California Grid Operations: Current Conditions and Future Needs

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Your Link to Power

Global Climate & Energy Project

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Our objective today is identify R&D needs to build the power grid of the future

- **Future Energy Resource Needs**

  Renewable Requirements (20/33)

  Faster more dynamic / less predictable Supply Characteristics

- **Regional Transmission**
  Complex Delivery System

  Advanced Supply Chain Modeling & Analysis

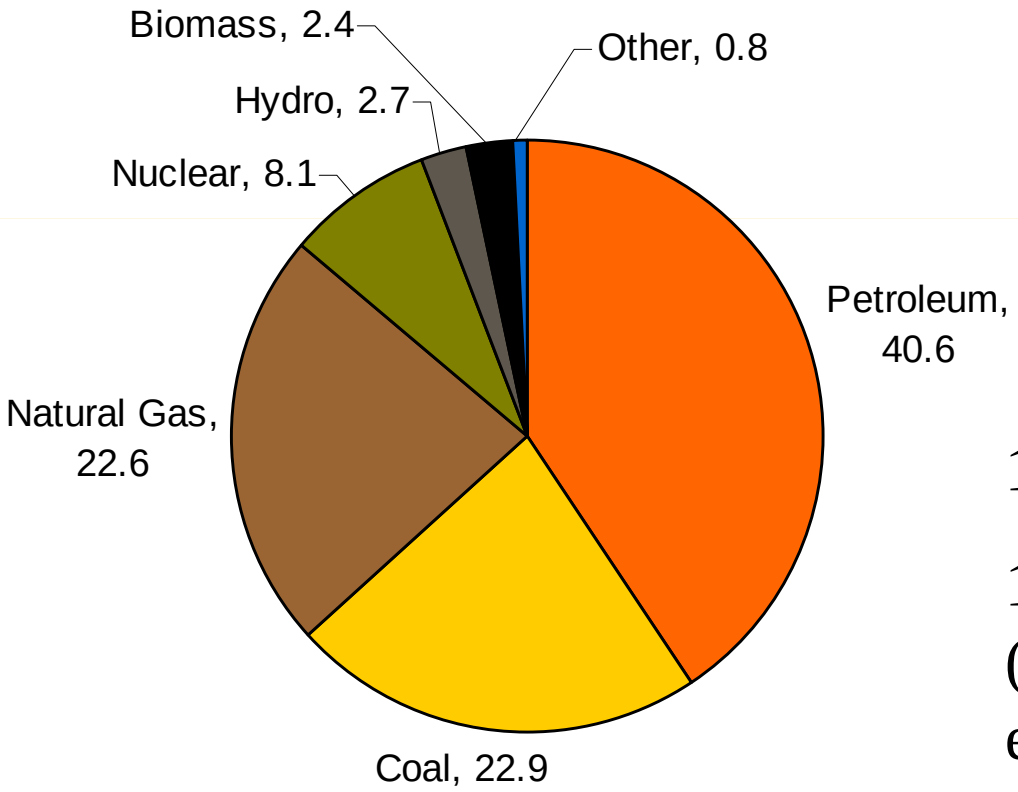
- **Smart Grid - Smart Energy Systems**
  New Grid Technologies

  Smart responsive Demand

  Energy Storage systems

Annual US Energy Pie: Total of 100 Quad (Btu)

About 86% Fossil Fuels



CO2 Emissions (millions of metric tons, and per quad

Petroleum:	2598,	64.0
Natural Gas:	1198,	53.0
Coal:	2115,	92.3

1 Quad = 293 billion kWh (actual)

1 Quad = 98 billion kWh (used, taking into account efficiency)

Source: DOE/EIA Energy Outlook 2007, Table 1, 2005 Data

Scale of Change

- Converting all our corn (81 million acres) to ethanol gives about 2.6 quad
- Annual gasoline consumption is 140 billion gallons or about 17.5 quad
- One 1200 MW reactor = 0.1 quad
- Wind currently (2005) provides 0.15 quad, with capacity of 9600 MW. Getting to 1 quad would require about 64,000 MW of capacity, mostly in areas with little transmission

What does it take to integrate a higher RPS in California.

