Transactive Energy Systems Valuation

Farrokh Rahimi, Ph.D.
Senior Vice President
Market Design and Consulting

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Trade Secret

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Key Questions

- What are the value drivers for deployment of transactive energy systems?
- What are the most relevant future power grid composition scenarios that should be considered?
- What are the operational and control objectives for an integrated grid in a high Distributed Energy Resource (DER) scenario?
- How can the value associated with those objectives be quantified and monetized?
- What is the relationship between the value of a transactive energy system from an operational perspective and a long-term planning perspective?

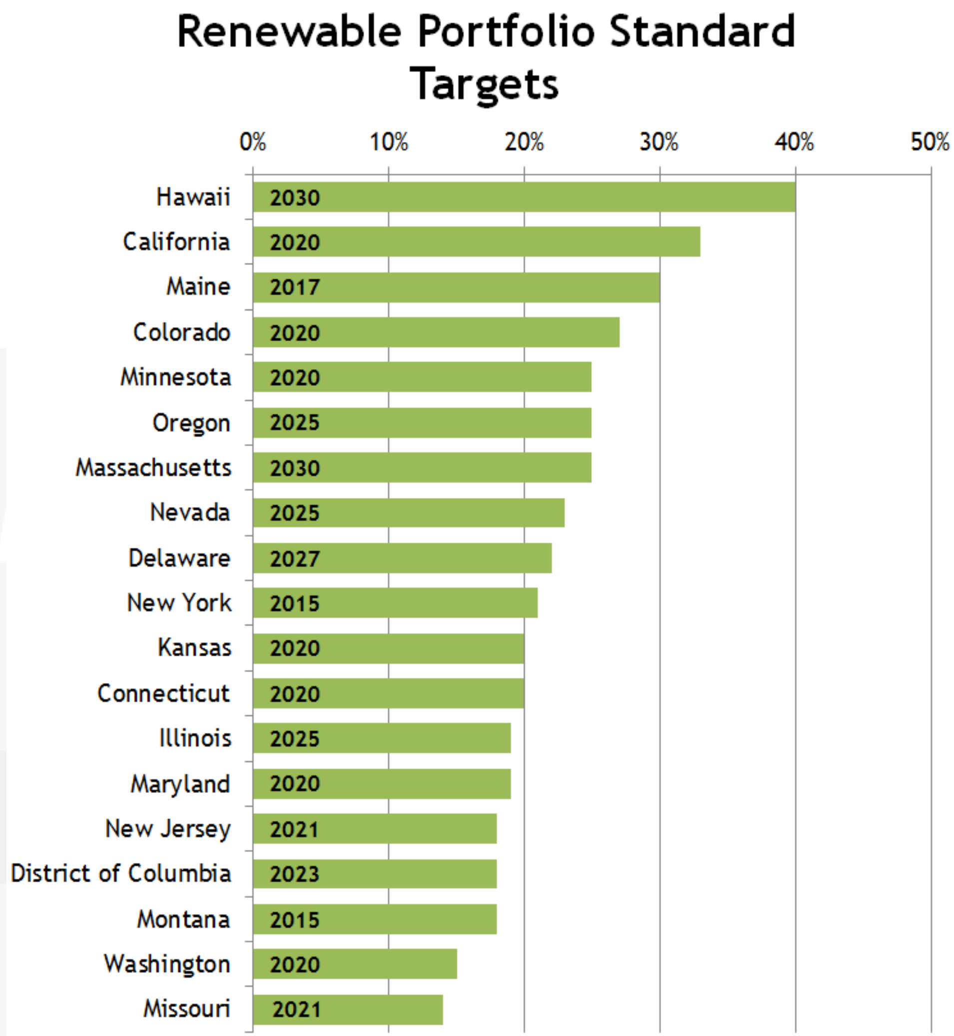
Value Drivers

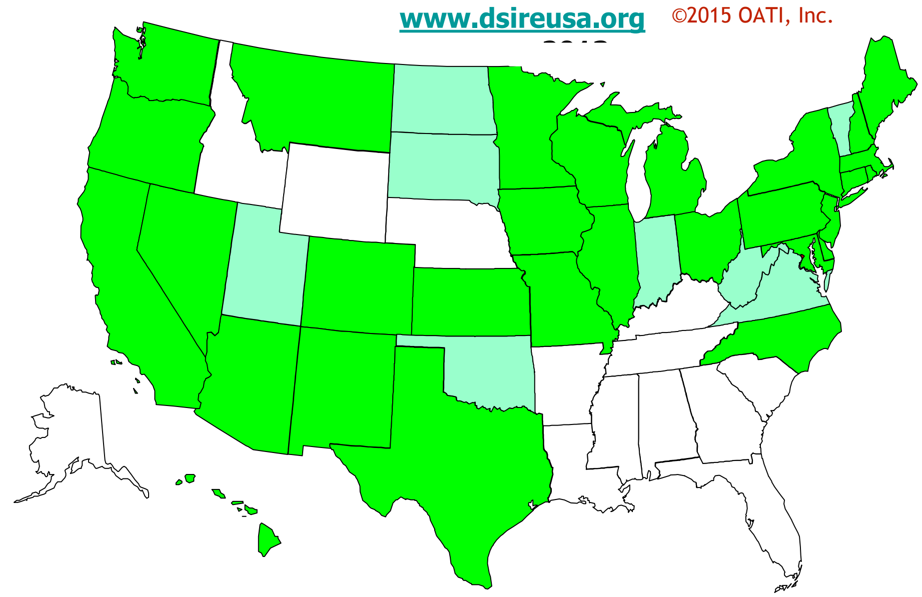
- What are the value drivers for deployment of transactive energy systems?
  - *Reduce consumer energy cost; increase prosumer energy revenue*
  - *Enable participation of demand-side capabilities to enhance power system reliability and reduce power system operation costs*
    - Distribution Operations
    - Bulk Power Operations
  - *Improve environmental impact of energy production and consumption*
  - *Provide investment signals for clean energy technologies*
  - *Achieve the above*
    - Within consumer/prosumer comfort range
    - With minimal imposition on power system operators (minimal or no additional manual intervention)

