31ST ENERGY MANAGEMENT CONGRESS WEST

Intelligent Agents that Enable a Smarter Grid

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aesc
energy solutions for a changing world

35
YEARS OF ACHIEVEMENT

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THE ASSOCIATION OF ENERGY ENGINEERS

INTELLIGENT AGENTS
THAT ENABLE A SMARTER GRID

Agenda

- AESC Background

- Agent / Project(s) Background

- "Agents for Renewables" System Description

- Demonstration Results

- Questions?

AESC AT A GLANCE

- Engineering consulting services company specializing in the energy industry

- Incorporated in CA in February 1994

- Currently, thirty-eight employees

- Personnel in Carlsbad, San Diego, Pasadena, Sacramento, Fresno & Concord

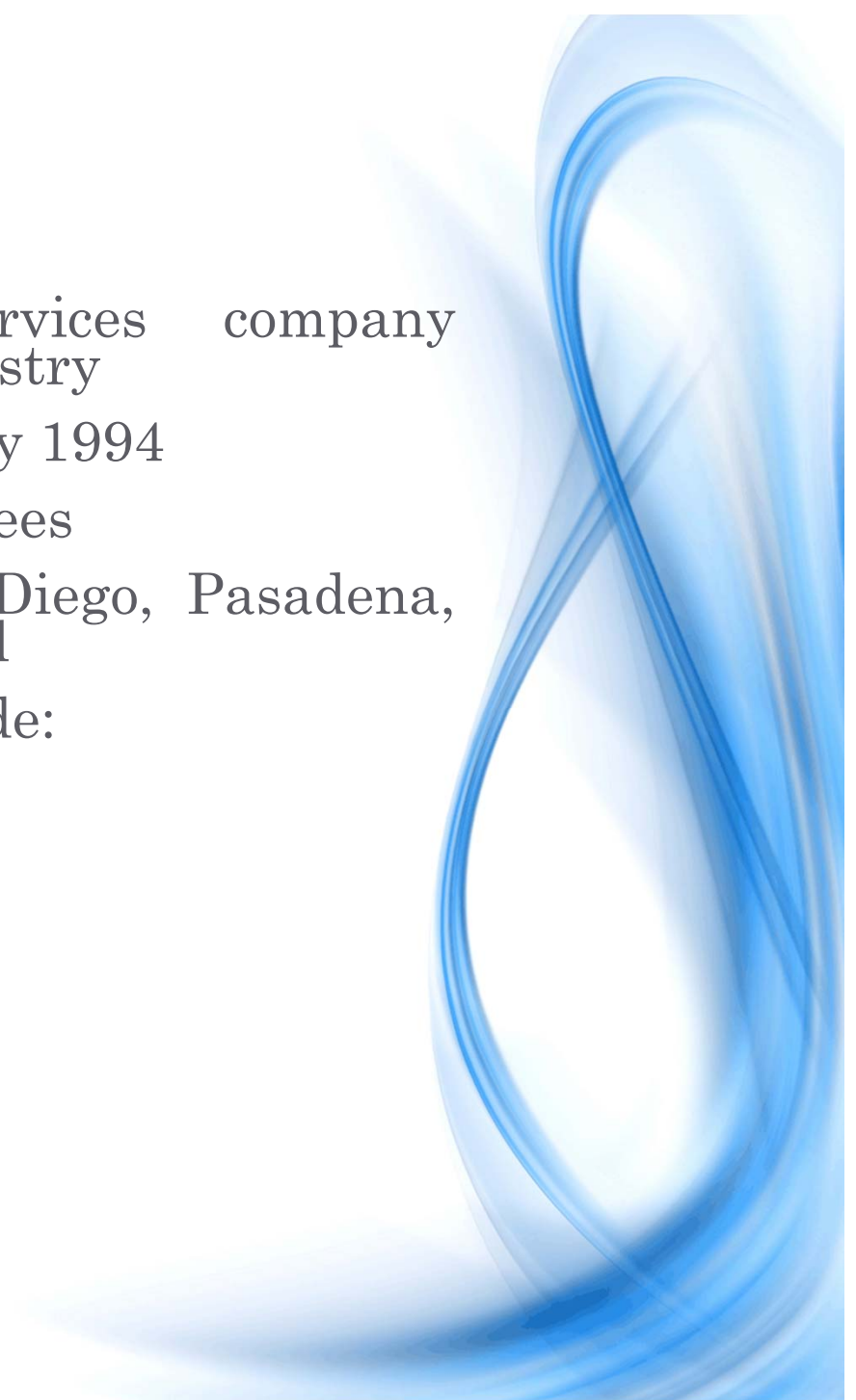- Primary Business Areas Include:

    Energy Efficiency
    Distributed Generation
    Technology Development
    Technology Evaluations
    Utility Engineering Support

    see www.aesc-inc.com and
        www.smartder.com

WHAT IS AN INTELLIGENT AGENT?