Case	GWh	Avg. Mw	Nameplate Mw
20% RPS	55,657	6,353	13,614
33% RPS	~ 93,000	10,500	26,000

- Achieving 33% requires us to meet two times load growth with renewables between now and 2020.
- The increase in need for capacity, ramping, and regulation to achieve 33% RPS is not linear – it is much greater.
- Regional diversification is important technically and economically.
- Key questions are:
  - Can we retain and invest in more non base-load fast ramp facilities?
  - Does retirement or replacement make sense?

"There isn't anything we cannot do."

"What is it?" and "How much does it cost?"

Base Case RPS Targets by Region
Year 2020

- RPS currently in effect in CA, OR, WA, MT, CO, NM, AZ, NV
- Interpolation for 2020 targets for RPS targets beyond 2020
- Voluntary target in BC (50% of load growth)
- Assume 5% for other regions to reflect known plans to acquire renewables
- Total WECC target: 129,000 GWh, or 14,736 MW (at 100% capacity factor)

Region	Base Case Target	New RPS Resources (GWh)
Alberta	5%	3,268
Arizona-Southern Nevada	13%	18,109
British Columbia	12%	9,371
California	20%	55,025
Colorado	15%	12,375
Montana	15%	676
New Mexico	18%	3,639
Northern Nevada	20%	2,113
Northwest	14%	21,198
Utah-Southern Idaho	5%	2,808
Wyoming	5%	509
WECC Total	15%	129,091

Source: Based on principal data from California Energy Commission, Northwest Power & Conservation Council, Utility integrated resource plans, Energy Information Administration, PLEXOS Solutions, Inc., and media reports compiled and analyzed by Energy & Environmental Economics, Inc.

What Does That Tell Us?

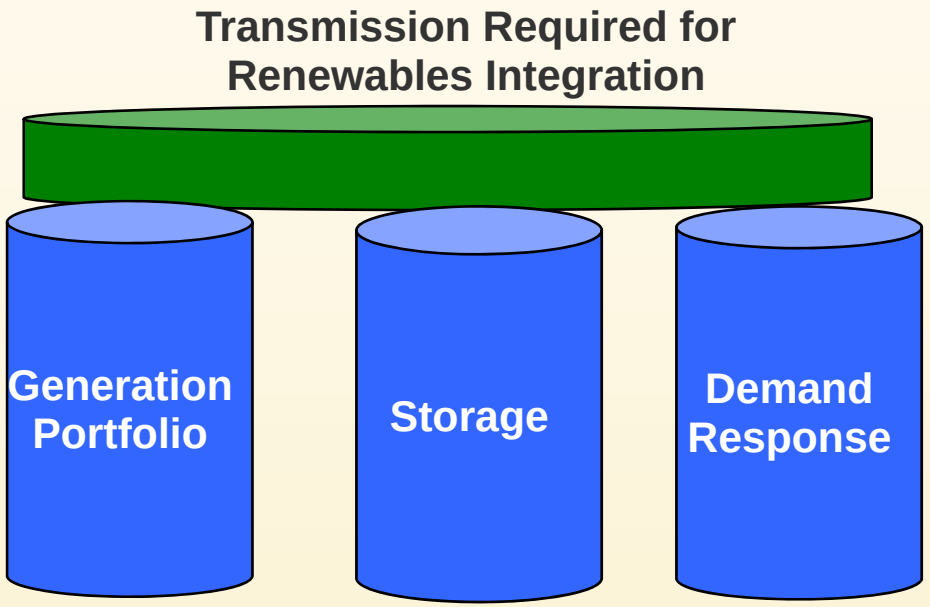
- The majority of the resources to meet growth will be of the renewable type.
- The majority of the initial renewables will be Wind and Solar Thermal.
- The majority of the cost effective wind is spread well beyond where it is needed.
- Regional diversity will be crucial for both reliability and economics.
- Transmission is required to access reliable and economic resources.

What Will It Take?
Totally Different Paradigm

Operation – different, challenging

- It is doable with cost & technical implications
- Needs for new products including Ramping, fast reserve, and storage.
- We must understand the Supply characteristics, Transport and Storage Limitations
- Regional operation coordination critical

Requirements for Grid Integration of Renewables



Quick Start Units

Fast Ramping

Wider Operating Range

Regulation capability

Large Scale

Shift Energy from off-peak to on-peak

Mitigate Over Generation

Voltage Support

Regulation capability

Price responsive load

Responsive to ISO dispatches

Frequency Responsive

Responsive to Wind Generation Production

Challenges for energy storage?

