Pacific Northwest Smart Grid Demonstration Project

Technical Status Update for GWAC Transactive Energy Workshop

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Pacific Northwest Demonstration Project

What:

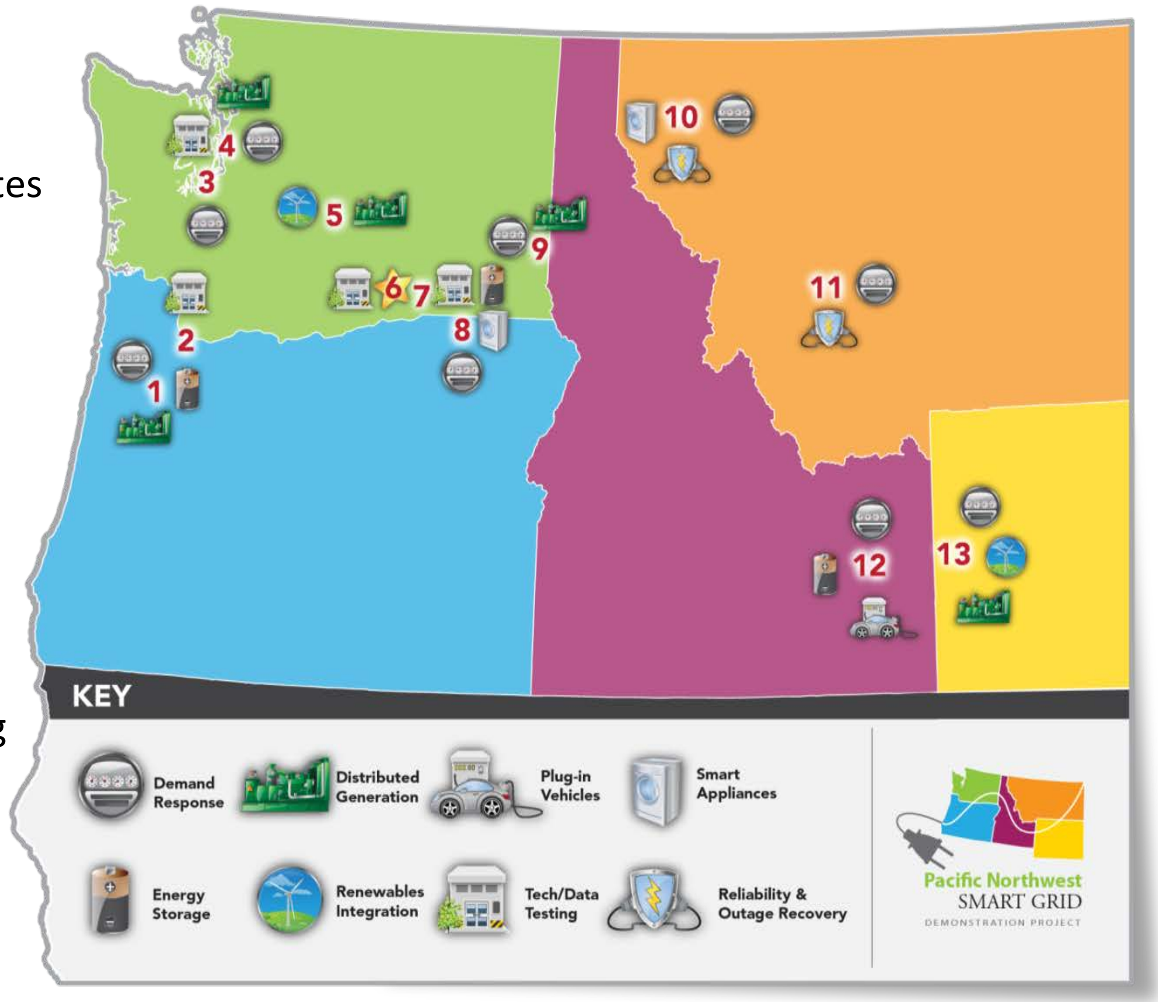
- $178M, ARRA-funded, 5-year demonstration
- 60,000 metered customers in 5 states

Why:

- Quantify costs and benefits
- Develop communications protocol
- Develop standards
- Facilitate integration of wind and other renewables

Who:

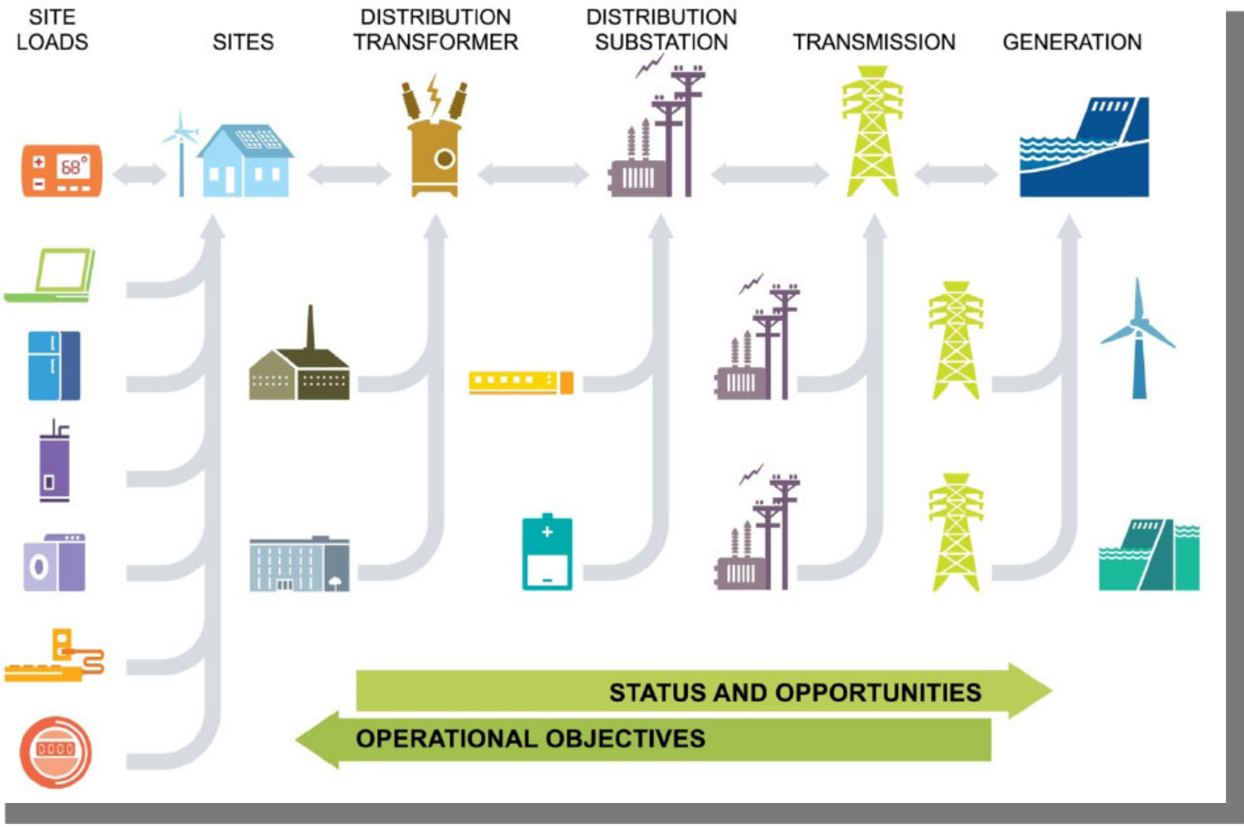
Led by Battelle and partners including BPA, 11 utilities, 2 universities, and 5 vendors



Project Basics

Operational objectives

- Manage peak demand
- Facilitate renewable resources
- Address constrained resources
- Improve system reliability and efficiency
- Select economical resources (optimize the system)



Aggregation of Power and Signals Occurs Through a Hierarchy of Interfaces

Some Definitions

- Transactive Control

  A single, integrated, smart grid incentive signaling approach utilizing an economic signal as the primary basis for communicating the desire to change the operational state of responsive assets.

- Transactive Incentive Signal (TIS)

  A representation of the actual delivered cost of electric energy at a specific system location (e.g., at a transactive node). Includes both the current value and a forecast of future values.

- Transactive Feedback Signal (TFS)

  A representation of the net electric load at a specific system location (e.g., at a transactive node). Includes both the current value and a forecast of future values.

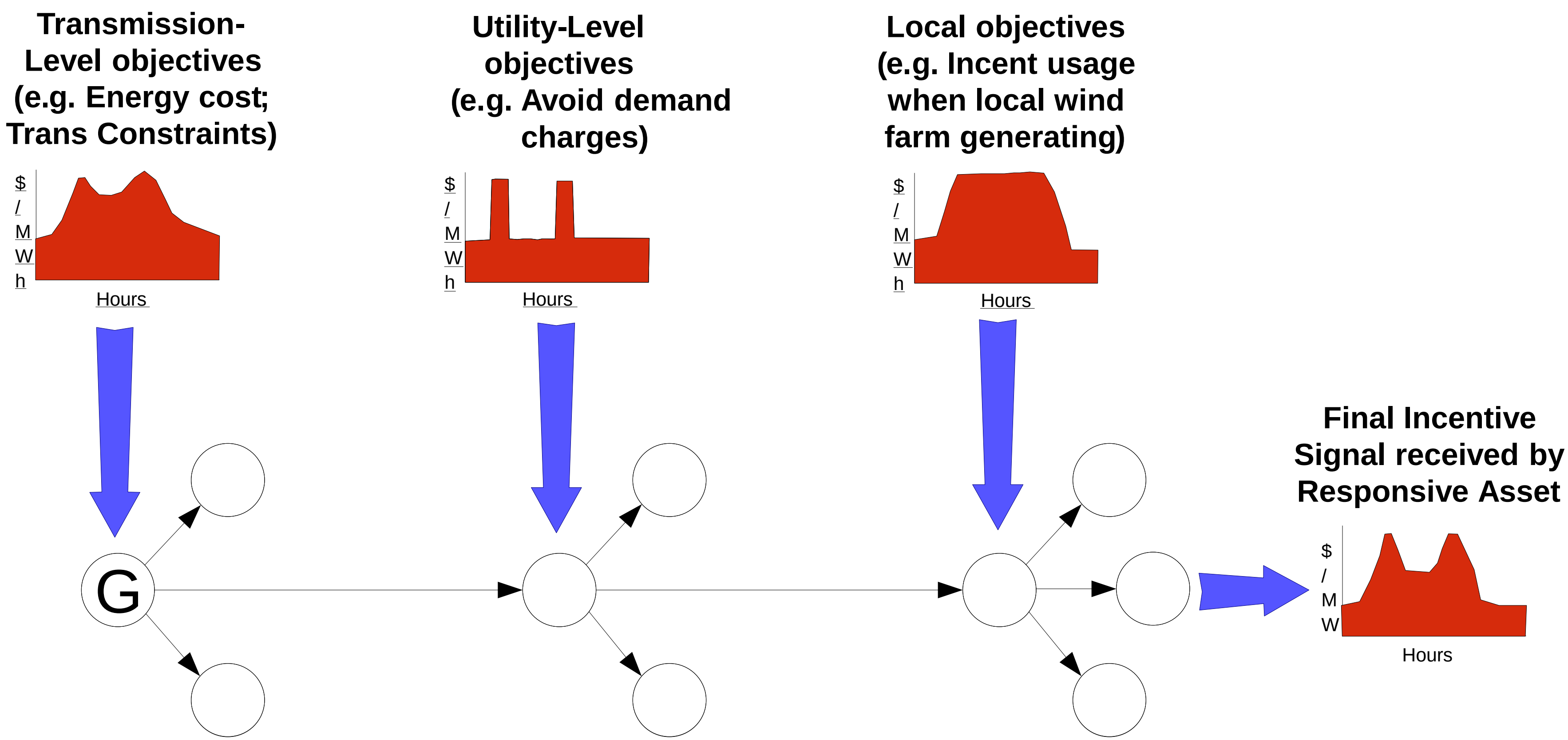
Role of a Transactive Node

- Respond to system conditions as represented by incoming Transactive Incentive Signals and Transactive Feedback Signals through
  - Decisions about behavior of local assets
  - Incorporation of local asset status and other local information
  - Updating both transactive incentive and feedback signals

