CONSULTANT REPORT

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

Strategic Energy Research

INTELLIGENT SOFTWARE AGENTS FOR CONTROL AND SCHEDULING OF DISTRIBUTED GENERATION

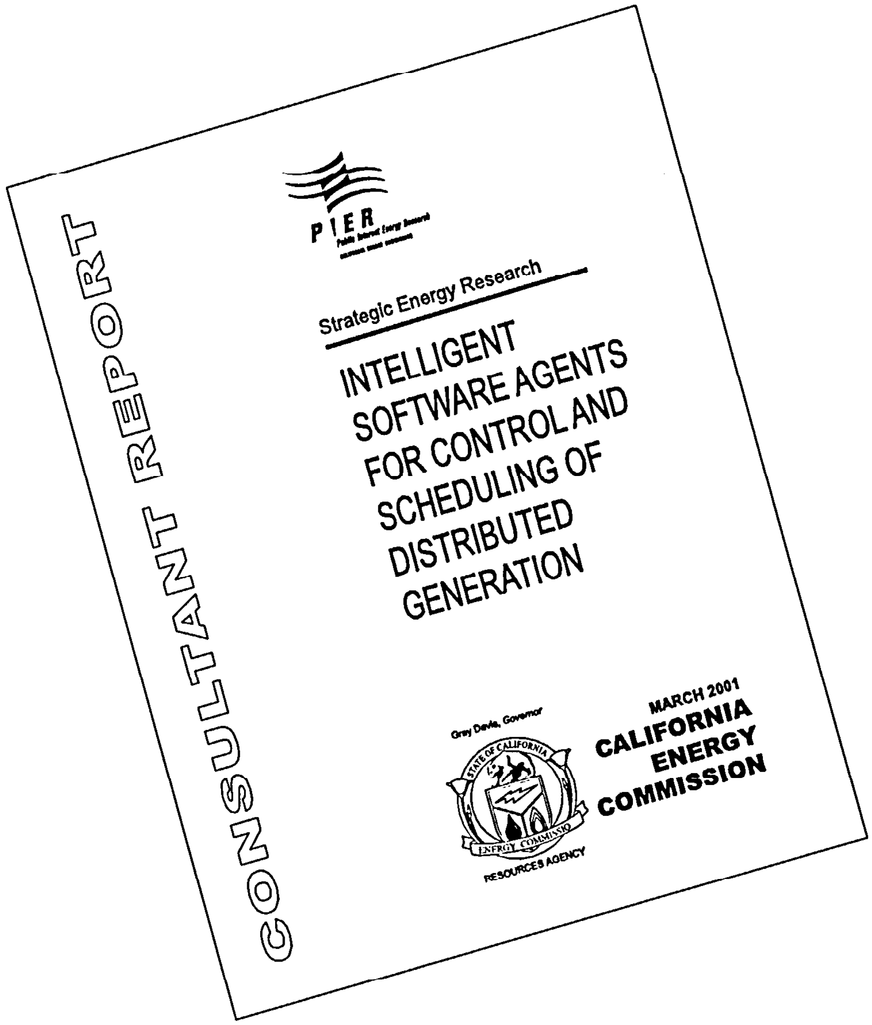
Gray Davis, *Governor*

MARCH 2001

CALIFORNIA ENERGY COMMISSION

RESOURCES AGENCY

P600-01-010



CALIFORNIA ENERGY COMMISSION

Prepared for:
CALIFORNIA ENERGY COMMISSION

Prepared by:
Gerald L. Gibson, PE

ALTERNATIVE ENERGY SYSTEMS CONSULTING, INC.
Carlsbad, CA

Contract No. 500-98-040
Contract Amount: $554, 010

Jamie Patterson, *Contract Manager*
RESEARCH AND DEVELOPMENT OFFICE

Laurie A. ten Hope, *Team Lead*
STRATEGIC ENERGY RESEARCH OFFICE

Legal Notice

Acknowledgements

In performing this research, Alternative Energy Systems Consulting, Incorporated (AESC) wishes to thank the Commission for their valuable assistance and commitment to furthering this important new technology. Commission participants were Jamie Patterson, Commission Contract Manager and Laurie A. ten Hope, Strategic Energy Research Program Lead. AESC also wishes to acknowledge the valuable contribution and consultation of our subcontractor, Reticular Systems, Incorporated.

We would like to express our thanks to all members of the Virtual Evaluation Group for their cooperation and valuable contribution to the project. These include:

Dave Hawkins	California Independent System Operator
Eric Wong	Caterpillar
Carlos Martinez	Southern California Edison
Scott Castelaz	Encorp
David Wolins	EnFlex
Chris Marnay	Lawrence Berkeley National Laboratory
Kurt Kammerer	San Diego Regional Energy Office
Victor Romero	San Diego Gas & Electric

Finally, we would like to thank all of the members of the AESC project team. These include Donald Pratt, Ronald Ishii, Mark Tran, Michele Jansma and Dorothy Campbell.

Table of Contents

Section **Page**

Appendices

List of Figures

Figure **Page**

List of Tables

Table **Page**

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Renewable Energy
- Strategic Energy Research.

What follows is the final report for the Intelligent Software Agents for Control and Scheduling of Distributed Generation contract, contract number 500-98-040, conducted by Alternative Energy Systems Consulting, Inc. The report is entitled Intelligent Software Agents for Control and Scheduling of Distributed Generation. This project contributes to the Strategic Energy Research program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

One need only look at the daily newspaper to appreciate the dynamic nature of California's energy markets. The imbalance between available energy supplies and increasing energy demand have necessitated rolling blackouts and renewed requests for conservation. The use of Distributed Energy Resources to help defer the need for construction of large generating stations has long been recognized as a means of improving this situation. A Distributed Energy Resource (DER) is an efficient electrical generation or storage device that, unlike large central generating plants, can be remotely located and is often sited on a customer's site. In addition, numerous benefits studies have shown that DER technology improves the reliability and cost effectiveness of electric distribution systems. While it was clear that DER assets could play a significant role in a competitive energy market, there were formidable barriers to its use. DER technology requires control and scheduling of large numbers of distributed assets, but the centralized decision and control paradigm employed in the electric power industry is ill suited to this task.

In response to this need the California Energy Commission (Commission) contracted with Alternative Energy Systems Consulting, Incorporated (AESC) as part of a Public Interest Energy Research (PIER) project that addressed this problem using a new and innovative approach. The primary goal of this highly successful PIER project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation" was to demonstrate the viability of using intelligent software agents for control and scheduling of one or more distributed energy resources in California's competitive energy market.