1. A good economic model for making storage payoff at the Scale Req.
    - How do storage investors get compensated?

2. Quantification of storage benefit
    - Fast ramp rates
    - High Speed Regulation
    - FRR-Frequency Responsive Reserves

3. A lack of government subsidies and incentives to encourage expansion & investment

4. Possible Regulatory constraints and limitations

5. The uncertainty of selling electricity storage systems at a price that will allow both developers and customers to profit

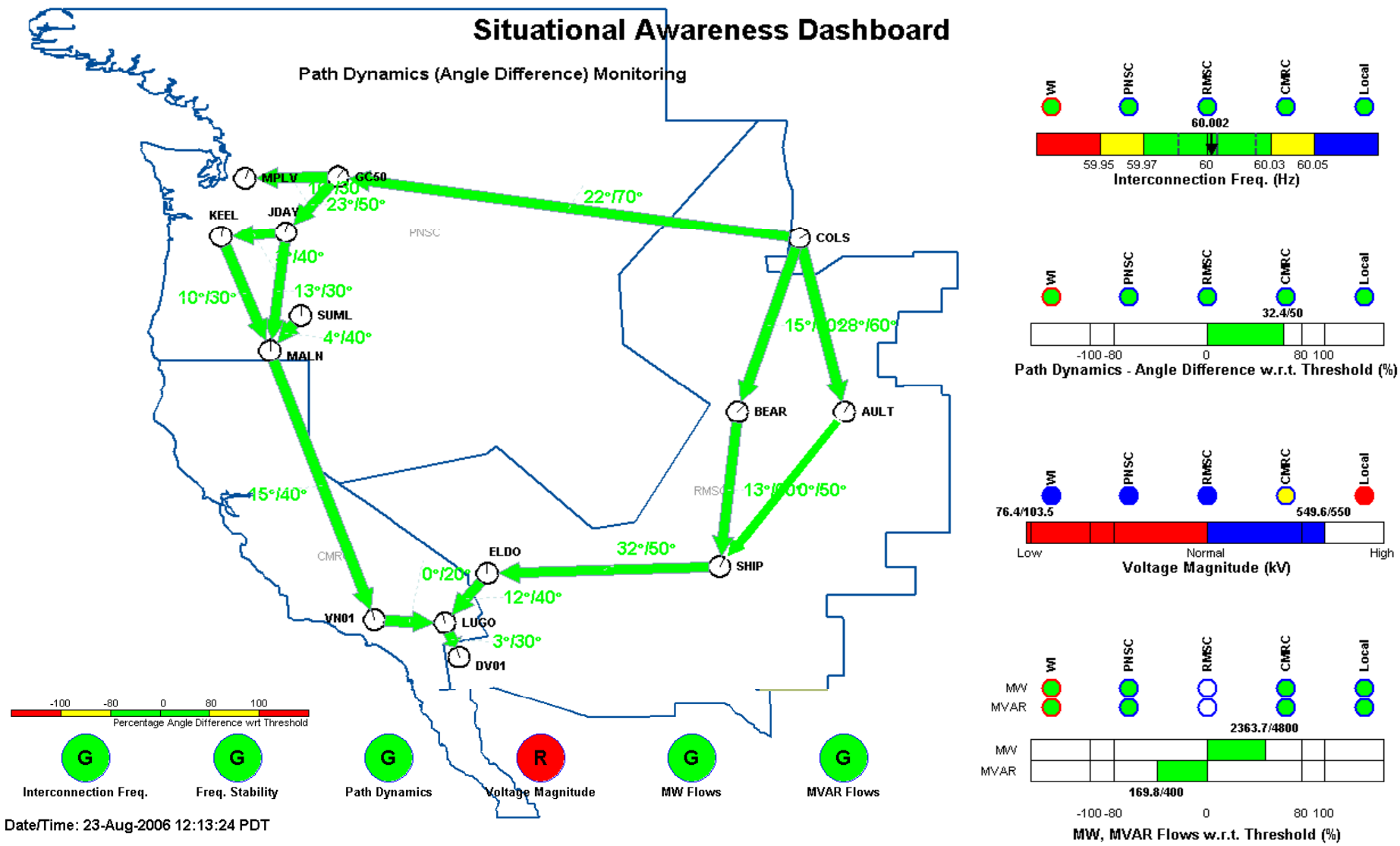
6. Political will (it will take time to influence decision-makers. Will the window of opportunity stay open long enough for that to happen?