- Inputs are needed from node-owners to calculate incentive and feedback signals
- Each signal is a sequence of forecasts for a time-series, so inputs will also be sequences of future (forecast/planned) values

End-to-End View of Transactive Control System – TIS Example

Below is an example of a signal being modified as it flows from supply towards consumption through the transactive network



Computing the Transactive Incentive Signal

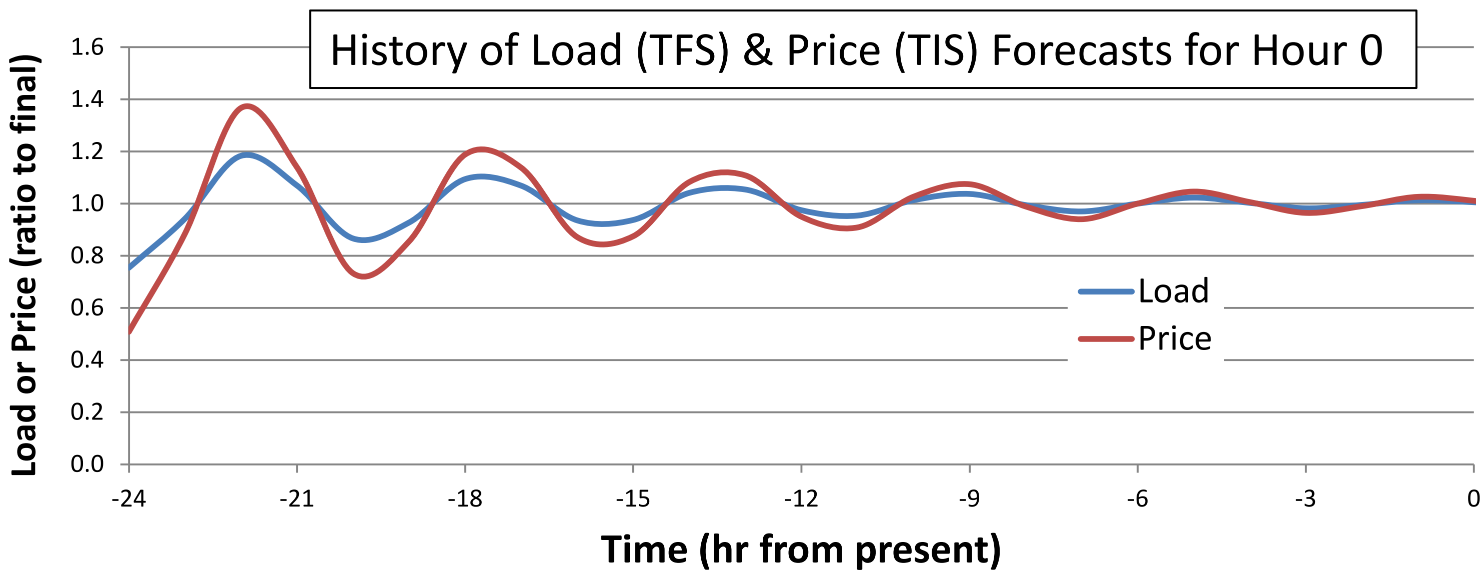
$$\mathrm{TIS}(t) = \frac{\text{(Energy Cost + Capacity Cost + Infrastructure Cost + Other Costs)}}{\text{Total Energy Generated or Imported}}$$

Transactive Control Feedback Loop

New incentive signals and feedback signals are generated on an event-driven basis.

The most recently available information is used.

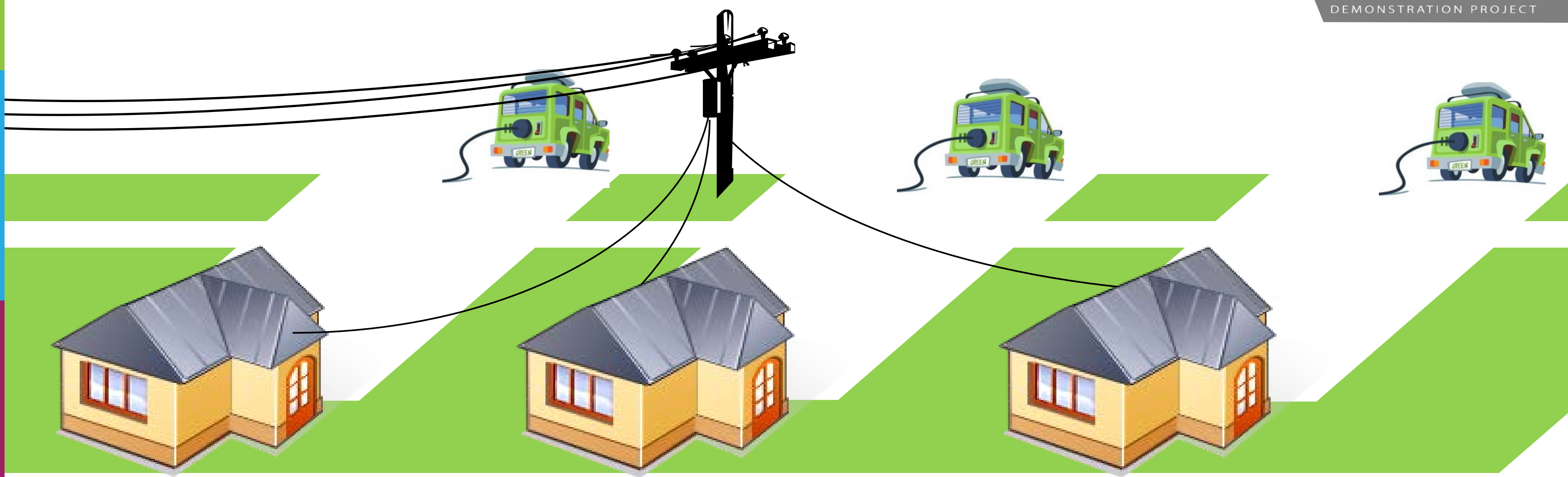
Each signal responds to changes in the other, and the values converge .

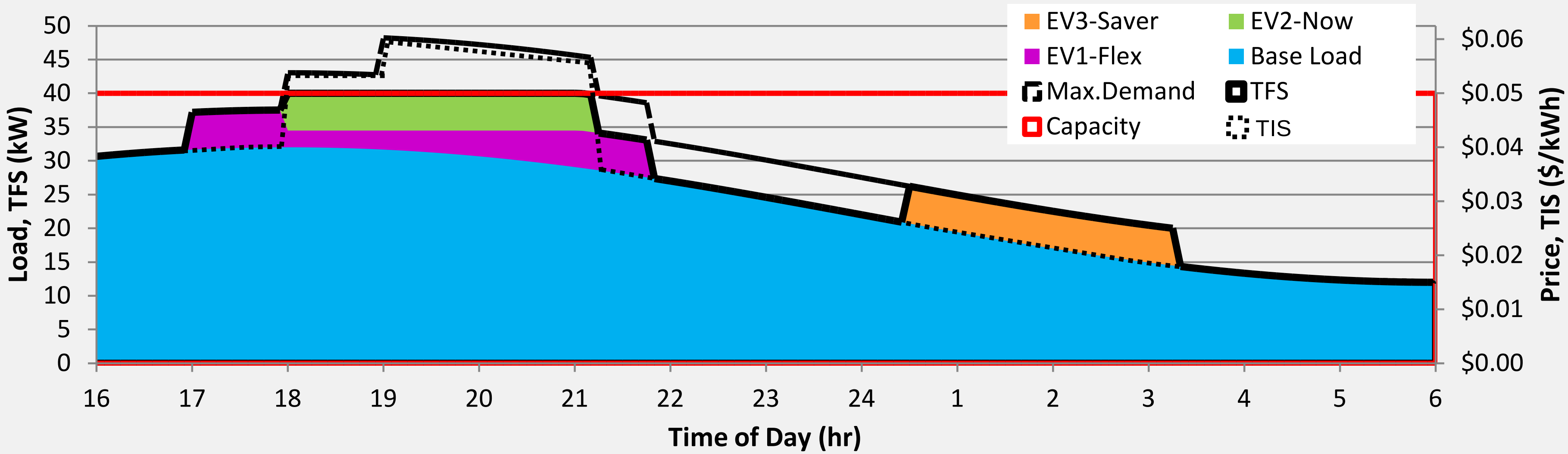


Simple Example – Local EV Charging

- Imagine the following situation:
  - Three neighbors with electric vehicles and different charging strategies
  - All three fed by same distribution transformer
  - All three come home and want to do a fast charge at the same time!
- Problem – transformer is overloaded if all three fast charge at the same time
- Transactive control solution –
  - Transformer sees in feedback signal that all three plan to fast charge
  - Transformer raises value of incentive signal during planned charging time to reflect decreased transformer life
  - Smart chargers and transformer "negotiate" through TIS and TFS until an acceptable solution is found

