Integration of Renewable Resources

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California ISO
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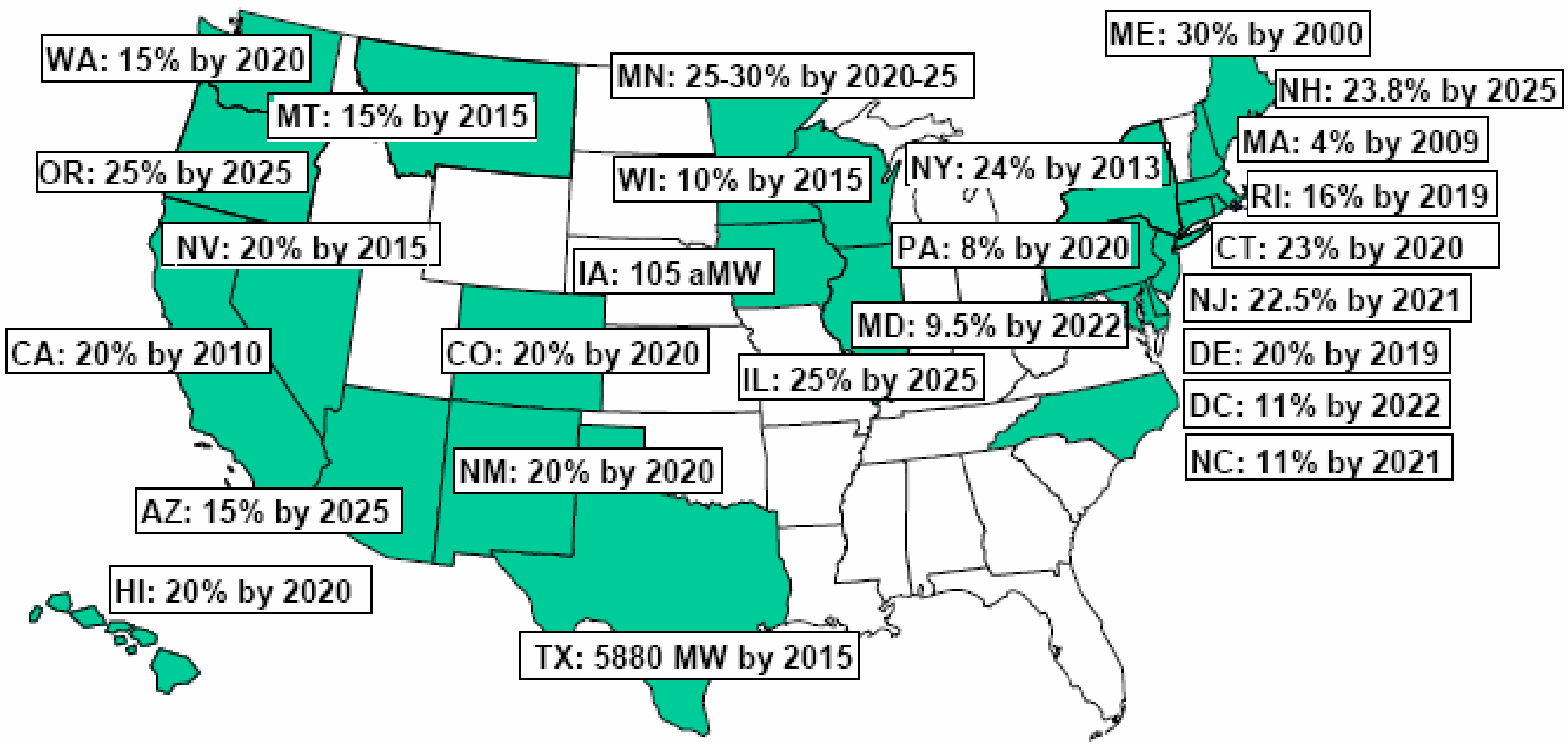
PSERC Presentation
October 2, 2007

Renewable Portfolio Standards Goals

State RPS Policies: 25 States and D.C.