Intelligent Software Agents

- An Intelligent Agent acts on behalf of another and ….

- Executes autonomously & operates in real-time

- Communicates/collaborates with other agents or users

- Is able to exploit domain knowledge

- Exhibits goal-oriented behavior

- Think "real-estate agent"

Multi-agent (Agency) Advantages

- Provide distributed processing

- Agent complexity is kept low while agency intelligence is high

- *Agent-based solutions are more open and extensible*

- *More robust solution*

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WHY INTELLIGENT AGENTS?

An Already "Smart" Grid Needs to Get "Smarter"

- **Grid control is already "smart"**

    - Dynamic control of a system without any appreciable storage that balances supply and demand in real time.

- **But Grid control isn't "smart" enough**

    - The system was designed for power flows in one direction – from centrally located generation to end users.

    - Local intelligence/decision-making is needed in order to cope with:

        - Increased penetration of renewables / DG / Storage.

        - Increased importance of demand response as a alternative to generation

        - Presence / availability of smart end use devices (e.g., smart charging, etc.)

        - Presence of/availability of smart inverters that can provide assistance with VAR/voltage control.

        - Smart/connected end users

        - Transactive Energy??

AGENT-BASED PROJECT HIGHLIGHTS

- 1998 – California Energy Commission (CEC) Public Interest Energy Research (PIER) project, Smart*DER Research.

  Developed operating model, algorithms, and software, referred to as Smart*DER, to manage Distributed Generation (DG) assets and peak loads utilizing real time pricing signals, weather data, and building performance inputs.

- 2000 – California Energy Commission (CEC) Public Interest Energy Research (PIER) project, Smart*DER Demonstration:

  Follow on 'real world' demonstration of Smart*DER technology, this pioneering effort demonstrated the viability of intelligent agents to effectively control DG assets and effectively manage peak loads in a complex Critical Peak Pricing (CPP) environment.

AGENT-BASED PROJECT HIGHLIGHTS

- 2003 – Department of Energy (DOE) Small Business Innovative Research (SBIR) Grant, Power Neighborhoods Aggregation:

  Project demonstrating the potential of integrating DG assets at previously unrelated sites within a feeder or multiple feeders, and forming 'Power Neighborhoods' whose assets and loads were intelligently managed utilizing Intelligent Software Agents and a web-based auction hierarchy.

- 2008 – California ISO (CAISO) & California Energy Commission (CEC), Renewable Generation, Dynamic Control & Capacity Management:

  The CAISO required a solution that enhanced both the visibility and dynamic control of intermittently available generation and transmission resources.

"AGENTS FOR RENEWABLES" PROJECT PARTICIPANTS

- AESC (Prime) -- Agent Technology
- BPL Global Ltd – Communications / enerView / Power SG
- Beacon Power -- Flywheel Storage Unit
- Quanta Technology – Load Flow Modeling
- E-Marc Engineering – Field Support
- SCE (Engineering and Operations Support)
- CEC
- CAISO
- Western Wind (Wind Farm Operator)
- Stakeholder's Working Group
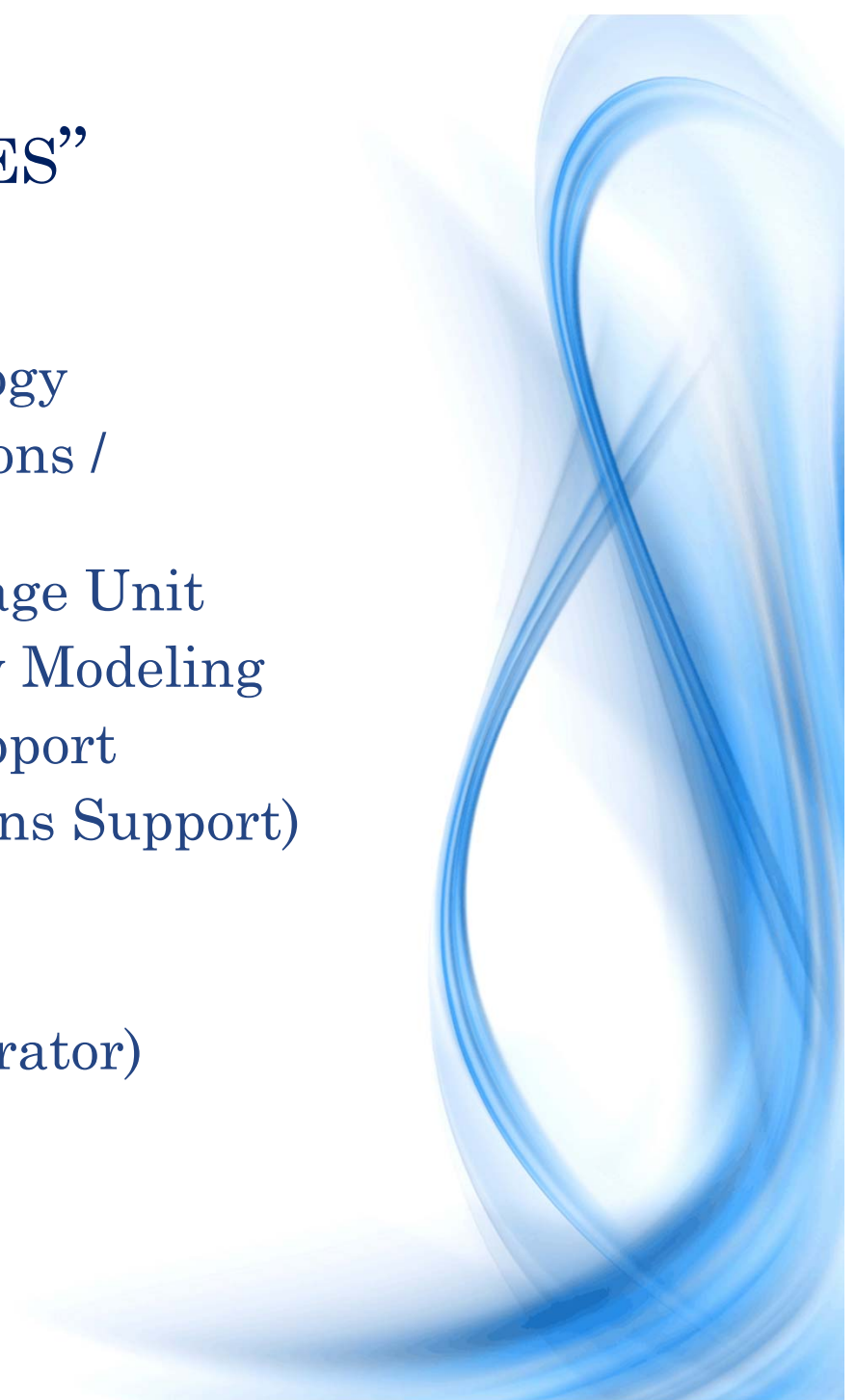
"AGENTS FOR RENEWABLES" PROJECT GOALS & OBJECTIVES