Future Power Grid Composition Scenarios

- What are the most relevant future power grid composition scenarios that should be considered?
  - Increased use of renewable energy resources
    - Bulk power renewables
    - DER
  - *Merging of Balancing Areas for voluntary sharing of imbalances and dispatchable resources in the face of proliferation of bulk power renewable resources*
  - *Growth of MicroGrids and pseudo Control Areas for self balancing vis-à-vis distributed generation and storage*
  - *Increased use of value-based soft constraints in lieu of hard constraints derived from off-line/planning studies*
  - *Extension of bulk power markets to distributed retail markets*
  - *DSO/DSP construct as facilitator/interface between bulk power and retail markets*

Industry Drives: Environmental Regulations Renewable Portfolio Standards (RPS)

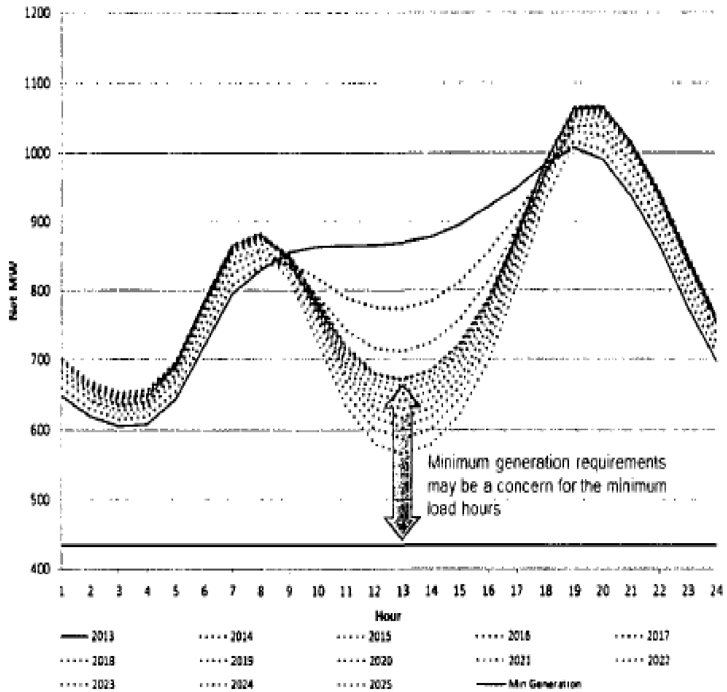




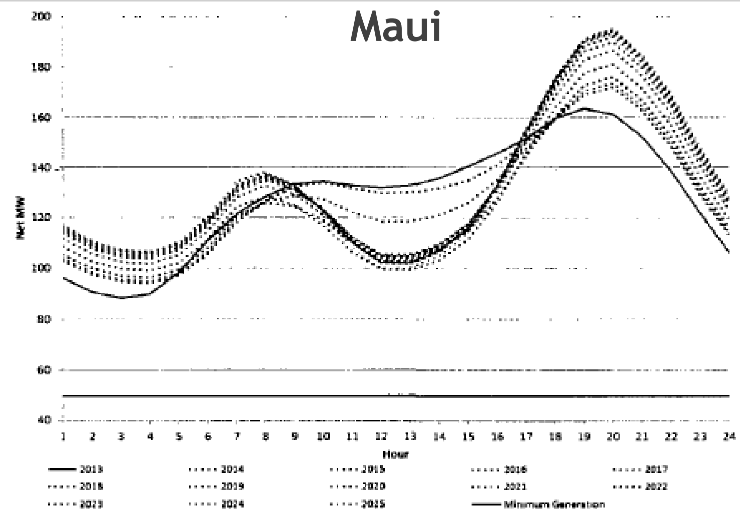
- Hawaii Utilities Recently Approved higher targets (100% by 2045)
- California is Considering a higher target (50% by 2030)

