Developing Tools for Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation

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Problem

- Unpredictable variability of wind and solar generation affects grid operation. Higher the penetration of renewables, greater the effect on grid operation.
- Some combination of a multitude of solutions needed.
- We focus on a probabilistic approach to forecast errors and how to incorporate them into the grid operations

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Problem

- Generation: “Ramp Tool”
  Capacity (MW), Ramp (MW/min), Ramp Duration
- Transmission Congestion: “Congestion Tool”
  Power, voltage, reactive power

Algorithms

Alerts and Alarms

Remedies

Visualization

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Wind Integration and Visualization

- Funded by California Energy Commission
- Time: 03/2009 – 10/2011
- Objective: facilitate wider penetration of renewable resources without compromising system reliability
  - Develop EMS integrated tools
  - Work closely with the CAISO engineers
  - Install the tools at CAISO

  - Some tools developed/being developed under a DOE project are implemented

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- CAISO has more urgent need for the “Ramp Tool”. Have much more to say about it.

- Work continues on the “congestion tool”. A few slides about it:
  - Visualization based on Google Earth
  - Network reduction

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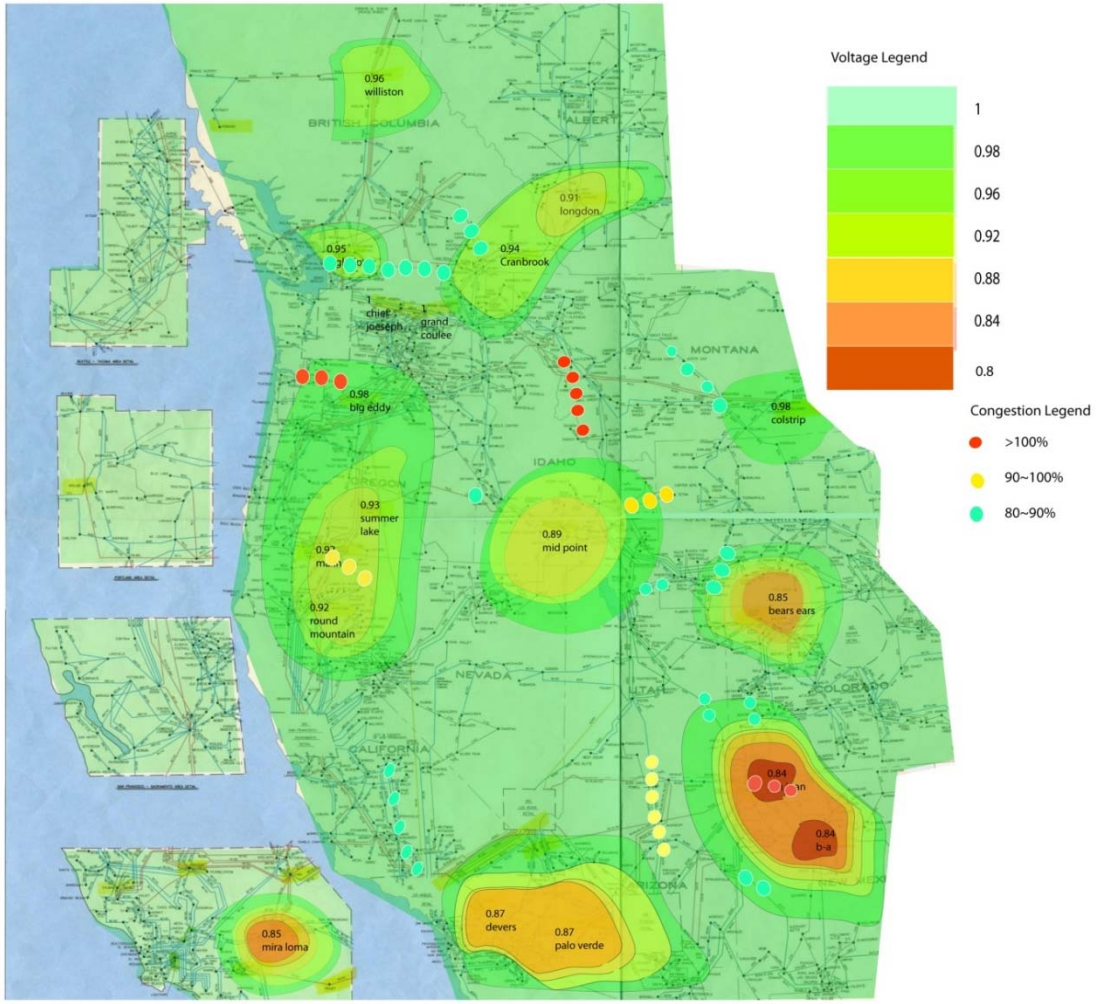
Visualization of Congestion



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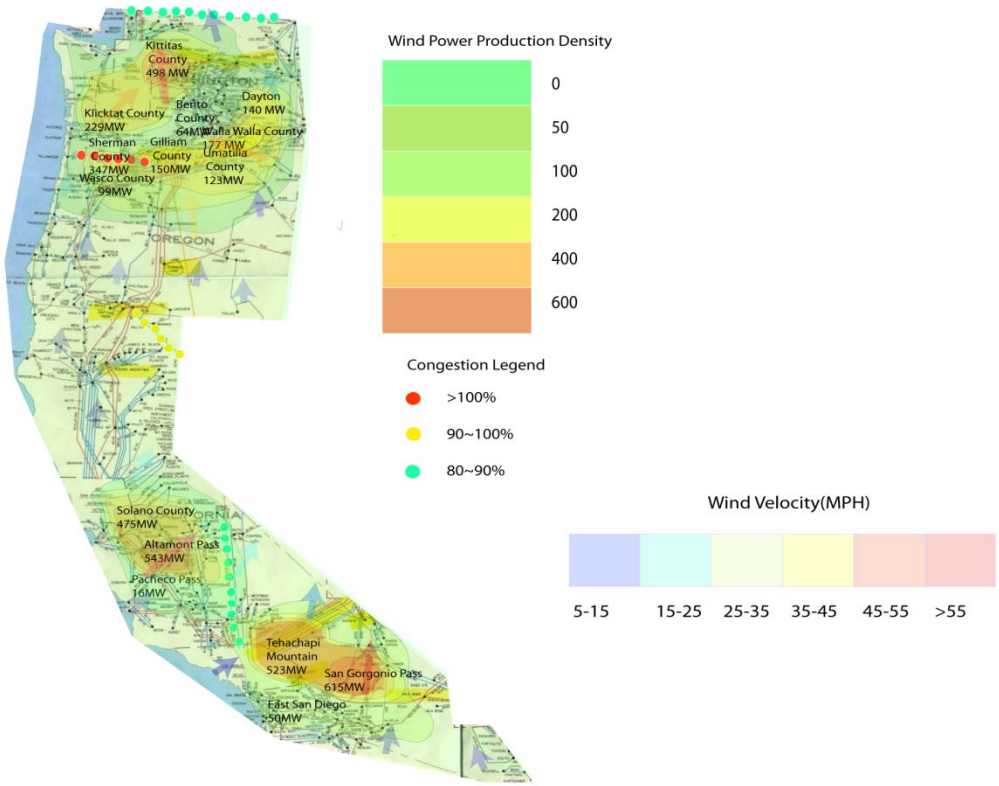
Visualization of Wind Forecast