- The GOAL was to successfully apply and demonstrate that agent technology with storage:
  - Increases the capacity and use of existing transmission facilities for the benefit of the consumers in California.
  - Control Flywheel storage technology to improve the dynamic control of the wind generation resources.
  - Coordinate energy production and delivery from wind generation.
- Targeted Opportunities after Phase 1 Investigation effort:
  - 66 kV Subtransmission System Limitation Opportunities
    - Improve capacitor bank control to reduce Tehachapi area limitations resulting in wind curtailment events.
    - Coordinate wind farm assets (kW & kVAR) to mitigate curtailment
  - Storage System Opportunities
    - "Behind the meter" location to facilitate installation
    - Assist with voltage / VAR control

System Schematic
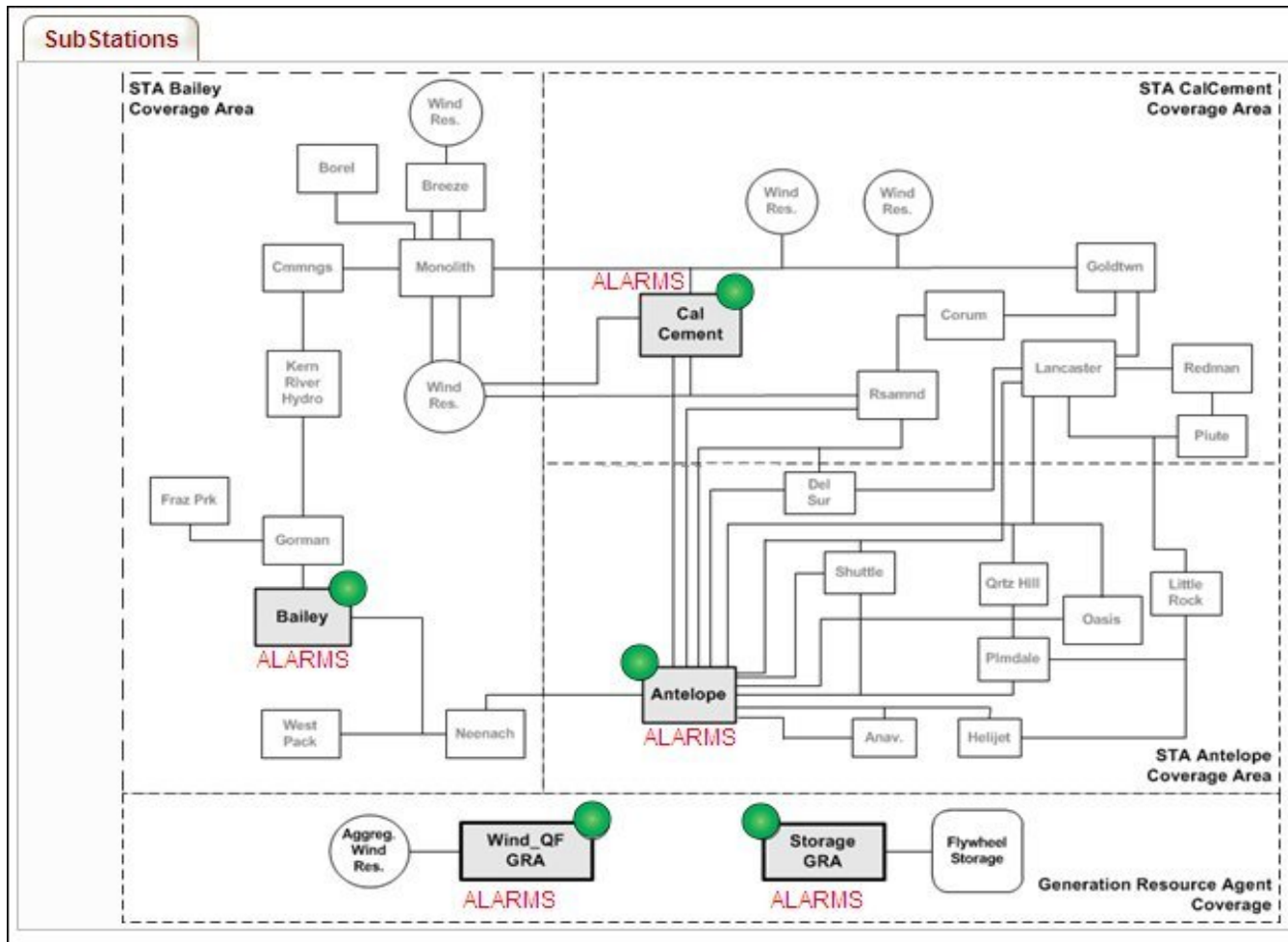
Three Subtransmission Agents (STA) and two Generation Resource Agents (GRAs), monitor and manage subtransmission, generation & storage assets.

