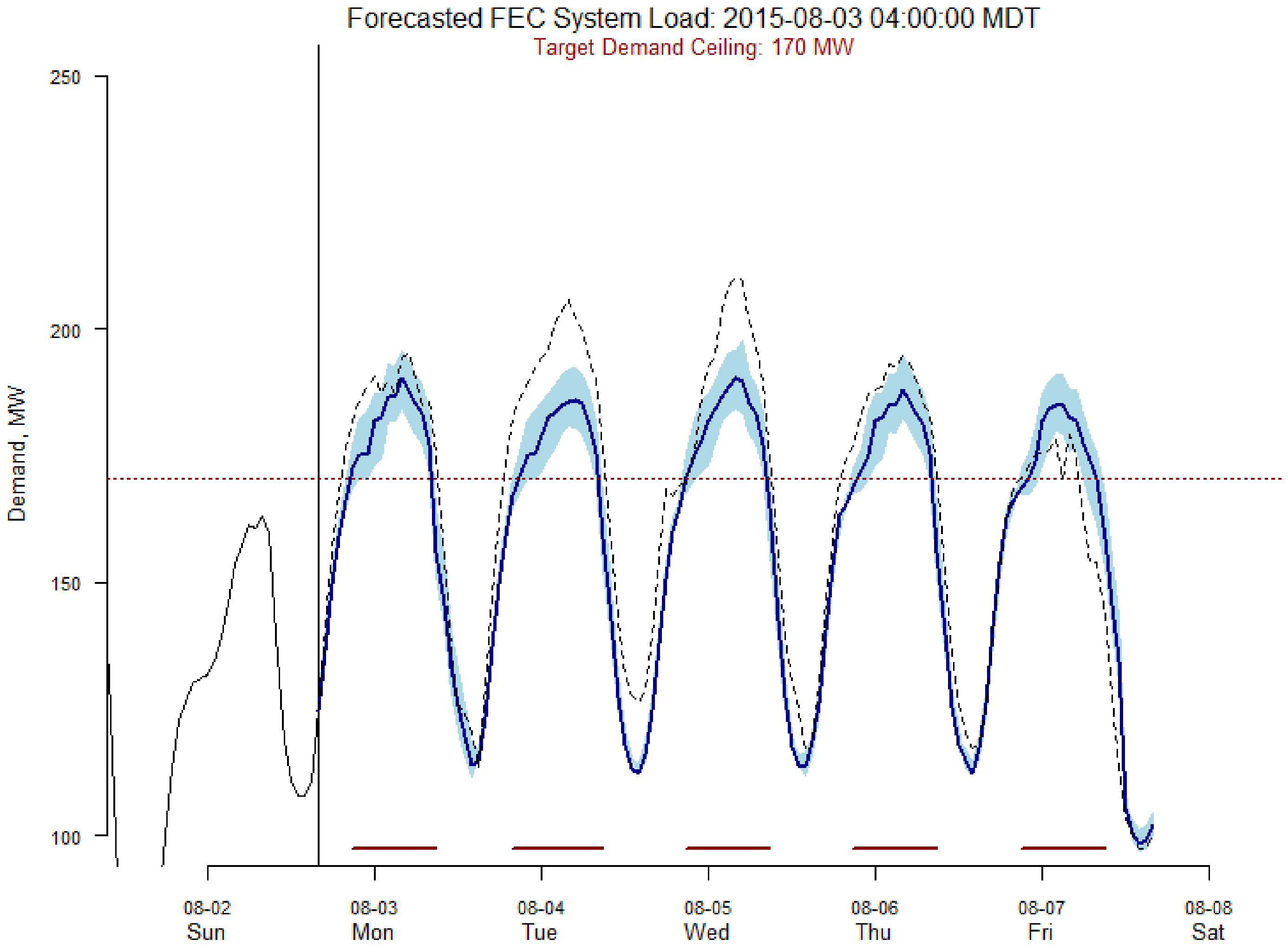
- Simulation study results, assuming no dispatchable assets, used to test/verify that the dispatch plan(s) update as the realized "month-to-date" peak increases.
- Realized power demand (black) v. forecasted demand (blue)
- Initial target = 170 MW (dotted red)
- At midnight, the DR determines that the assets will need to be dispatched each day (dark red)



FEC Simulation: Forecast and Dispatch Plan Evolution

Note(s)