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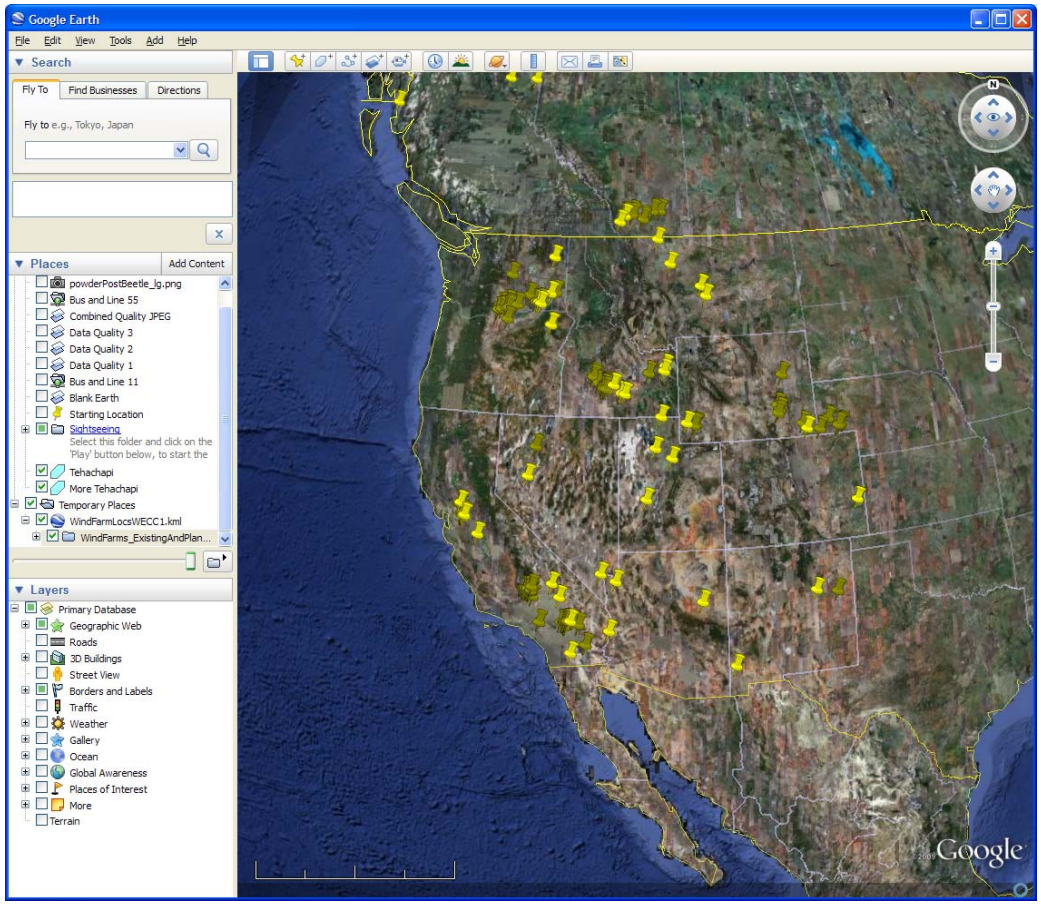
Wind Farm Locations



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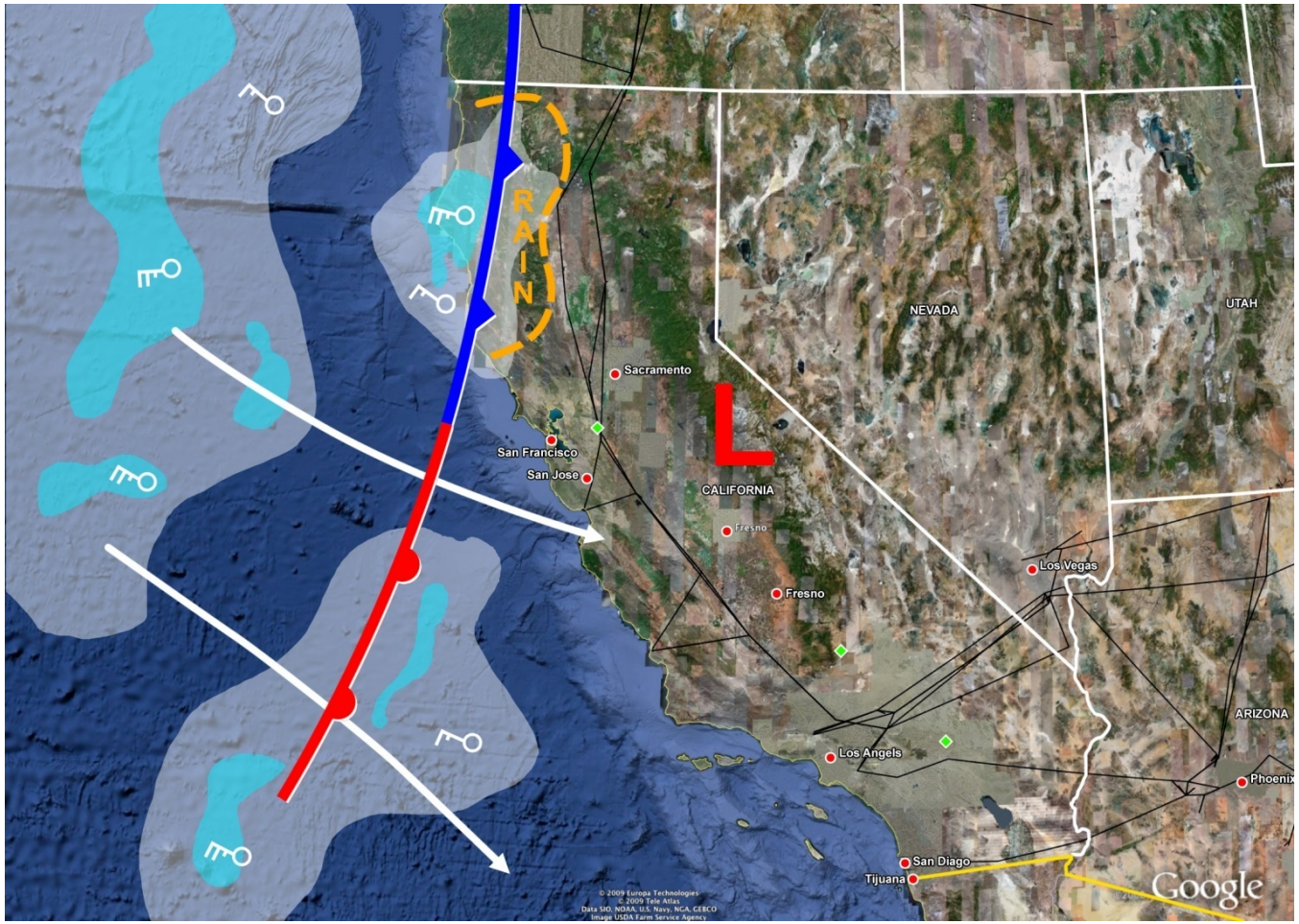
Wind and Congestion Visualization