AGENT-BASED MANAGEMENT SYSTEM SUMMARY

- Agent connectivity and asset mix are driven by the physical configuration of the system (connectivity, available SCADA data, etc.).

- Each STA:

  ✓ Manages subtransmission system assets within the confines of its coverage area (i.e., capacitor banks, etc.).

  ✓ Continuously monitors parameters (SCE SCADA data) associated with its own physical environment and shares status information with other "connected" STAs within the control area

  ✓ Uses a _Bayesian Belief Network (BBN)_ to determine when action is warranted.

  ✓ Takes or recommends action based on an "action table" developed based on SCE operating orders, load-flow modeling results and SCE Operator input – action, when taken will be consistent for all STAs

- Any STA can detect, and initiate an action in response to a condition.

- All actions occur within a 5 second window defined by the SCADA data update rate.

AGENT-BASED MANAGEMENT SYSTEM SUMMARY CONT'D

## Flywheel Storage System Operation

- The agent-based system will control the flywheel energy storage system.
- Specifically, a GRA located at the flywheel storage unit:
  - Develops a pseudo frequency regulation signal based on the CAISO ACE to operate the flywheel storage unit during "normal" operation.
- GRA communicates with the STAs to:
  - Provide flywheel storage unit status information
  - Receive short term flywheel storage system operating commands from STAs as dictated by the system action table

BAYESIAN BELIEF NETWORK (BBN)
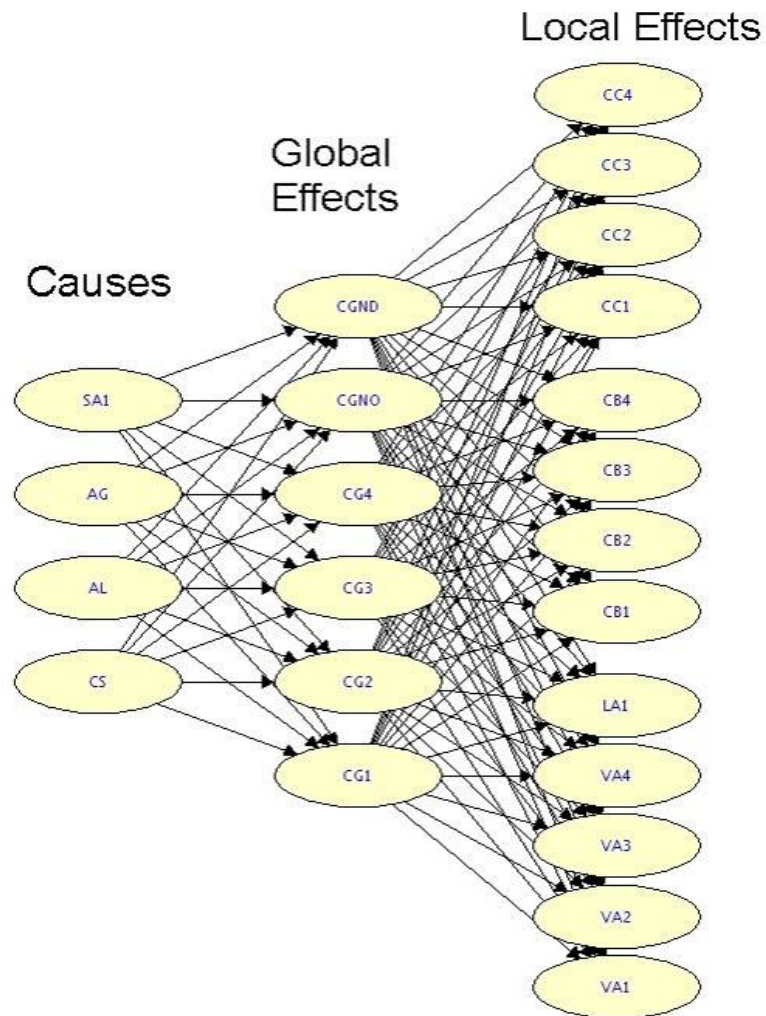
o A network of cause and effect "nodes" (each node with multiple states)