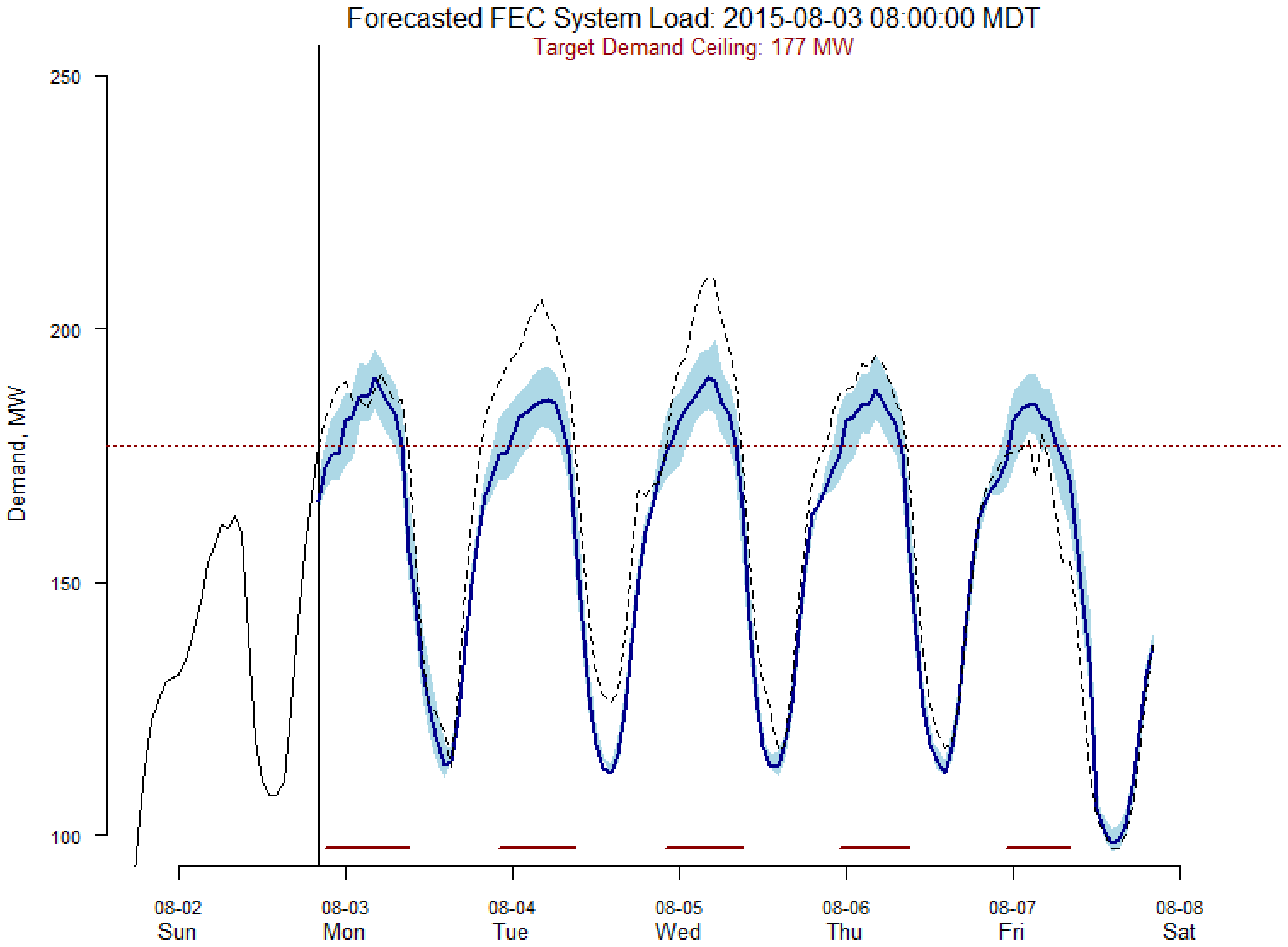
- At 04:00 MDT, minimal changes to the load forecast and dispatch plan(s)



FEC Simulation: Forecast and Dispatch Plan Evolution

Note(s)