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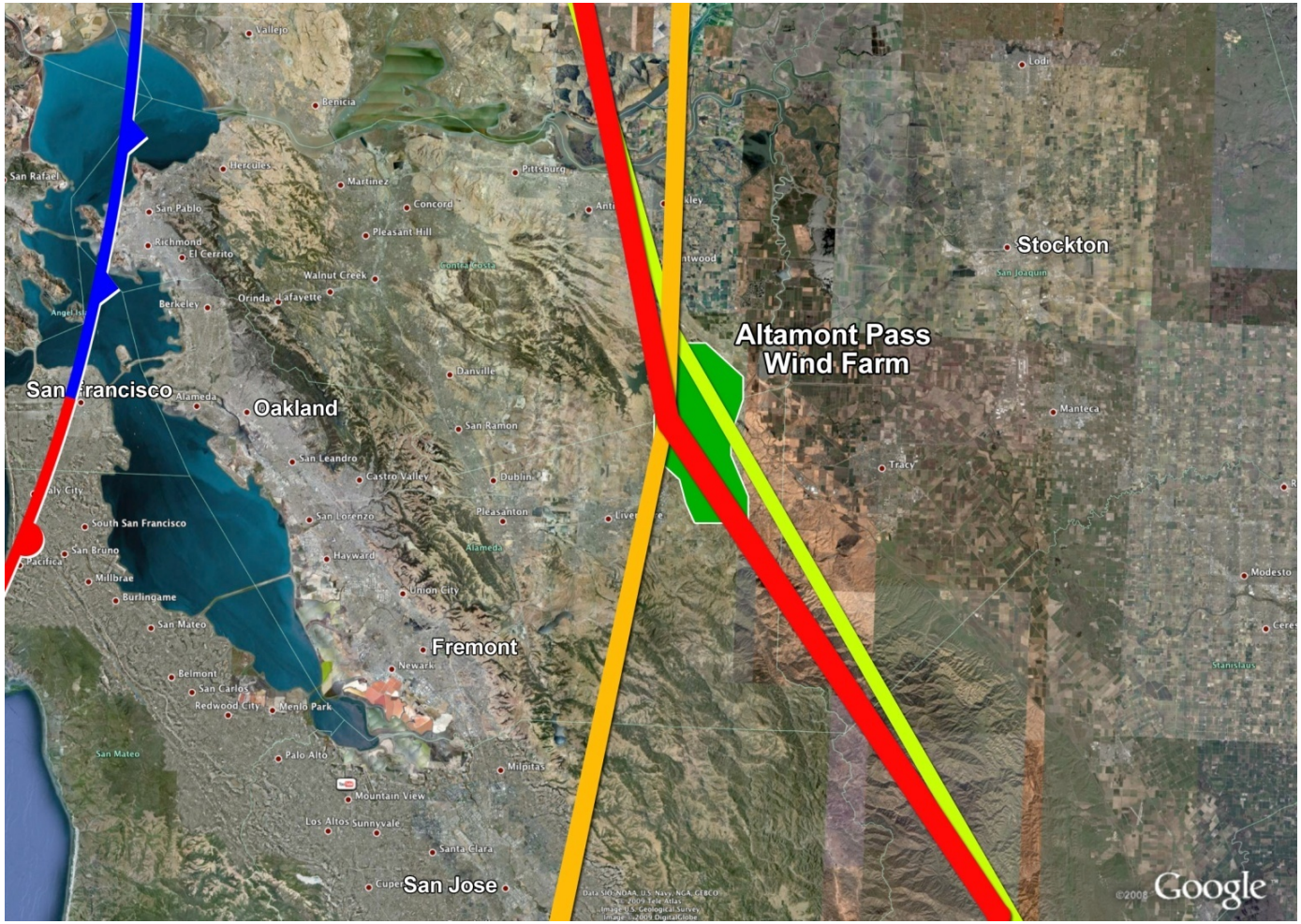
Wind and Congestion Visualization