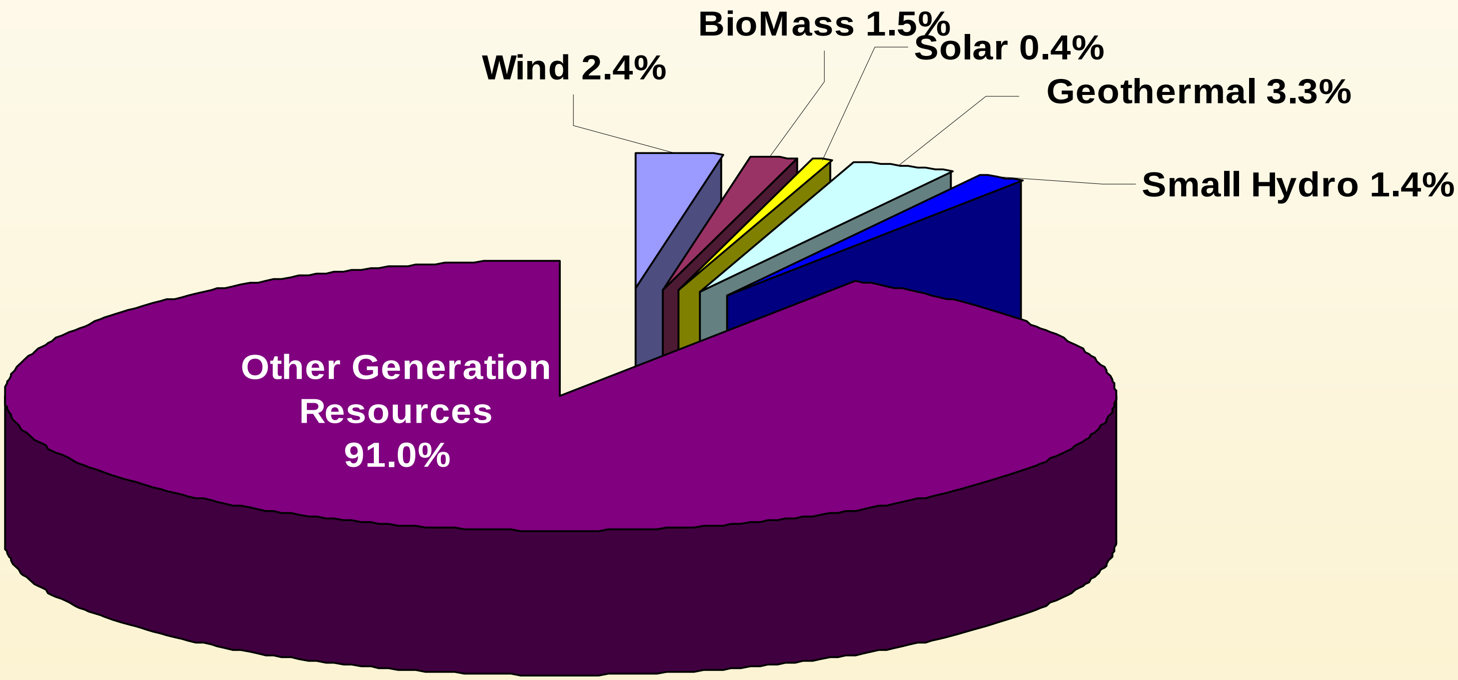


Additional renewable energy "goals" established in IA, VT, VA, MO, ND, and ME

Source: Kevin Porter; Exeter Associates, Inc

Current Level of Renewable Generation in California

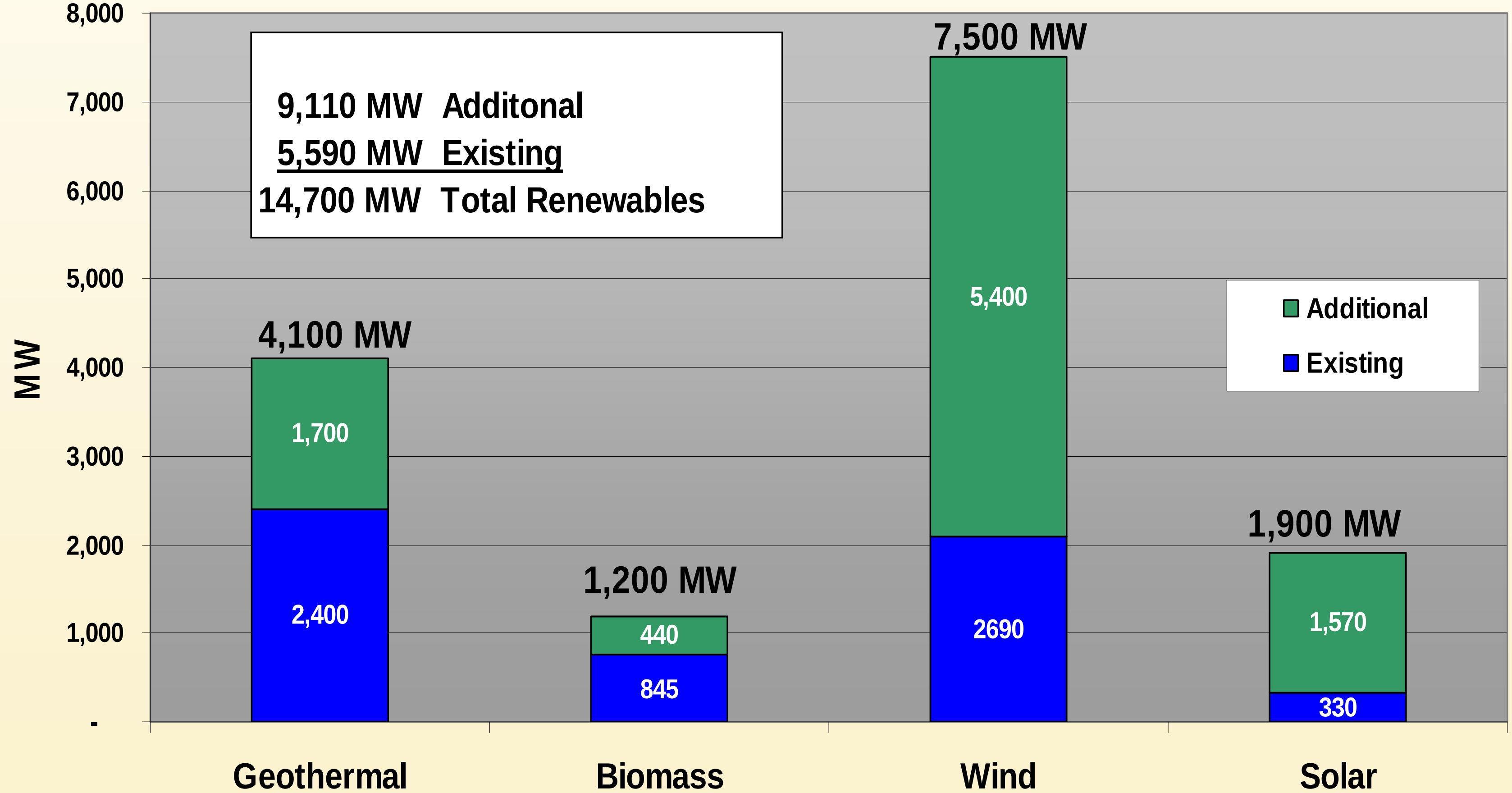
Summer 2006



Renewables Provided 9% of the Energy to Serve Customer Load for the period May through September

20% Renewables

Existing California Renewable Generation and Possible Additions to meet the 20% RPS by 2010-2012*



* Source of data on additional renewable resource is from Table 2-2 in the CEC IAP report, published July, 2007

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California's abundant wind resources have a key role to play.

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CAISO Renewables Integration Program

Primary Goal(s) / Objectives:

One of the ISO Corporate Goals is a project to support the integration of renewable resources on the California power grid to support the State's policy regarding renewables.

This is a coordinated project that encompasses the integration of renewable resources into CAISO's

- **Transmission planning**
- **Markets, and**
- **Grid Operations**

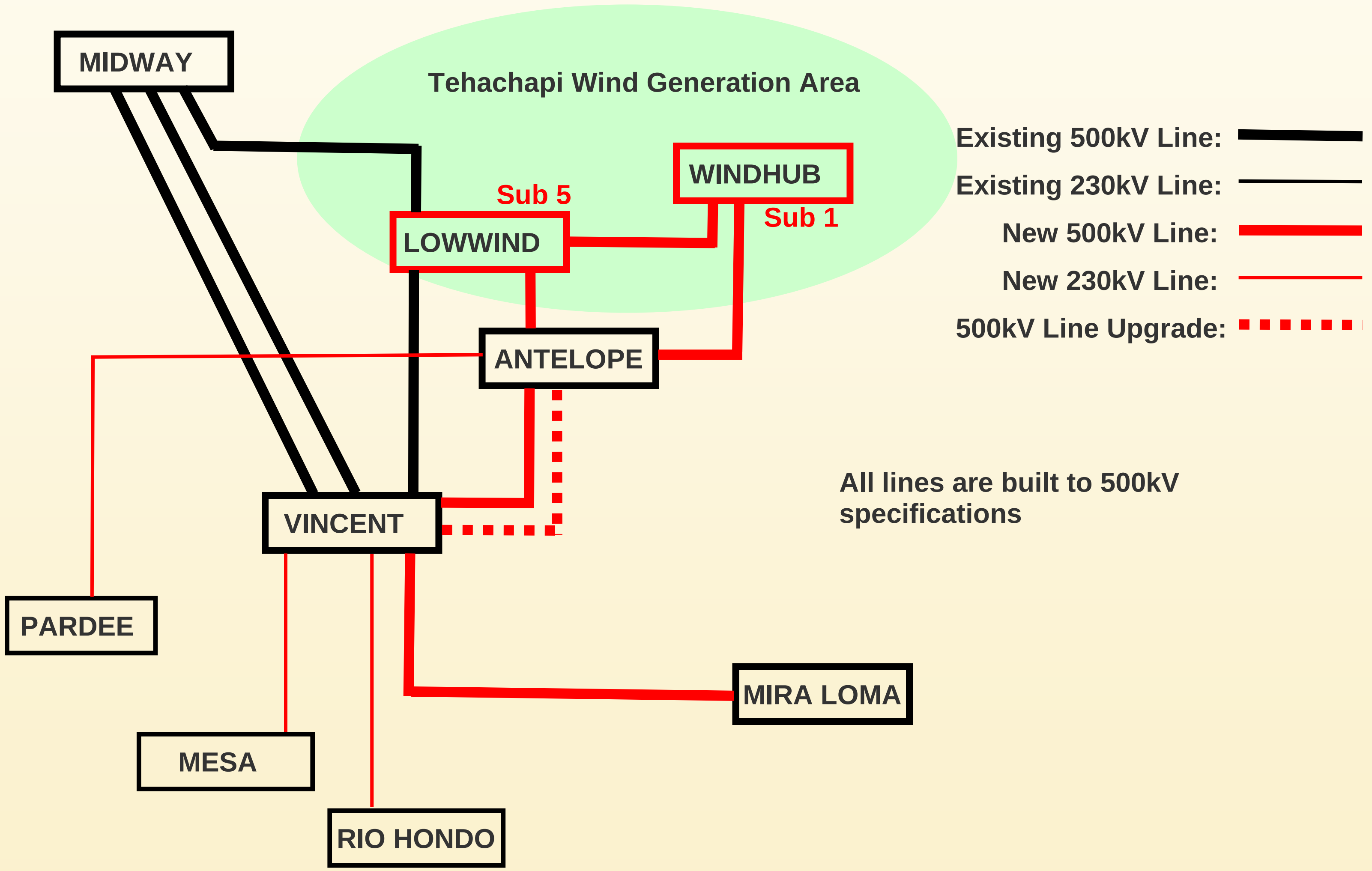
The objective is to support the State's RPS goal of 20% of customer load being served by renewable resources by the end of 2010.