Projected Load Profile Hawaii Islands

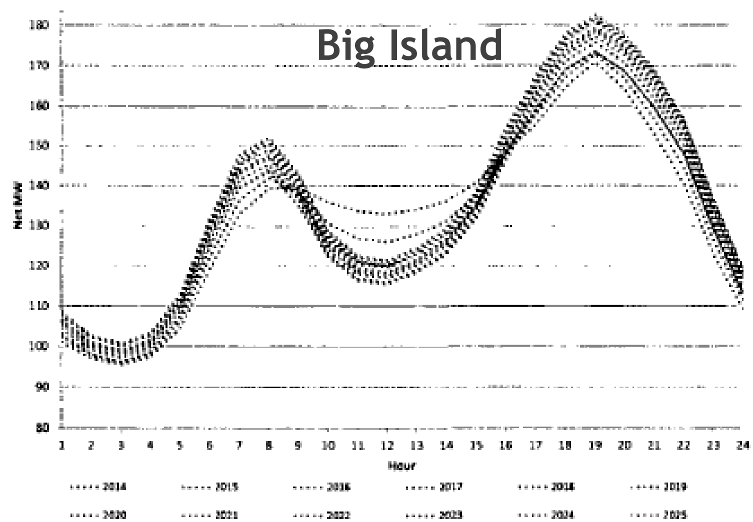
Oahu



Daily load profile, O'ahu — 2013 actuals, 2014-2025 projections



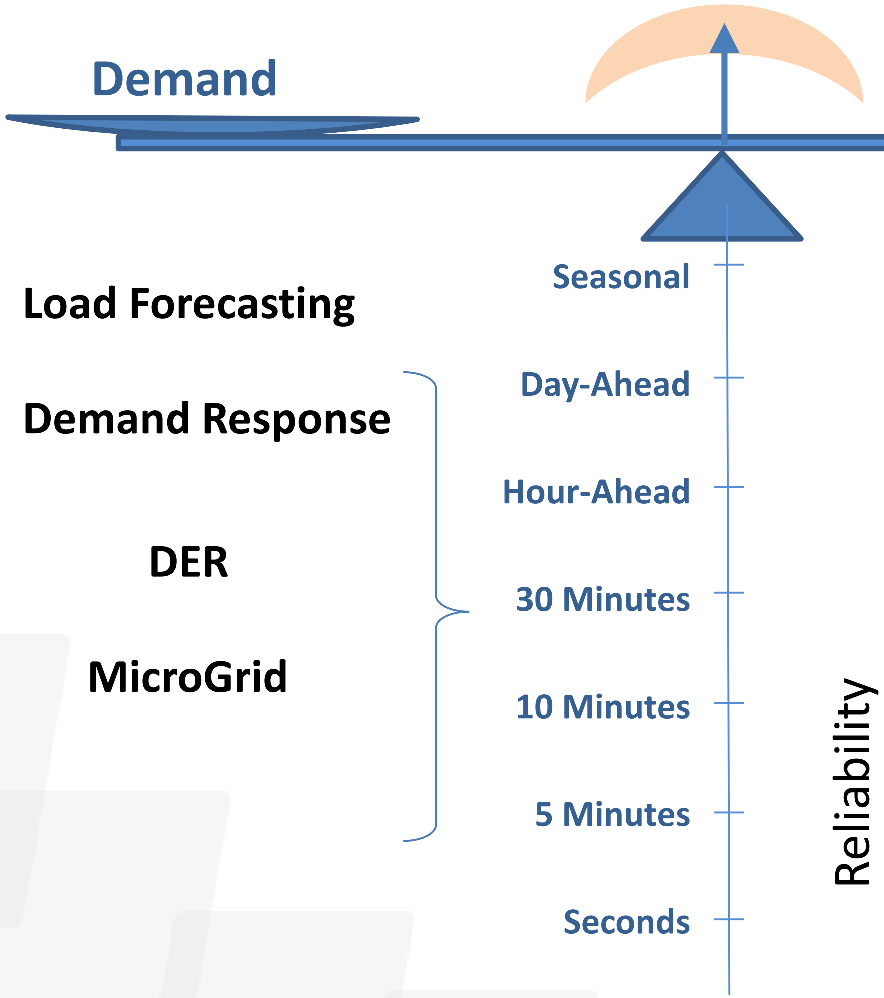
Daily load profile, Maui - 2013 actuals, 2014-2025 projections



Daily load profile, Hawai'i - 2014-2025 projections

Power System Operations

- Balance Supply and Demand at all Times In Each Balancing Areas



Load Forecasting

Demand Response

DER

MicroGrid

- Resource Adequacy
- Capacity Programs
- Energy
  -- Day-Ahead (DA)
  -- Real-Time (RT)
- Load Following – Balancing Energy
- Ramping Product
- Reserves
  -- Non-Spin
  -- Spin
  -- Regulation

Tradable Market Products

- Existing Market Products
  - *Capacity (forward markets)*
  - *Energy (forward; DA; RT)*
  - *Ancillary Services (forward; DA; RT)*
    - Contingency Reserves
      - *Spinning Reserve/Responsive Reserve/Synchronized Reserve*
      - *Supplemental Reserve/Non-Spinning Reserve*
    - Regulation (Symmetrical; Upward/Downward)
- Emerging Market Products (Flexibility Reserves)
  - *Flexible ramping*
  - *Load following*
  - *Balancing Energy*

Reserve Definitions

	Service	Response Speed	Duration	Cycle Time	Market Cycle	Price Range (Avg./Max) $/MWh
Normal Conditions	**Regulating Reserves**	4 Sec. - ~1 Min	Minutes	Minutes	Hourly	$33-$60
	Load Following or Real-Time Energy	~5-10 Min	5 min to Hour	5 Min to Hour	Hourly	
Contingency Conditions	**Spinning (Synchronized) Reserves**	Seconds to < 10 Min	10 to 120 Min.	Hourly to Days	Hourly	$6-$27
	Non-spinning Reserves	< 10 Min	11 to 120 Min.	Hourly to Days	Hourly	$1-$3
	Replacement or Supplemental Reserves	< 30 Min	2 Hours	Hourly to Days	Hourly	$1-$4
Other Services	**Voltage Control**	Seconds	Seconds	Continuous	Year(s)	$0-$4/kVar-Yr
	Black Start	Minutes	Hours	Monts to Years	Year(s)	

Flexible Capacity New Products:

- Flexible Ramping
- Balancing Energy
- Generation Following

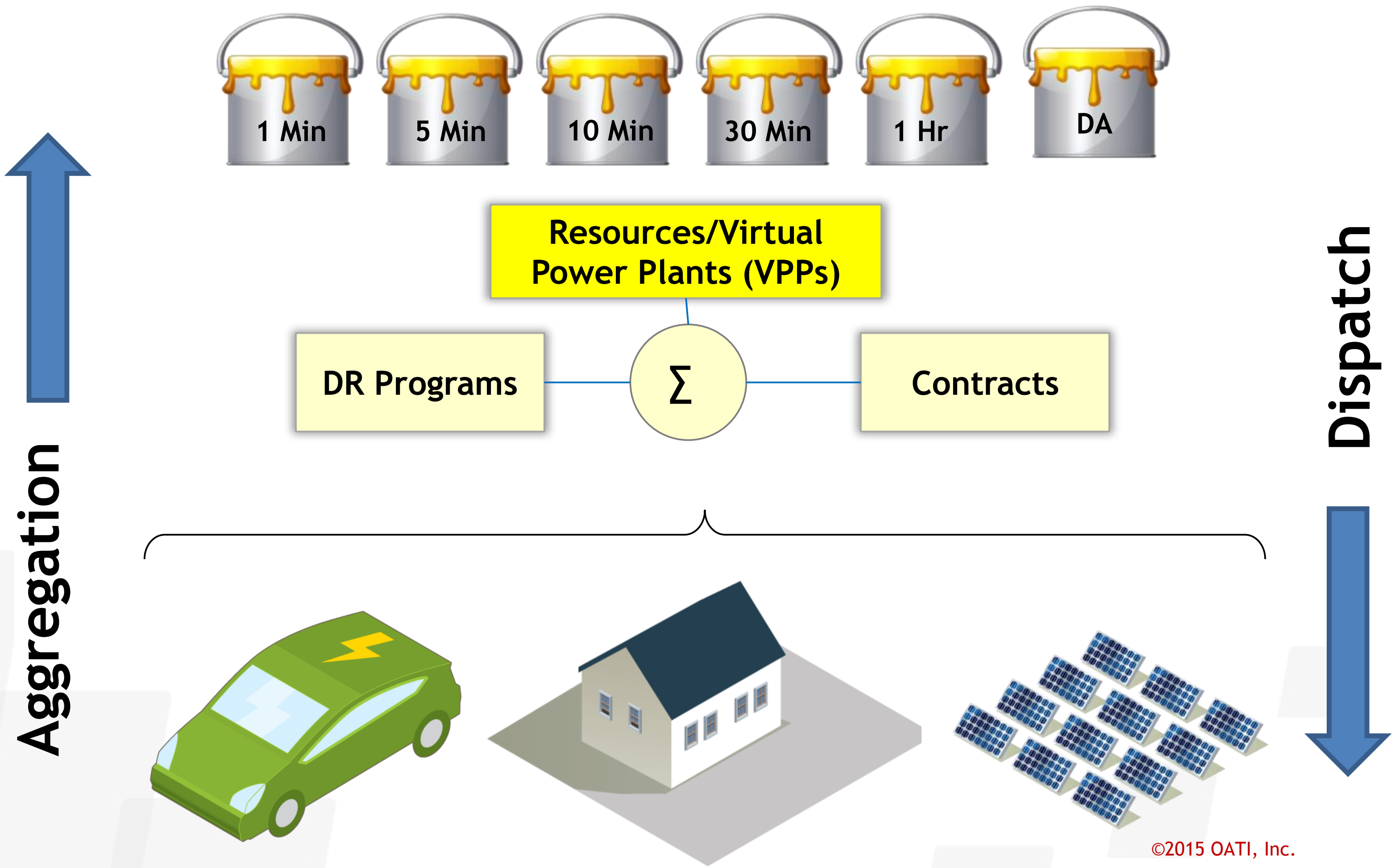
Source: NERC IVGTF Report: Operating Practices, Procedures and Tools; March 2011

Product Differentiation

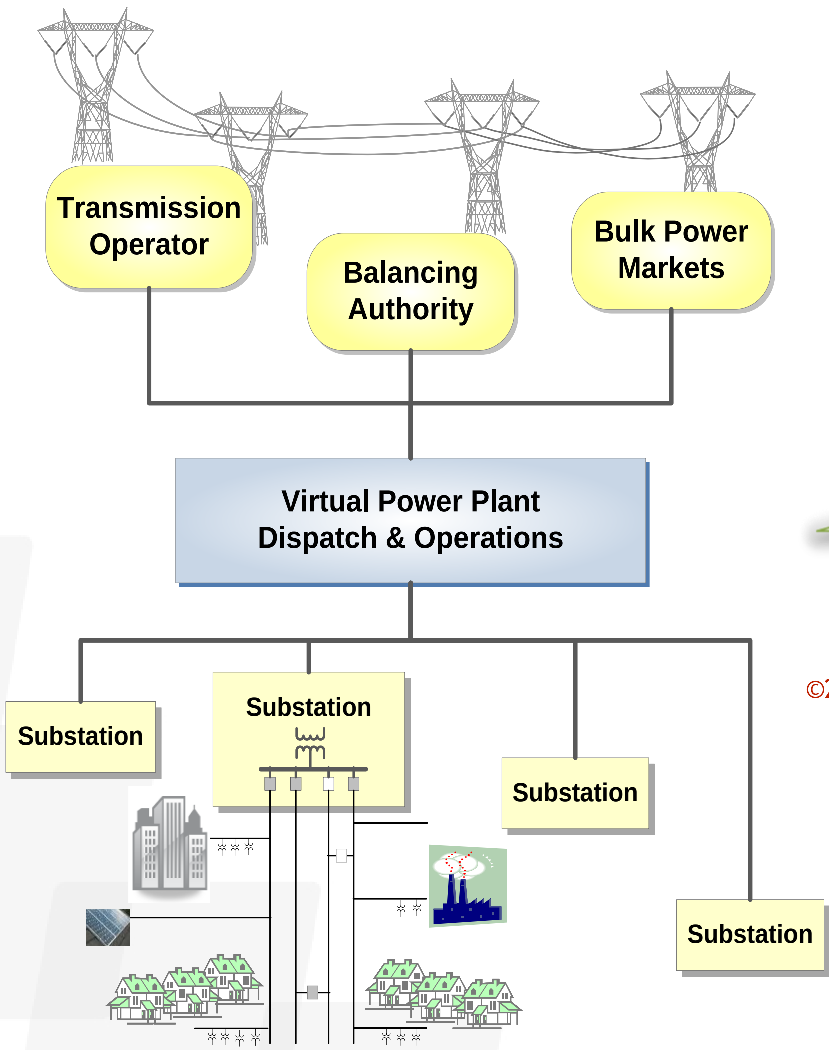
- Retail/Distribution Operation
  - *Energy differentiated by*
    - Speed of response
    - Minimum size
    - Directional change
    - Automatic vs. manual control
- Need to map Retail Capabilities to Bulk Power Operations Services
  - *Energy*
  - *Capacity (Forward Market-based Auctions; Resource Adequacy Requirements)*
  - *Ancillary Services*
    - Non-Spinning/Supplemental Reserve (10 minutes; 30 minutes)
    - Spinning Reserve (10 minutes)
    - Regulation (5- to 10-minute ramp; 4-second response)
  - *Emerging Flexibility Reserves (5- to 15-minute: Ramping; Load Following)*