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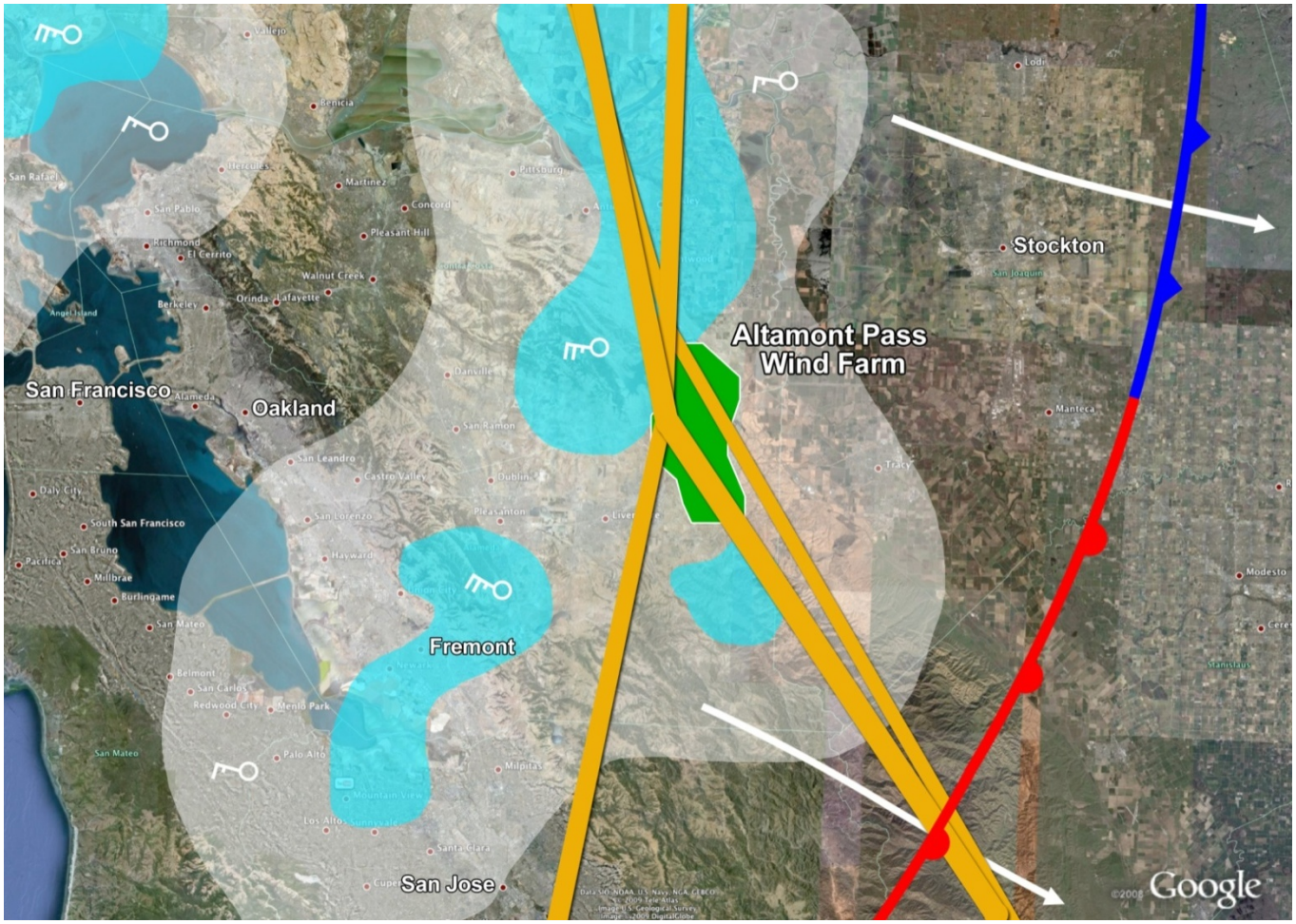
Wind and Congestion Visualization



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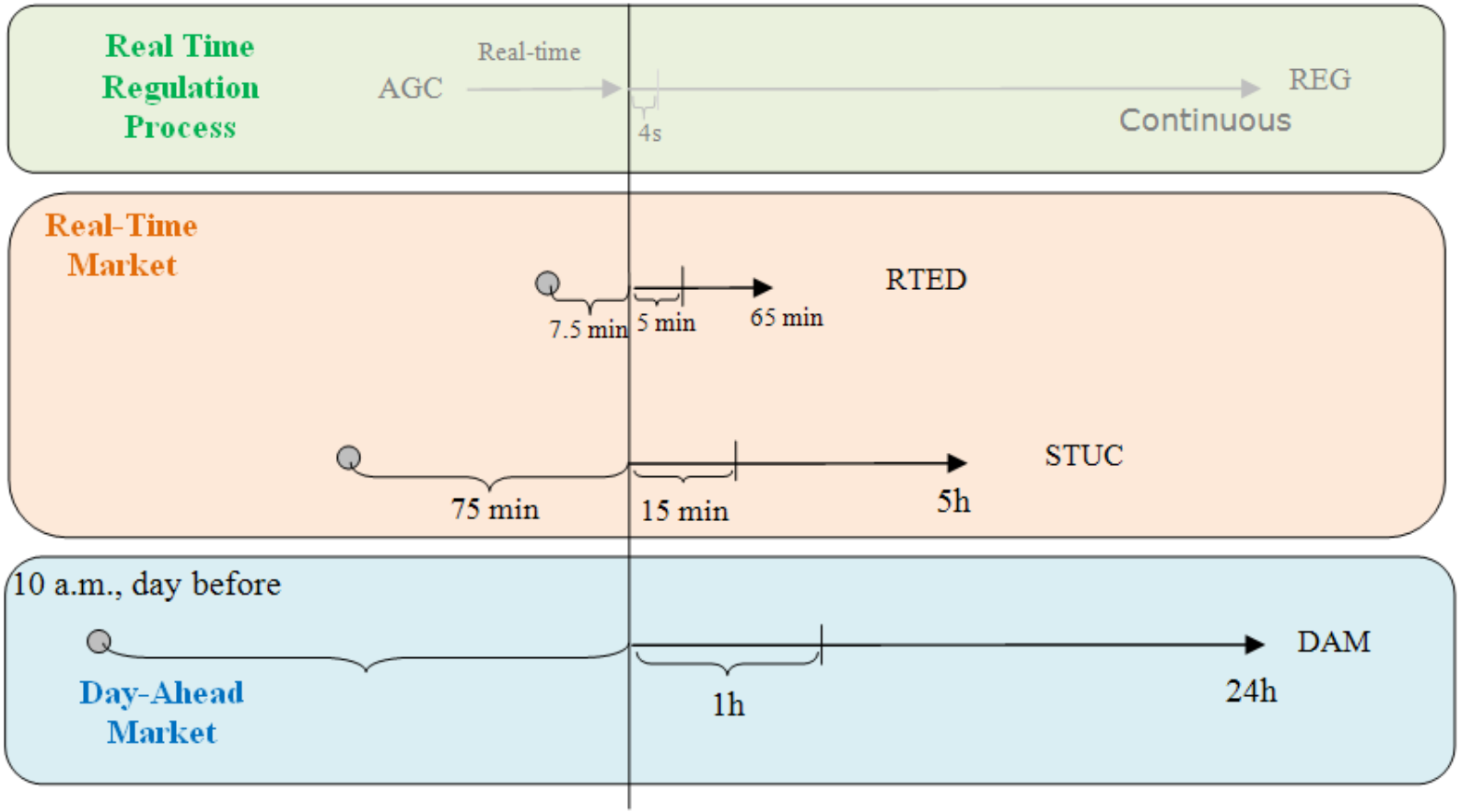
Ramping Tool
CAISO Timeline