At its most basic level, an intelligent software agent is software programmed to act on behalf of the user. Software agents have a number of capabilities including the ability to operate autonomously, monitor their environment and communicate with others (agents or the user). Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). Therefore, the project technical objectives were structured to address this issue by demonstrating the viability of this technology along with the basic tools (i.e., demonstration software, test reports, etc.) needed to facilitate transfer of this technology into the energy industry. To facilitate the eventual commercialization of this technology the economic objective required that AESC identify and initiate discussions with one or more potential partners willing and able to participate with continued commercialization of the intelligent agent approach.

Objectives

The technical and economic objectives of this project were to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.
- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of *Smart**DER technology.

Outcomes

AESC achieved the project's objectives:

- Successfully demonstrated how a prototype network of intelligent software agents (*Smart**DER), communicating over the Internet and operating without direct human intervention can coordinate and schedule one or more distributed energy resources.
- Developed a demonstration package that will facilitate transfer of the project results into the private sector.
- Identified and initiated discussions with one or more potential partners who are willing and able to participate with commercialization of *Smart**DER technology.

Conclusions

- Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution).
- During the project AESC succeeded in bringing this intelligent-agent technology to a Stage 3 (Bench testing / proof of concept) level of development. Thus demonstrating the potential of this technology to radically change the way that DER assets are dispatched in the California marketplace. In addition, AESC laid the groundwork for further development beyond Stage 3 by developing and demonstrating software that can be used to facilitate the Stage 4, Product Development and Field Experiments as well as establishing dialogues with potential commercialization partners.

Benefits to California

There is little question that integration of DER assets into the marketplace, the overriding premise behind this PIER project, continues to be of paramount importance. Intelligent software agents with their ability to communicate and collaborate are well suited to the task of scheduling and coordinating the activities of large numbers of DER assets. Use of intelligent software agents in this fashion reduces the level of expertise needed to own and operate distributed energy resources, which in turn, allows greater participation by owners of distributed energy resources in California's competitive energy industry. The benefits of this project are therefore tied to the benefits of increased DER participation in California's deregulated marketplace:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade / construction
- Customer cost reduction by direct displacement of load
- Energy price reduction (as new DER assets displace existing load and / or centralized generation)

Recommendations

AESC recommends that the Commission fund a follow-on PIER effort that would move this technology forward to completion of Stage 4. This effort would involve the following:

- Review and Evaluate the Feedback from the existing project,
- Identify Feasibility Field Test Participants,
- Refine the *Smart**DER Technology and Integrate / Interface it with existing network infrastructure software products,
- Conduct a Feasibility Field Test For Control of Actual Loads

For Additional Information

For additional information on application of *Smart**DER technology or the potential benefits of applying intelligent software agents in general contact:

Gerald L. Gibson PE
Vice President
Alternative Energy Systems Consulting, Incorporated
858-560-7182
gibsonj@aesc-inc.com

Abstract

The use of Distributed Energy Resources (DER) to help defer the need for construction of large generating stations has long been recognized as a means of improving the serious imbalance that exists in the competitive California energy markets. Use of DER technology requires control and scheduling of large numbers of distributed assets yet the centralized control paradigm employed in the electric power industry is ill suited to this task. In response to this need the Commission contracted with Alternative Energy Systems Consulting, Incorporated (AESC) as part of a PIER project that addressed this problem using a new and innovative approach. The primary goal of this PIER project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation" was to demonstrate the viability of using intelligent software agents for control and scheduling of distributed energy resources in California's competitive energy market.

During this highly successful project, AESC and its principal subcontractor, Reticular Systems, succeeded in bringing this intelligent-agent technology to a Stage 3 (Bench testing / proof of concept) level of development. Testing confirmed that use of *Smart**DER™ agents could enable sites with excess generating capacity to collaborate via the Internet and aggregate this capacity for participation in the Ancillary Services (AS) markets operated by the California Independent System Operator (CAISO). In other words, testing showed that *Smart**DER technology could bring generating capacity to the California marketplace that may not otherwise have been able to participate.

During the course of the project AESC established dialogues with potential commercialization partners that expressed an interest in moving this technology forward. AESC therefore recommended that the Commission fund a follow-on PIER effort that would move this technology forward to completion of Stage 4 and more specifically to conduct a feasibility field test for control of actual loads and generation assets.

Keywords: distributed generation, distributed energy resources, software agents, resource scheduling, and resource dispatch

1.0 Introduction

This report has been prepared by Alternative Energy Systems Consulting, Incorporated (AESC) as part of a California Energy Commission (Commission) Public Interest Energy Research (PIER) project titled, “Intelligent Software Agents for Control & Scheduling of Distributed Generation”. The overall goal of this PIER project was to demonstrate the viability of using intelligent software agents for control and scheduling of one or more distributed energy resources (e.g., distributed generation, energy storage, cogeneration, curtailable loads, etc.) in a competitive energy market.

1.1 Background

A Distributed Energy Resource (DER) is an efficient electrical generation or storage device that, unlike large central generating plants, can be remotely located and is often sited on a customer’s site. Numerous benefits studies have shown that DER technology improves the reliability and cost effectiveness of electric distribution systems. CADER (California Alliance for Distributed Energy Resources) summarized these benefits[2] as:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade / construction
- Customer cost reduction by direct displacement of load
- CalPX market clearing price (MCP) reduction (new DER reduces overall system demand which displaces the highest cost resource)

While it is clear that DER assets can play a significant role in a competitive energy market there are significant barriers to the use of this technology. Use of DER technology requires control and scheduling of large numbers of distributed assets. The centralized decision and control paradigm employed in the electric power industry is ill suited to this task.

1.1.1 What is an Intelligent Agent?

At its most basic level, an intelligent agent is a software-based device that acts on behalf of the user. Software agents have a number of capabilities including the ability to monitor their own execution environment, communicate with other agents or the user and maintain some representation of their own internal mental state. Software agents are characterized by their ability to operate autonomously. This means that after an agent starts executing, no further interventions are required from the user. An autonomous agent is able to complete its task on its own.

Software agents can be used in a wide variety of applications. An intelligent software agent can contain significant amounts of expertise and can be applied in systems requiring planning or learning capabilities. Agents are particularly useful in applications

[2] See CADER Collaborative Report and Action Agenda, January 1998

involving machine to machine or man to machine communications. One popular use of agents is information seeking and cataloging on the Internet. Agents can be used in applications where they learn about an individual user and modify their own behavior to suit the information-seeking needs of the user. Agents are also useful in applications where multiple agents can communicate and cooperate with other agents for solving a given problem. These agents can be physically located on the same computer or distributed in a variety of locations. Multiple agents operating in conjunction, as an agency, can achieve goals and objectives that would not be otherwise achievable by a single agent.