Demand-Side Asset Modeling

- Modeling assets and aggregating them into dispatchable resources



Linking Demand-Side Capabilities to Wholesale Operations – VPP Construct



Bulk Power Products

- Hour-Ahead Firm
- Non Spin
- Spinning Reserves
- Market-Based Prices

VPP

- Grid Location
- P_{MAX} , P_{MIN}
- Ramp Rate
- Min/Max Up and Down Time
- Incremental Cost Curve

Capability Data Telemetry

Dispatch Instructions

Retail Tariff

- Direct Load Control
- Time of Use
- Critical Peak Price
- Dynamic Pricing
- Commercial and Industrial Curtailment Contracts
- Etc.

Consideration of Power System Characteristics for End-to-End Operation

- Power system characteristics can impact delivery of transacted quantities from distributed DR/DER assets
  - *Cold load pickup and snapback impacts*
  - *Reactive power/voltage impacts*
  - *Phase unbalance impacts*
  - *Impact of distribution losses*
  - *Impact of distribution congestion*
- Bulk Power/Wholesale Operator is oblivious to such distribution system impacts associated with its DR/DER resource scheduling and dispatch
- Distribution Management Systems (DMS) can help determine such impacts
- DSO can act as facilitator to ensure such impacts are avoided or mitigated

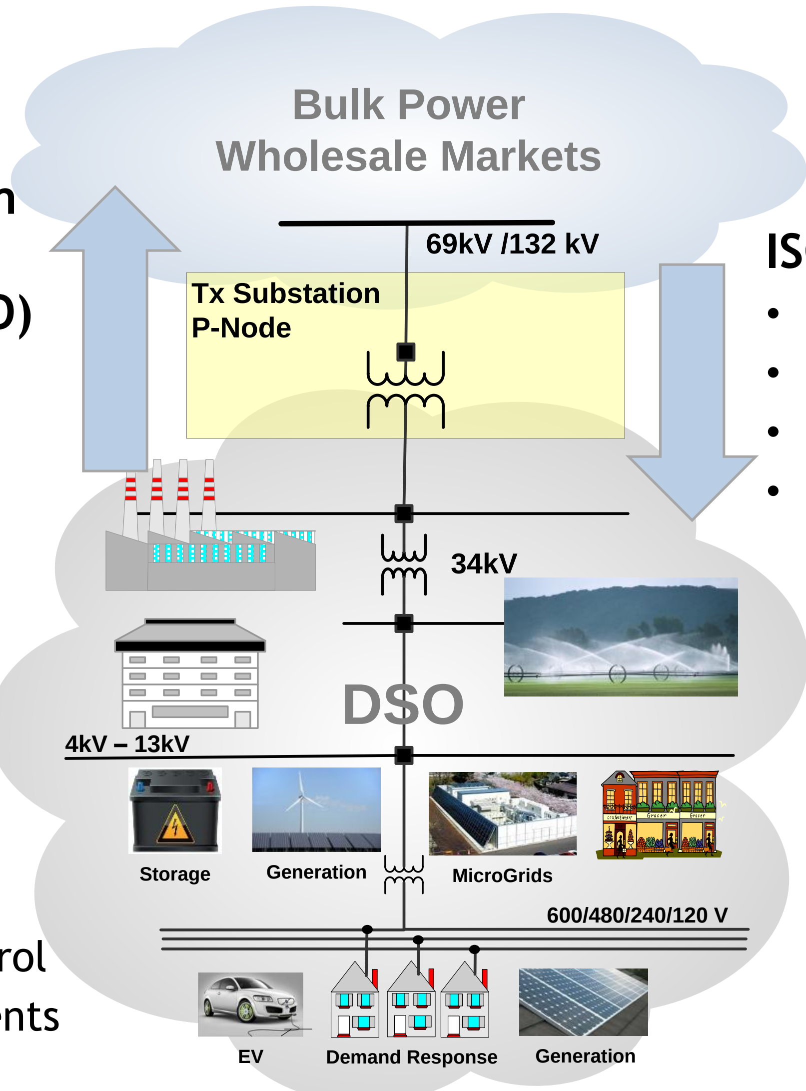
The DSO Construct – Linking Bulk Power and Distributed Resource Operations

DSO to Independent System Operator (ISO)/Regional Transmission Operator (RTO)

- Forecast Net Load and Dispatchable Products
- Schedules and Bids
- Metering and Telemetry

DSO Functions

- Distribution Planning
- Distribution Reliability
- Operations Scheduling
  - *Forecasting (Load, DR, DER)*
  - *Scheduling* (DR, DER, Market)
- Dispatch and Real-Time Control
- Retail Metering and Settlements
- Retail Market Administration



