



Innovative Distributed Power Interconnection and Control Systems

Subcontract Number: 30605-04

Principal Investigator: Karen DePodesta - GTI

Subtier Principal Investigator: Randall West - Encorp

NREL Technical Monitor: Tom Basso

Electric Distribution Transformation Program

**2004 Annual Program and Peer Review Meeting,
October 28-30, 2003, Coronado (San Diego), California**

..... Presentation Overview

- Project Objectives
- Relevance to Problems & Needs
- Technical Challenges of Current Practices
- Life-Cycle Project Timeline with Milestones and Budget, by FY
- Technical Approach
- FY03 Progress and Accomplishments
- Planned Activities for FY04
- Summary of Out-year Activities
- Impacts and Benefits
- Interactions & Collaborations
- Contact Information



Project Objectives

..... Project Objectives



Key enabling technologies and system-level integration to help Distributed Energy market participants more *fully capture the total value provided by Distributed Generation products.*

- Cost-effective DG grid interconnection products, software, and communication solutions
- Improved economics for broad range of DG power systems
- Enhanced DG product capability to integrate, interact, and provide operational benefits

Relevance to Problems & Needs

..... Relevance to Problems and Needs



- Electric Distribution Transformation Program
 - Supports GridWise™ operations of all distribution systems and components for interoperability and seamless operation of modernized electric infrastructure
 - Supports the development of technologies and standards that enable the integration of Distributed Energy Resources (DER) including distributed generation
 - Supports Distribution Interconnection Standards and Technologies Program Area to better integrate DER with the electric distribution system

..... Relevance to Problems and Needs



- EDT's Distribution Interconnection Standards & Technologies Program Area Needs:
 - Develop standards for DER interconnection, testing, applications, safety, and control/monitoring
 - Develop advanced modular plug-and-play interconnection and control technologies for integrating DER with electric power systems and local loads for seamless operation
 - Cost effectiveness of these technologies is a major challenge of "Grid 2030" roadmap

..... Relevance to Problems and Needs

- Project meets EDT's needs by providing:
 - Active participation in DER interconnection standards
 - Industry standard IEEE 1547 compliant controller
 - Lower cost interconnection for DG systems
 - Open but secure interconnection communications
 - Distributed energy and grid interoperability
 - Interconnection protection
 - Site metering
 - Communications
 - Aggregate level commands
 - On site power system control and management

..... Relevance to Problems and Needs

- High total installed cost for interconnection of DG systems
 - Reduce physical costs for equipment (switchgear, relays, controls)
 - Reduce transaction costs of working with utilities and others
 - Reduce costs to integrate and interact with electric grid
- Small scale systems below utility minimum DG size limits
 - Enable aggregation to improve economic value of DG systems
 - Provide value-added benefit to electric power system

..... Relevance to Problems and Needs

- Lack of cross-platform compatibility among systems
 - Enable various DG products to work together (engines, fuel cells, etc.)
 - Enable pooling of DG systems by networking and control
- Limited functionalities and features
 - Provide higher processing performance and control sophistication
 - Allow for remote monitoring and detection of system fault conditions

..... Relevance to Problems and Needs

- Technology Driven By Customer Needs
 - Cost savings
 - Reliability
 - Good power quality
 - Interconnect security & safety
 - Ease of system integration
 - Ease of use
 - Access to data & knowledge
 - Flexibility
- Application Flexibility
 - Customer/Utility-Owned DG
 - Interruptible rate programs, relieving utility constraints
 - Retail-Type DG
 - Campus power, inside utility meter
 - Critical Power Systems
 - Institutional, financial, e-commerce, industrial
 - CHP/Cogeneration
 - Wholesale-Type DG
 - Wholesale energy/capacity trading, Distribution grid peaking

...control and software solutions that are flexible and can simplify complicated system problems

Technical Challenges of Current Practices

Technical Challenges of Current Practices



- Coordination of multiple interest groups
- Overcoming proprietary nature of communications
- Acceptance of new technologies in marketplace
- Time and cost required to implement systems
- Aggregation of small DG systems