o "Connection" strengths based on probabilities

o Probabilities developed based on "training" (simulated or actual data or set manually based on experience.

o BBNs are robust in that inputs can be missing/unknown and the system will continue to operate.

BBN Status Display Example
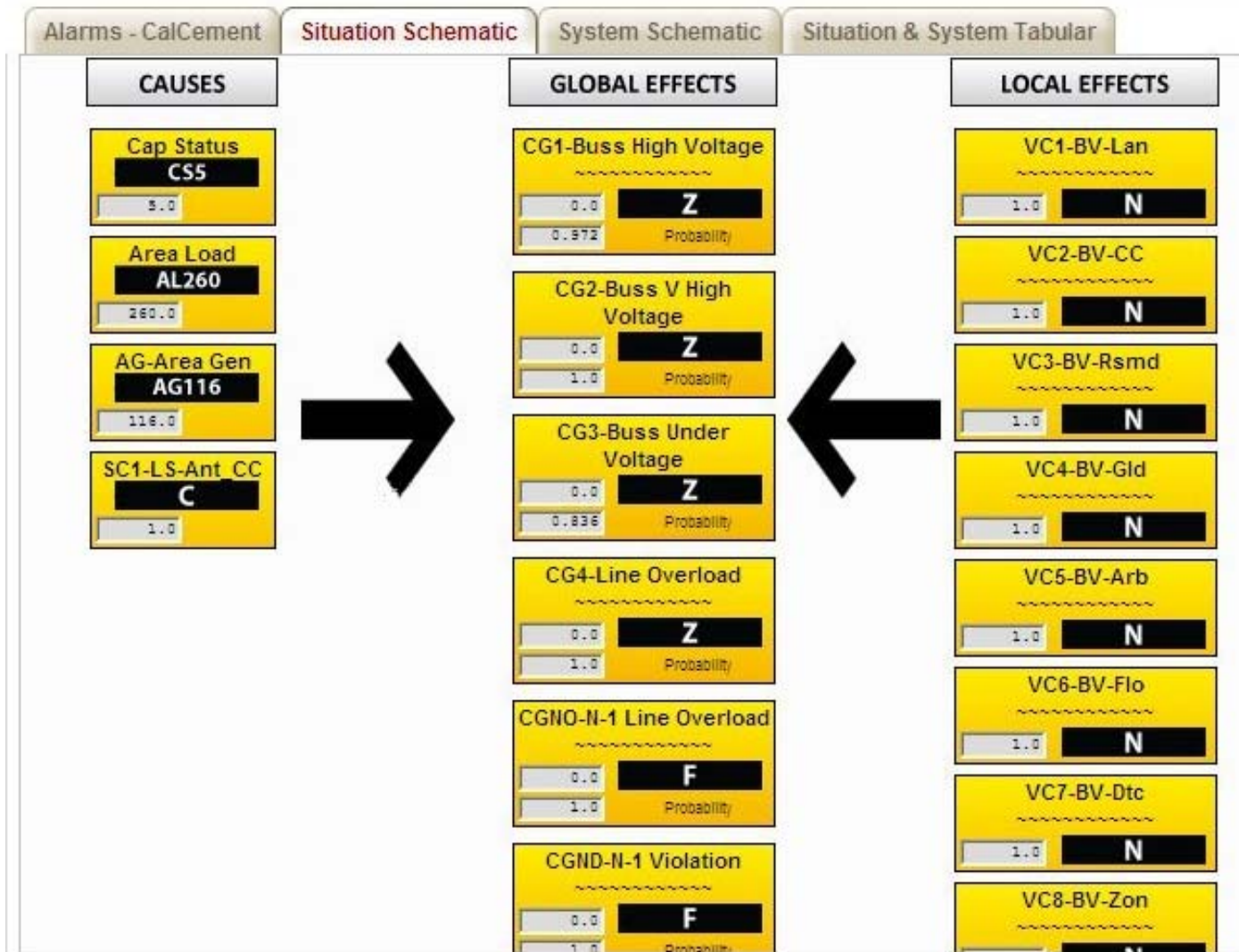
AGENT-BASED MANAGEMENT SYSTEM SUMMARY CONT'D