Transactive Control – An Illustration

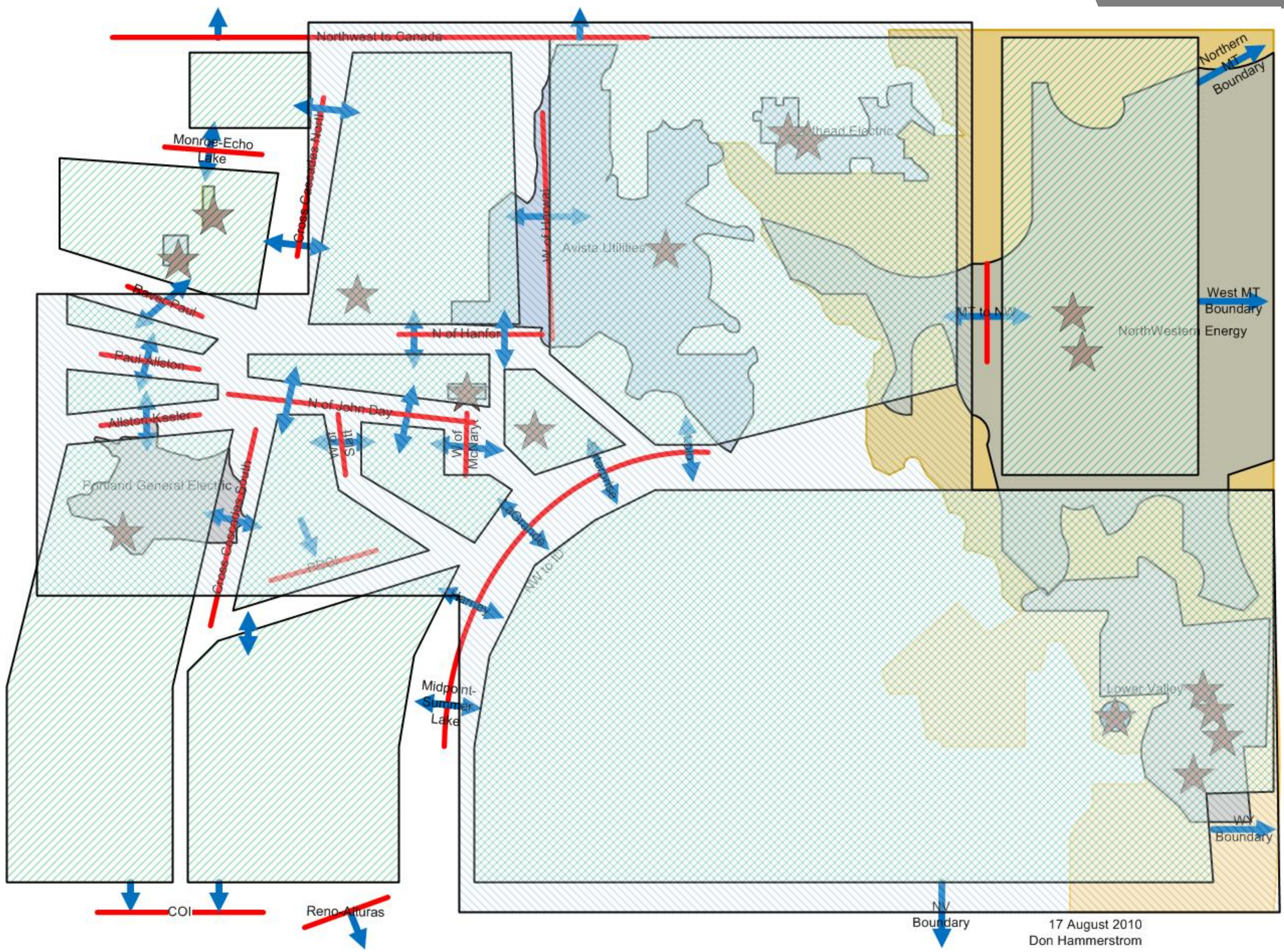




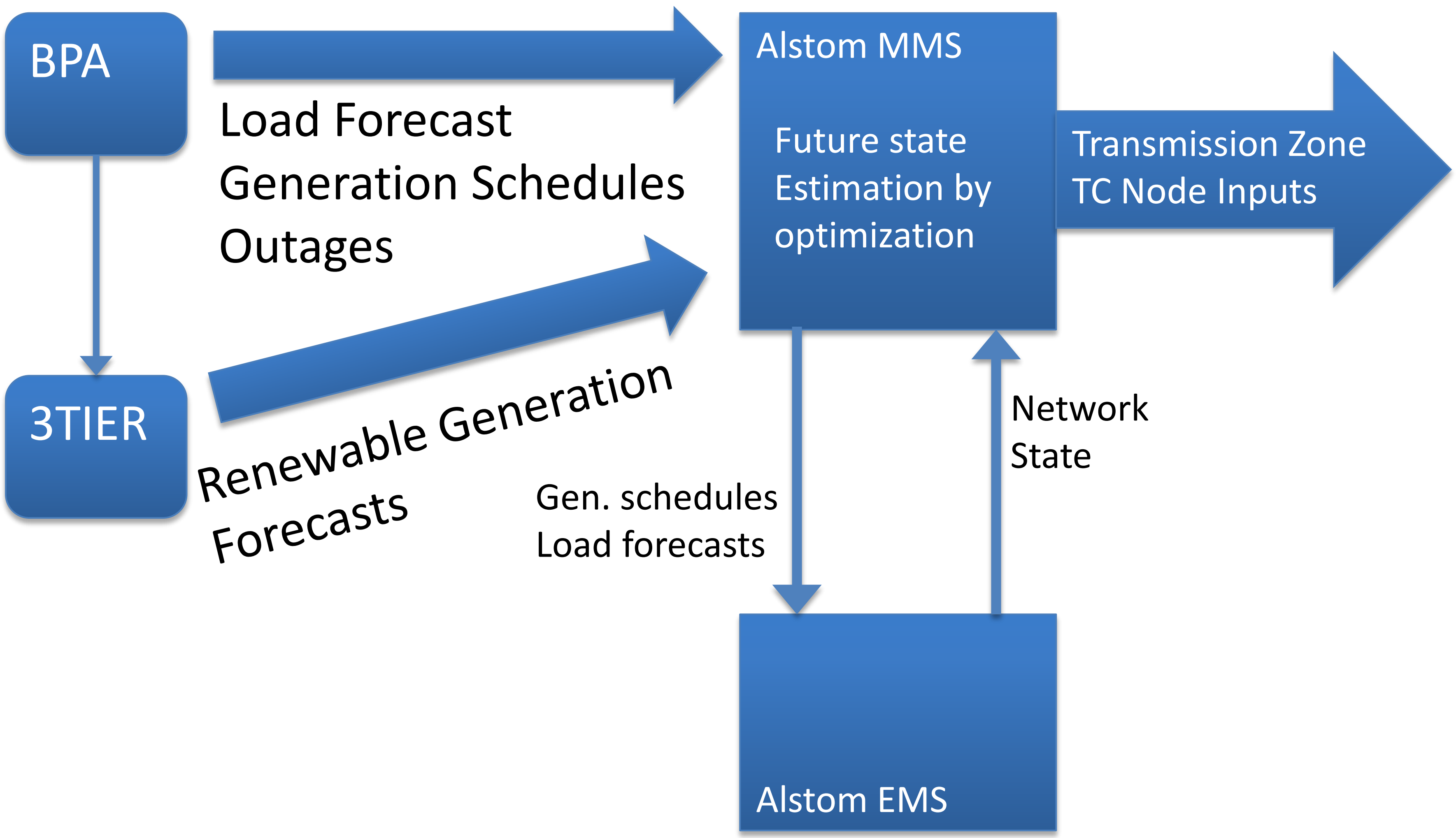
NW Region “Influence Map”--Topology

Cut Plane

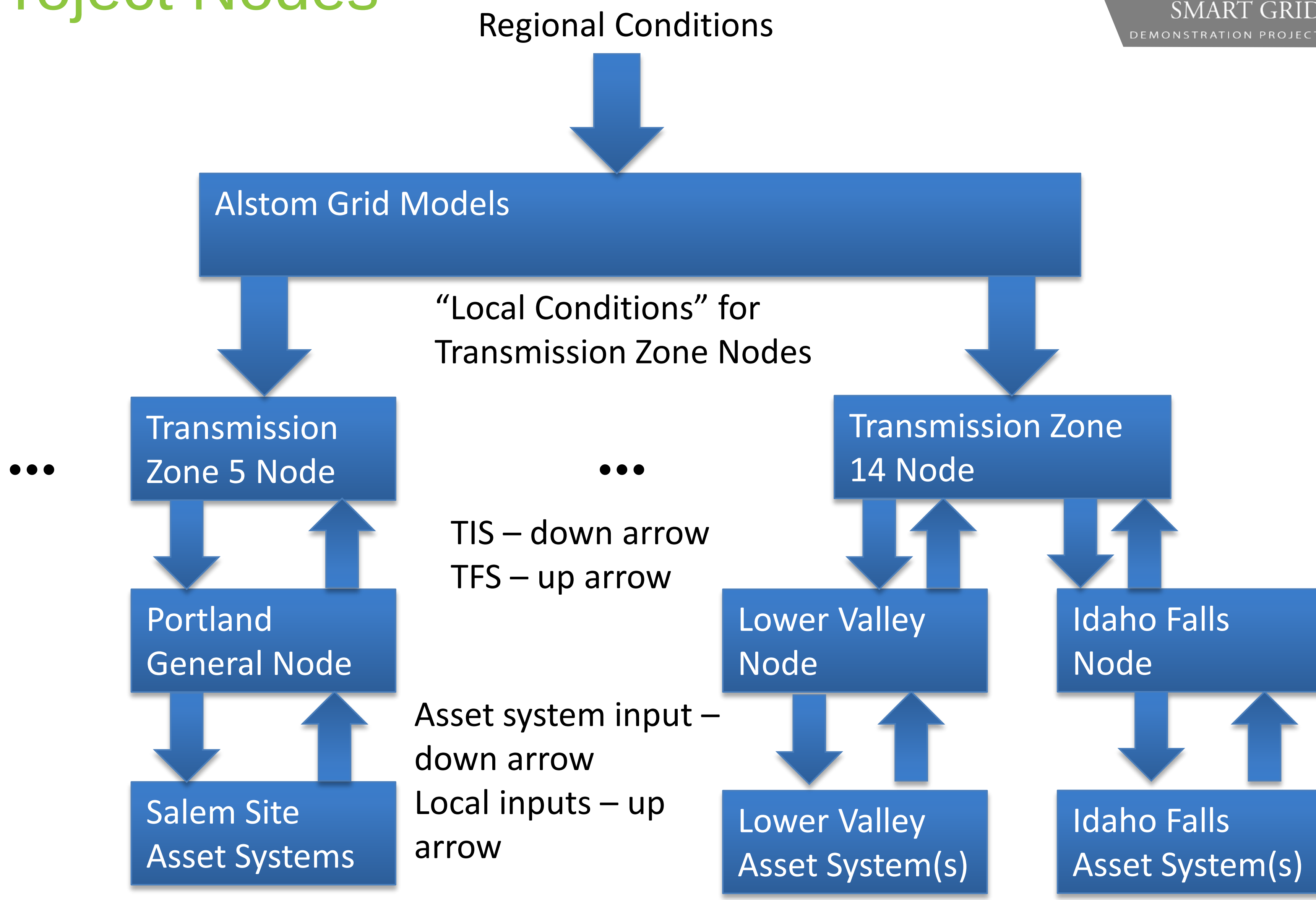
Flowgate



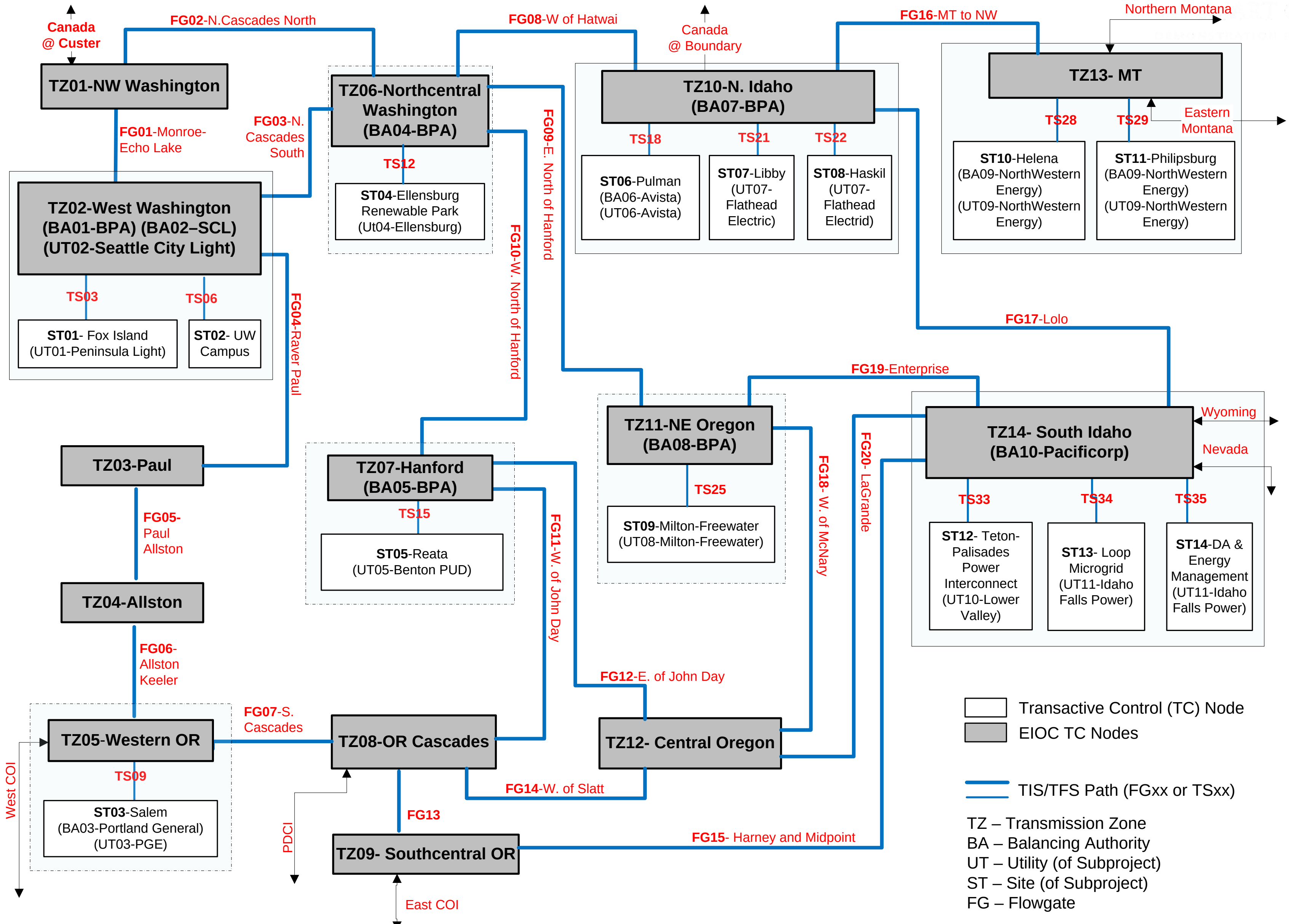
Regional Modeling



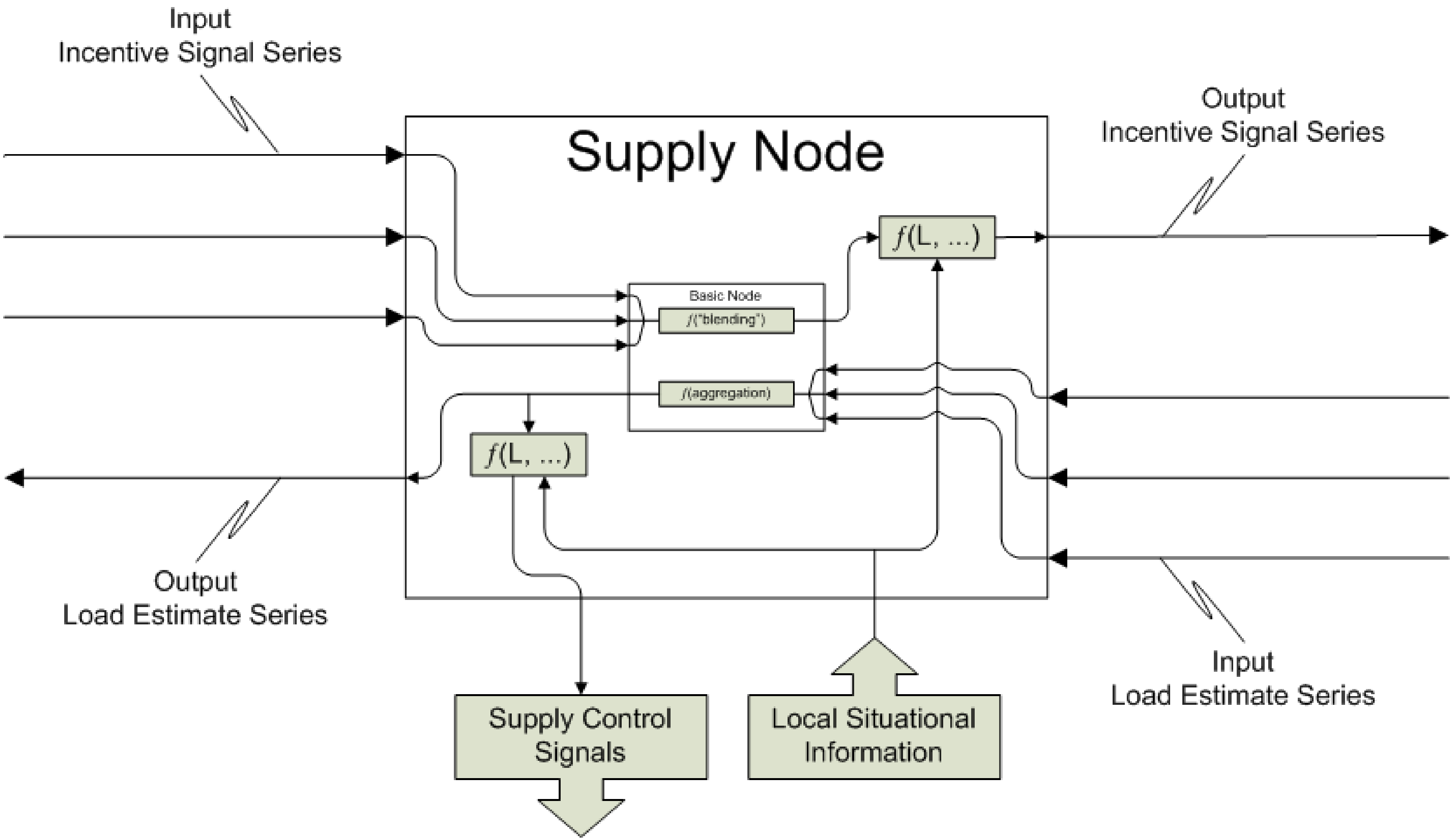
Project Nodes



Transactive Node Structure for Demo



Transactive Node Inputs & Outputs



Formalizing Transactive Control

- A formal model of transactive control has been designed with the following features:
  - Scalable
  - Algorithmic
  - Support for interoperability
- A standardized approach is being promoted through design and implementation of a toolkit
  - Well defined interfaces for utility asset systems
  - Simple, common, algorithms for updating transactive signals and determining “control” signals to responsive asset systems

Bulk Power System Inputs to TIS Calculation

Pacific Northwest SMART GRID DEMONSTRATION PROJECT

1.0 Imported electrical energy

- 1.1 Non-transactive imported energy

2.0 Renewable energy resource

- 2.1 Wind energy
- 2.2 Solar energy
- 2.3 Hydropower

3.0 Fossil generation

4.0 General infrastructure cost

5.0 System constraints

- 5.1 Transmission flowgate
- 5.2 Equipment and line constraints

6.0 System energy losses

- 6.1 Transmission losses
- 6.2 Distribution losses

7.0 Demand charges

- 7.1 BPA demand charges

8.0 Market impacts