Use of intelligent software agents with their ability to communicate and collaborate thus distributing the decision process, is well-suited to the task of scheduling and coordinating the activities of large numbers of DER assets. Use of agents in this fashion reduces the level of expertise needed to own and operate distributed energy resources, which in turn, allows greater participation by owners of distributed energy resources in California's competitive energy industry.

1.2 Project Approach

The project approach can be divided into three basic task areas. Two areas, Project Start-up Tasks and Project Reporting Task pertain to the project management and reporting efforts required of all PIER projects while the third area, Technical Tasks deals with the effort to develop and test the *Smart**DER agent based technology.

1.3 Project Start-Up Tasks

AESC hosted a project kick-off meeting at its San Diego offices on June 9, 1999 to formally begin the project efforts. Project objectives, tasks and the associated schedule/budget were reviewed with the Commission Contract Manager. Just prior to the meeting AESC formally documented the planned matching contributions from both AESC and its principal subcontractor, Reticular Systems in correspondence dated June 8, 1999. In addition, AESC documented the fact (correspondence dated June 8, 1999) that no permits would be needed during the course of the project.

1.4 Project Objectives

Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). The technical objectives of this project were structured to address this issue by demonstrating the viability of this technology along with the basic tools (i.e., demonstration software, test reports, etc.) needed to facilitate transfer of this technology into the energy industry.

The technical and economic objectives of the existing project are to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.
- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of the DER*S agency.

1.5 Report Organization

The remainder of this Final Project Report is organized into four main sections. The first section, Section 1, Introduction, briefly describes the basic project approach and project tasks, Section 2, Discussion, describes both the approach and results by task. Section 3, Project Outcomes, is divided into two basic subsections, one describing outcomes by project technical objective and the second by describing the outcomes pertaining to the project economic objective. Section 4.0 presents conclusions and recommendations derived from the project.

2.0 Discussion

Project technical efforts were divided into the following five tasks (excluding Project Management efforts):

1 Domain Analysis and Market Research

2 DER*S Agency Development and Testing

3 EASE Development and Testing

4 *Smart**DER – EASE Integration and Testing

5 *Smart**DER Documentation and Demonstration Development

Project tasks are shown graphically in Figure 1. As the figure shows, some of the project tasks occurred concurrently thus allowing for a shorter overall development period. Specific task descriptions follow.

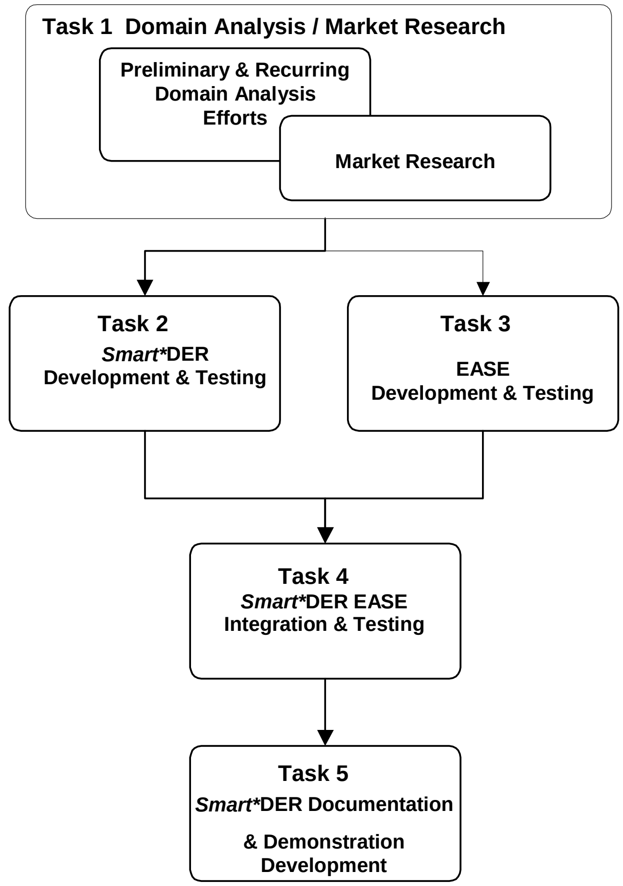


Figure 1. Project Technical Task Flow

2.1 Task 1 Domain Analysis and Market Research

The purpose of this task was to evaluate the California energy market as it relates to the operation of distributed energy resources in order to describe the environment, or domain, in which the agents and agency developed in this project must operate.

This task was divided into two separate but interactive efforts: domain analysis and market research. In the initial domain analysis effort we examined the energy industry domain as it related to our planned development of an agent and agency for scheduling of distributed energy resources. Thus we were able to characterize the *Smart**DER operating environment. This effort yielded a preliminary description of the *Smart**DER concept along with questions/issues requiring additional investigation.

During the market research effort we identified key market participants who were willing to share their views on distributed energy resources in the deregulated energy environment. Having identified questions and issues during the initial domain analysis phase, we solicited feedback from market participants to answer these questions and resolve the open issues and to set broad goals and objectives for the final product. This group of market participants became our Virtual Evaluation Group (Appendix III) and provided feedback both during this market research task and throughout the remainder of the project. Another objective of the market research task was to identify potential commercialization partners for *Smart**DER technology that could also participate in our Virtual Evaluation Group of market participants.

AESC provided the following deliverables as part of the Task 1 effort:

- Preliminary Domain Analysis Report
- List of Market Participants
- Project Summary Description (used for contacting / informing Market Participants)
- Market Research Report
- Final Domain Analysis Report

The Commission Contract Manager conducted the first Critical Project Review at the conclusion of this task.

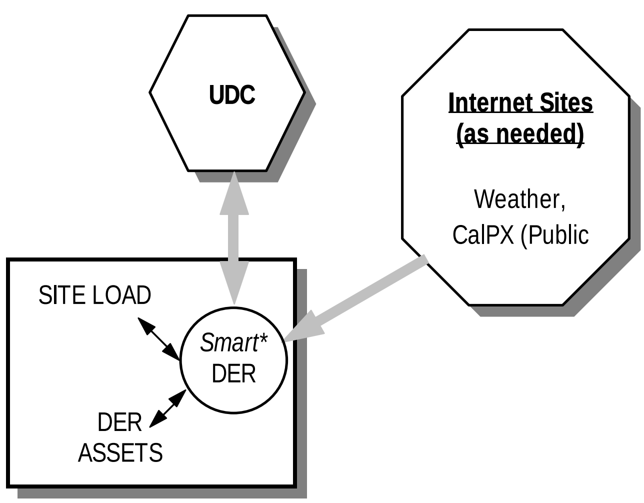
2.1.1 Task 1 Results

The preliminary domain analysis was the first task in the PIER project. In this task AESC analyzed the California energy industry in order to characterize the potential *Smart**DER markets (e.g., end-users / potential owners, benefits and capabilities). The results of this analysis effort were summarized in the Preliminary Domain Analysis Report. During the preliminary domain analysis effort AESC identified basic *Smart**DER operating scenarios based on analysis of the current energy marketplace in California, potential DER technologies and their potential benefits. As part of the market research effort, AESC formed a market participant evaluation group comprised of key individuals and companies that operate in, or have knowledge of, the competitive energy industry and / or distributed energy resources. The market participant evaluation group provided vital feedback on key issues and questions raised in the preliminary domain analysis. Specifically, the market participant group was used to prioritize the potential *Smart**DER markets. Results of this market research effort were summarized in the Market Research Report (Appendix I). Ultimately, our objective was to characterize the *Smart**DER operating environment, or domain, for the most likely *Smart**DER markets. Results of the Domain Analysis effort were summarized in the Final Domain Analysis Report (Appendix II).