Life-Cycle Project Timeline

..... Life-Cycle Project Timeline by FY

- Milestones/Deliverables
 - FY2004 Q1 – 1st Quarterly Report
 - FY2004 Q2 – 2nd Quarterly Report
 - FY2004 Q3 – 3rd Quarterly Report
 - FY2004 Q4 – Draft Annual Report
 - FY2005 M2 – Final Annual Report

- Budgets

	Total (\$)	DOE/NREL (\$)	Subcontractor (\$)
Base Period (FY2001-FY2003)	\$656,550	\$321,710	\$334,840
Option Period 1 (8/03-9/04)	\$656,550	\$321,710	\$334,840
Option Period 2 (8/04-9/05)	\$656,550	\$321,710	\$334,840
Total	\$1,969,650	\$965,130	\$1,004,520

..... Life-Cycle Project Timeline by FY



ID	Task Name	2001				2002				2003				2004				2005			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	
1																					
2	Base Year	[Bar]																			
3	Contract Extentions					[Bar]															
4	Option Year 1									[Bar]											
5	Contract Signed																				
6	Task 6: Type Testing of Advanced controller																				
7	Task 7: Develop System Command and Control System																				
8	Task 8: Demonstration of Controlled DP Resources																				
9	Final Report																				
10	Option Year 2																				

..... Program Plan/Tasks



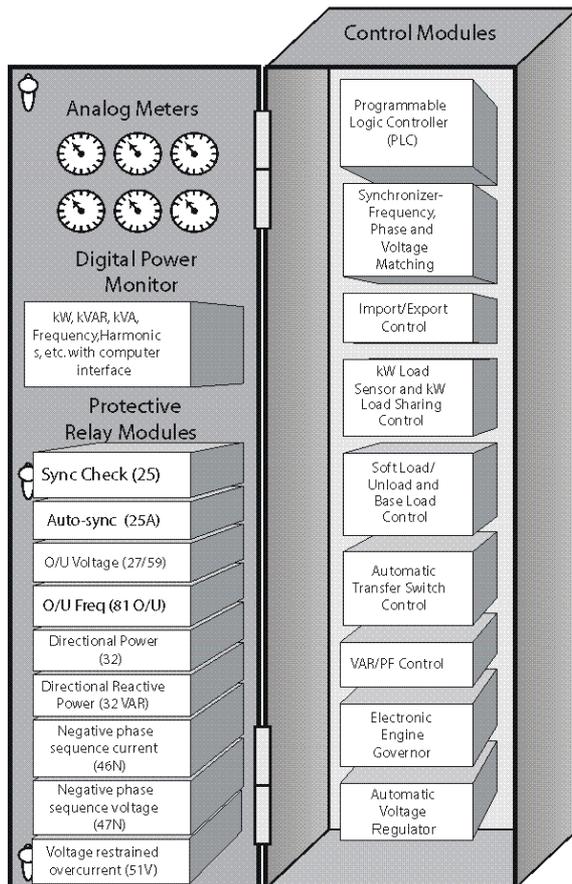
Core Enabling Technology	
Base Year	(1) Develop Prototype Advanced Controller
	(2) Develop Prototype Power Sensing Board
	(3) Expanded Suite of Communication Capabilities
	(4) Interface for Revenue-Grade Meter
	(5) Demonstrate Interconnect DG Device
System Level Command & Control	
Option Year 1	(6) Type Testing
	(7) System Command and Control
	(8) Demonstration of Controlled DG
Interoperability & Communications	
Option Year 2	(9) Interoperability Systems Analysis
	(10) Demonstration of Grid-DG Interoperability