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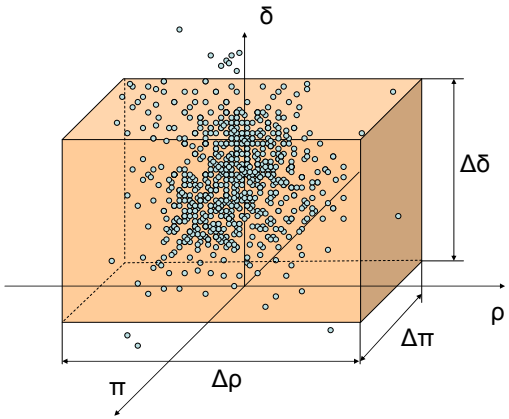
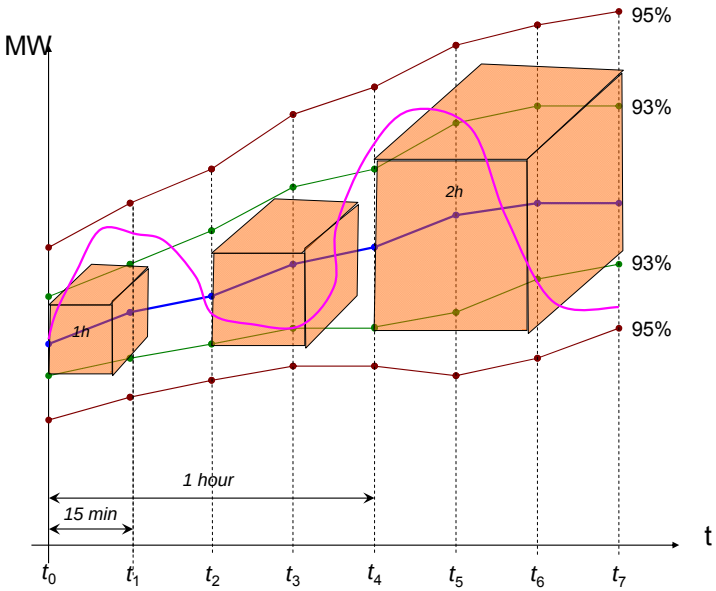
Flying brick method

- Capacity, ramp rate, ramp duration





Swinging door algorithm for ramp rate

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Uncertainty Models Development

- Uncertainties in forecast generation
  - Load forecast uncertainties
  - Wind generation forecast uncertainties
  - Forced Outage
- Contingency Reserve Activation

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Data from CAISO

	Overview of data request	Business area	Resolution	Time Horizon
A				
	Generation and Interchange Schedules			
A1	Day-ahead Generation Schedulen(total and for each individual generator)	Market	1 hr	24 h
A2	Short Term Unit Commitment (total and for each individual generator)	Market	15 min	5 h
A3	Pumped Hydro Schedule	Market	1h	24 h
A4	Real-Time Economic Dispatch (total and for each individual generator)	Market	5 min	65 min
A5	Day-ahead Day-ahead nInterchange Schedule (total)	Market	1h	24 h
	Dynamic Schedules			
A6	Hour-ahead Interchange Schedule (total)	Market	15 min	5 h
A7	Day-ahead (total and for each individual generator)	Market	1 h	24 h
A8	Short Term Unit Commitment (total and for each individual generator)	Market	15 min	5 h
A9	Real-Time Economic Dispatch (total and for each individual generator)	Market	5 min	65 min
	Operating Reserves (total and for individual generators)			
A10	Regulation Up Procurement	Market	1 h	24 h
A11	Regulation Up (available)	Market	5 min	-
A12	Regulation Down Procurement	Market	1 h	24 h
A13	Regulation Down (currently available)	Market	5 min	-
A14	Spinning Reserve	Market	1 h	24 h
A15	Non-Spinning Reserve	Market	1 h	24 h
B				
	Load Forecast			
B1	Day-Ahead Load Forecast	Load forecast (ALFS)	1 h	24 h
B2	Hour-Ahead Load Forecast	Load forecast (ALFS)	30 min	24 h
B3	Real time Load Forecast	Load forecast (ALFS)	5 min	60 min

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Data from CAISO - continued

29		**Wind Generation Forecast (total and per generation zone)**			
30	C1	Day-ahead Wind Forecast	Renewables forecast	1 h	24 h
31	C2	Hour-ahead Wind Forecast	Renewables forecast	5 min	8 h
32	C3	Real Time Wind Forecast	Renewables forecast	5 min	65 min
33	C4	Day-ahead Solar Forecast	Renewables forecast	1 h	24 h
34	C5	Hour-ahead Solar Forecast	Renewables forecast	5 min	8 h
35	C6	Real Time Solar Forecast	Renewables forecast	5 min	65 min
36	**D**				
37	D1	Actual Load	Real time data (PI)	5 min	-
38	D2	Actual Load (total and for each individual generator)	Real time data (PI)	5 min	-
39	D3	Actual Wind Power Generation (total and per generation zone)	Real time data (PI)	5 min	-
40	D4	Actual Solar Power Generation (total and per generation zone)	Real time data (PI)	5 min	-
41	D5	Actual Interchange (total)	Real time data (PI)	5 min	-
42	D6	Actual Regulation (total and for each individual generator)	Real time data (PI)	1 min	-
43	D7	Actual Load Following (total and for each individual generator)	Real time data (PI)	5 min	-
44	**E**				
45	E1	Generator Type (Hydro, Nuclear Gas Turbine, Combined-cycle, Wind, Solar, …)	Master File	-	-
46	E2	Ramp Rate	Master File	-	-
47	E3	Regulation Ramp Rate	Master File	-	-
48	E4	Startup Time	Master File	-	-
49	E5	Startup Cost	Master File	-	-
50	E6	Maximum Capacity	Master File	-	-
51	E7	Minimum Capacity	Master File	-	-
52	E8	Minimum Run Time	Master File	-	-
53	E9	Minimum Down Time	Master File	-	-
54	E10	Failure to Start Up (% of start ups)	WECC	-	-
55	E11	Production Cost Characteristic (piecewise linear characteristics)	Master File	-	-
56	E12	Force Outage Rate (FOR)	WECC	-	-
57	E13	In Service Hours	Master File	-	-
58	E14	Out of Service Hours (due to Forced Outages)	WECC or SLIC	-	-
59	E15	Number of Occurrences (per year for forced outages)	WECC or SLIC	-	-
60	E16	Must-Run Units (Yes/No)	WECC or SLIC	1 h	24 h
61	E17	Availability for Redispatch (Yes/No)	WECC or SLIC	1 h	24 h