We concluded from our analysis that *Smart**DER is only applicable to DER equipment that can be dispatched. Non-dispatchable technologies, such as wind, solar, and energy efficiency, are not compatible with *Smart**DER because their production output is not controllable. However, in some DER technologies, the addition of energy storage *can* provide dispatching capability. Other DER technologies such as ultra-capacitors and SMES provide short bursts (i.e., milliseconds) of electric energy to improve power quality. Although dispatchable, these technologies are triggered by power quality events and do not affect the aggregate value of electric energy. Curtailable loads are dispatchable but to varying degrees depending on the type of load involved. For example, remote control of cycling of residential or small commercial air conditioners is a dispatchable resource that could be bid into the ancillary services market as non-spinning reserve (available within 10 minutes). Loads (i.e., process loads, etc.) requiring additional time could still be classified and scheduled / dispatched as replacement reserves (available within 60 minutes).

Entities that could benefit from *Smart**DER operation are envisioned as building owners / operators, ESCOs (or other load aggregator) or Utility Distribution Companies (UDC). A building owner / operator could benefit by using DER scheduling to lower overall energy costs and increase power supply reliability. An ESCO (or other load aggregator) could use *Smart**DER for bundling of customer on-site DER services with power and fuel contracts to increase customer value and improve contract margins. *Smart**DER could also enable building owners / operators and ESCOs to bid into one or more of the California energy or ancillary services markets. UDC participation in *Smart**DER applications may be based on a connection between potential DER benefits and UDC Performance Based Ratemaking (PBR) mechanisms. Several studies have identified power delivery cost and performance benefits derived from DER installations and past studies by the Electric Power Research Institute (EPRI), Pacific Gas and Electric (PG&E) and others have identified potential UDC benefits from DER that include; capital deferral, reduced energy loss and improved reliability. Direct UDC ownership of DER assets continues to be the subject of debate. Therefore, in the near-term it is unlikely that a UDC will own or operate DER assets, however this could change as the marketplace continues to evolve.

The *Smart**DER operating environment can vary significantly in terms of the number and types of entities that are involved. Based on our assessment of the California marketplace we believe that there are three basic *Smart**DER operating scenarios, each with a differing level of complexity. In the first scenario (Figure 2), *Smart**DER agents



operate one or more DER assets at a single site to minimize site energy costs.

Figure 2. Single Site Operation

Agents(s) monitor site load and DER performance and access weather data via the Internet in order to predict site loads. In addition, or in lieu of this information, agents may receive pricing signal(s) from the local UDC depending on the applicable electric rate. Electricity and possibly natural gas prices (depending on the DER asset involved) could also be accessed via the Internet as needed. In this scenario *Smart**DER agents operate the DER asset to reduce on-site loads and associated costs without any direct involvement in the various energy and demand markets. Note that this operating scenario could also apply to *Smart**DER scheduling / dispatching of DER assets installed at a substation with UDC operation / ownership of *Smart**DER (if UDC ownership / operation of DER assets is permitted).

The second scenario (Figure 3) provides for *Smart**DER aggregation of multiple assets without direct involvement in any of the competitive markets. Under this operating scenario *Smart**DER agents aggregate load or otherwise coordinate operation of DER assets at multiple sites. This would allow sites / businesses to respond to interruptible rates or could provide an ESCO with load shaping capabilities.