- 8.1 Spot market impacts

Load Models

1.0 Bulk inelastic load

- 1.1 Bulk commercial load
- 1.2 Bulk industrial load
- 1.3 Bulk residential load
- 1.4 Small wind generator negative load
- 1.5 small-scale distributed generator negative load
- 1.6 Small-scale solar generator negative load

2.0 General event-driven demand response

- 2.1 Commercial
- 2.2 Distribution system voltage control
- 2.3 Residential behavior
    - 2.3.1 Portals

Load Models--continued

3.0 General time-of-use demand response

- 3.1 Battery storage
- 3.2 Commercial
- 3.3 Residential behavioral
  - 3.3.1 Portals
- 3.4 Residential
- 3.5 Distribution system voltage control

4.0 General real-time continuum demand response

- 4.1 Battery storage
- 4.2 Commercial
- 4.3 Residential behavioral
  - 4.3.1 Portals
- 4.4 Residential

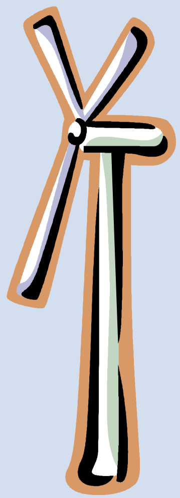
Cause and Effect Examples

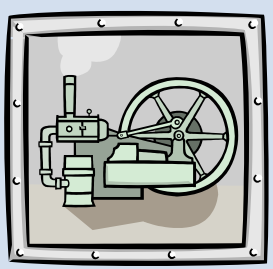
- Three wind related scenarios:
  - Case 1: Incentive for wind availability
  - Case 2: Incentive for wind ramp rate
  - Case 3: Incentive for balancing objective(s)

Case 1: Incentive for wind energy availability

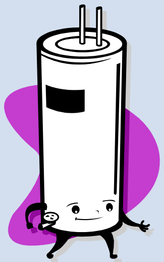
- Predicted incentive signal increases when wind energy decreases and visa versa
- Incentive is communicated and mixed between transactive nodes
- Assets respond to improve consumption of wind
  - When wind energy is available
  - Near where wind is available