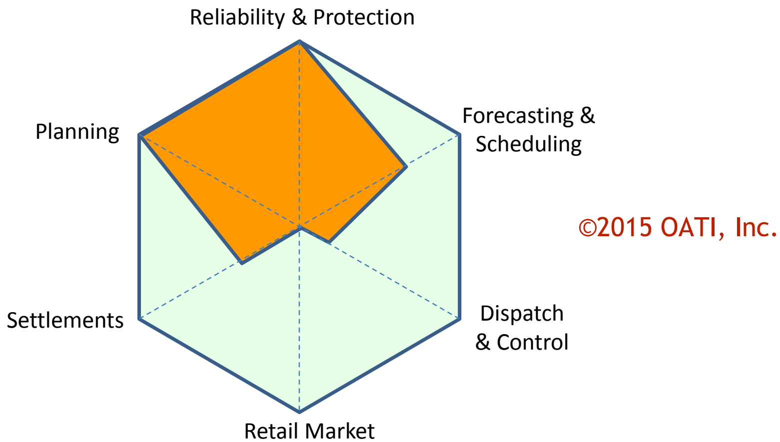
ISO/RTO to DSO

- Schedules
- Dispatch Instructions
- Prices
- Settlements

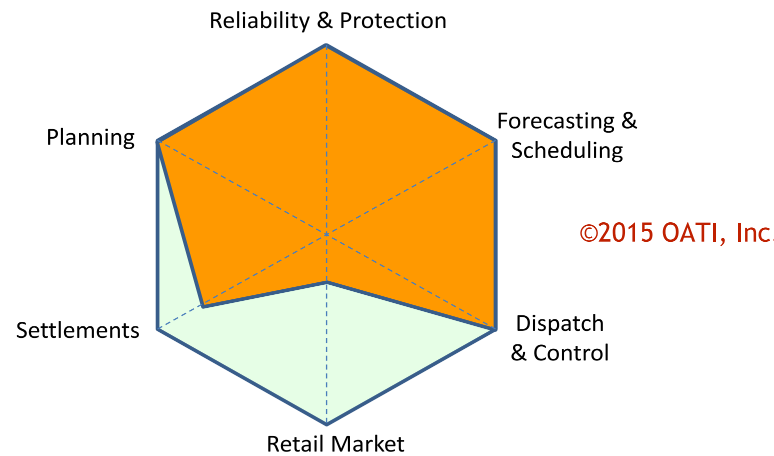
Source: Farrokh Rahimi and Sasan Mokhtari, “From ISO to DSO”, Public Utilities Fortnightly, June 2014, pages 42-50

Different DSO Models

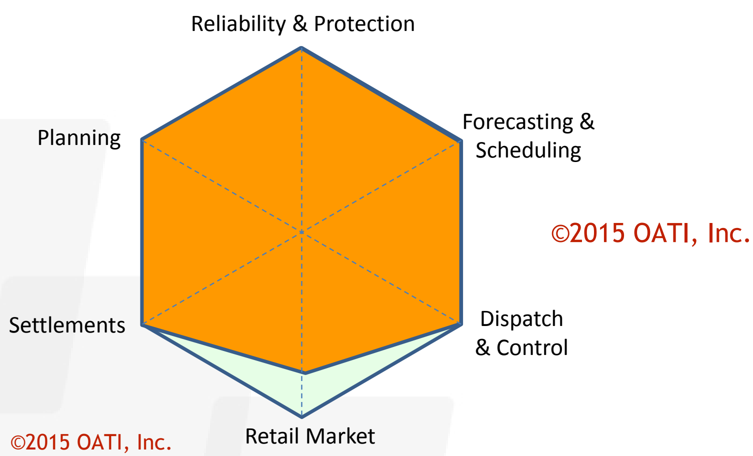
DSO-Lite



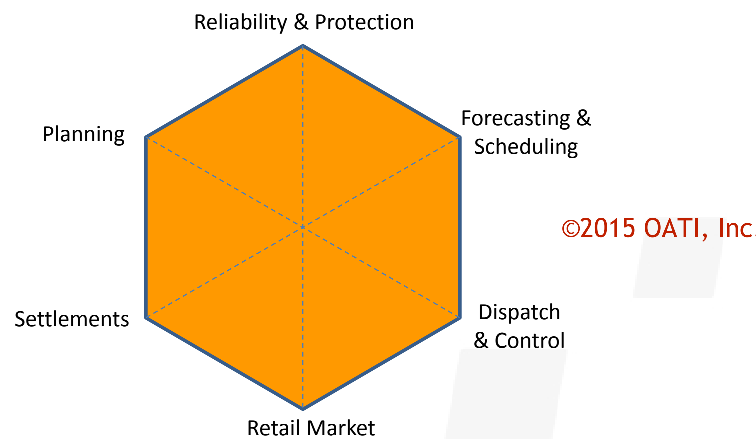
Pseudo BA DSO



Comprehensive DSO



Maximalist (Fully Transactive) DSO



Source: Farrokh Rahimi and Sasan Mokhtari, “From ISO to DSO”, Public Utilities Fortnightly, June 2014, pages 42-50

DSO/DSP Operation: Need for New Standards

<table>
<tr><th>Attribute</th><th>Wholesale / Transmission</th><th colspan="3">Retail / Distribution</th></tr>
<tr><td rowspan="2">Location:</td><td rowspan="2">POR / POD</td><td colspan="3">Street Address</td></tr>
<tr><td colspan="3">Service Delivery Point (SDP)
Point of Common Connection (PCC)</td></tr>
<tr><td rowspan="2">Products:</td><td></td><td>Response Time</td><td>Direction</td><td>Duration</td></tr>
<tr><td>Capacity
Energy
- Day-Ahead, R/T
Ancillary Services
- Non-Spin, Spin, Regulation
Balancing Services
- 5 Min Energy</td><td>• 4 Seconds
• 1 minute
• 5 minutes
• 15 minutes
• 1 hour
• Day Ahead</td><td>• Increase
• Decrease
• Both</td><td>• 10 minutes
• 60 minutes
• 90 minutes
• 120 minutes
• 180 minutes</td></tr>
<tr><td rowspan="4">Congestion:</td><td rowspan="4">Transmission Capacity</td><td colspan="3">Distribution "Capacity"</td></tr>
<tr><td colspan="3">Line/Transformer Loading</td></tr>
<tr><td colspan="3">Line Voltage</td></tr>
<tr><td colspan="3">Phase Imbalance - Neutral Flow</td></tr>
</table>