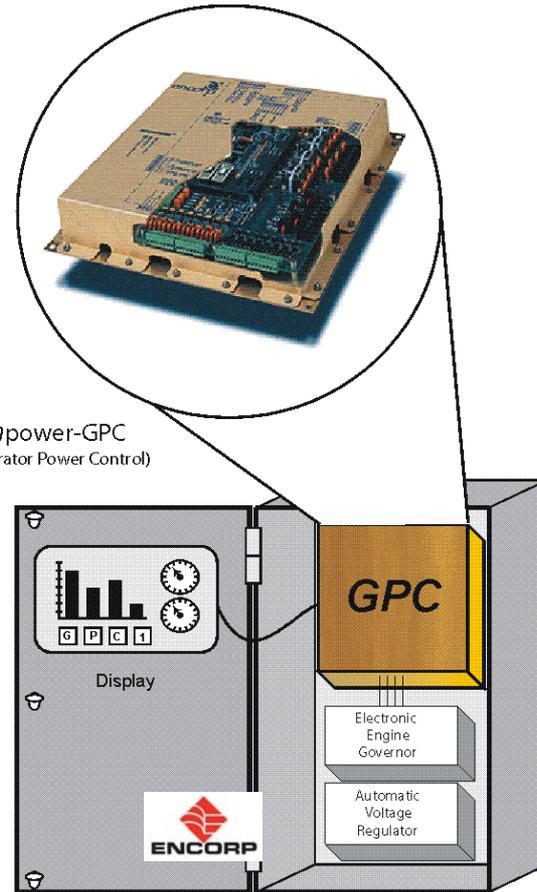
Technical Approach

..... Technical Approach

Traditional Method (Analog)