Consider a Very Simple Topology



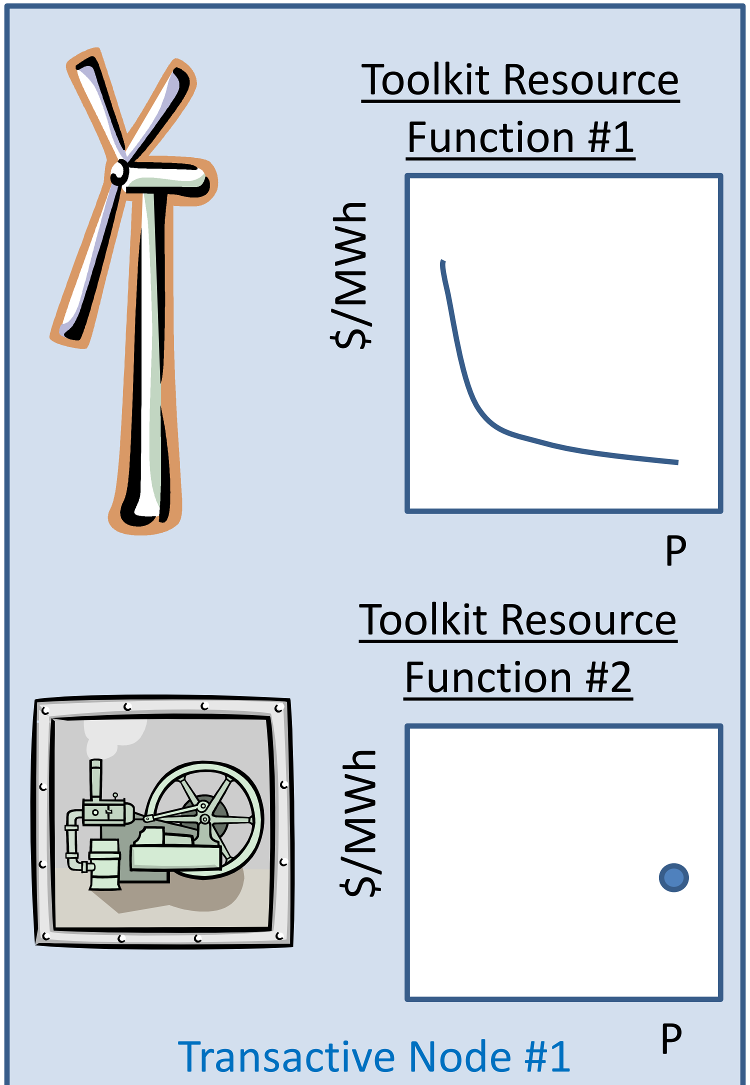


Transactive Node #1



Transactive Node #2

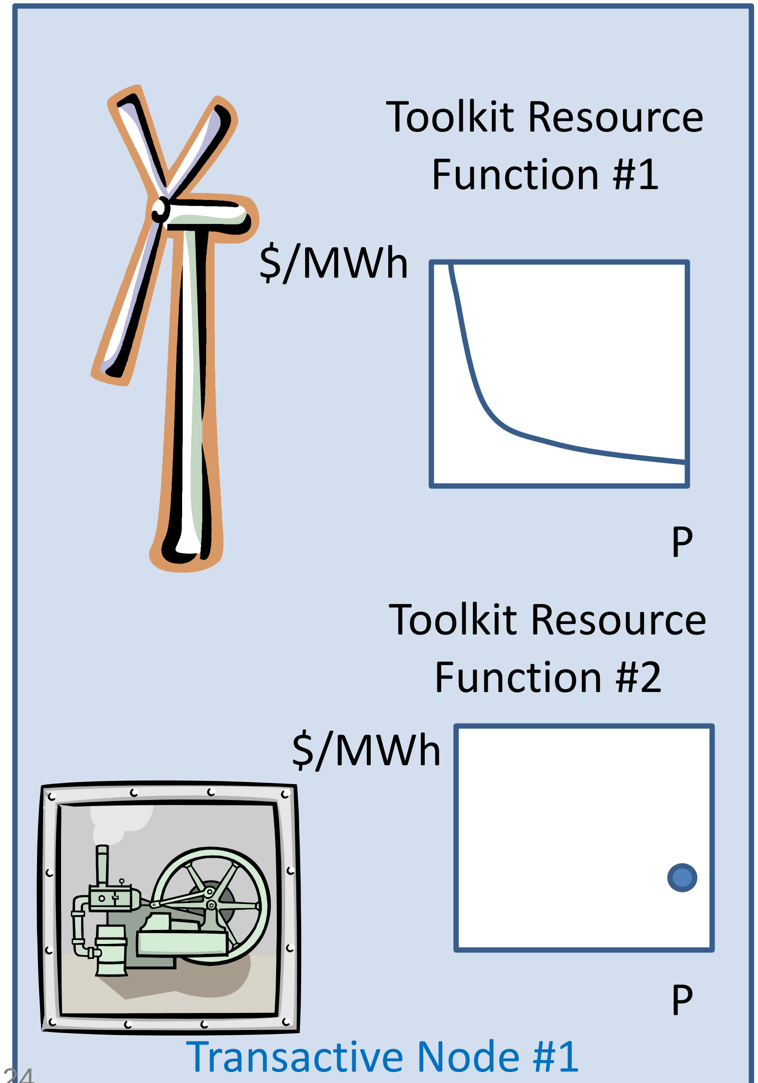
Assign Cost as a Function of Energy, Power and Time

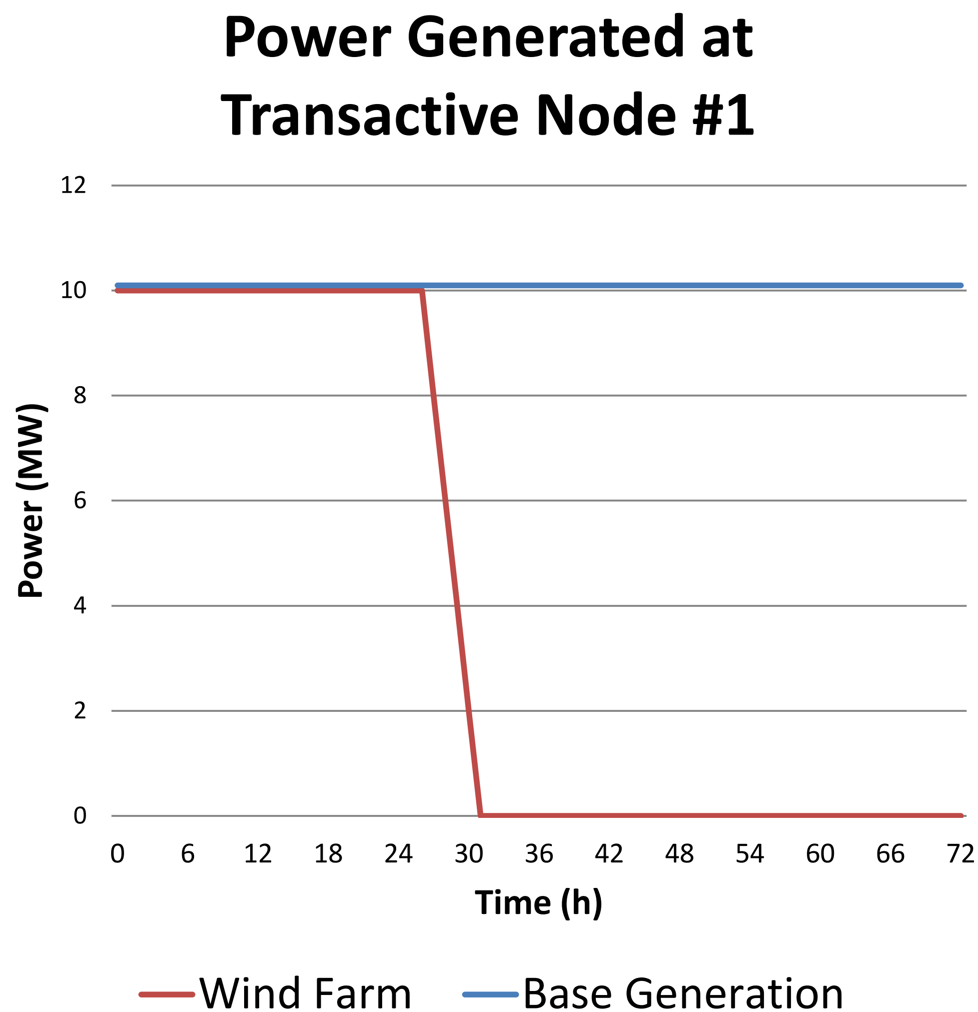


Toolkit Resource Functions

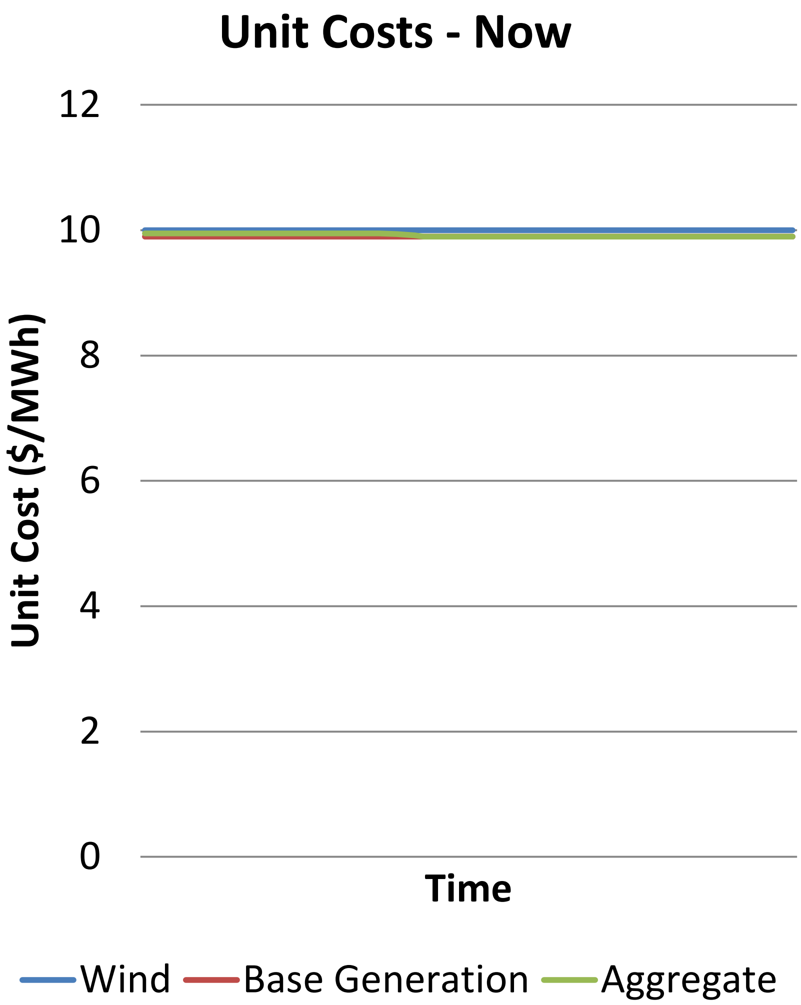
- Assign cost in a way that will incentivize desired outcomes.
- Many different functions are possible, but acceptable functions must incur the same total cost over relatively long periods of time.

