A Day in the Life of a Transactive Grid

GridWise® Architecture Council
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• Increased penetration of DER, especially in distribution systems
• Increased variability – due to increased renewable resource integration
• Load growth low or declining
• Potential for peak load growing
• Increasingly “intelligent” devices – loads and in the electricity network
Trend impacts

• Move from central power station, load following operation to a coordinated multi-resource, supply following operation

• Changes in load patterns, e.g., the California “duck” curve with much different net load shape

• Need to effectively engage all resources and loads to maintain or improve system reliability and efficiency
Transactive Systems

• One approach for engaging the diverse set of active parts
• How would this work from view of
  – Regional system operator?
  – Distribution system operator?
  – End-user?
Our TE grid scenario

– TE deployed in a distribution system

– RTO offers markets for energy & services:
  • Day-ahead
  • Hourly
  • Spot markets

– All parties involved engage in planning of:
  • Load activity
  • Prices
  • Etc.

– A simple network topology
Our network topology

Wind: 5¢ / kWh
Fossil: 20¢ / kWh
Nuclear: 10¢ / kWh

Transmission System (TS)

Distribution Systems:
- DS 1
- DS 2
- DS 3

Residential Systems:
- Residential 1
- Residential 2

Commercial & Industrial
Our story begins at 6 PM

We plan the day ahead

– Weather forecast
  • A moderate spring day is expected
  • Not unusually warm
  • Moderate winds overnight

– Power forecast
  • Wind power available
  • Low consumption expected
  • Low overnight electricity price

– No transmission or distribution constraints expected
Price and Load Forecasts

**Price Forecast**

- TS - P ($/kWh)
- DS1 - P ($/kWh)
- DS2 - P ($/kWh)
- DS3 - P ($/kWh)

**Load Forecast**

- TS - Q (kWh)
- DS1 - Q (kWh)
- DS2 - Q (kWh)
- DS3 - Q (kWh)
A revised weather forecast

– New weather forecast
  • Hotter than previously forecast
  • Unseasonably warm

– Loads and prices respond
  • More afternoon load than previously expected
  • Prices forecast to rise in response

– Loads and price adjust
  • Buildings moderate power consumption
    - Pre-cool from mid-morning through mid-day
    - Flatten load in late afternoon, early evening
  • Prices moderate – still higher than forecast
Updated Price & Load Forecasts

Price responds to load forecast

Load responds to adjusted price forecast
Wind forecast update

- Winds stronger than forecast until 7 AM
- Price drops to encourage use of excess wind power
- Loads adjust and new load forecast provided
- No need to adjust wholesale prices
- Distribution feeder constraint
  - Causing local distribution price differences
  - Iteration of load & price to resolve constraint
Updated Price & Load Forecasts

**DS2 - local price adjustment**

**DS loads respond to manage local problem**
Real time constraint

– Temperature increases
  • Loads increase
  • Unexpected transmission constraint

– Prices changes
  • Price at constrained node (LMP) increases
  • Prices downstream rise now and later

– Loads changes on affected feeders
  • Load curtailment
  • Load shifting

LMP = Local Marginal Price
Updated Price & Load Forecasts

Unexpected transmission constraint - prices jump

Loads respond to transmission constraint
Key points from the “simulation”

– Exchange of information between systems
  • Systems: bulk power, distribution, and end-uses
  • Critical to engaging all elements of the system

– Price changes based on:
  • Time
  • Location
  • Grid conditions

– Price changes must be transparent to all

– Various mechanisms for price-response actions

– Forecasts of price and load are useful at all levels
Key points: End-user view

– End-user response is useful if:
  • Based on “actionable information” such as price forecast
  • Magnitude of price change $\rightarrow$ Magnitude of response

– End-users should:
  • Provide more information than available now
  • Provide information about planned consumption

– Responses will vary across categories of end-user
Key points: Distribution view

– Distribution system coordinates:
  • Response of end-users
  • “Needs” of the bulk power system

– Roles of distribution system
  • Moderate responses
  • Maintain distribution reliability

– Distribution compared to transmission
  • Distribution system is more dynamic
  • Flexible approaches are required
Key points: Regional operator view

– Regional operations manage:
  • Financial risk
  • Reliability risk

– Reduce risks with better information about:
  • Present loads
  • Future load behavior

– Reducing risk reduces costs to all stakeholders
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