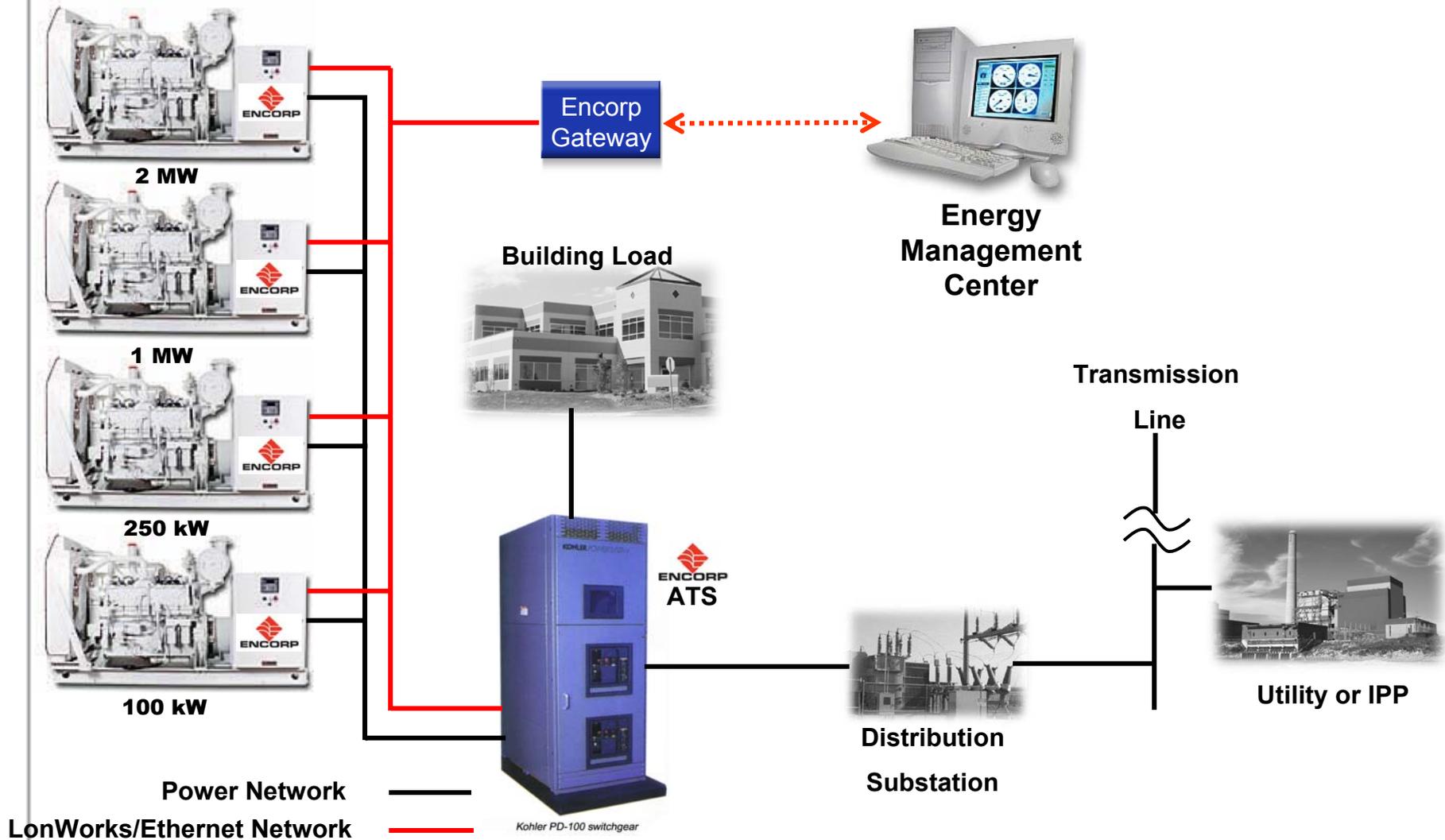


Digital Solution



Technical Approach

End-to-End Energy Solutions



Technical Approach: Three Phase Work Plan



- Base Year: Completed
 - Prototype Controller Developed and Demonstrated
- Option Year 1: Now
 - Type Test Base Year Controller
 - Develop Remote System Command and Control
 - Field Demonstrations
- Option Year 2: Future
 - Further Development/Demonstration of System Benefits and Validation of Industry Communication Standards

..... Technical Approach: Option Year 1



- Task 6: Type Testing of Advanced controller
 - A: Test plan
 - B: Perform Testing and prepare a report
- Task 7: Develop System Command and Control System
 - A: Functional Specification for Command and Control System
 - B: Incorporate these functions into controller
 - C: Develop extended dispatch capabilities
- Task 8: Demonstration of Controlled DG Resources
 - A: Demonstration Plan
 - B: Demonstrations implements several DGs
 - C: Demonstration report with recommendations

..... Technical Approach

- Task 6: Type Testing of Advanced Controller

Really concerned about the overall quality of product

- Starts during the design phase and involves manufacturing, suppliers, customers, engineering, etc.
- Understands test requirements and Engineers the product to meet or exceed these requirements
 - Participate in Test Standards development (e.g.-IEEE 1547.1)

..... Technical Approach

- Task 6: Type Testing of Advanced Controller (Cont'd)
 - Use Structured design methodology and simulation of design
 - Design that performs critical path analysis, stack up tolerances and creating a design with some design margin
 - Early transition of firmware to target system to perform continuous board and code tests during the development process.
 - Perform critical type tests on engineering units prior to certification testing.

..... Technical Approach

- Task 6: Type Testing of Advanced Controller (Cont'd)
 - Evaluate overall test approach
 - Engineering development tests (critical path analysis, design margin, firmware verification, etc)
 - Bench Tests (sub systems/functions, systems single/multiple controllers, etc)
 - Production tests (ICT, Functional – board/module, Calibration, burn-in, FGA, on-going reliability, etc)
 - Systems Tests (sub systems/functions, on generator, multiple generators, etc)
 - Certification Testing “Type Tests” (IEEE, UL, ANSI, IEC, etc)
 - ***Develop a strategy to address each area***