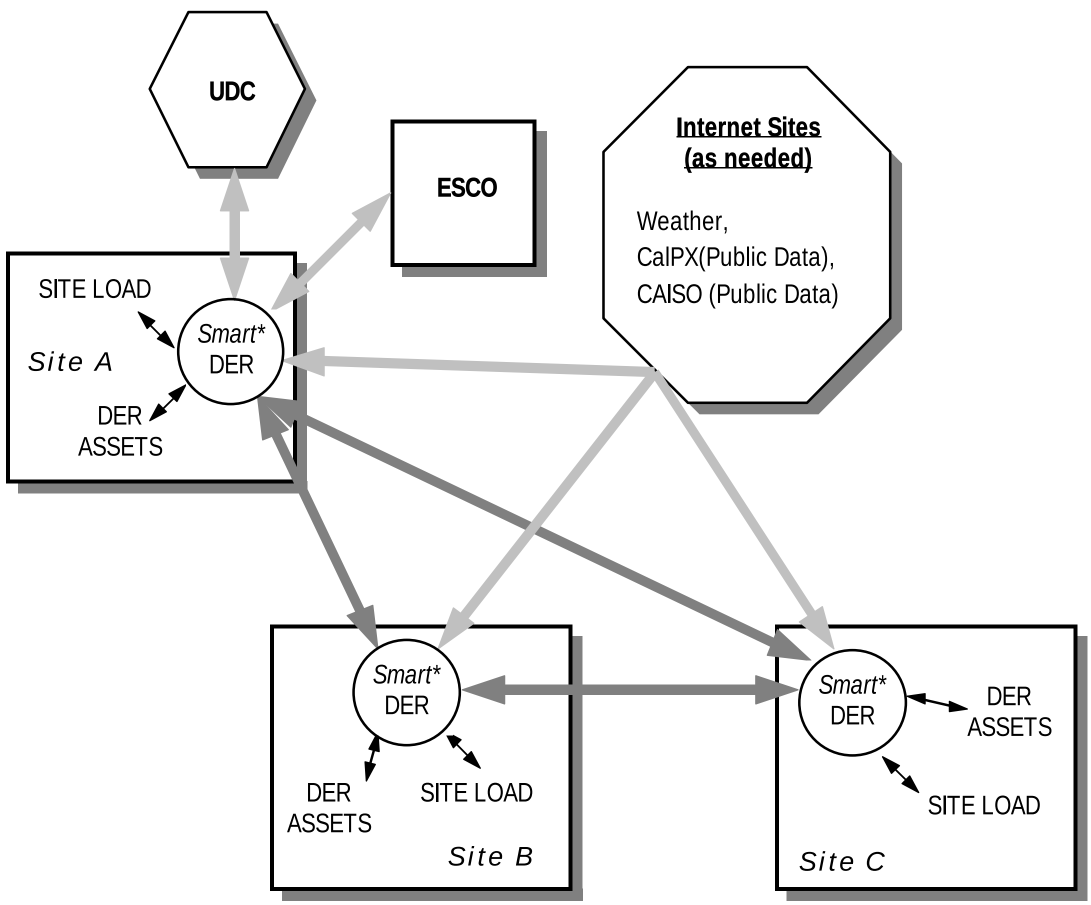


Figure 3. Multiple Sites – No Market Participation

The *Smart**DER agents at each individual site would have knowledge of site load and DER asset performance and would "represent" its site's interests in responding to UDC pricing signals (if provided) or ESCO load shaping constraints. As with the single site operating scenario, *Smart**DER agents could access the Internet for weather and possibly for electricity and natural gas prices depending on the DER asset involved. In this scenario *Smart**DER operates to reduce site energy costs but with the added complexity of operating in conjunction with other *Smart**DER equipped sites. In this scenario there is no direct involvement with external competitive markets.

The third operating scenario involves both aggregation of multiple assets and participation in one or more of the competitive markets. This operating scenario (Figure 4) is similar to the second scenario in that multiple sites are involved. However, in this case *Smart**DER agents are responding to, and participating in, one or more of the competitive markets operated by either the California Power Exchange (CalPX) or the California Independent System Operator (CAISO). Market participation could be either via the CalPX or another Scheduling Coordinator (SC). In this scenario, the *Smart**DER agents would have to balance site loads and costs against the potential return of bidding into one or more of the competitive markets. For instance, if high ancillary service pricing is predicted then bidding of standby generator capacity or curtailable load(s) could be justified.

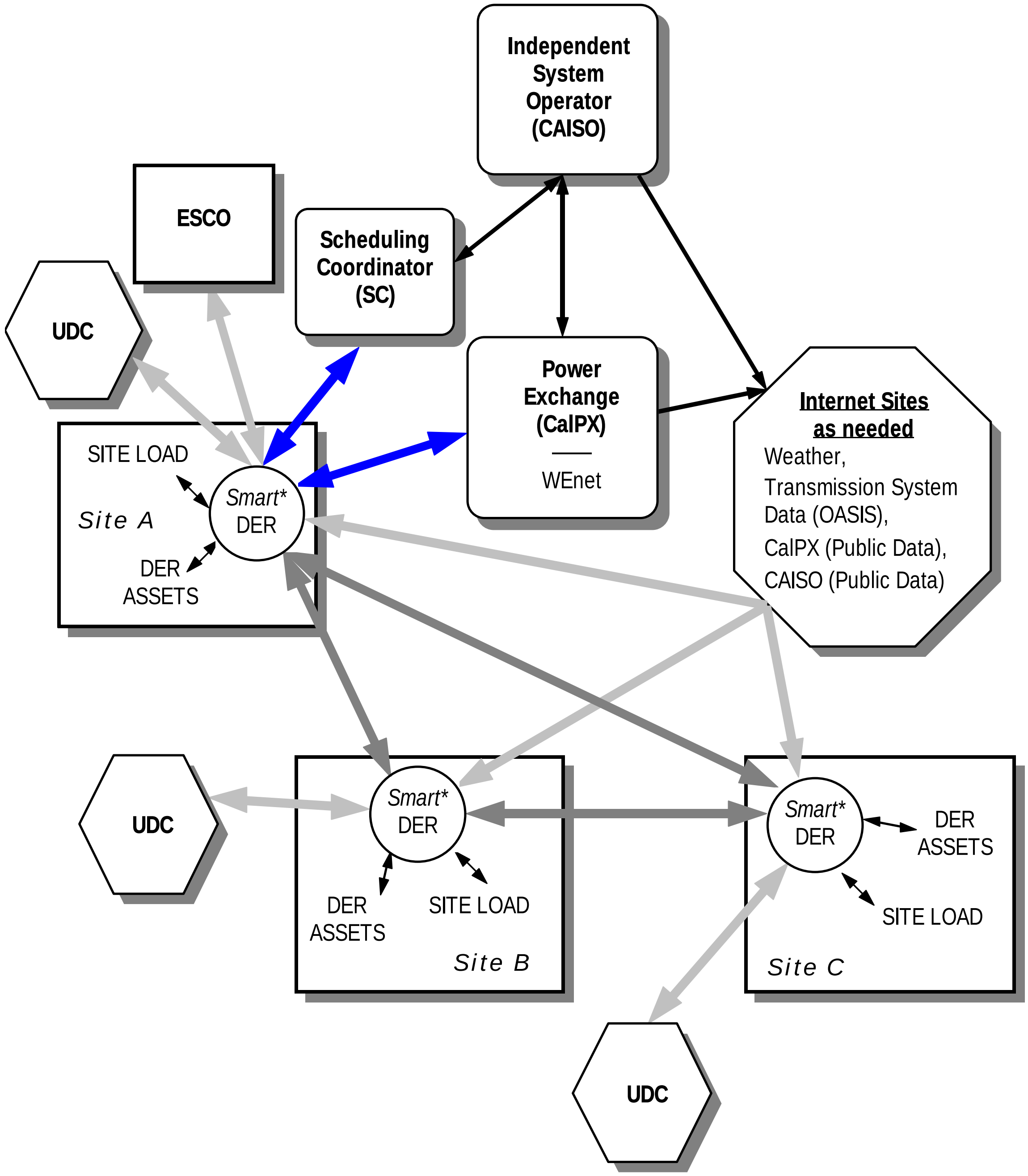


Figure 4. Multiple Sites – Direct Market Participation

The market participant group identified the first two operating scenarios as the most likely to occur in the near-term and intermediate-terms. Although in both cases, UDC involvement in the form of ownership or operation of DER assets is uncertain. While *Smart**DER could enable direct involvement in California energy and demand markets (operating scenario 3) this is seen as unlikely in the near-term. This type of involvement is seen as a more long term operating scenario as the California market continues to evolve and DER integration into the California marketplace progresses.

Based on the three basic operating scenarios and the potential DER assets involved we have identified the most likely *Smart**DER capabilities, which can be divided into two basic categories. The first category contains essential capabilities and the second contains capabilities that could improve product performance or market acceptance (e.g., bells and whistles). The seven basic capabilities considered essential to *Smart**DER product viability are:

- Monitor and Forecast DER Asset Performance / Output
- Monitor and Forecast Site Load (energy and demand) Requirements
- Monitor and Forecast Relevant Market Pricing
- Schedule DER Operation to Maximize Economic Benefit
- Graphical User Interface (GUI)
- Data Storage & Retrieval
- Communicate with External Entities (i.e., Internet, DER controls, etc.)