CAISO Renewables Project – Major Tasks

- **Transmission upgrade plan**
  - Transmission for the Tehachapi Area – 4500 MWs of new wind generation
  - Additional Transmission upgrades to move renewable energy to customer load centers and to storage facilities (Helms, etc.)
- **Operations Issues Identified and Solutions Proposed**
  - Ramping issues & accurate hourly forecasts
  - Regulation/Load Following & supplemental energy dispatch
  - Visibility of wind & solar energy forecasts for operators
  - Mitigation of potential transmission problems
  - Mitigation of over generation conditions
  - Feasible generation schedules for real time operations
  - Quick generating start units and hydro redispatch to mitigate major changes in wind/solar generation energy production

Tehachapi Transmission Project

- *New infrastructure to deliver renewable energy*



All lines are built to 500kV specifications

Tehachapi Transmission Study

Transient Stability, Voltage Control, Post Transient Study

Review transmission plans for Tehachapi Area with 4,146 MW of total wind generation

2012 Light Load Spring Conditions – Heavy Path 15 flow S-N

2010 Heavy Summer Peak Load conditions – Path 15 flow N-S

For each seasonal condition, three wind generation scenarios were analyzed:

- **Full Wind: All Tehachapi area Wind Turbine Generators on line operating at rated MW,**
- **Low Wind: All Tehachapi area Wind Turbine Generators on line operating at 25% of rated MW,**
- **No Wind: All Tehachapi area Wind Turbine Generators off line,**

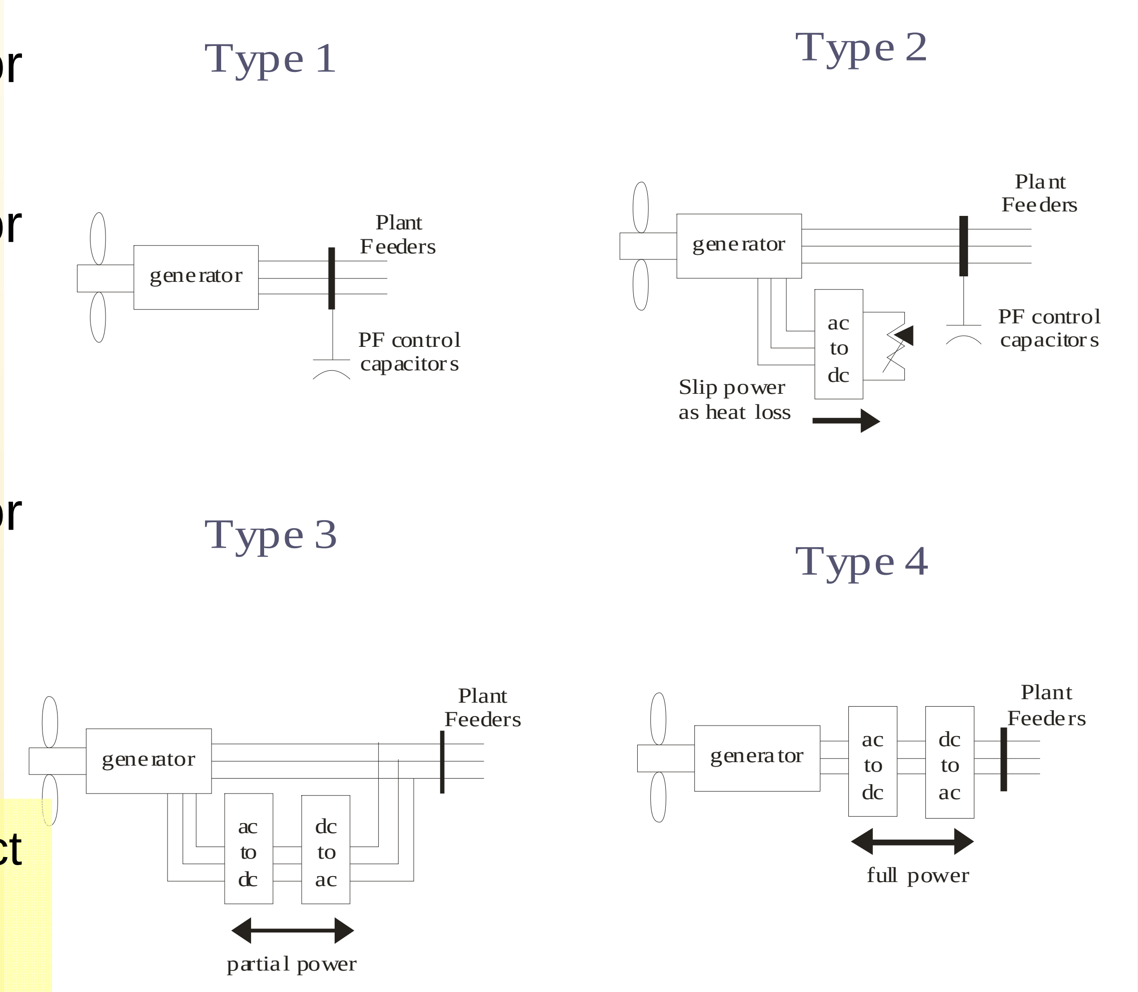
WECC Wind Turbine Models

Type 1 – conventional induction generator

Type 2 – wound rotor induction generator with variable rotor resistance

Type 3 – doubly-fed induction generator

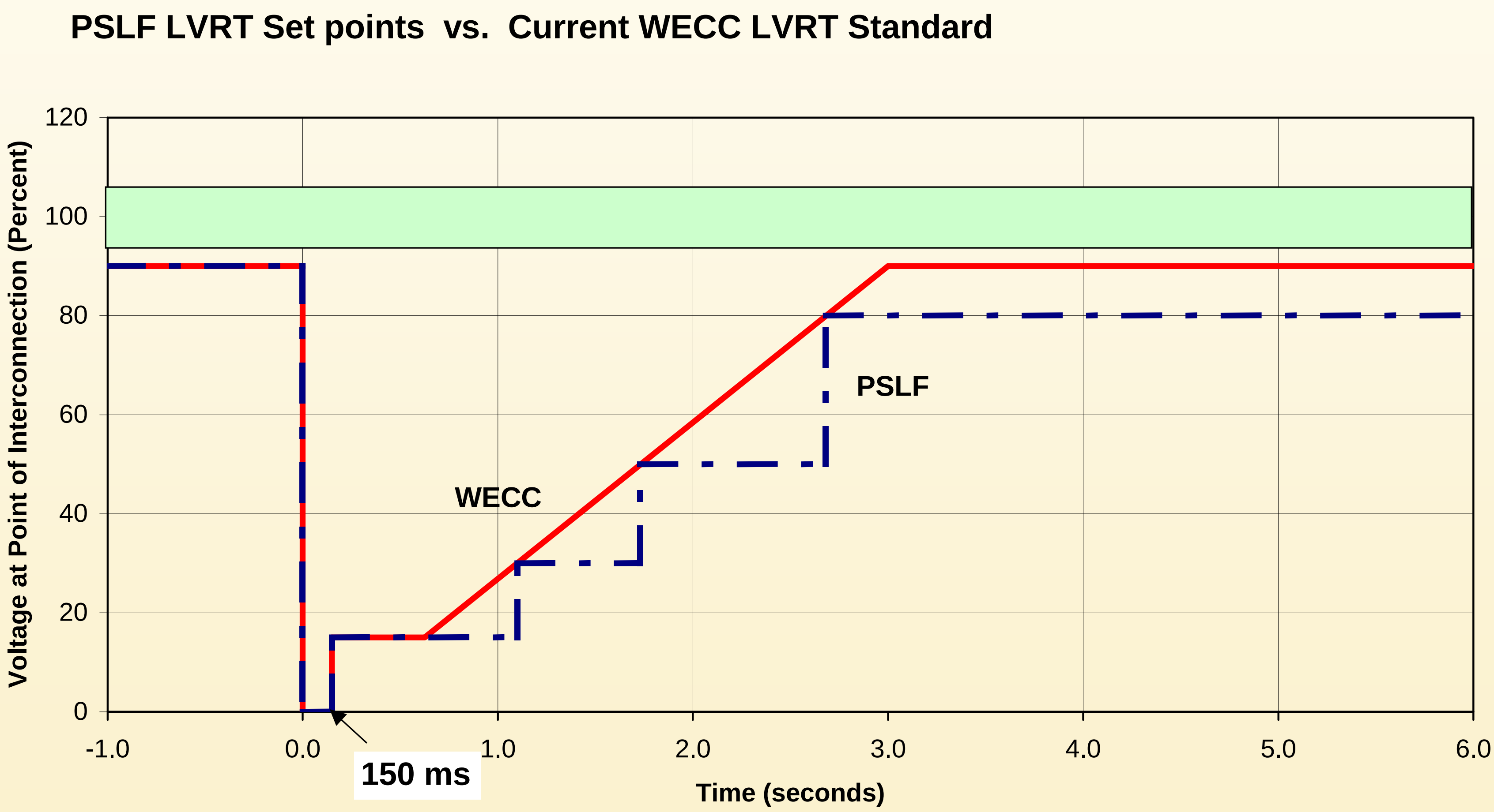
Type 4 – full converter interface



CEC sponsored research project in progress to improve the accuracy of the WG models