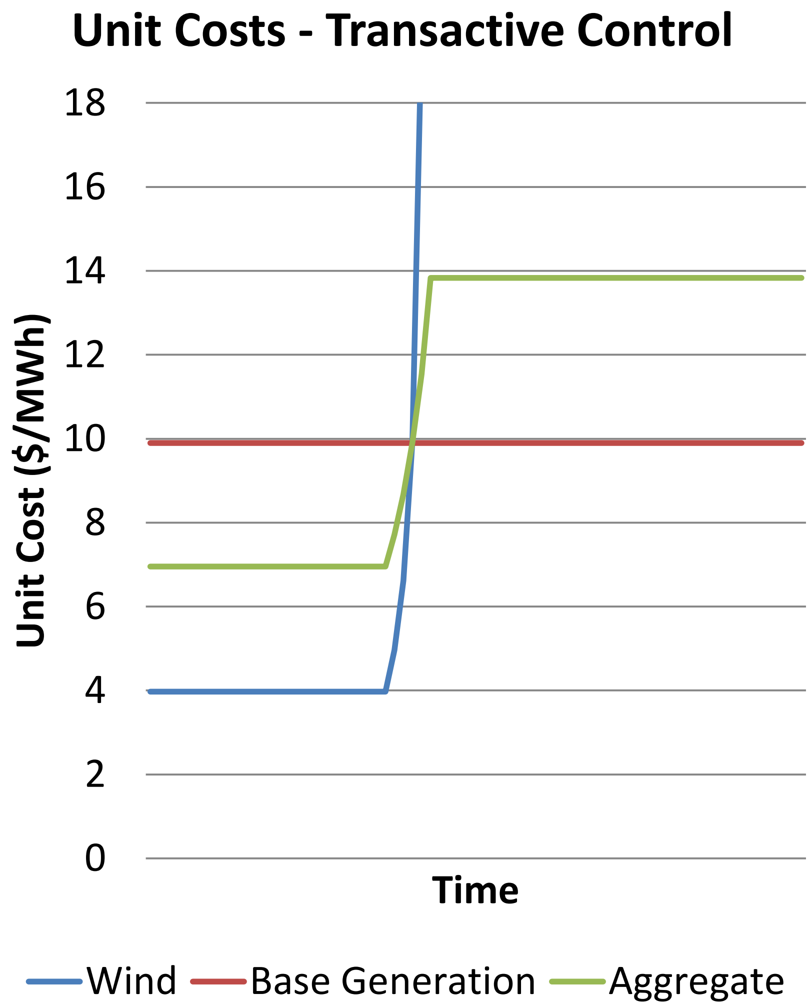
Power from these Resources is Predicted into the Future



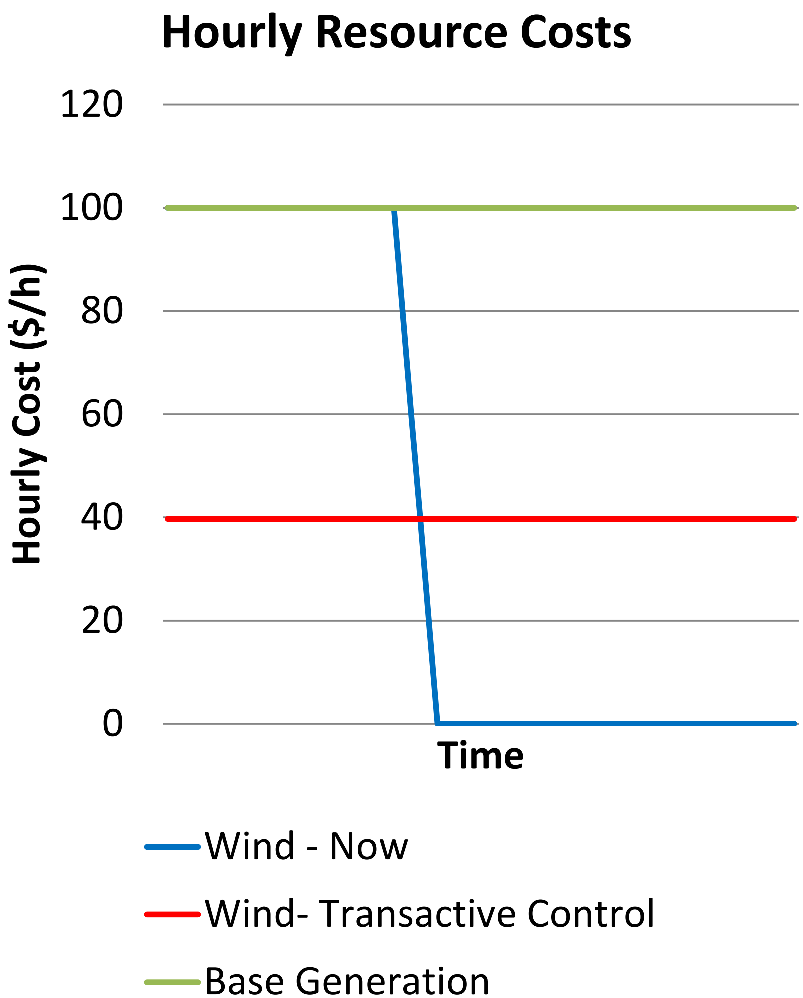


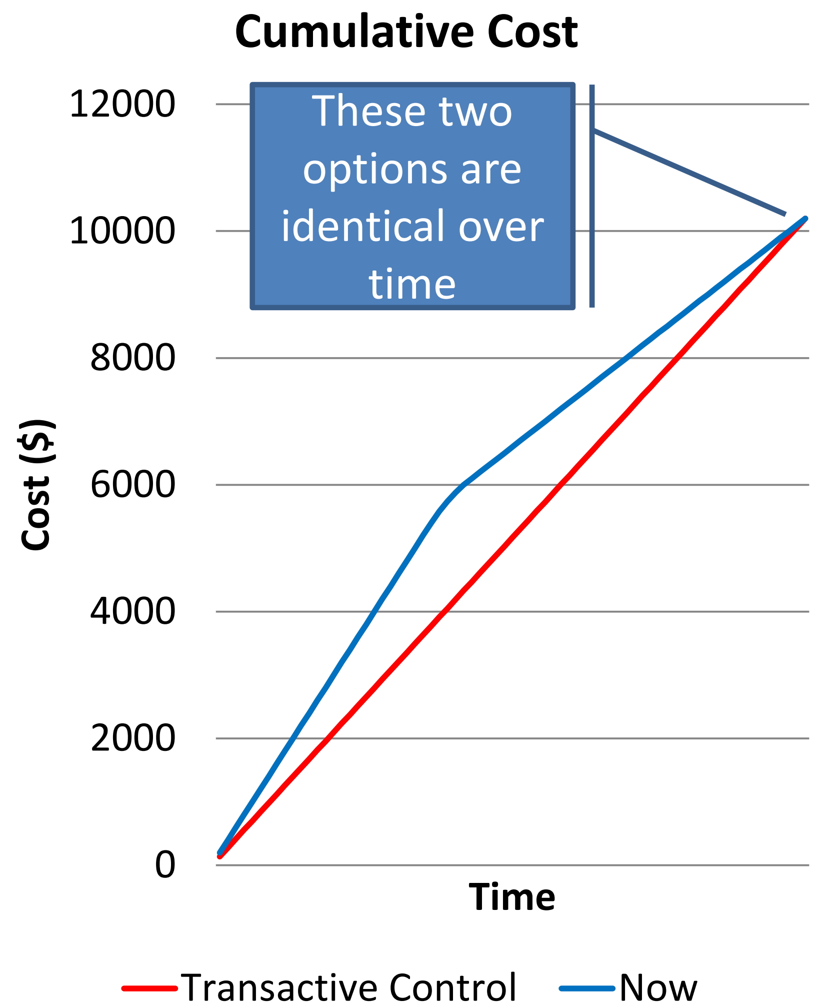
Compare Two Ways to Assign Unit Cost to these Resources