2.1.1.1 Virtual Evaluation Group

One of the primary objectives of the market research effort was to identify and engage key market participants in a "Virtual Evaluation Group". This group of individuals would then provide valuable feedback throughout the course of the project. During the market research effort, we were successful in assembling a diverse market participant group consisting of knowledgeable individuals that were well suited to providing the desired feedback.

Overall, the market participant group agreed with our description of the California electric market(s). Panel members understood the intelligent agent concept and confirmed the need for new scheduling and dispatch technologies. These technologies are necessary to facilitate widespread DER operation and grid integration. The market participants agreed with our initial assessment of how *Smart**DER agents could be integrated into the California marketplace but indicated that we were overly focused on the bulk power and ancillary services markets. We subsequently made changes to provide for *Smart**DER management of curtailable loads in response to either interruptible electric rates and / or the ancillary services markets. In addition, we now recognize the importance of *Smart**DER operation at an individual site to directly offset facility utility costs without any need for involvement in either the bulk power or ancillary services markets.

A Virtual Evaluation Group consisting of individuals that participated in our market participant group was formed (Appendix III). We had initially envisioned a relatively large base of market participants from which to choose. What we found was that market participants that had provided comments did so because they had both an interest and desire to participate throughout the project. For this reason, the Virtual Evaluation Group was comprised of all of the market participants that provided comments / feedback.

2.1.1.2 Identify Potential Commercialization Partners

It would have been premature to negotiate with, or otherwise engage, a commercial partner given the early stage of our project. However, we were able to identify the commercial partner traits that will maximize the benefit to the *Smart**DER development and commercialization efforts. These traits call for a commercial partner that has:

- An existing product or technology that enhances potential Smart*DER market penetration,
- An existing product distribution/support infrastructure, and
- Industry Name/Trademark Recognition

In addition, we were able to identify potential commercialization partners having some or all of these traits. Some of these potential partners agreed to participate in the evaluation group. Other partners will be more approachable as the Smart*DER product development process progresses.

2.2 Task *2 Smart**DER Agency Development and Testing

Development of the *Smart**DER agency and its individual agents was the goal of this project task. This effort was broken down into nine subtasks. The development effort began with tasks devoted to defining the *Smart**DER agency and its agents and progressed to testing of the individual agents and then the agency as a whole. The nine subtasks that comprised this task are briefly described in the following subsections. A critical project review was conducted during this effort so the following descriptions and deliverables are summarized prior to and following the critical project review.

2.2.1 DER*S Task Analysis and Characterization

The purpose of this task was to clearly describe the functional requirements of each agent as well as the overall agency based on the product requirements developed during the domain analysis and market research efforts.

2.2.2 DER*S Agency/Agent Specification

The purpose of this task was to prepare a detailed product specification that could be used as the basis for the remaining development activities. In addition to the overall product specification, the product specification also contained the requirements associated with the individual agents.

2.2.3 Ontology Development

The purpose of this task was to identify the major components of the energy industry ontology as it relates to the application of distributed energy resources. Ontology is a formal description of a problem domain that gives meaning to the symbols and expressions used to describe a domain. For one agent to properly understand the meaning of a message from another agent, both agents must ascribe the same meaning to the symbols (constants) used in that message. In other words, a network of agents uses the ontology to make sure they are comparing apples with apples.

2.2.4 Algorithm and Tool Research

The purpose of this task was to determine the software tools and algorithms that are needed to support *Smart**DER technology. In some cases tools or algorithms already existed while in other cases it would be necessary to develop algorithms based on each agents needs. As part of this effort we developed an agent technology matrix that detailed the needs as well as candidate algorithms.

2.2.5 Algorithm Development and Testing

The purpose of this task was to develop algorithms identified in the previous subtask and to test and evaluate these algorithms to identify the most promising tools and algorithms for each of the agents.

AESC provided the following deliverables prior to the second critical project review as part of first five subtasks of the Task 2 effort:

- Preliminary Agency Specification
- DER*S Specification Report
- Ontology Report
- Algorithm Research Report
- Algorithm Development and Testing Report

The Commission Contract Manager conducted the second Critical Project Review at the conclusion of this subtask.

2.2.6 Agent Software Module Development and Testing

The purpose of this task was to develop and test the individual agents and supporting software modules that were identified in the previous subtask. As part of this effort we designed, developed and tested software modules that provided the agent functionality identified previously. These software modules are known as the Private Accessory Classes (PAC) of intelligent agents. PACs were developed and tested for each agent.

2.2.7 Agency Construction

The purpose of this task was to construct the *Smart**DER agency and conduct basic agency testing to prepare for integration of the PAC software developed and tested in the previous subtask.

2.2.8 Integration of PAC Software

The purpose of this task was to integrate the PAC software into the *Smart**DER agency. At the end of this task a fully functional *Smart**DER agency would be ready for further testing.

2.2.9 Agent and Agency Testing

The purpose of this task was to extensively test the *Smart**DER agency prior to fully integrating and testing in the simulated operating environment (EASE) that was being developed concurrently under Task 4.

AESC provided the following deliverables prior to completion of the Task 2 effort (following the second critical project review):

- Report describing the PAC software.
- Preliminary EnerAgent™ test report.
- DER*S Test Report (included in the Task 4, Final DER*S Test Report deliverable)

2.2.10 Task 2 Results

During Task 1 we defined the basic *Smart**DER product operating scenarios, requirements, and capabilities. In this Task 2 effort we proceeded to define the various agents that would be needed within a *Smart**DER agency and then developed and tested these agents. Initially we concentrated on analyzing and characterizing the various tasks associated with *Smart**DER operation. This resulted in the seven agent *Smart**DER agency depicted in Figure 5 and described in detail in the following sections (see also DER*S Preliminary Agency Design Report).

Communication between agents is Internet-based and utilizes TCP / IP protocols. While it is not evident from the figure, which appears to depict all of the agents in close proximity to one another, agents may actually be located on multiple machines. Use of web-based communications as well as JAVA based code facilitates the use of multiple platforms. For example, the Data Manager agent shown on the figure could easily reside on a server located in the information systems or data processing center while the owner interface agent could be located on a PC in the facilities management area. Likewise the Facility Interface Agent could be running on the same PC that communicates with building energy management system software.

2.2.10.1 *Smart**DER Agency Review

*Smart**DER™ technology operates to schedule the operation of one or more DER assets at a single or multiple sites. *Smart**DER agencies utilize intelligent agent technology to distribute the decision-making and data processing workload among multiple agents. Each agent operates independently yet collaborates with other agents to achieve the overall scheduling objective. Just as an individual *Smart**DER agency consists of multiple agents, multiple *Smart**DER agencies (each assigned to a specific DER equipped site) can operate independently yet cooperatively to coordinate activities at multiple sites.