Detailed Discussion of WG Models available on UWIG web site in presentation by Abraham Ellis; PS New Mexico

LVRT Standard



Transmission Study Results

The Tehachapi Transmission Plan is sound and there are no serious transient stability or voltage control problems

- Key conclusions
  - **Power factor control is critical - New wind generators must meet WECC criteria for ±0.95 power factor control**
  - **Low Voltage Ride Through Standard – all new units must meet WECC LVRT Standard.**
  - **New wind generators should be Type 3 or Type 4 units**
  - **Existing Type 1 Wind Generators in Tehachapi area do not meet LVRT standards and will probably be lost in event of voltage collapse**

Operational Studies

- Objectives of Operational Studies

To Determine:

Magnitude of multi-hour ramps

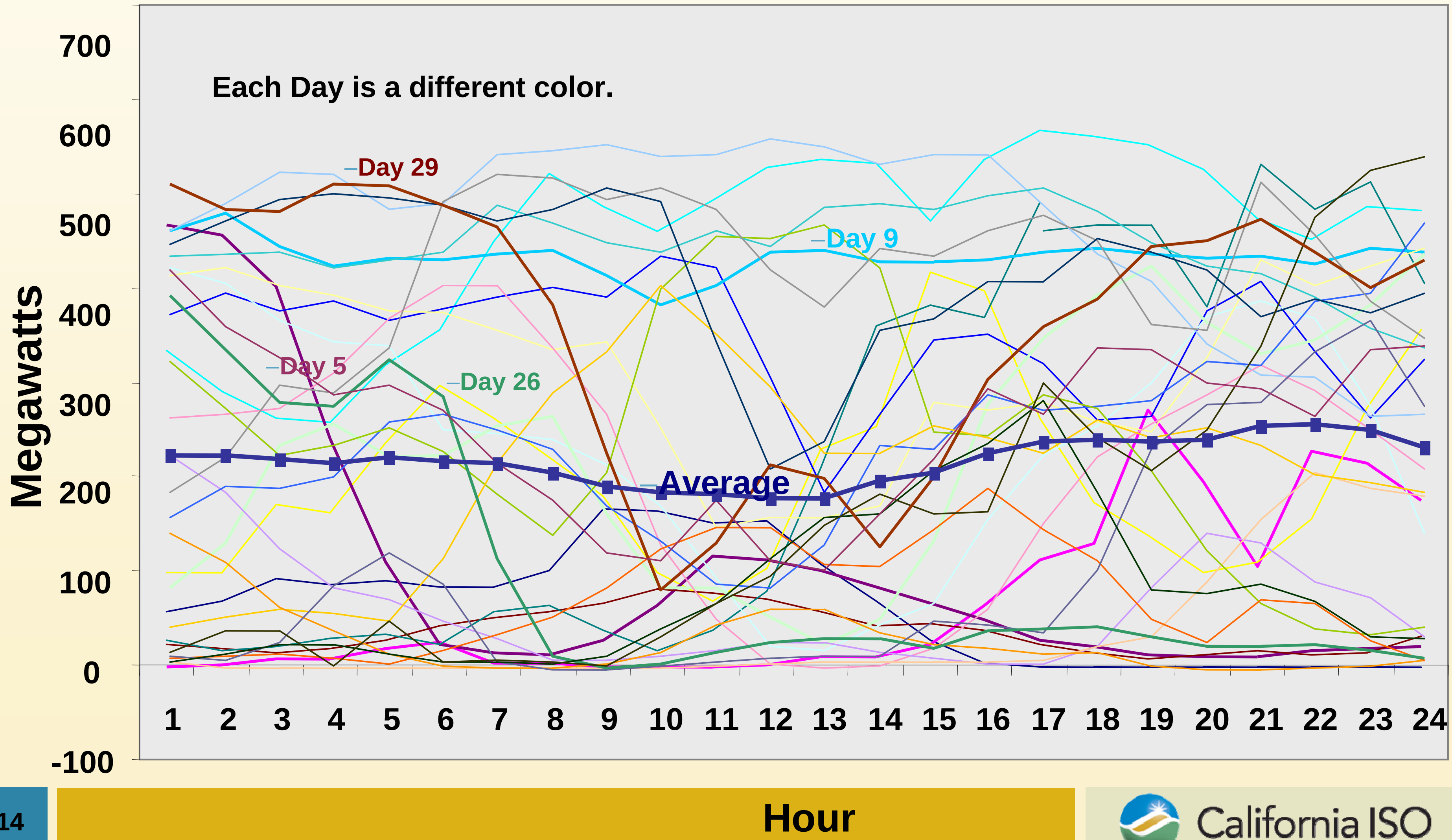
Load Following Capacity and Ramping Requirements

Regulation Capacity and Ramping Requirements

Over generation Issues and Potential Solutions

Tehachapi Wind Generation in April – 2005

Could you predict the energy production for this wind park either day-ahead or 5 hours in advance?



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Study Methodology

- Study conducted jointly with Battelle – Pacific Northwest National Labs

  Day Ahead and Hour Ahead Scheduling Process

  Real-Time Dispatch

  Regulation Process

- Determined load forecasting and wind forecasting errors
- Obtained projected hourly wind generation data from AWS Truewind Company
- Build Mathematical Model to Mimic Actual Operations
  - Model details available in Appendix B of the CAISO Integration of Renewables Report on our web site

Operations/market study assumptions reflect likely operational and market conditions

- Load growth assumed at about 1.5% per year
- Results based on 2006 actual operating data.
  - Assumption is that load and wind generation operating characteristics in 2012 will have similar patterns
- New wind generators participate in CAISO PIRP program, with centralized Day-Ahead and Hour-Ahead forecasting service
- New MRTU market design is implemented
  - Hour-ahead load and wind generation energy forecasts provided no less than 105-minutes before beginning of next operating hour
  - Real Time five-minute load forecasts provided 7.5 minutes before beginning of five-minute dispatch interval
- Real Time telemetry from wind resources sent to CAISO on a four-second basis, similar to non-intermittent resources