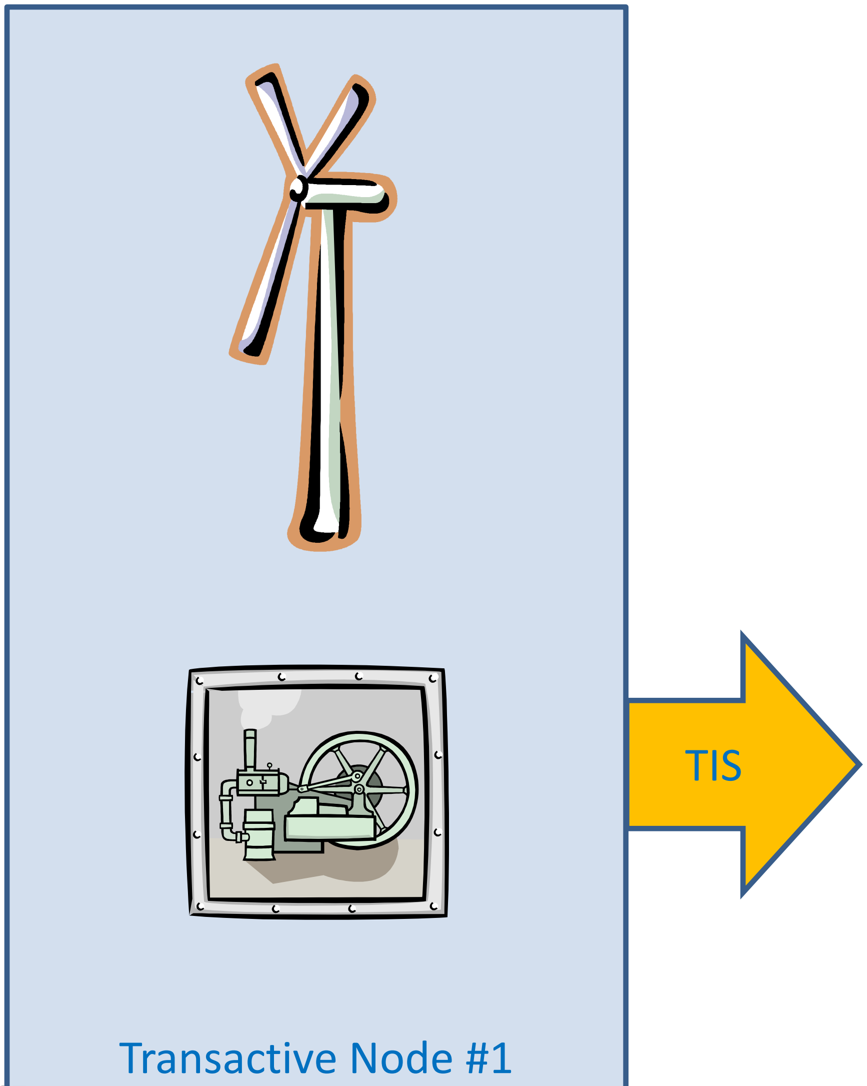


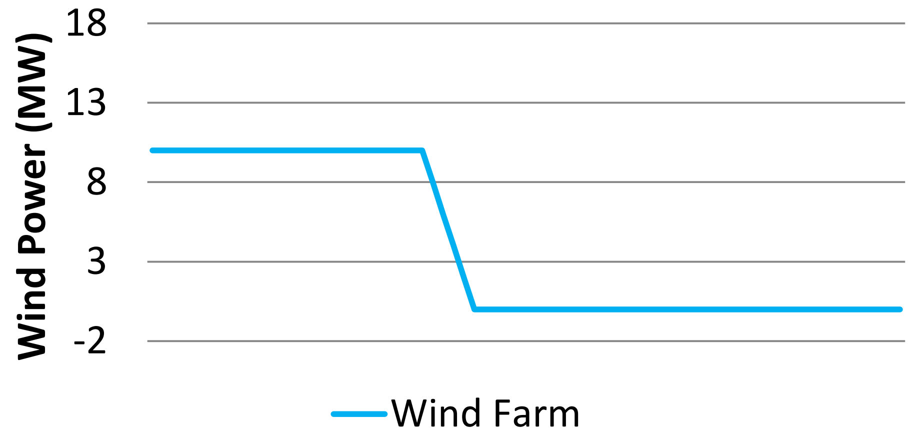
Compare How Costs Accumulate

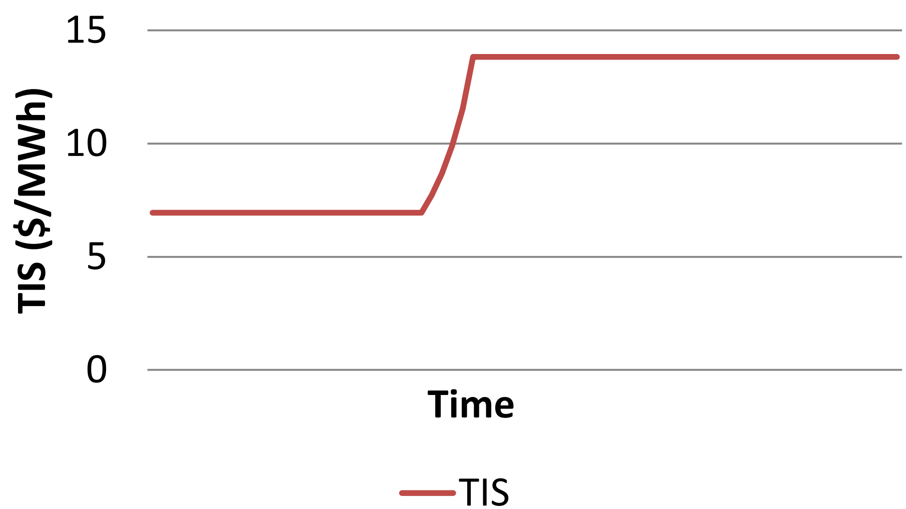




The Weighted Incentive (TIS) follows the Energy Exported from this Location



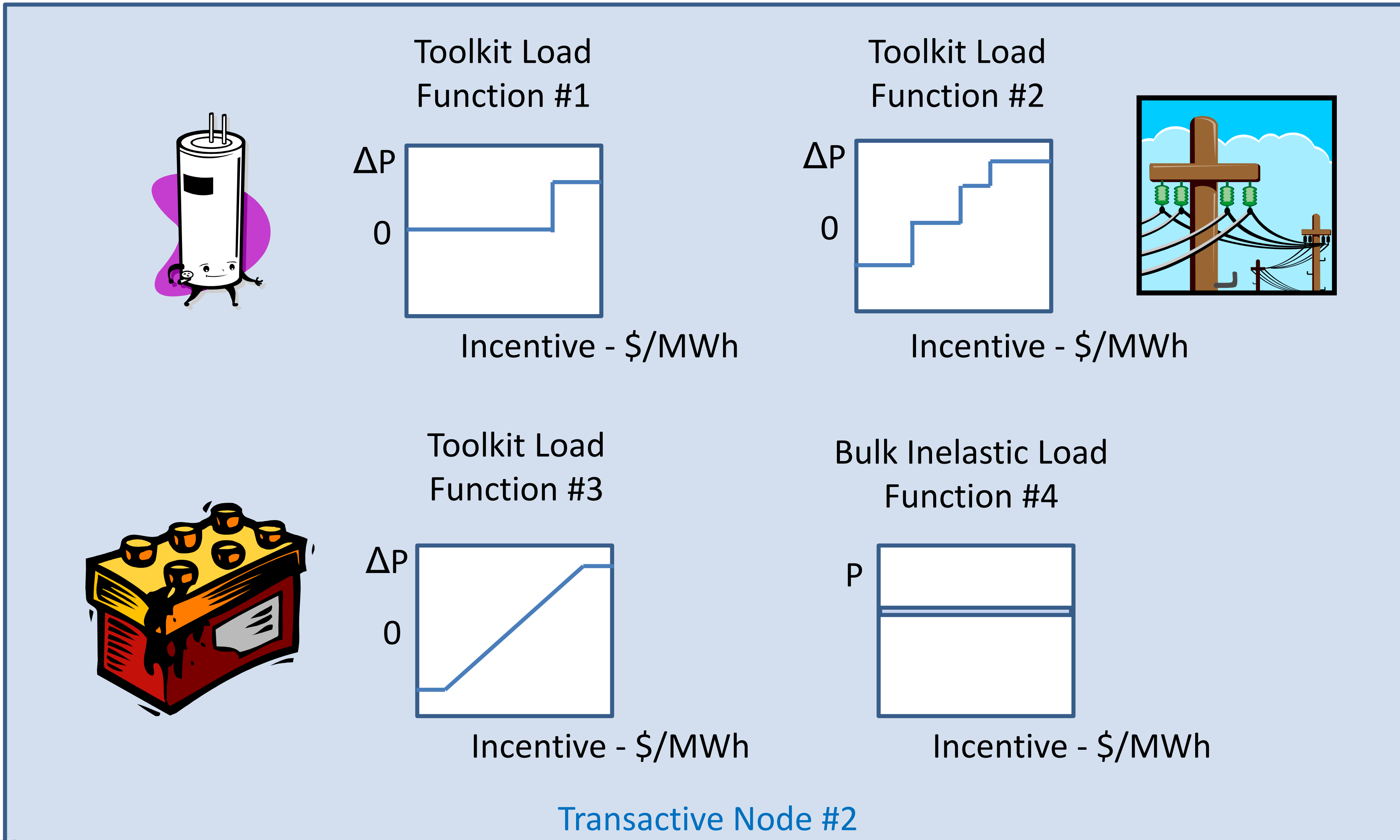




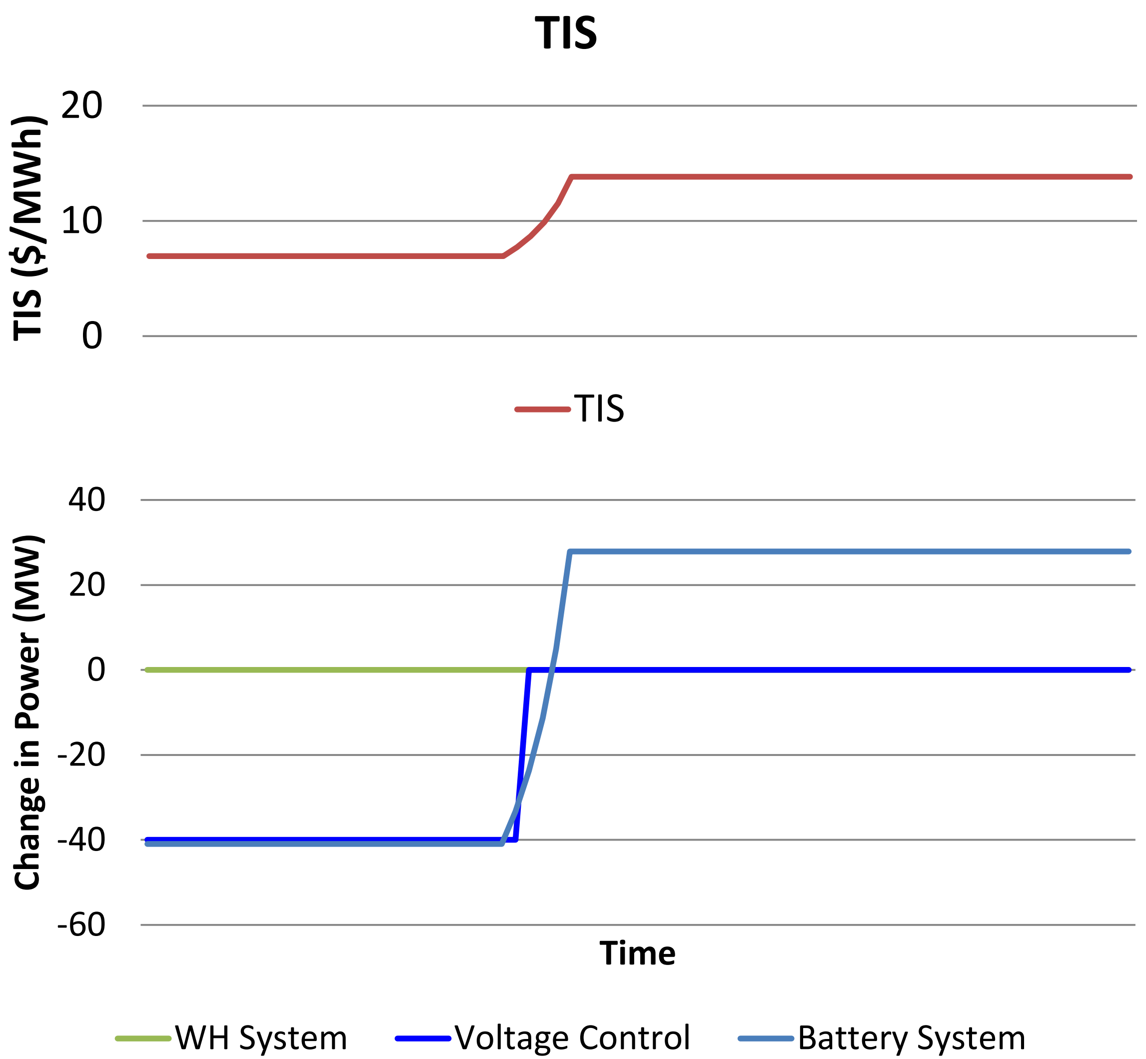
Responsive Assets and Toolkit Load Functions

- Some system locations have controllable, responsive generation and load assets
- A “toolkit load function” is selected or created from scratch to predict and model how the asset will respond as a function of
  - The incentive signal
    - Absolute representation
    - Relative, statistical representation
    - History
    - Predictions
  - Status of the asset
  - Other local information and conditions (e.g., weather)

To Neighboring Locations that have Demand-Responsive Assets



The Battery and Voltage Systems Figure Out When and How to Respond

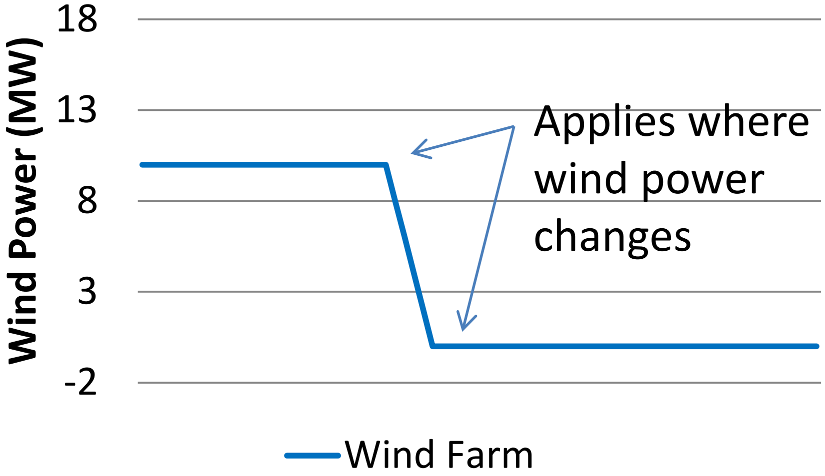


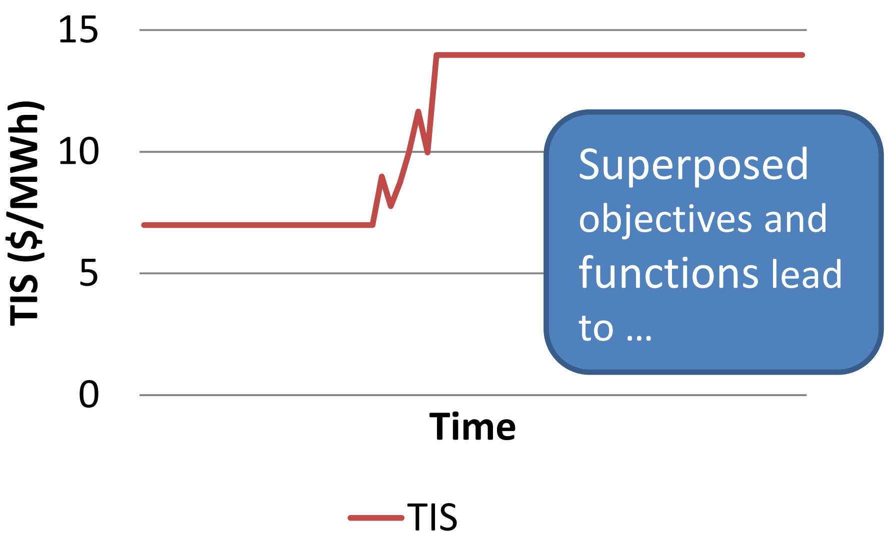
- The battery and voltage control system used the entire predicted time horizon to determine when to best charge and discharge.
- The water heater system was not engaged by this modest event.