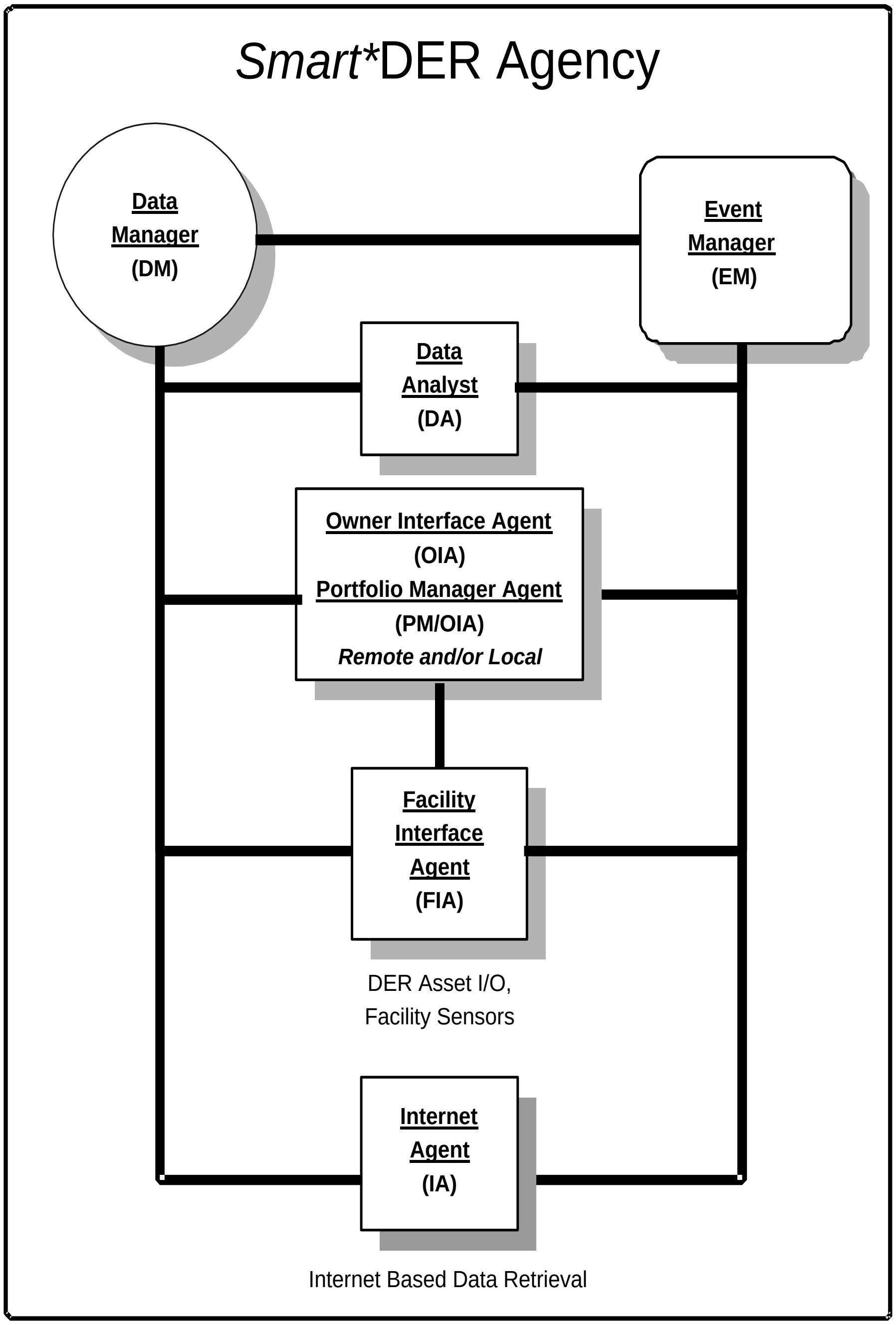


Figure 5. *SmartDER™ Agency Diagram**

2.2.10.2 Agent Descriptions

The following sections, organized by agent, summarize the functionality of each individual agent that was developed and tested during the project.

Owner Interface Agent (OIA)

The Owner Interface Agent (OIA) is devoted to communication between the Smart*DER agency and the owner/user. The primary feature of the OIA is its graphical user interface (GUI), which facilitates user input (manual overrides, site set-up, etc.) and review of Smart*DER information. All Smart*DER equipped sites have an OIA located at the site that communicates directly with the remaining Smart*DER agents directly using protocols provided by the AgentBuilder® development system.

Portfolio Manager (PM)

In some operating scenarios a portfolio of *Smart**DER equipped sites may cooperate in order to participate in either the energy (CalPX) or ancillary services markets (AS). In these situations a single OIA is designated as the market manager and is provided with additional functionality. The portfolio manager OIA (PM/OIA) aggregates portfolio assets through an auction process and communicates with the marketplace on behalf of the portfolio. The PM/OIA may be located at one of the portfolio sites or may be remotely located at the offices of a third party owner/operator.

Event Manager (EM)

The Event Manager (EM) is responsible for accomplishing periodic *Smart**DER agency activities. The EM monitors system time and requests action by other *Smart**DER agents to accomplish the needed activity. Examples of routine *Smart**DER functions include DER operating schedule updates and weather data collection. During agency start-up the EM reads the *Smart**DER set-up data provided by the DM and initializes *Smart**DER scheduled activities. The EM subsequently acts independently from all other agents to accomplish the scheduled activities.

Data Manager (DM)

The Data Manager (DM) agent is the central repository for all *Smart**DER data and provides data archiving and retrieval services for the *Smart**DER agency. The DM responds to requests from any *Smart**DER agent that requires data. DM functionality is limited to data storage and retrieval as well as examination of stored data to determine its suitability relative to the data request. The DM works via the Facility Interface Agent (FIA) to access facility and DER sensor information and uses the Internet Agent (IA) to obtain data that are external to *Smart**DER (i.e., weather data, transmission availability, relevant pricing data, etc.). The DM may also request that the DA generate new operating schedules and or predicted pricing information if stored schedules and information do not meet the needs of the requesting agent.

Facility Interface Agent (FIA)

The Facility Interface Agent (FIA) serves as the *Smart**DER agency connection to all of the facility sensors as well as the DER asset sensors and associated controls. The FIA routinely accesses the site sensor (including DER asset sensors) using existing facility communication networks and provides 15-minute data to the Data Manager for storage. In addition, the FIA transmits operating commands to the DER asset in response to Event Manager requests. The FIA communicates primarily with the Data Manager and Event Manager agents. FIA functionality is limited to data conversion, transmittal and receipt of data from facility and DER asset sensors. Note that the FIA accesses text files for data that would normally come from facility / DER sensors for testing and demonstration software purposes.