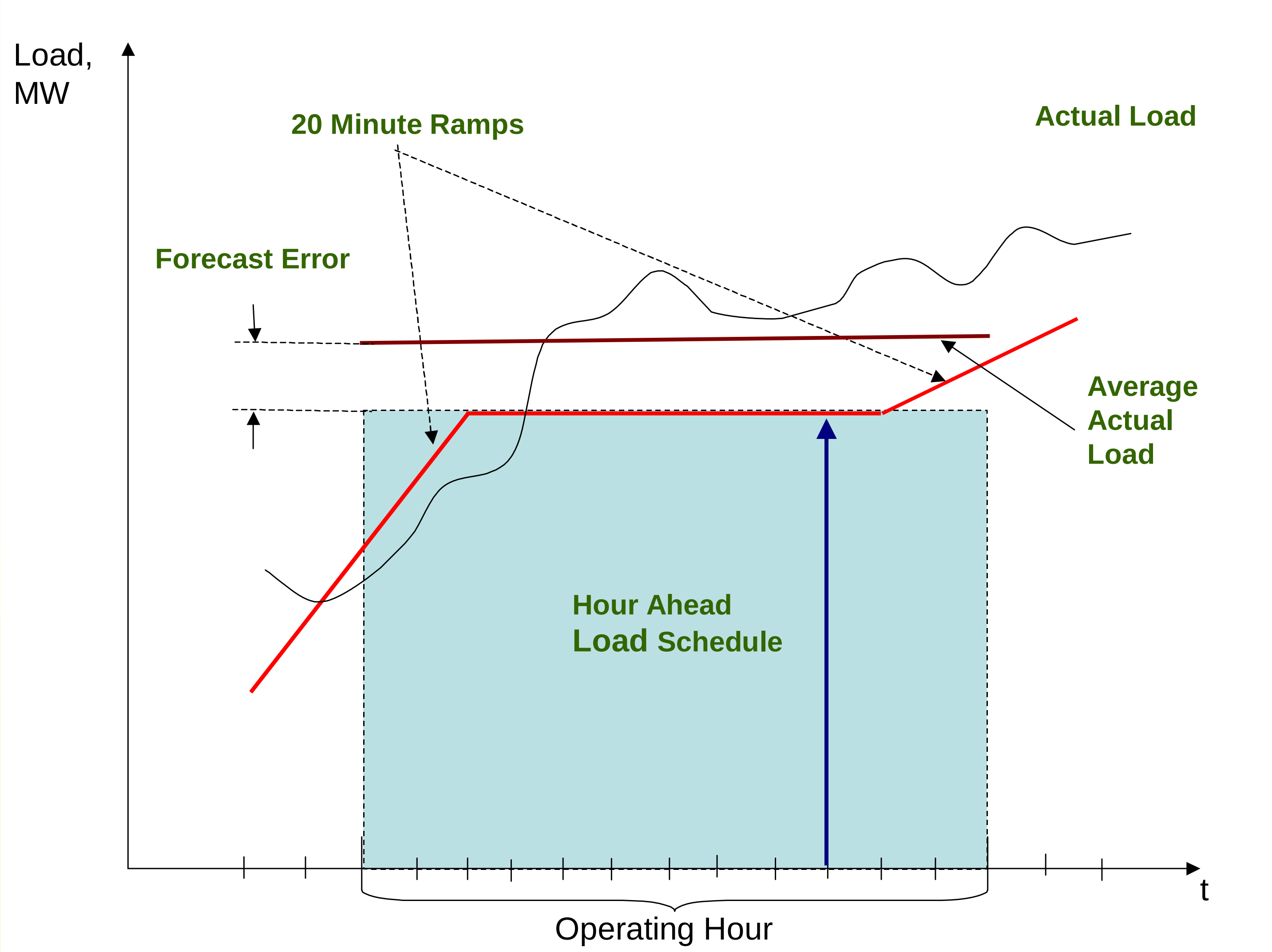
What is Regulation?

- Regulation is required for the CAISO to maintain scheduled frequency and maintain interchange schedules on the ties
- Regulation is not dispatched based on its Energy Bid Curve Price
- Regulating resources are dispatched through Automatic Generation Control every four-seconds to meet moment-to-moment fluctuations in the system

What is Load Following?

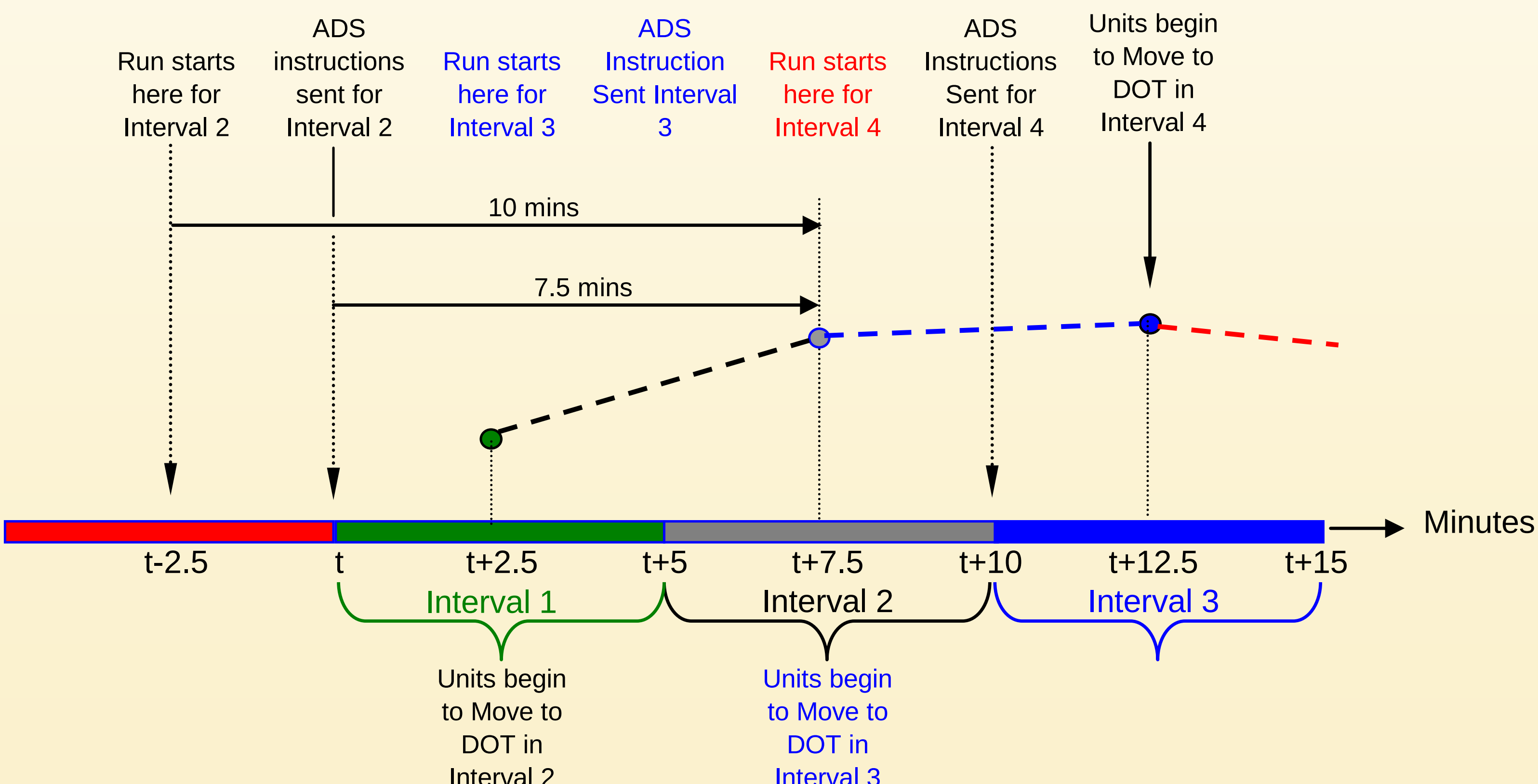
- Load following necessary to maintain stable operations
- The CAISO's Real Time Market balances Load and Generation on a forward looking basis
- Some generators are dispatched upwards to meet their next hour schedules other generators may have to be moved downwards to maintain a generation load balance
- Real Time Economic Dispatch software runs every 5-minutes and dispatches generation based on economics and ramping capability