..... Technical Approach

- Task 7: Develop System Command and Control System
 - Critical system information is gathered by the controller's processor
 - Data can be accessed from the controller via web pages that can be stored on the control
 - Data can also be accessed via an OPC server from a separate workstation
 - Events are captured and stored on the control and can be accessed from a separate workstation
 - Information gathered from the control can be uploaded to the Encorp EMC
 - Encorp's EMC will analyze the data and process it into very meaningful web reports such as system performance reports and energy savings reports

..... Technical Approach

- Task 8: Demonstration of controlled DG Resources
 - Create a Demonstration Plan
 - More than 1 site, more than 1 DG in Demonstration
 - Purpose is to evaluate System Command and Control features in a real time grid interconnected environment.
 - Evaluate functionality, features and capabilities
 - Remote dispatch, monitoring and control of DG units
 - Remote Data collection and report generation
 - Remote debug, maintenance and support capabilities/functions
 - Implement Plan
 - Summarize and report results/recommendations



FY03 Progress and Accomplishments

Base Year Accomplishments

..... Base Year Accomplishments

- Core Technology Development
- Functional Product Specifications Outlined for Advanced Controller
 - More powerful processor and enhanced controller architecture
- New Controller Provides Several Advances
 - Up to twenty fold improvement in processing speed
 - Reduced manufacturing costs
 - Simplified strategy for wiring and terminal connections
 - Reduced manufacturing and field installation costs
 - Expanded set of controller functions & scalability
 - Expanded communications capability

..... Base Year Accomplishments

- Developed anti-islanding control scheme
- Developed loss-of-synchronization control scheme
- Prototype Controller field implementation
- Results from field application of GPC controller
 - Communications requirements
 - Communications topology
 - Communication protocols
 - Monitoring points
 - Load management
- Annual report published as NREL subcontract Report

..... Case Study



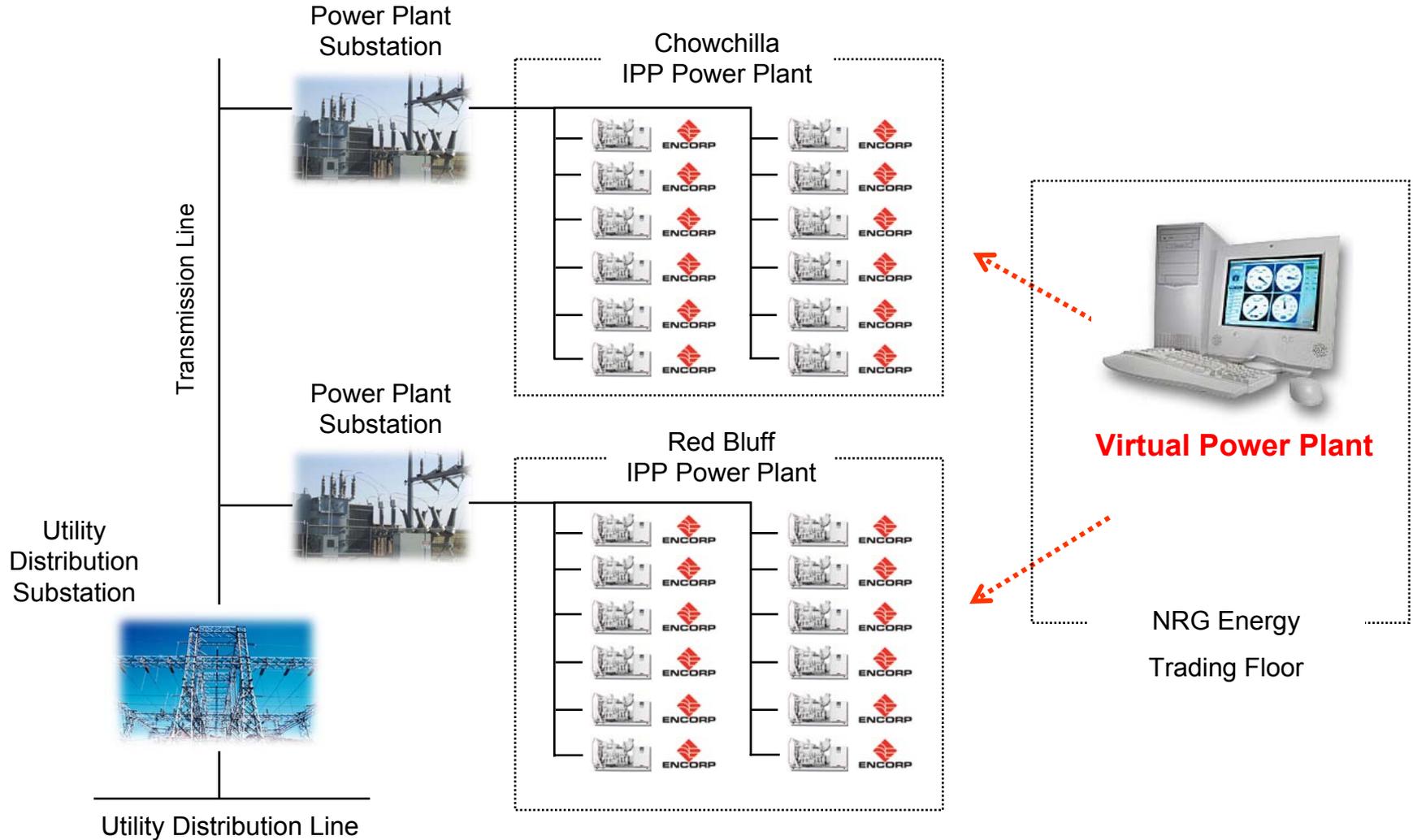
- Field Testing Case Study – Chowchilla II (California)
 - Wholesale-type DG Application
 - California ISO
 - Application of GPC controller and related Encorp products
 - 16 natural gas fired Deutz generator sets (25 MW)
 - Owned & Operated by NRG Energy/NEO
 - Run from remote site (Minneapolis)
 - Operated in parallel with utility (PG&E)