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Data from CAISO – Transmission Congestion

Computation Data

1) Network model (2009 updated model)[2] **F**
2) 'Snapshot' power flow of a base case (season base flow) **G**
3) Line/transformer outage rate **H**
4) Wind/solar, load and generation forecast information (every 5 minutes)

Visualization Data

5) Geographic data – location of each bus and wind/solar farm[3] **I**
6) Boundary of zones **J**
7) All transmission lines connecting between zones **K**
8) Constraints- maximum transfer capacity of main transmission path **L**
9) Location of weather towers which collect the weather information **M**

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CAISO feedback

- Working with CAISO for a mechanism for getting the most useful feedback on the ramp tool.

- Developed specifications for a simplified version of the ramp tool

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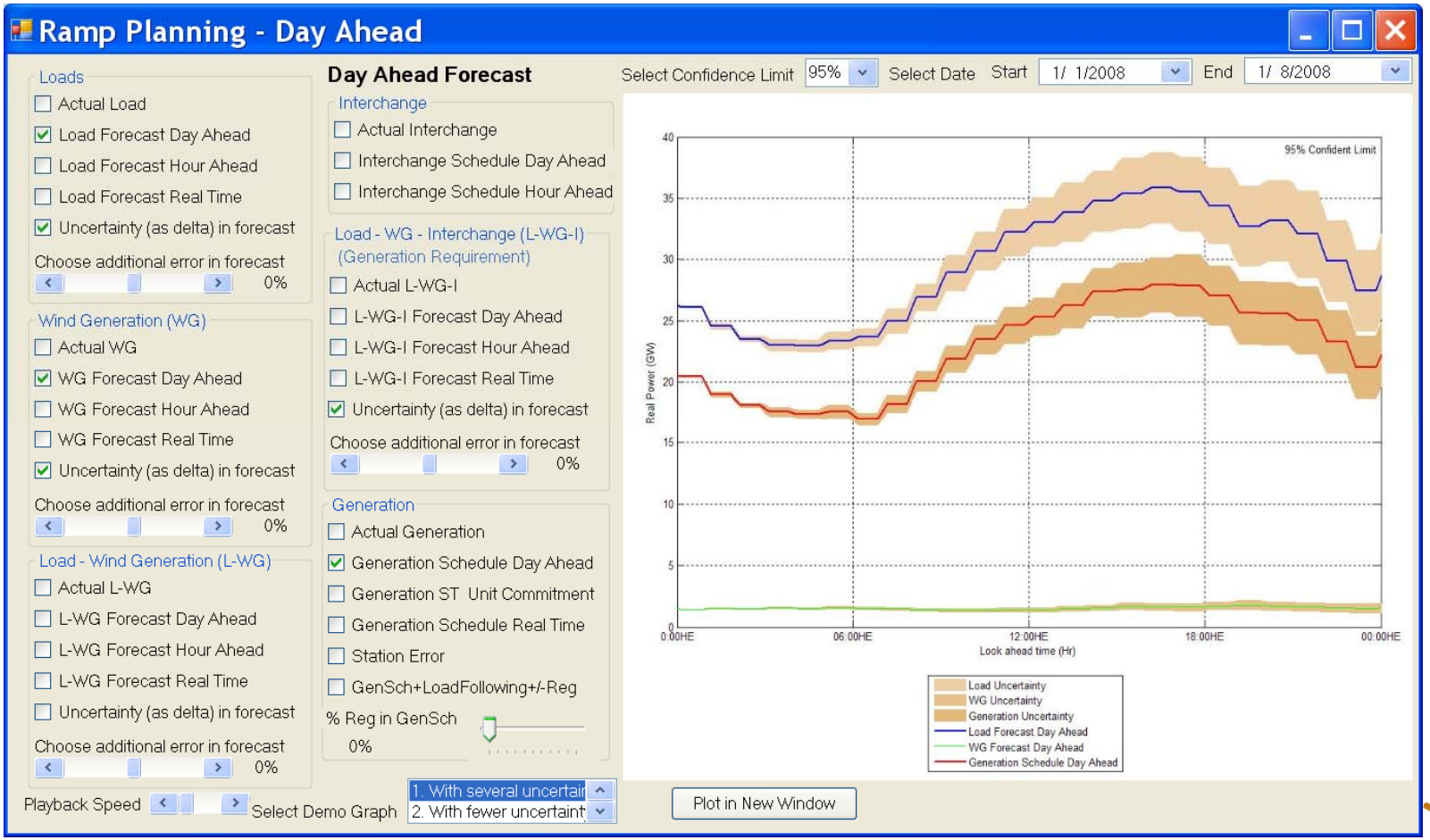
CAISO Feedback – 1 hour ahead and 5-hour ahead Ramping and Capacity Probabilities