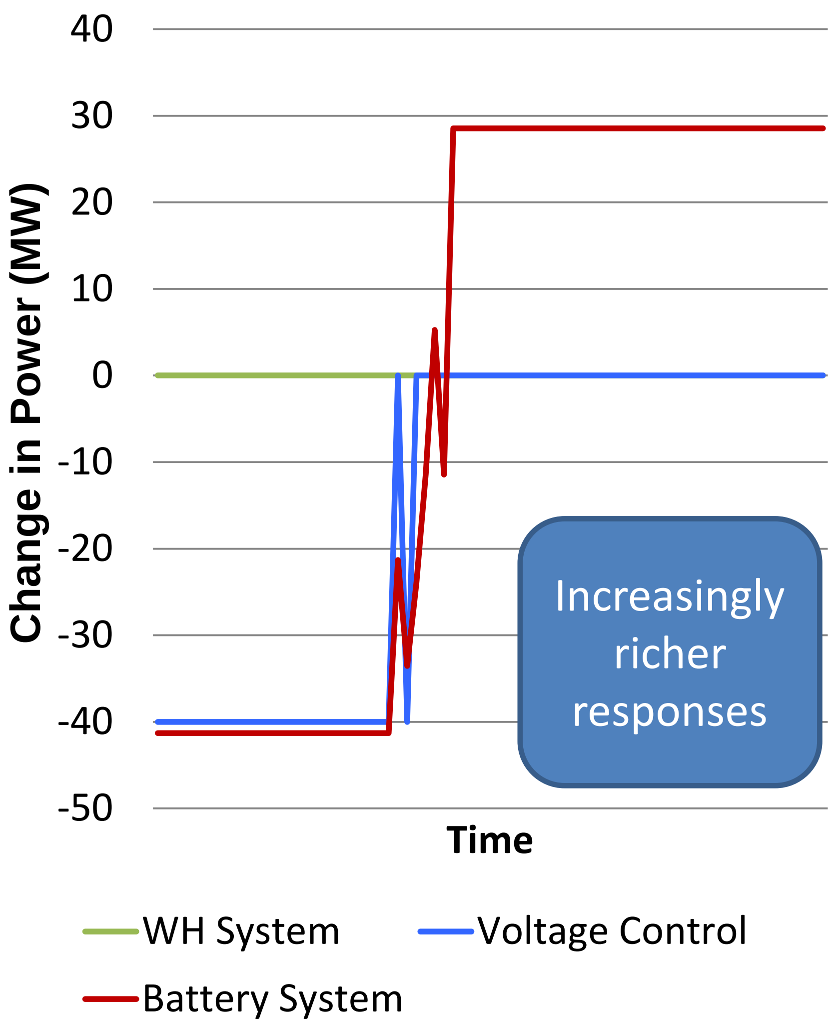
Case 2: Incentive for Wind Ramp Rate

- Predict rate of change in predicted wind energy
  - Function of first and/or second derivatives of predicted wind resource
- Increase incentive at times wind will be decreasing and visa versa
  - Encourage other generation resources or even curtailment of load at times that wind energy is decreasing
  - Discourage other generation resources or even increase load at times that wind energy is increasing

Case 2: Add Incentive for Rate of Wind Ramping



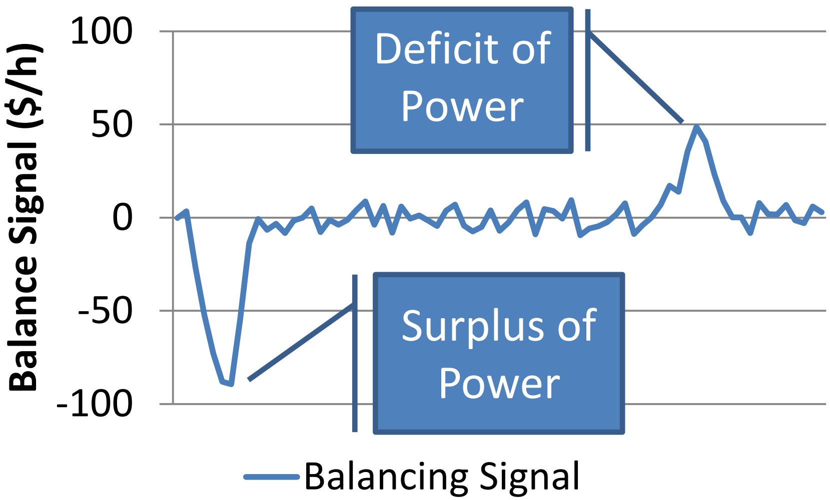


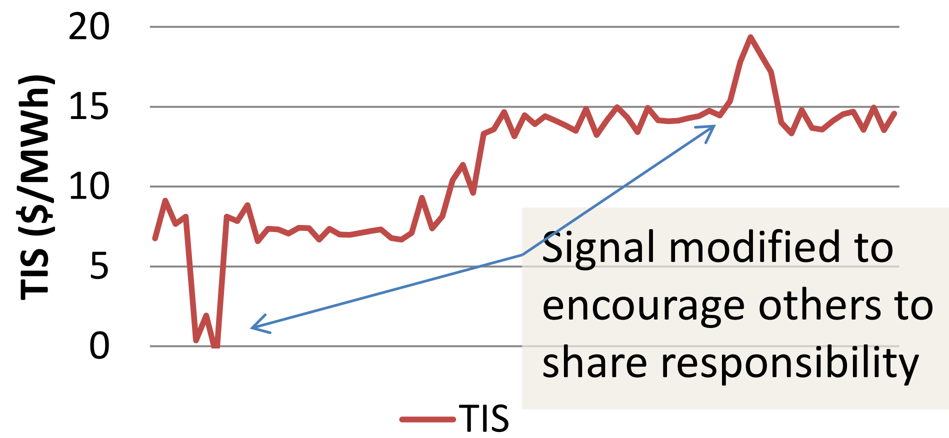


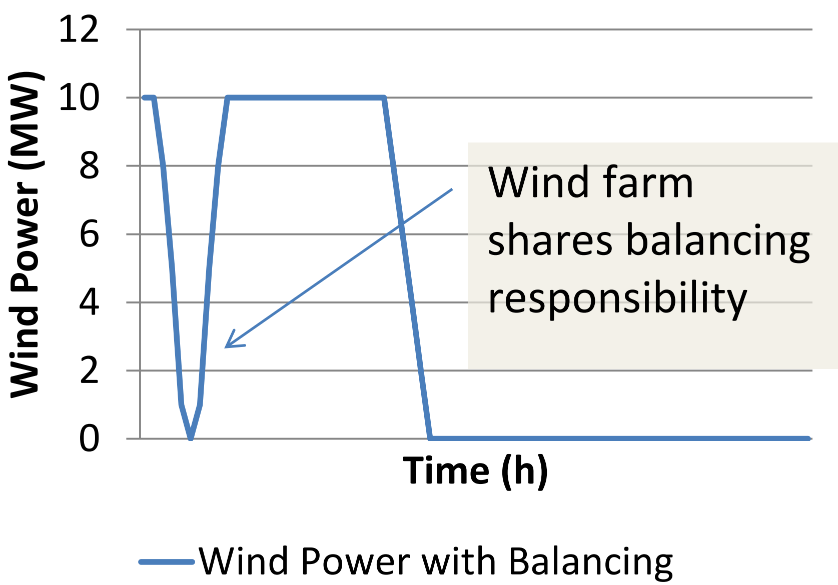
Case 3: Incentive for Balancing Objective(s)

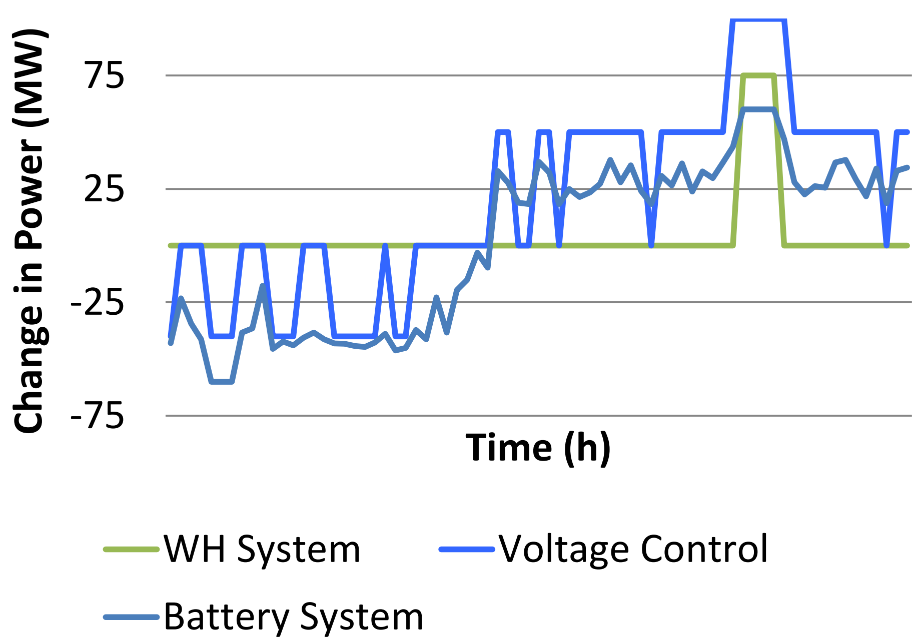
- Create function to increment or decrement incentive based on anticipated balance of resource and load
  - Increase incentive when there may be a deficit
  - Decrease incentive when there may be a surplus
- Address special circumstances, like times where wind farm production may become curtailed

Case 3: Add Incentives for Balancing Objectives









Questions?

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