Actionable Conditions and Associated Actions

| Condition	Priority	Threshold	Delay (sec)	Potential Actions (in order of occurrence)
Line Overload	1	> 1 P.U.	60	Curtail Wind & Storage – Absorb Energy
Very High Voltage	2	> 115%	15	Deactivate cap bank, Storage - Absorb Max VARS
Under Voltage	3	< 95%	60	Activate cap bank, Storage – Inject Max VARS
High Voltage	4	> 105.9% (66kV) > 110% (12kV)	120	Deactivate cap bank, Storage – Hybrid, Storage – Abs Max VARS
N-1 Overload	5	NA	30	"Consider Action"
N-1 Violation	5	NA	30	"Consider Action"

- Capacitor bank actions and curtailment(s) are recommendations

- Flywheel storage system actions are implemented.
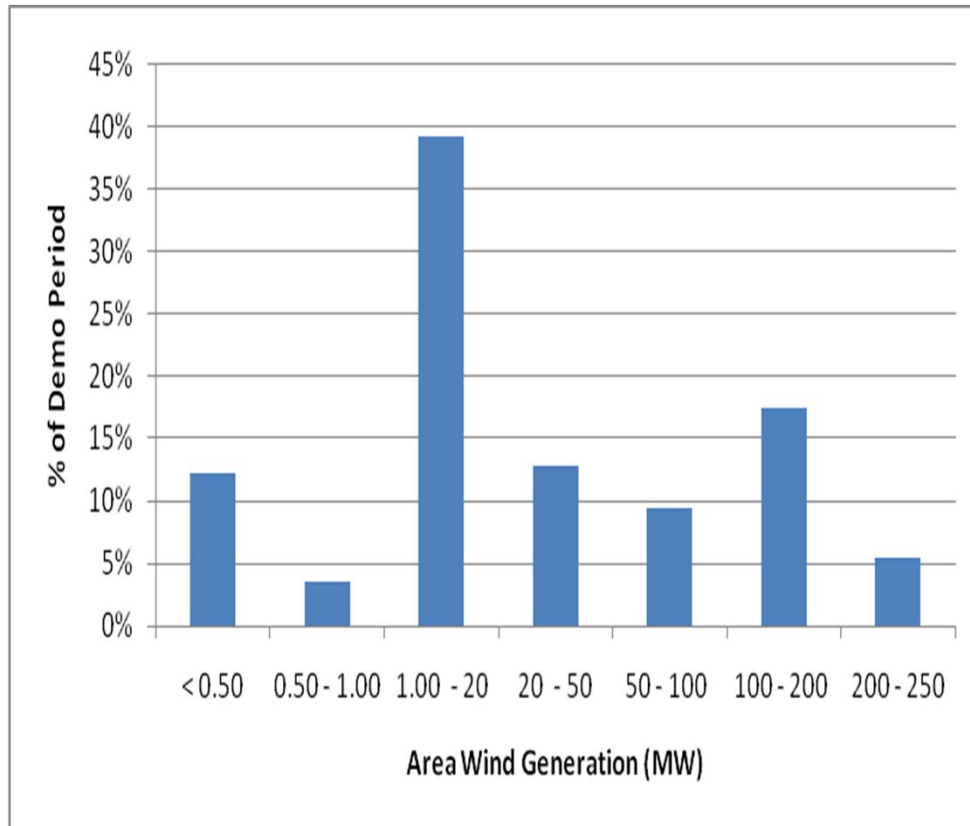
SYSTEM PHOTOS