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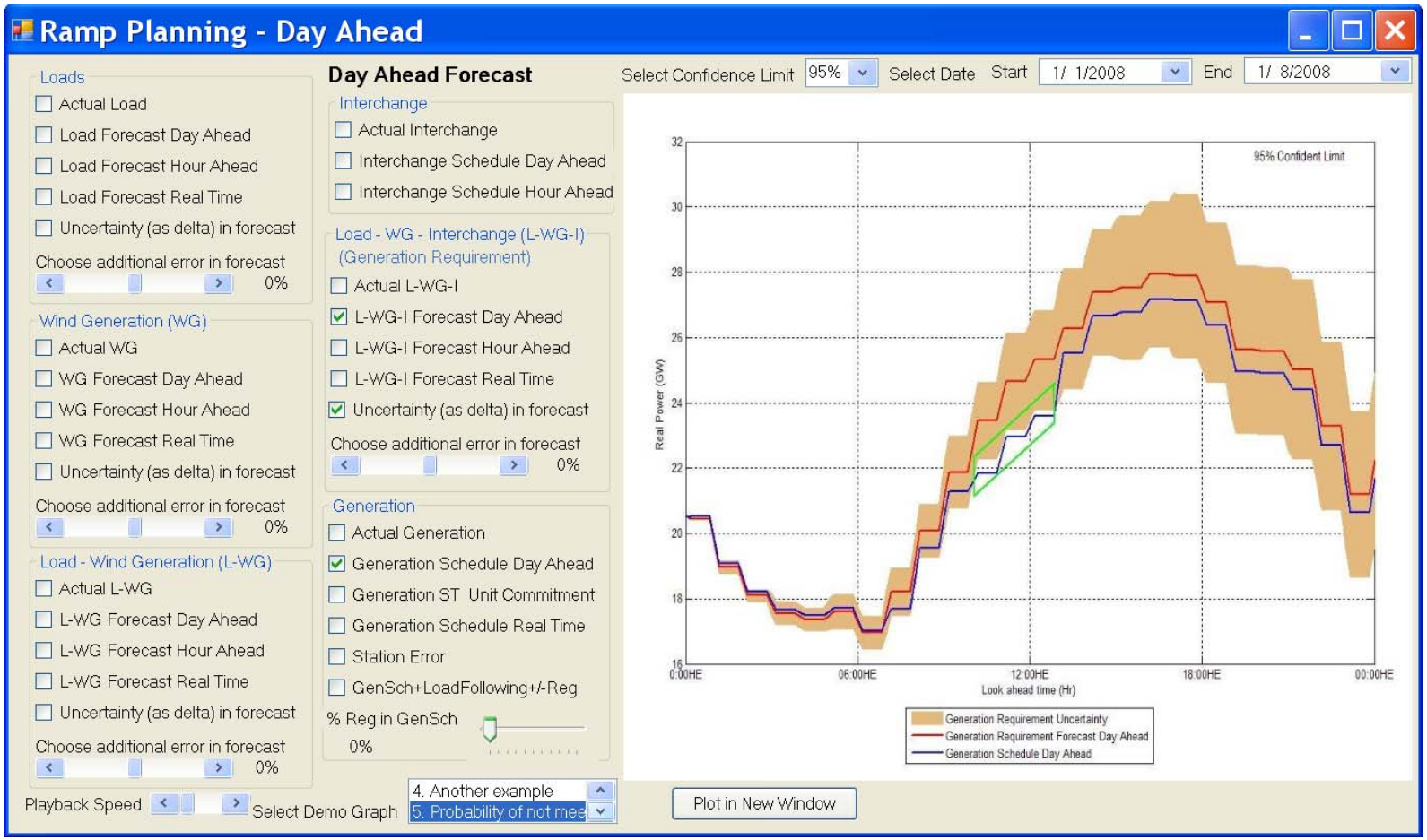

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Summary - I

- Ramping Tool
  - Draft Specifications
  - Simplified Tool designed for CAISO feedback under development
  - Many models developed

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Summary - II

- Schedule:
  - Development of System Specifications - draft
  - System Development – Aug 2010
    - Simplified Ramp Tool for CAISO feedback – Dec 2009
  - Offline testing and evaluation using historical data – Sept 2010
  - On-Line Testing, Linked with EMS - Jan 2011
  - Installation of System and Operator training –Sept 2011
  - Operating Manual Sept 2011

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Summary - III

- Emphasis on
  - good specifications (use cases)
    - Feedback
  - Design (sequence diagrams)
  - Database
  - Validation with historical data
  - Testing
  - Documentation

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Questions/Comments?

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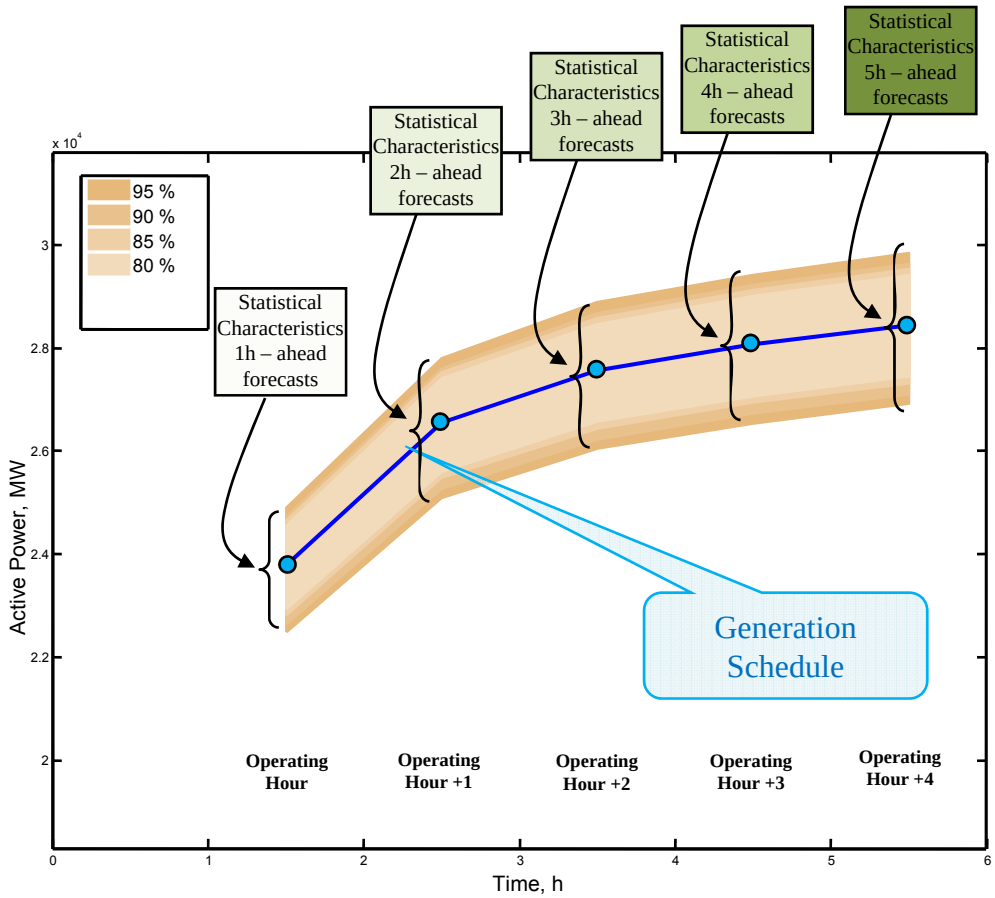
Forecasted Capacity Requirement



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Main Tasks

- Development of System Specifications (6 months)
- System Development (12 months)
- Offline testing and evaluation using historical data (6 months)
- On-Line Testing, Linked with EMS (4 months)
- Installation of System and Operator training (5 months)
- Operating Manual (3 months)

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Development of System Specifications

- Develop a detailed requirements document and functional specification for the online analysis and visualization system
  - User requirements
  - External systems interface requirements (export from and import to CAISO EMS system)
  - System database design
  - Desired system functionality
  - Conceptual system screens
  - Etc.