One-hour block energy schedule includes 20-minute ramps between the hours

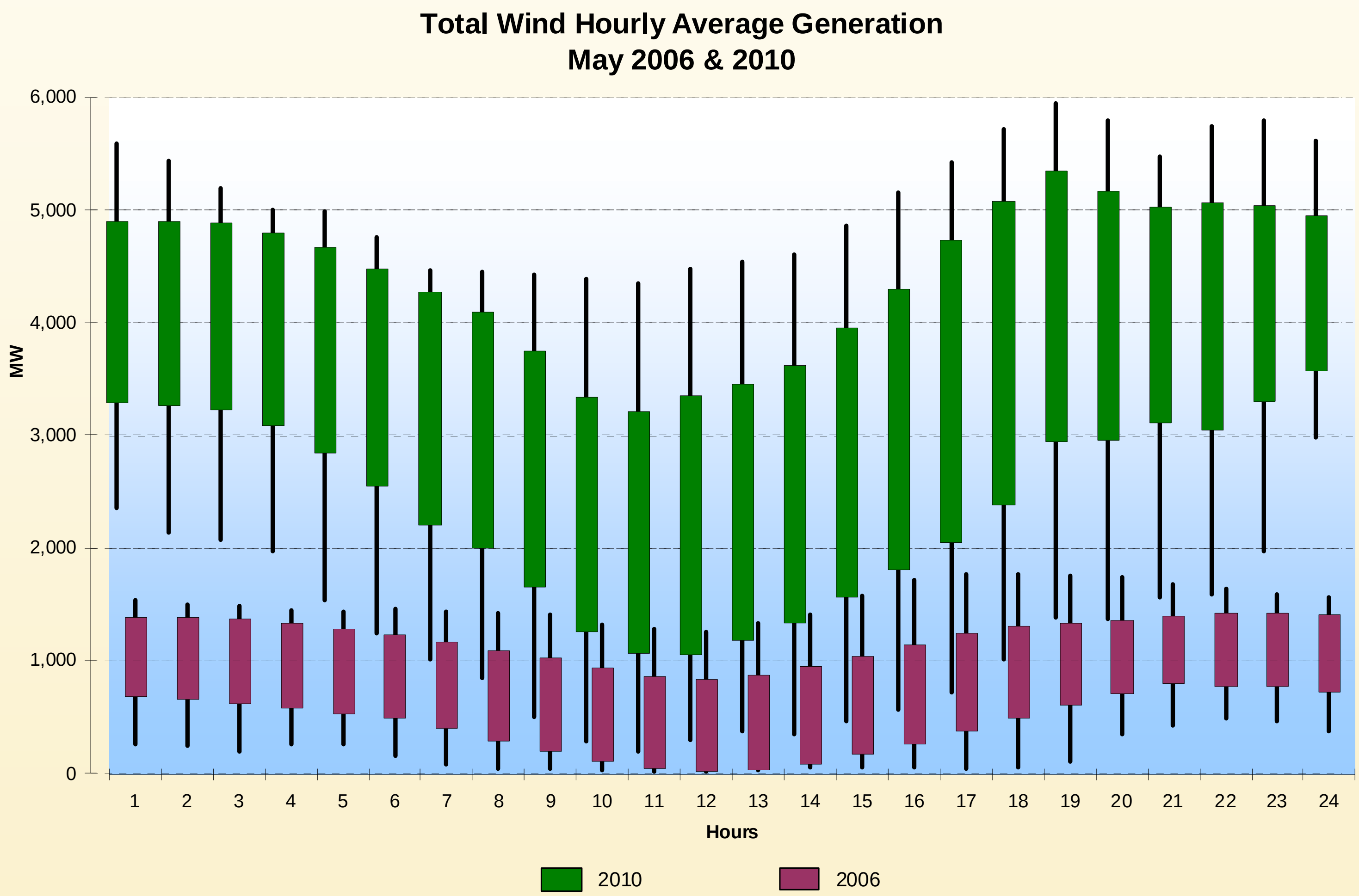


MRTU timelines benefit renewable integration

The Real Time Economic Dispatch software runs every five-minutes starting at approximately 7.5 minutes prior to the start of the next Dispatch Interval and produces Dispatch Instruction for Energy for the next Dispatch Interval and advisory Dispatch Instructions for as many as 13 future Dispatch Intervals.



Actual Wind Generation 2006 vs. Expected Wind Generation 2010



2006 - HE19: 50 to 1800 MW
2010 - HE19: 1,400 to 6,000 MW

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Conclusion – Regulation Requirement

- Today, the CAISO can effectively operate the system by procuring ± 350 MW of regulation on an hourly basis (700 MW total)
- By 2012, regulation capacity requirements will increase by 170-250 MW for “up regulation” and 100-500 MW for “down regulation” depending on the season and time of day

Season	Max Regulation Up, MW	Max Regulation Down, MW	Max Hourly Increase (Up), MW	Max Hourly Increase (Down), MW
Spring	+510	-550	+240 (HE18)	-300 (HE18)
Summer	+480	-750	+230 (HE09)	-500 (HE18)
Fall	+400	-525	+170 (HE06, HE18)	-275 (HE18)
Winter	+475	-370	+250 (HE18)	-100 (HE10)

Seasons	***Max Increase Regulation Ramp Up, MW/min***	***Max Increase Regulation Ramp Down, MW/min***
Spring	+20	-25
Summer	+10	-18
Fall	+25	-20
Winter	+15	-15

Conclusion – Load Following Requirement

- Load following ramping requirements will increase and require more generation to be available for both upward (700-800 MW) and downward (500-900 MW) dispatch

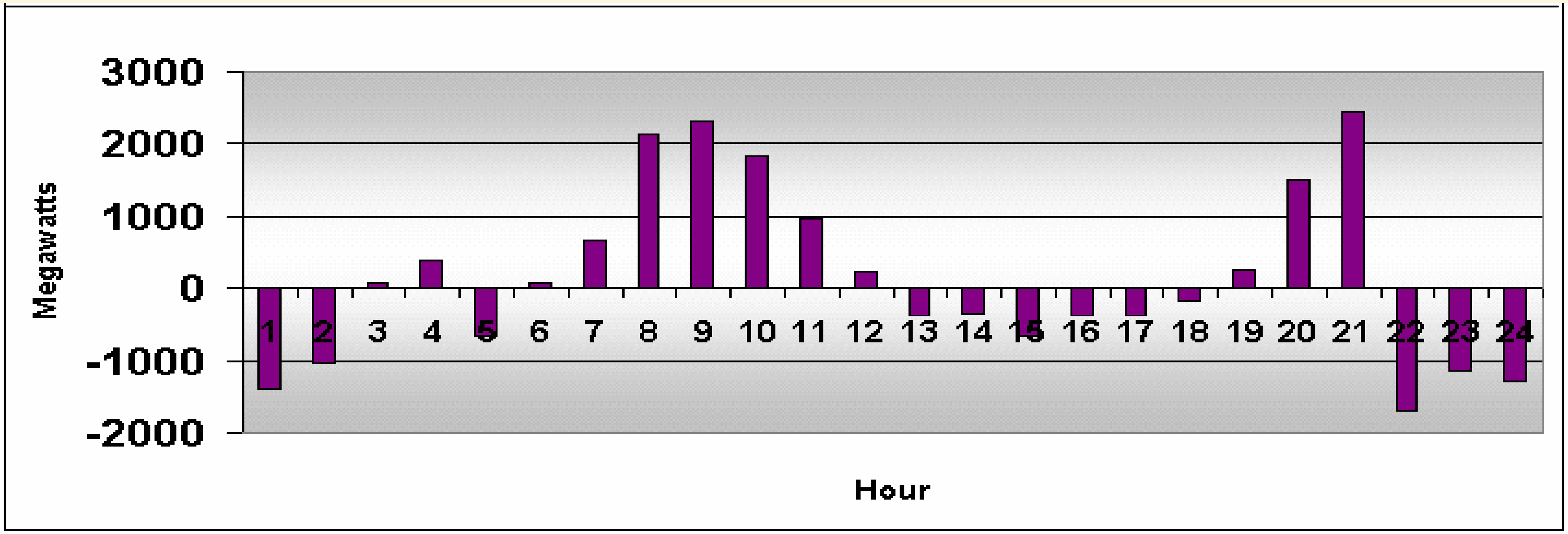
Season	Max Load Following Inc, MW	Max Load Following Dec, MW	Max Hourly Increase (Inc), MW	Max Hourly Increase (Dec), MW
Spring	+2,850	-2,950	+800	-500
Summer	+3,500	-3,450	+800	-600
Fall	+3,100	-3,250	+750	-900
Winter	+2,900	-3,000	+700	-750

Season	Max Load Following Ramp Up, MW/min	Max Load Following Ramp Down, MW/min
Spring	+35	-30
Summer	+40	-40
Fall	+40	-30
Winter	+30	-40

Ramping issues

• In California, the wind generation energy production tends to be inversely correlated with the daily load curve. The wind energy production peaks during the night and falls off during the morning load pick up. The net result will be morning ramps of 2000 to 4000 MW per hour for 3 hours – a total of 6000 to 12,000 MW over 3 hours.