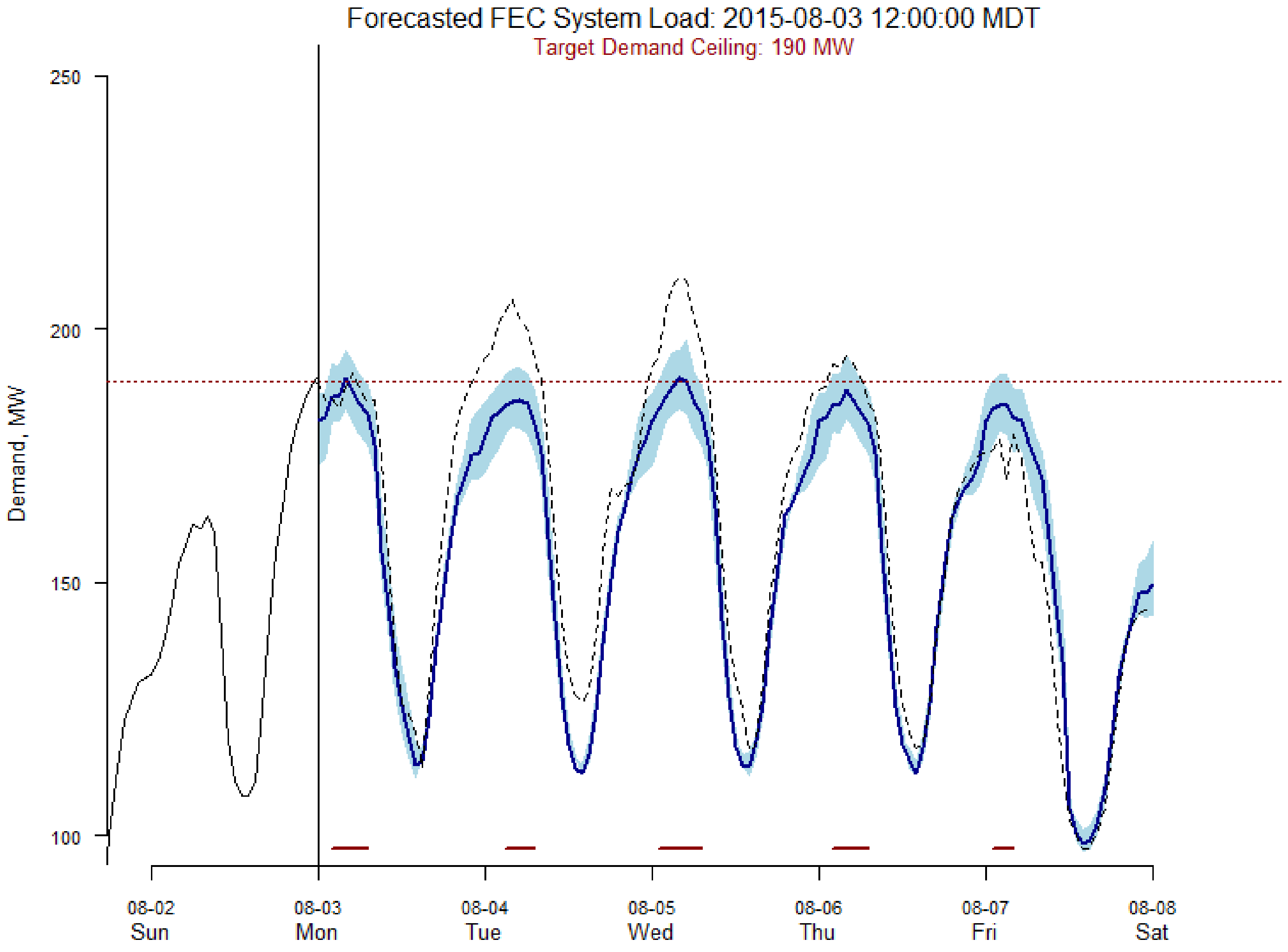
- At 08:00 MDT, nearing initial scheduled dispatch



FEC Simulation: Forecast and Dispatch Plan Evolution

Note(s)

- At 12:00 MDT, a new “month-to-date” peak has been realized (190 MW)
- All subsequent dispatch plans updated to reflect the new target of 190 MW



FEC Simulation: Forecast and Dispatch Plan Evolution

Note(s)

- By 20:00 the realized "month-to-date" has exceeded 191 MW
- All subsequent dispatch plans have been updated including the cancelation of Friday's dispatch (since the forecast peak is not expected to exceed 191 MW)