..... Chowchilla 50 MW Power Plant

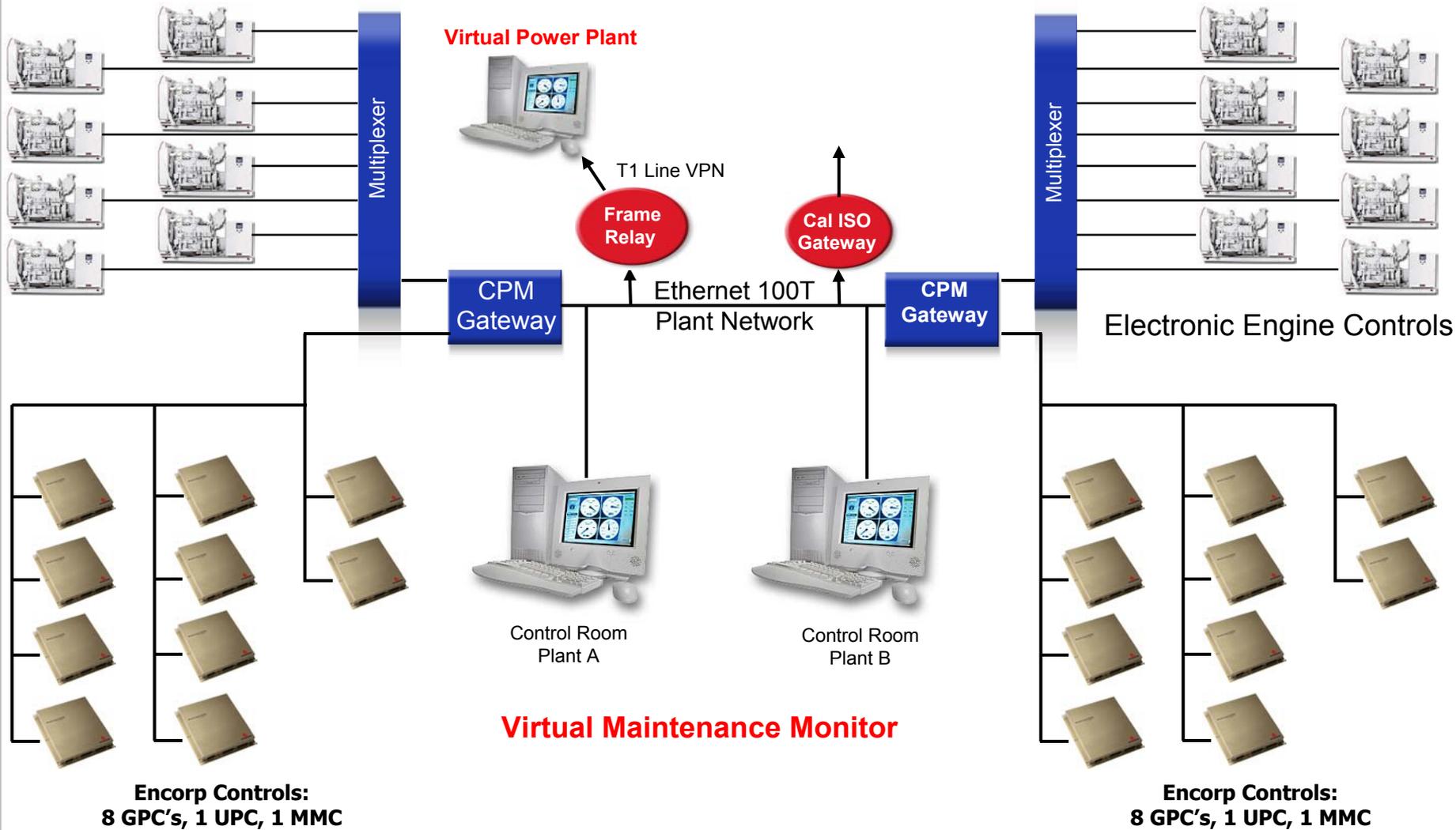


Case Study: Chowchilla II

Wholesale Distributed Generation ISO Capacity and Energy Trading Systems



Chowchilla 50MW Power Plant (Wholesale DG) Communication Architecture



Option Year 1 Contract
Initiated 8/1/2003

AUG/SEPT 2003
Accomplishments

..... FY03 Progress and Accomplishments



- General
 - GTI/NREL contract signed 8/1/2003
 - GTI/Encorp sub contract signed 9/4/2003
 - Project kick off meeting with GTI/Encorp 8/13/2003
- Option Year 1 Tasks
 - Task 6: Type Testing of Advanced controller
 - Task 7: Develop System Command and Control System
 - Task 8: Demonstration of Controlled DG Resources

..... FY03 Progress and Accomplishments



- Task 6: Type Testing of Advanced Controller
 - General
 - Added Systems Test Engineer to development team
 - Adding Type Test Engineer to development team
 - Active participant on the IEEE 1547.1 DG Interconnection Test Standard

..... FY03 Progress and Accomplishments



- Task 6: Type Testing of Advanced Controller (cont'd)
 - Overall Test Plan
 - Engineering development tests
 - Completed critical path analysis on 3 PCAs
 - Completed Engineering Thermal testing of 3 PCAs
 - Currently performing object module testing of completed firmware modules
 - Bench Tests
 - Currently analyzing sub-system module interconnections
 - Initiated sub-system functional testing
 - Production tests
 - Defined Production test flow
 - Developing Functional Tester (multiple functions)– board, module, calibration, burn-in, FGA, on-going reliability for the GDU module.