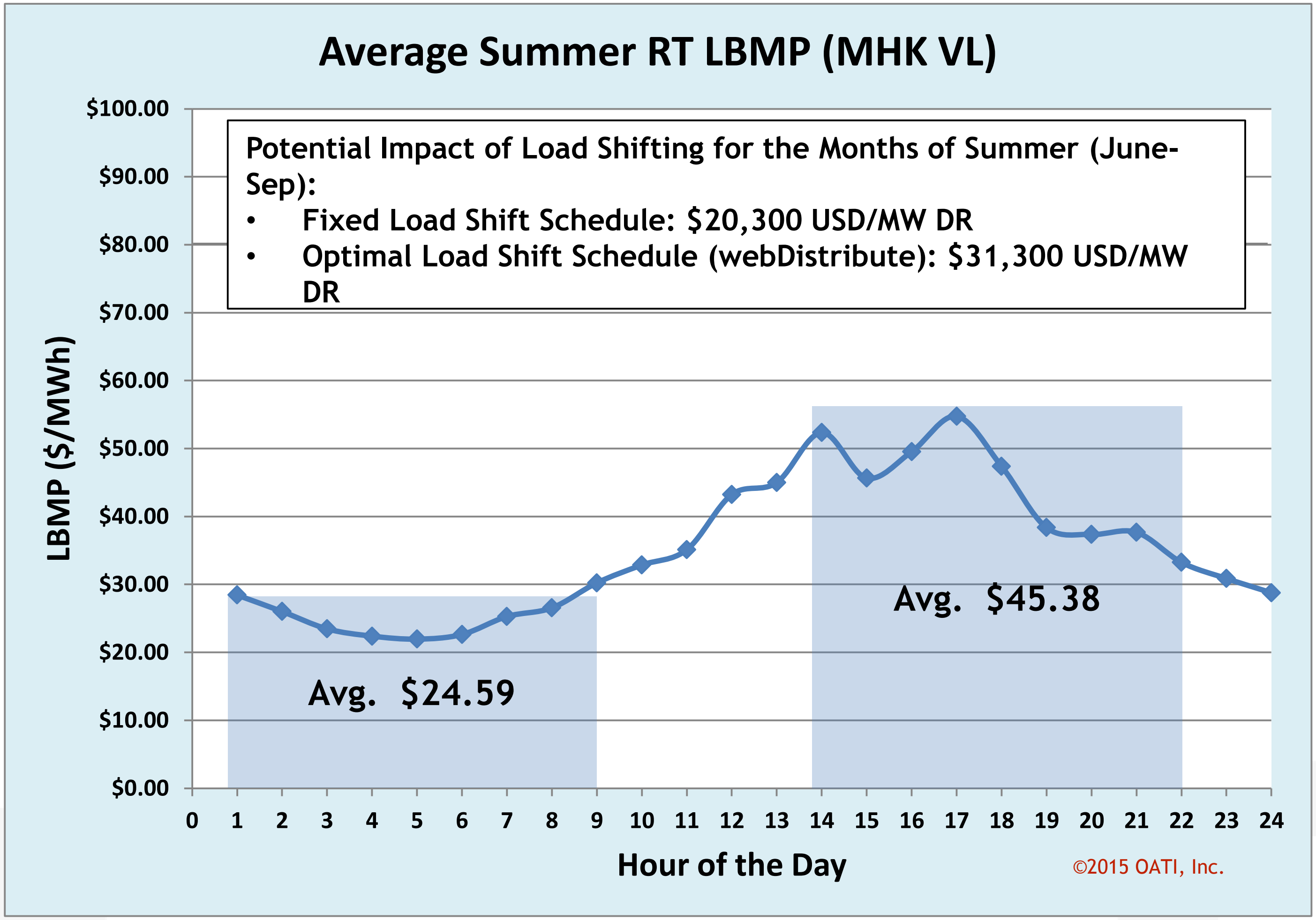
High DER Operational and Control Objectives

- What are the operational and control objectives for an integrated grid in a high DER scenario?
  - *Improved load and renewable forecast*
    - Multi-temporal forecasts for transactive, operations planning and dispatch time frames
    - Geographically more granular load forecast (less reliance on conventional LDFs)
    - Improved assessment of forecast confidence levels for determination of flexibility reserve and regulation needs.
  - *Incorporate state variables in addition to input-output characteristics for controlled devices (improved distributed storage modeling)*
  - *Consideration of consumer/prosumer preferences*
    - Mapping of consumer/prosumer preferences to bid/offer quantities and prices
    - Incorporating explicit consumer/prosumer preferences as part of the objective function
  - *Hierarchical control based on*
    - Explicit Dispatch Signals
    - Price/value propagation

Value Quantification and Monetization

- How can the value associated with those objectives be quantified and monetized?
  - *Use available bulk power market product prices as reference to*
    - Quantify values of transactive system products and services contributing to bulk power operation
    - Map to retail markets and distributed resources while considering distribution losses, constraints, and consumer/prosumer bids and offer
  - *Perform sensitivity analyses*
    - With and without analyses
    - Sensitivity to device modeling parameters
    - Sensitivity to prosumer/consumer preference parameters

Example: Load Shifting Benefit (Based on NYISO RT Market LBMPs for Mohawk Valley Zone January 01 – December 31, 2012)