Forecasted Hourly Ramps due to Additional Wind Generation



Recommendations

- Implement a state-of-the-art (DA, HA, RT) wind forecasting service for all wind generator energy production within the CAISO operational jurisdiction
- Incorporate the Day and Hour Ahead wind generation forecasts (block energy schedules) into the CAISO's and SC's scheduling processes
- Integrate the Real Time wind generation forecast (average wind generation for 5-minute dispatch intervals) with the Real Time unit commitment and MRTU dispatching applications
- Develop a new ramp forecasting tool to help system operators anticipate large energy ramps, both up and down, on the system
- Change the ISO generator interconnection standards to require compliance of all intermittent resources with the interconnection rules established for the PIPR

Recommendations (cont.)

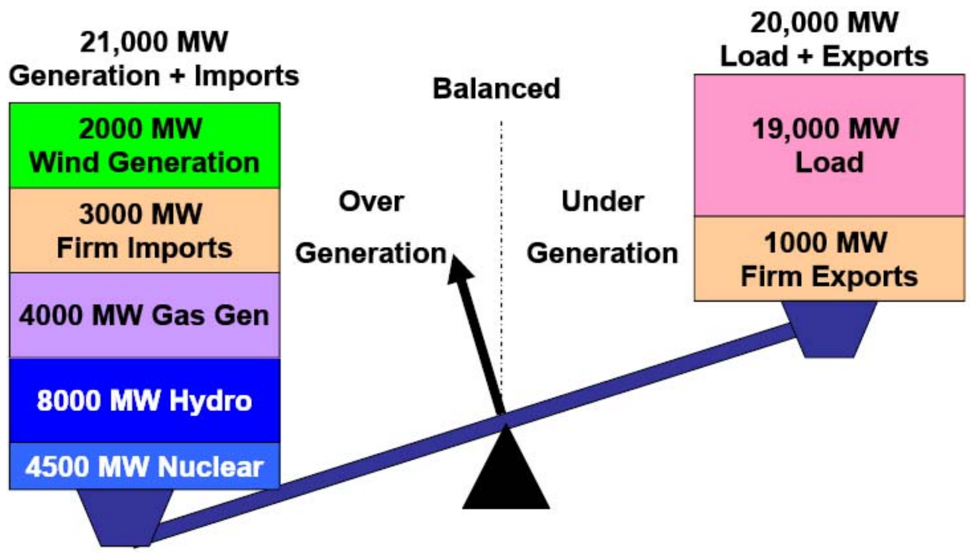
- Implement a procedure where the CAISO Dispatcher can send dispatch notices to wind generation operators and require them to implement pro-rata cuts in their energy production.
- Analyze the impact of solar power intermittency with load and wind generation intermittency
- Evaluate the benefits of participating in a wider-area arrangement like ACE sharing or Wide Area Energy Management system
- Study the impact that additional cycling (additional start ups) and associated wearing-and-tearing issues and associated additional costs and environmental impacts on conventional generation
- Recommend changes in Resource Adequacy standard to require more generation with faster and more durable ramping capabilities that will be required to meet future ramp requirements
- Recommend changes in Resource Adequacy standard to require additional quick start units that will be required to accommodate Hour Ahead forecasting errors and intra-hour wind variations.
- Encourage the development of new energy storage technology that facilitates the storage of off peak wind generation energy for delivery during on-peak periods

Over Generation Conditions

Typical conditions that lead to over generation

- Light load conditions - loads around 22,000 MW or less,
- All the nuclear plants on-line and at maximum production,
- Hydro generation at high production levels due to rapid snow melt in the mountains,
- Long start thermal units on line and operating at their Pmin levels because they are required for future operating hours,
- Other generation in a "Must Take" status or required for local reliability reasons, and
- Wind generation at high production levels.

Imbalance between Generation and Load



In Area Generation + Imports ≠ Load + Exports

Minimum Generation Levels during light load conditions

Generation/Load	Production Level Spring 2006 (MW)
Nuclear	**4,528**
Minimum "Must Take" such as QFs	**2.400**
Minimum Geysers	**650**
Minimum Thermal	**1,000**
Minimum Hydro	**3,700**
Minimum Interchange	**2,880**
Total Generation plus Interchange	***15,158***
Minimum Load	**18,070**
Difference	***2,912***

If wind generation exceeds 2,912 MW, then there is no room for the excess generation

Minimum thermal generation could be 2,000 to 3,000 MW.

Need for lower P_{min} values and more units that have fast start

Accurate forecasting of day-ahead wind generation production will be essential to minimize over-generation schedules

Key Issue is what gets cut?

- Spill some wind ?
- Spill some water?
- Spill some of both?

Conclusions & Recommendations about Over Generation

- Over generation occurs with the existing amount of wind generation but it is relatively rare occurrence.
- The lack of good Day Ahead wind generation forecast contributes to the problem.
- The addition of large amounts of wind generation facilities will exacerbate the problem.
- MRTU Integrated Forward Market should help to mitigate the problem
  - Generation schedules match the load forecast.
  - Accurate Day Ahead wind generation forecasts will be a key component for the Day Ahead RUC process.
- Wind generation operators should be prepared to curtail some wind generation production to mitigate serious over generation conditions in the future. The amount of renewable energy lost will be small.
- The CAISO must work with the wind generator operators to ensure procedures, protocols, and communication facilities are in place so dispatch commands can be communicated to the plant operators.
- Additional storage capability on the system would help to mitigate both over generation and large ramp conditions.

How to make the 20% RPS Target work

- Increase the amount of regulation resources

  Add 170 MW to 500 MW of regulation resources to accommodate rapid changes in wind and other variables.

  - Amount required varies with the season (winter, spring, summer, fall)

- Ramping requirement increases

  Fast ramping increases by ±15 MW/min to ±25MW/min

  Regulation by hydro units will be most important

- Supplemental energy dispatches will increase

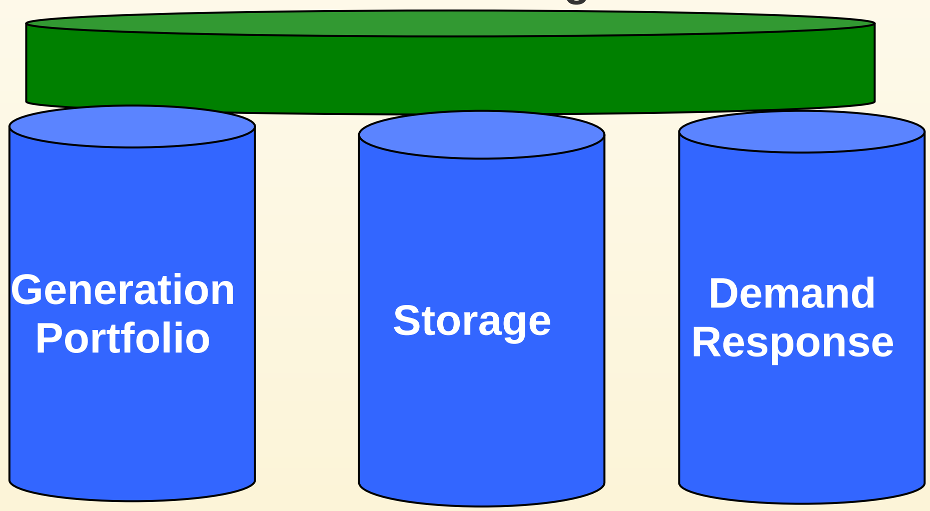
  Morning ramp up will increase by 1000 to 2000 MW per hour

  Evening ramp down will increase by 1000 to 1800 MW per hour

- Potential Over Generation problems will increase for light load periods

Three RA requirements for Integration of Renewables

Resources Required for Renewables Integration



Generation Portfolio

- Quick Start Units
- Fast Ramping
- Wider Operating Range
- Regulation capability

Storage

- Shift Energy from off-peak to on-peak
- Mitigate Over Generation
- Voltage Support
- Regulation capability