..... FY03 Progress and Accomplishments



- Task 6: Type Testing of Advanced Controller (cont'd)
 - Overall Test Plan (Cont'd)
 - Systems Tests
 - Evaluating Test facilities capable of performing
 - Encorp's systems test lab
 - GTI's systems test lab (visited on 8/13/2003)
 - DUIT test facilities (visited at dedication 8/5/2003)
 - NREL (visited 9/30/2003)
 - In discussions with AEP Dolan Technologies Lab and EPRI PEAC
 - Certification Testing "Type Tests" (IEEE, UL, ANSI, IEC, etc)
 - Updating Certification Test Plan based on current market requirements
 - UL Laboratories (visited on 8/12/2003)
 - » Ongoing discussions on testing
 - Participating on IEEE 1547.1 DG Interconnection Test Standards Committee (next meeting Nov 2003)
 - Monitoring UL-1741 Test Standards Activities

..... FY03 Progress and Accomplishments



- Task 7: Develop System Command and Control System
 - E2I (Electricity Innovation Institute) CEIDS (consortium for Electric Infrastructure to Support a Digital Society) – DER/ADA (Open Communication Architecture for Distributed Energy Resources in Advanced Distribution Automation)
 - Participated in Sept, 2003 Meeting in Chicago, IL
 - 1547.3 Writing Committee and Working Group Support
 - Participated in Writing Group Meetings during 2003
 - Plan to attend Working Group and Writing Group Meeting in November, 2003

..... FY03 Progress and Accomplishments



- Task 8: Demonstration of controlled DG Resources
 - Evaluating potential Demonstration Sites
 - Selected 1 Site
 - Encorp's Corporate Facilities in Windsor, CO
 - Other Sites are under evaluation
 - DUIT test facilities (visited at dedication 8/5/2003)
 - Additional site evaluations are ongoing
 - Eliminated
 - GTI's Corporate Facilities Retrofit would be too expensive (visited on 8/13/2003)



Planned Activities FY04

..... Planned Activities for FY04

- Task 6: Type Testing of Advanced controller
 - A: Finalize Test plan
 - B: Perform Testing and prepare a report
- Task 7: Develop System Command and Control System
 - A: Functional Specification for Command and Control System
 - B: Incorporate these functions into controller
 - C: Develop extended dispatch capabilities
- Task 8: Demonstration of Controlled DG Resources
 - A: Demonstration Plan
 - B: Demonstration implements several DGs
 - C: Demonstration report with recommendations



Summary of Out-year Activities



Summary of Out-Year Activities

- Option Year 2
 - Task 9: Interoperability Systems Analysis
 - A: System Interoperability Analysis
 - B: Application of Analysis to Candidate System
 - C: Incorporation of results into requirements and methodologies

 - Task 10: Demonstration of Grid-DG Interoperability
 - A: Functional specifications for grid-DG interoperability software.
 - B: Implementation of software into appropriate products
 - C: Demonstration including operation and test and report on results of tests

Impacts and Benefits

..... Impacts and Benefits

- **Performance** (Over 20x processing improvement)
- **Communications** (Greatly enhanced communications capabilities)
- **Scalability** (Ability to implement new systems approaches and add functionality)
- **IEEE P1547 Compliant**
- **Functionality** (Enhanced functionality and capabilities)
- **Programmability** (Additional programmability & flexibility in systems implementations)
- **Serviceability** (Greatly Improved System Serviceability)
- **Lower System Cost** (System savings of 5% to 30% depending on implementation)
- **Integration Enhancements** (Additional analog devices moved into digital realm)



Interactions and Collaborations

..... Interactions & collaborations *

- Gas Technology Institute
- Encorp, Inc
- NREL (National Renewable Energy Laboratory)
- DUIT (Distributed Utility Integration Test)
- UL (Underwriters Laboratories Inc.)
- EPRI PEAC
- AEP (American Electric Power), Dolan Technology Center
- E2I (Electricity Innovation Institute) CEIDS (consortium for Electric Infrastructure to Support a Digital Society) – DER/ADA (Open Communication Architecture for Distributed Energy Resources in Advanced Distributed Automation)
- IEEE 1547 Standards (1547.1, 1547.2, 1547.3)
- Chowchilla II, CA Base Year - CA ISO

*Summary of collaborations/interactions discussed in this presentation.



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