Tehachapi Installation – Control Enclosure w/ Flywheel Unit in Ground

SYSTEM PHOTOS
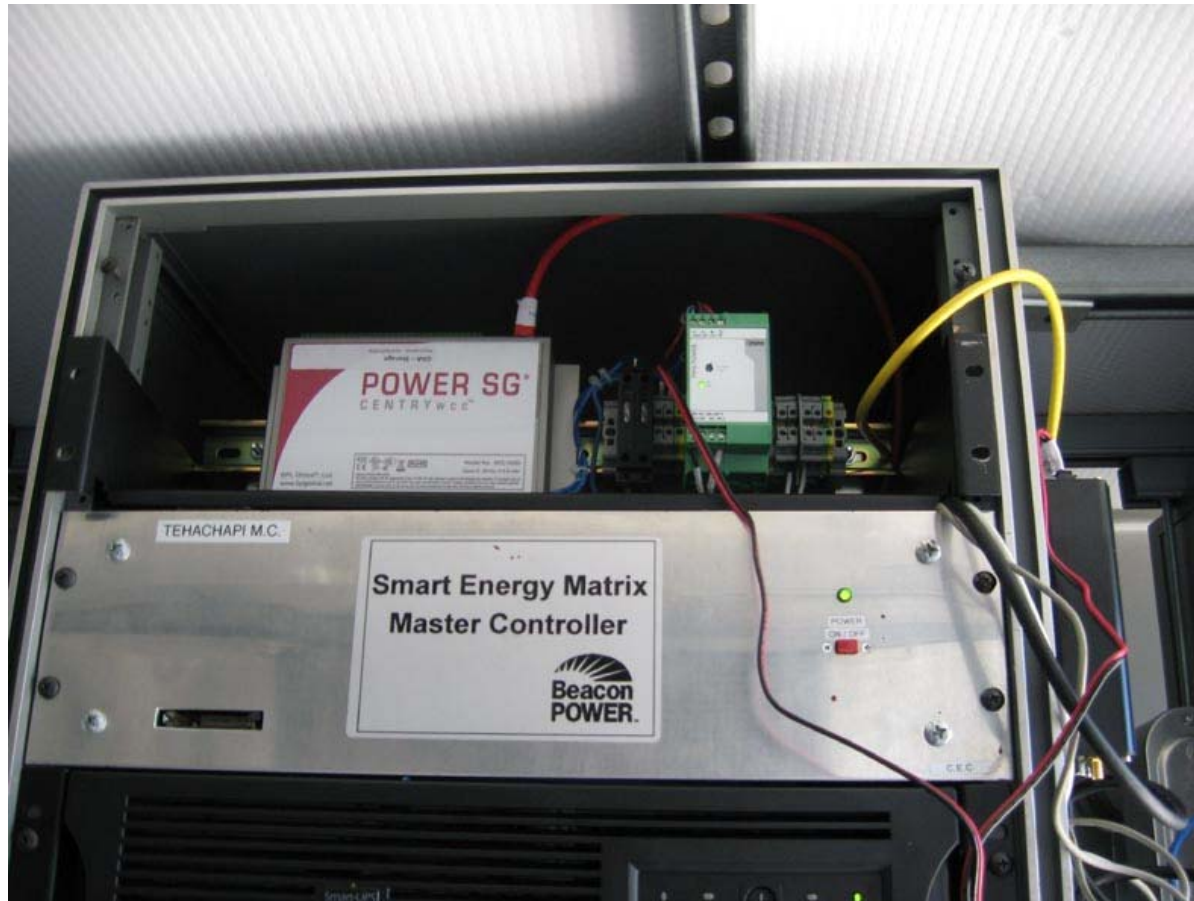
Tehachapi Installation – Centry WCC / GRA Agent above
Flywheel Master Controller

DEMONSTRATION RESULTS

- The demonstration period began on December 1, 2010 at 4 p.m. and ended on February 11, 2011 at 5 p.m.

- Area wind generation levels were relatively low with levels below 20 MW 55% of the time and over 200 MW just 5.5% of the time.

- Minimal capacitor banks were needed with 6 banks or less operating over 90% of the time.

DEMONSTRATION RESULTS CONT'D

o Agent availability was measured based on an agent's ability to accomplish its overall mission.

o Based on these broad criteria, the agents still achieved a high level of availability. With the exception of the GRA Storage agent, the agents were available over 99% of the time.

o Factors affecting availability included messaging issues, cell modem outages.

o A more fully integrated system would not experience these types of messaging issues.

Agent	December	January	February	Total Availability
STA Antelope	99.6%	99.0%	99.8%	**99.4%**
STA Bailey	99.5%	99.0%	99.7%	**99.3%**
STA Cal Cement	99.6%	99.0%	99.6%	**99.4%**
GRA Wind	99.9%	99.3%	100.0%	**99.7%**
GRA Storage	93.1%	83.4%	99.46%	**90.1%**

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DEMONSTRATION RESULTS CONT'D

Storage system operation summary:

○ Operated in Frequency Regulation mode 97% of the time, 'Hybrid' mode operation for remaining 3%.

○ Was depleted approximately 7% of the time and was at full charge just 4% of the time. The average power output command provided to the storage system by the Storage GRA was 0.001.

Operation	December	January	February	Overall Demo Period
Frequency Regulation	96.7%	97.8%	97.1%	97.0%
Hybrid Mode (Freq Regulation + Mod. VARS)	3.3%	2.2%	2.9%	3.0%
Depleted (Stored Energy < 500 Wh)	6.1%	7.2%	7.0%	7.0%
Full Charge (Stored Energy > 25000 Wh)	4.6%	3.6%	2.4%	4.0%

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DEMONSTRATION RESULTS CONT'D

BBN Performance Summary:

o The BBN performed well given the configuration and training limitations:

   o 5 or more capacitor banks on-line;

   o 260 MW or more of area load; and

   o 116 MW or more of area generation.

o BBN performance was optimized over the limited range specific to curtailment. Operation within this range was characterized by detection of system conditions either in step with, or in advance of operator actions.

o The BBNs operated successfully outside of the original configuration range as a result of BBN training using data collected prior to and during the demonstration period (as opposed to simulated data).

o Additional modeling and associated statistical analysis is needed to configure/train the BBN to operate consistently across the full range of potential operation.