Demand Response Programs

- Required
  - Price Sensitive load products that are willing to reduce demand for the right price and duration. Demand that is bid into Day-Ahead markets to reduce peak load
  - Interruptible Load – Loads that are willing to be interrupted or curtailed under System conditions – 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 / storage that is willing to consume based on availability of excess wind / solar generation production.

Smart Grid Characteristics

- Interconnection wide view
- High Speed Time Stamped data that can be used for analysis and control
- High Speed devices that can respond to control signals and dampen oscillations (High speed Flywheels)
- Smart Substations – local controls, visual information on health of the station, and devices to speed system restoration if needed
- Control of customer loads as a system resource and safety net
- Successfully accommodates and integrates many different resources


Situational Awareness Dashboard
Path Dynamics (Angle Difference) Monitoring
MPLV
GC50
KEEL
JDAY
COLS
SUML
MALN
BEAR
AULT
ELDO
SHIP
VN01
LUGO
DV01
22°/70°
23°/50°
13°/30°
10°/30°
4°/40°
15°/28°/60°
45°/40°
32°/50°
0°/20°
12°/40°
3°/30°
PNSC
RMSC
CMRC
-100 -80 0 80 100
Percentage Angle Difference wrt Threshold
G
Interconnection Freq.
G
Freq. Stability
G
Path Dynamics
R
Voltage Magnitude
G
MW Flows
G
MVAR Flows
Date/Time: 23-Aug-2006 12:13:24 PDT
WI
PNSC
RMSC
CMRC
Local
60.002
59.95 59.97 60 60.03 60.05
Interconnection Freq. (Hz)
32.4/50
-100 -80 0 80 100
Path Dynamics - Angle Difference w.r.t. Threshold (%)
76.4/103.5
549.6/550
Low
Normal
High
Voltage Magnitude (kV)
MW
MVAR
2363.7/4800
169.8/400
-100 -80 0 80 100
MW, MVAR Flows w.r.t. Threshold (%)

Potential Technology Research Topics

1. New models to simulate the supply chain – supply, transport, delivery and system operation scenarios.
2. Shaping customer energy usage (load) and customer generation (PV).
3. Evaluate energy storage technology benefits and financial compensation models
4. Increased Transmission Capacity by eliminating Transient Oscillations
5. Strategies for scheduling and transmission of renewables between control areas and States.
6. Analyze system impacts and control needs of a significant penetration of large, remote wind farms.

Extreme Weather Research Topics

1. Use predictions of regional climate change to estimate the rate of change of power system design parameters.
2. Robust monitoring and control techniques for harsh weather and increased load demand. More load in Central Valley
3. Combine climate predictions of extreme weather with emerging blackout risk assessment.
4. Faster restoration in case of natural disasters.
5. Analyze the likelihood and impact of increased wildfires.
6. Analyze loss of snow pack and resulting reduced hydro generation

Market Mechanisms Research Topics

1. Research the effect of conflicts and/or inconsistencies between *regional* cap-and-trade markets, and conflicts with renewable portfolio standards (RECs).
2. Develop new planning and risk management tools, focusing on the risk introduced by uncertainty in climate change and government policies designed to address climate change issues.
3. Analyze the effect on system and market operations if automated control systems are installed at customer locations.
4. Develop optimal bidding strategies for multi-period electricity markets with uncertainty in GHG policies and mandates.

Industry Planning Research Topics

1. Trade-offs between profits and power system security and reliability - fast computational methods that operate in real time to analyze the trade-offs.
2. Analyze the efficiencies of market structures with carbon trading – impact on the electric power industry and other GHG producing industries.
3. Reduced hydro-generation - consequences on system stability and responsiveness .
4. Demand-side Management - Technology, system control methods, and market designs.
5. Environmentally constrained system dispatch - Tools to improve understanding and operational impact