Demand Response

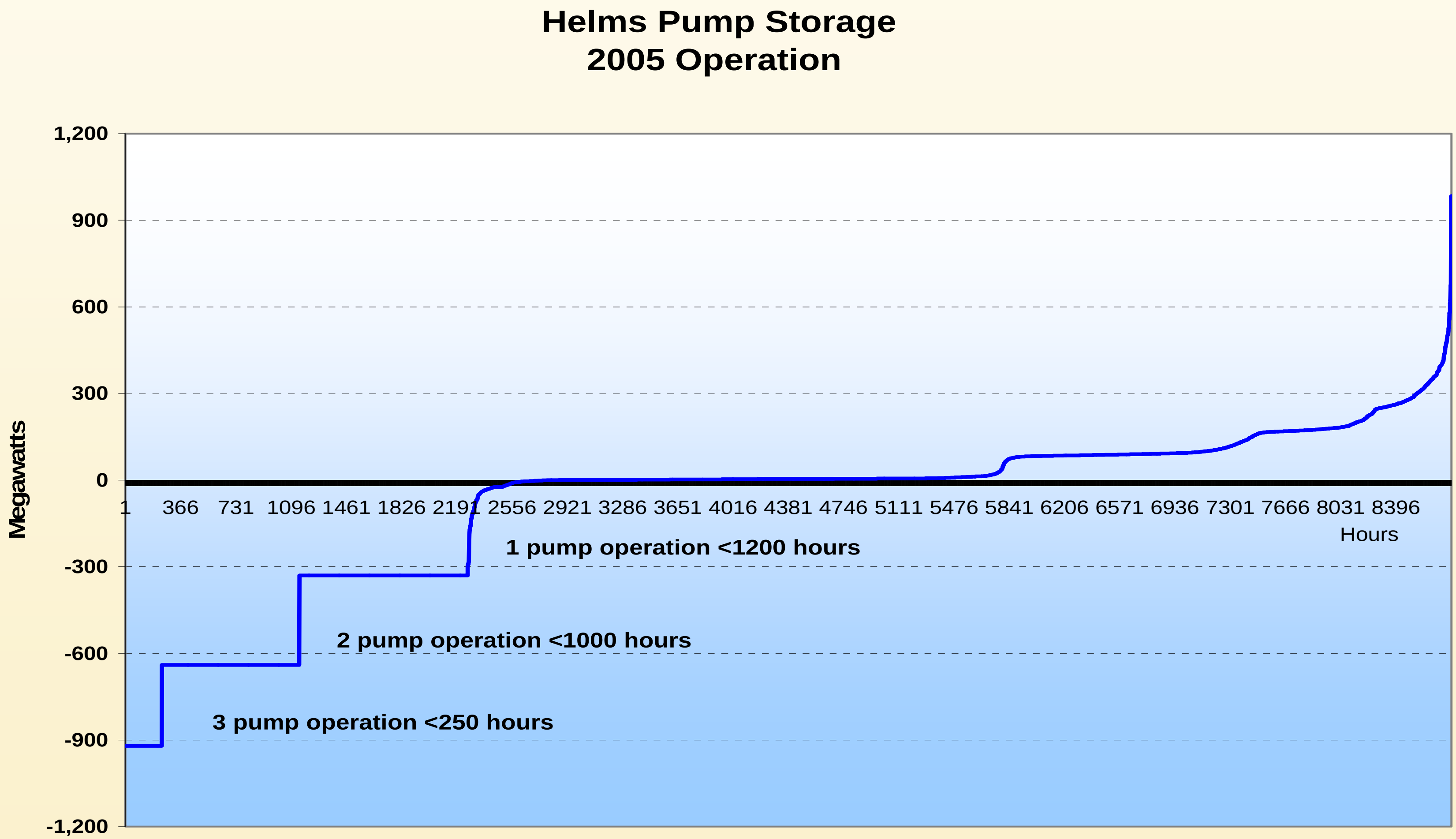
- Price sensitive load
- Responsive to ISO dispatches
- Frequency Responsive
- Responsive to Wind Generation Production

Storage Technology

- Pump Storage
  - Helms and potentially Leaps
- Hydrogen Storage
- Compressed Air Storage
- Flow Based Battery Storage
- Batteries
- Super capacitors
- High Speed Flywheel Storage
- Plug-in Hybrid Electric Vehicles

Storage Technology – Pump Storage

- Helms Pump Storage Plant rarely operates all three 300 MW pumps.



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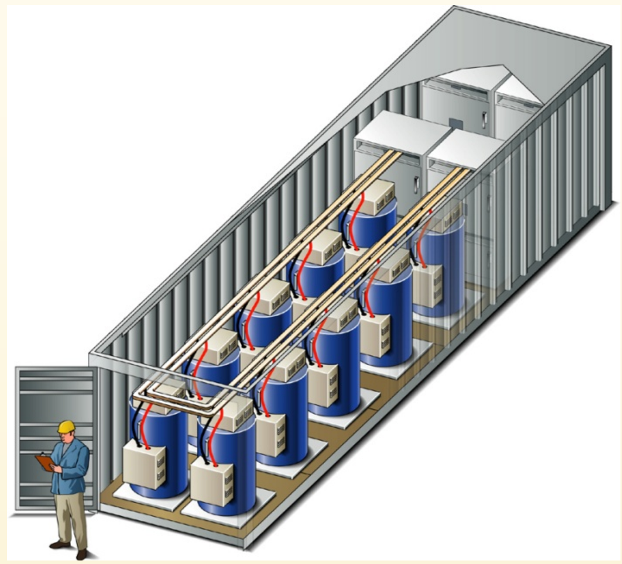
Storage Technology – High Speed Flywheels

- Flywheel Energy storage project for AGC Regulation Service and frequency control. Test system installed in Sept. 2005 at the Research Center in San Ramon. Research project successfully completed 2007
- Need a performance based contract with a market participant
- Can we justify a 20 MVA or 40 MVA facility for AGC?



A "Megawatt in a Box"

- Beacon Power technology
- (10) 25-kWh flywheels
- 1 MW for 15 minutes
- Quick deployment
- Price about 1 million $$

Storage Blockers

#1 A good economic model for making storage payoff. Is the differential between off-peak prices and on-peak prices large enough or sustained to make a compelling business case?

#2 What value added services can storage provide to improve the economic model? Fast ramp rates? High Speed Regulation? FRR-Frequency Responsive Reserves?

The storage industry has been working work with governments, regulators, utilities, and operators to address and attempt to overcome the challenges to the proliferation of electricity storage. Some of these include:

- A lack of government subsidies and incentives to encourage investment
- Regulatory constraints and limitations
- The uncertainty of selling electricity storage systems at a price that will allow both developers and customers to profit
- Political will (it will take time to influence decision-makers. Will the window of opportunity stay open long enough for that to happen?

Demand Response Programs

- 4 Types required
  - Price Sensitive load that is willing to reduce demand for the right price. Demand that is bid into Day-Ahead markets to reduce peak load
  - Interruptible Load – Loads that are willing to be interrupted or curtailed under emergency conditions – Stage 2 Emergencies – and will immediately take action in response to a dispatch notice.
  - Frequency sensitive load – Load that is willing to turn off or reduce consumption due to a drop is system frequency. Example is Plug-In Hybrid Vehicles that will automatically stop charging their batteries when the frequency is low.
  - Load that is willing to change based on availability of excess wind generation production

Next Steps

Major tasks

- Sharing of ACE deviations between BA's
- Strategy for Imports of Renewables
- Improve Renewables forecasting –
  Day-Ahead and Hour-Ahead
- Link forecasts into Market Systems
  - AS Procurement
  - RUC decisions
- Graphics displays for operations
- Transmission Line Loading and overload mitigation
- Ramp forecasting tools and planning tools for operations
- Improve Wind Generation models for transient stability studies

Sources of information

- CAISO Integration of Renewables Report

  http://www.caiso.com/1c60/1c609a081e8a0.pdf

- CEC Intermittency Analysis Project (IAP Report)

  http://www.energy.ca.gov/pier/final_project_reports/CEC-500-2007-081.html