DEMONSTRATION RESULTS CONT'D

BBN Performance Summary continued:

- The BBN detected one known curtailment event that officially began on 12/10/2010 at 18:58 and ended on 12/11/2010 at 09:49.

- Indications are that BBN managed curtailment would have been significantly briefer.

- BBN control of storage would also have come into play lessening the need for curtailment.

- More study is needed.
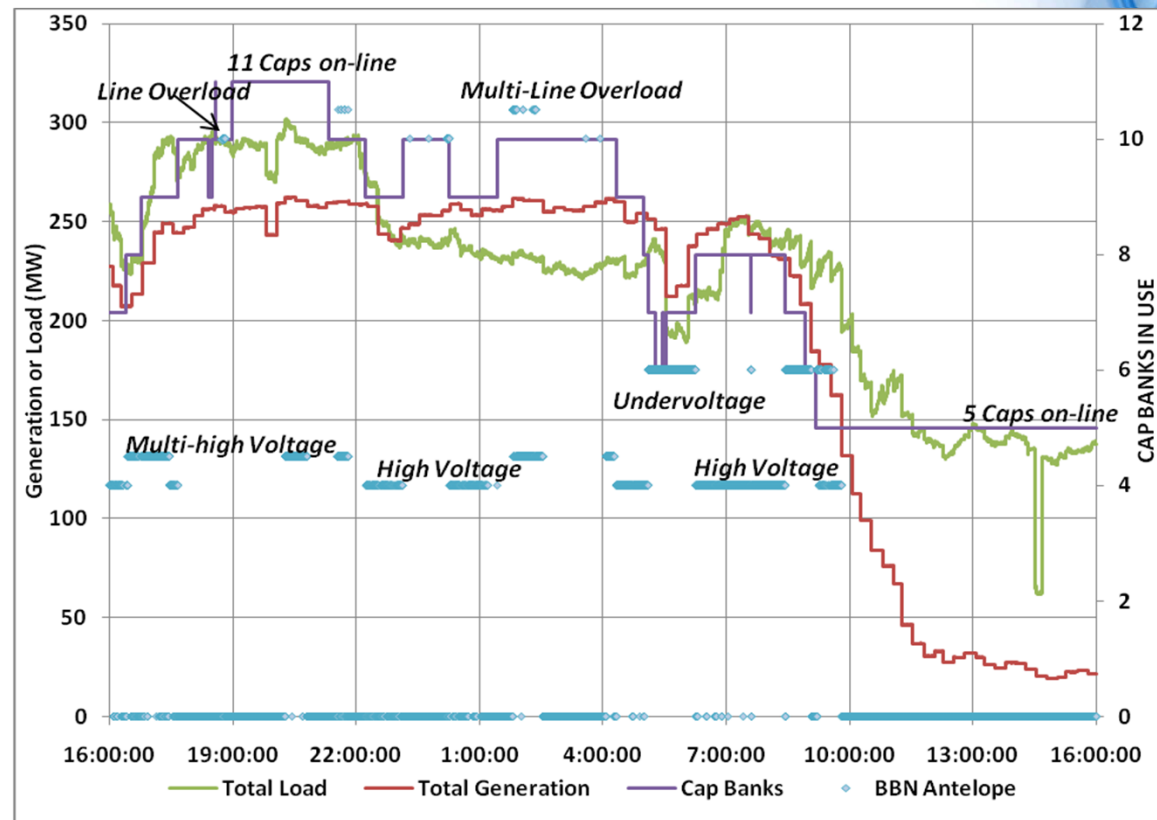
DEMONSTRATION RESULTS CONT'D

Two powerful BBN features were also demonstrated.

o BBN Operation with missing or unknown data

  ➢ At one point in the demonstration a faulty sensor was detected that was not easily replaced. The STA simply designated this BBN input as "unknown" and the BBN was subsequently able to operate normally.

o BBN Ability to "learn" system behavior

  ➢ On 14 different occasions one or more of the BBNs encountered an operating scenario (combination of BBN inputs) that it had not previously encountered. When this occurred AESC updated the BBN training using <u>actual data </u>from the period in question. The BBN configuration was updated to include the new training and the issue was resolved.

o An automated system that takes advantage of both of these features would provide for more robust operation.

CONCLUSIONS

To summarize, the CEC PIER project was highly successful. During the project, the project team successfully:

➢ Identified a significant opportunity to demonstrate the feasibility of the agent-based approach.

➢ Specified and implemented a multi-agent system (MAS) that operated reliably during the demonstration period.

➢ Configured and implemented a MAS that subsequently performed well during the demonstration, although it was limited by the boundaries of the initial modeling and configuration effort.

➢ Demonstrated powerful BBN capabilities, the ability to learn and the ability to operate in the presence of missing or unknown data.

CEC Legal Notice

THANK YOU

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