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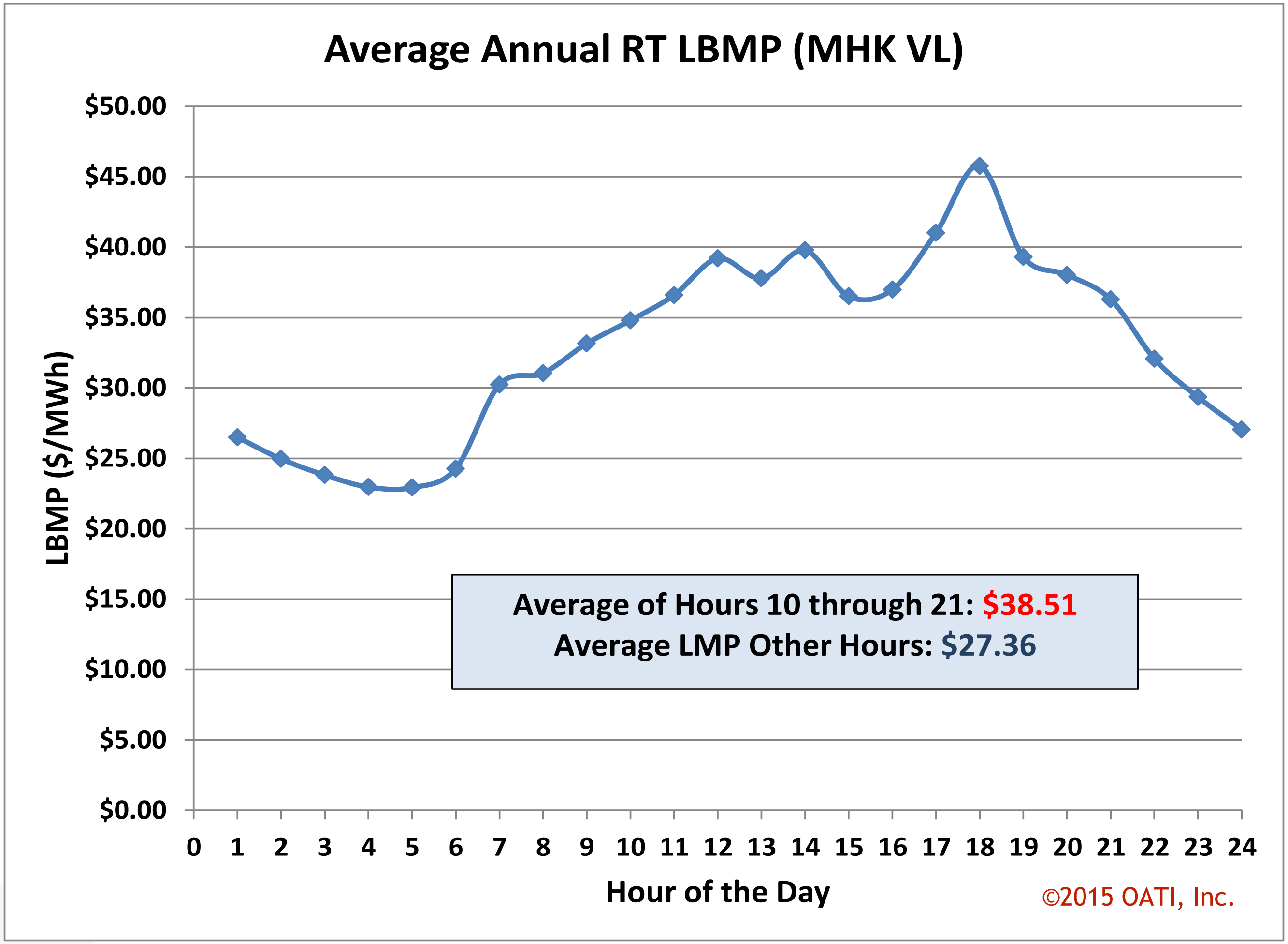

Potential Impact of Load Shifting for the Whole Year:
- Fixed Load Shift Schedule: $48,900 USD/MW DR
- Optimal Load Shift Schedule (webDistribute): $92,500 USD/MW DR

Typical Ancillary Service and Capacity Values

ISO/RTO	CAISO	PJM	MISO	NYISO (WEST)
Ancillary Services (Average Prices):				
Non-Spinning Res. ($/MW/h)	$1.50	$0.40	$1.50	$1.05
Spinning Res. ($/MW/h)	$5.00	$10.00	$4.00	$4.34
Regulation ($/MW/h)	$10.00	$30.00	$12.00	$10.00
Capacity Value ($/kW-yr)	$30.00	$40.00	$2.00	$64.00
Expected Annual Values ($/MW DR/yr)				
Ancillary Services:				
Non-Spinning Res.	$13,000	$3,500	$13,000	$9,000
Spinning Res.	$43,800	$87,600	$35,000	$38,000
Regulation	$87,600	$260,000	$105,000	$87,000
Capacity	$30,000	$40,000	$2,000	$64,000
Flexibility Reserves	$15,000 - $75,000			
A/S Capacity $/MW/Yr	$65,700	$173,800	$70,000	$62,500
Energy	$91,980	$78,840	$65,700	$91,980
Total	**$157,680**	**$252,640**	**$135,700**	**$154,480**

Operational vs. Planning Valuation

- What is the relationship between the value of a transactive energy system from an operational perspective and a long-term planning perspective?
  - *Transactive operations provide short-term price signals (e.g., Day-Ahead Hour-Ahead, or Real-Time LMPs, Distribution Marginal Prices, DMPs, etc.)*
  - *Planning decisions require long-run price signals (long-term LMPs and DMPs)*
  - *The latter must include consideration of*
    - Econometrics indicators
    - Transmission expansion alternatives
    - Gas-electricity coordination
    - Policy development scenarios

Questions

Thank You

Farrokh Rahimi, Ph.D.
Sales@oati.net
763.201.2000