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System Development

- Development of methods and algorithms for the underlying functions, along with a database, user interface, etc., as described in the system specifications

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Offline Testing and Evaluation

- Test and demonstrate the system and test plan using CAISO system historical data
- Make necessary modifications and improvements based on comments and opinions from power system operators and advisory board members

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On-line testing and Link with EMS

- Link the developed system with the CAISO EMS to obtain real-time data
- Test the system in a real-time environment
- Make modifications and improvement as necessary

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Installation of System and Operator training

- Install the developed system into the CAISO control room
- Provide training and maintenance
- Make modifications and improvement as necessary

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Advisories and Alarms

- Advisories and Alarms

  "Within the next hour xx MW must be committed with a ramp rate of at least yy MW/min"

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Data Request, Network Reduction, Models, CalSO request, Specs Document,AVI, VB

- Ppt in C:\Documents and Settings\d3x998\My Documents
- Docx in C:\Documents and Settings\d3x998\My Documents\Wind\DeliverableAugust2009\Wind\Integration

- Sequence diagrams, use cases
- AVI

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Wind Integration and Visualization

- EMS integrated tools will be developed to accomplish the following:
  - Make power grid operators aware of ramping requirements, compare them to available capability
  - Predict future ramping requirements (2-3 hours ahead) and provide alternative strategies, to help grid operators mitigate possible related problems
    - System should work with 5 minute resolution and provide confidence intervals and probabilities for meeting the expected ramps
  - Predict the impacts of intermittent generation on congested transmission paths, voltage levels and reactive power margins and provide re-dispatch options

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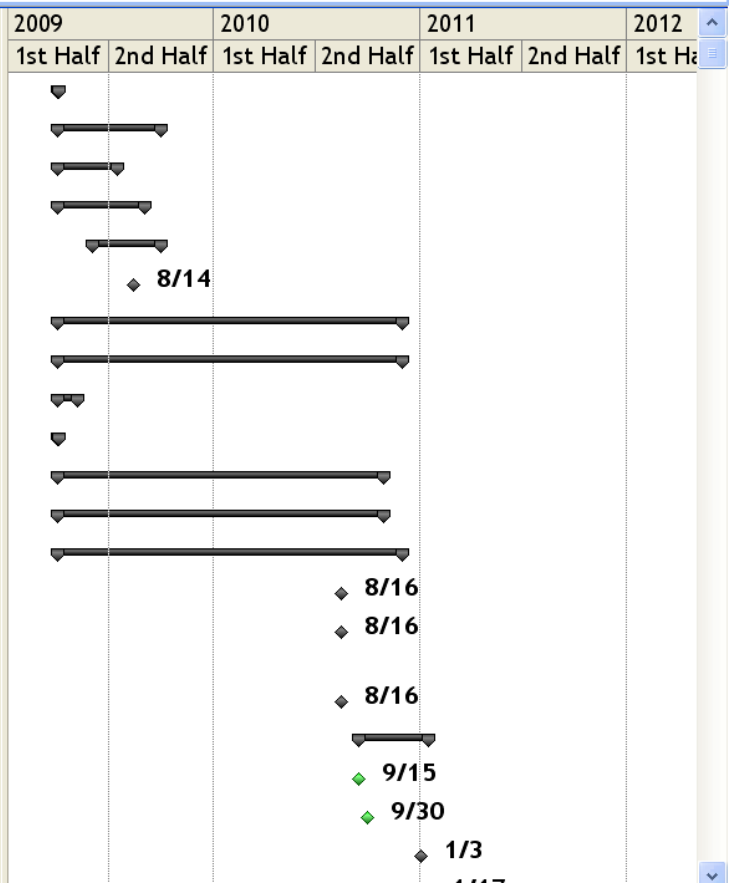
Gantt Chart

	Task Name
1	**1. Administration**
12	**2.Develop System specifications**
13	**user requirements and desired system functionality**
28	**conceptual system display screens**
33	**proposed development plan**
39	Requirements Document, Systems Specification and Development Plan
40	**3.System Development**
41	**Develop the system: design, methodology, software**
42	**Develop schematic system design**
53	**Data Access Layer Design**
58	**Ramping Tool**
132	**Congestion Tool**
153	**Software Development**
160	System Development Report
161	Alpha Version of System: Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation
162	Testing Specification: Off-line testing of Alpha System
163	**4.Offline testing and evaluation using historical data**
164	Draft Off-Line Test Plan
165	Final Off-line Test Plan
166	Performance Test Report: Off-Line Alpha Testing



Gantt Chart

	Task Name	2009		2010		2011		2012
		1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Ha
167	collect comments and opinions from power system operators and advisory board members					1/17		
168	Testing Specification: On-line testing of Alpha System					1/17		
169	**5.On-Line Testing, Linked with EMS**							
170	Testing Specification: On-line testing of Alpha System					1/17		
171	Acceptance Test Criteria: Requirements for the CAISO Installation					1/17		
172	Draft On-Line Test Plan					1/17		
173	Final On-Line Test Plan					1/31		
174	Performance Test Report: On-Line Beta Testing						5/16	
175	Beta Version of System: On-Line Analysis and Visualization of Operational Impacts of Wind and Solar Generation						5/31	
176	Performance Report: Acceptance Test						5/31	
177	**6.Installation of System and Operator training**							
178	Draft						8/1	
179	Final						8/11	
180	Draft Outline of the Final Report						9/5	
181	Final Outline of the Final Report						9/15	
182	Draft Final Report						9/30	
183	Final Report						10/20	
184	Fact Sheet: retrospective project summary						10/20	
185	**7.Operating Manual**							
186	Draft						10/3	
187	Final						10/17	