Internet Agent

The Internet Agent (IA) serves as the DER*S agency's connection to all Internet-based information sources. The IA responds to requests for information retrieval or transmittal and accesses the necessary Internet sites. The IA communicates almost exclusively with the Data Manager for retrieval of information and with the Event Manager for information transmittal (CalPX / SC, if needed).

Note that the *Smart**DER demonstration software retrieves market pricing, system load and weather data from a "pseudo" web site maintained by Reticular Systems. This will enable AESC to track use of the demonstration software.

Data Analyst

As the name implies, the Data Analyst (DA) agent provides data analysis in support of *Smart**DER operation. DA analysis activities include:

- Prediction of site electric and thermal (if applicable) load,
- Prediction of relevant pricing (energy, ancillary services, fuel, etc.),
- Generation of beneficial operating schedules for the various DER assets at a given site,
- Preparation of reports summarizing site or portfolio activities, and
- Analysis support for PM / OIA coordination of *Smart**DER actions between multiple sites.

The DA agent operates in response to analysis requests coming from the DM. In this way, the DM serves as the central repository for all analysis results. Note that prediction algorithms, while investigated, were not implemented during the PIER project since prediction capabilities are not essential to accomplishing the primary project objective of demonstrating the viability of the intelligent agent concept. In addition, we felt that *Smart**DER operation using predicted load and price information would insert a level of uncertainty that could be counterproductive.

2.2.10.3 *Smart**DER Agent Testing

During the course of development AESC personnel confirmed individual agent operation and functionality. In addition, AESC confirmed all of the agent-agent communications associated with normal operation. Results of these testing efforts were summarized in the Final DER*S Test Report.

2.3 Task 3 EASE Development and Testing

The purpose of this task was to develop and test the simulation environment (EASE) needed to test the *Smart**DER agencies in a realistic operating environment. The general goal was to develop EASE so as to allow the objective evaluation of the *Smart**DER agencies. This research and development effort was comprised of three subtasks.

2.3.1 Development of Detailed EASE Requirements

The purpose of this task was to develop the detailed EASE requirements. AESC's principal subcontractor, Reticular Systems, Inc. (Reticular), summarized these requirements in the EASE System Product Specification. This document also summarized the EASE Test Plan, which described the test plans, procedures and methods.

The Commission Contract Manager conducted the second Critical Project Review at the conclusion of this subtask (coincided with completion of Algorithm Development and Testing subtask of Task 2)

2.3.2 Create Comprehensive EASE Software Design

The purpose of this task was to design the EASE software and summarize the basic design in a Preliminary EASE Software Design Report.

2.3.3 Construct and Test EASE Software

The purpose of this task was to construct and test the EASE software in preparation for integration and testing with the *Smart**DER agencies that were also under development (Task 2). Reticular updated and submitted a Final EASE Software Design Report at the conclusion of this subtask.

AESC and its principal subcontractor, Reticular Systems, Inc. provided the following deliverables prior to completion of the Task 3 effort:

- EASE System Product Specification and Test Plan (provided prior to second critical project review)
- Preliminary EASE Software Design Report
- Final EASE Software Design Report

2.3.4 Task 3 Results

This project task effort was primarily the responsibility of Reticular Systems and occurred concurrently with the DER*S Development and Testing effort. As described previously, EASE is the EnerAgent Simulation Environment, which allows for realistic operation / testing of *Smart**DER agencies. Early efforts were focused on defining EASE functional requirements, which were summarized in the EASE Product Specification Report. These requirements were refined and the final EASE software design, which was developed and tested, is briefly summarized in the following sections (refer to the Final EASE Software Design Report for additional information).

2.3.5 EASE Description

EASE consists of several different components, the first of which is a *Smart**DER agency configuration tool. This is a standalone GUI application used for installing and configuring a *Smart**DER agency. The second component consists of a web server that emulates the various web-based entities that a *Smart**DER agency communicates with during normal operation. A third EASE component is a simulation control agent, which is used to monitor and control a simulation run for one or more *Smart**DER agencies. EASE simulation control includes a graphical user interface for control and monitoring of the simulation as well as multiple software components that are integrated directly into the *Smart**DER agents.

***Smart**DER Agency Configuration Tool Capabilities**

EASE provides a *Smart**DER Agency Configuration tool that is used for installing and configuring individual *Smart**DER agencies. *Smart**DER agents are able to run on separate computers and communicate across networks or the Internet to perform the tasks of a single *Smart**DER agency. In order to simplify the installation, configuration, and monitoring of the demonstration system, the *Smart**DER agency configuration tool installs all the agents for a single *Smart**DER agency onto a single computer. Using the configuration tool, multiple agencies can be installed on multiple computers to simulate operation of a distributed asset portfolio.

*Smart**DER agencies are self-configuring in that agents initiate communications with one another automatically. Therefore, agency configuration is relatively simple in that its sole function is to create a property file used by all of the agents. This property file provides enough information for the various agents to discover each other and begin communicating. The *Smart**DER agency has been designed such that the Data Manager (DM) agent is the central source of information. Therefore, each agent uses information from the property file to discover the location of the relevant DM agent. As the agents register with the DM they discover the locations of other agents within the agency thus enabling communication between all of the agents.

Participation in one the energy or ancillary services markets is the responsibility of the Portfolio Manager agent (PM / OIA). If market participation is not required (i.e., DER assets are used exclusively for local bill reduction) then there is no need for a PM / OIA. A single PM / OIA coordinates the actions of multiple agencies (a portfolio of agencies) via communications with the Owner Interface Agent (OIA) of each *Smart**DER agency. To enable market participation the property file contains information on market participation and, if needed, the location of the single PM / OIA. When market participation is required, the OIA of each of the agencies within a portfolio of *Smart**DER equipped sites uses the information in the property file to locate the PM / OIA and initiate communications. For testing and demonstration purposes the property file also contains the location of the EASE simulation control, which provides timebase and execution control capabilities for all agents operating in any of the participating *Smart**DER agencies.

The *Smart**DER agency configuration tool is a standalone graphical user interface (GUI) used for creating the properties file. A sample screenshot of the GUI is shown in Figure 6. In this screenshot, Market Participation has been selected without Local Portfolio Manager. These selections indicate that the site will participate in the energy or ancillary services markets but the PM / OIA is not located at this site. This combination of selections will notify the site OIA that it needs to contact the PM / OIA to initiate market participation activities. Thus the PM / OIA does not need to have any prior knowledge that a site will participate in portfolio activities and the process of adding sites and assets to the portfolio is simplified.

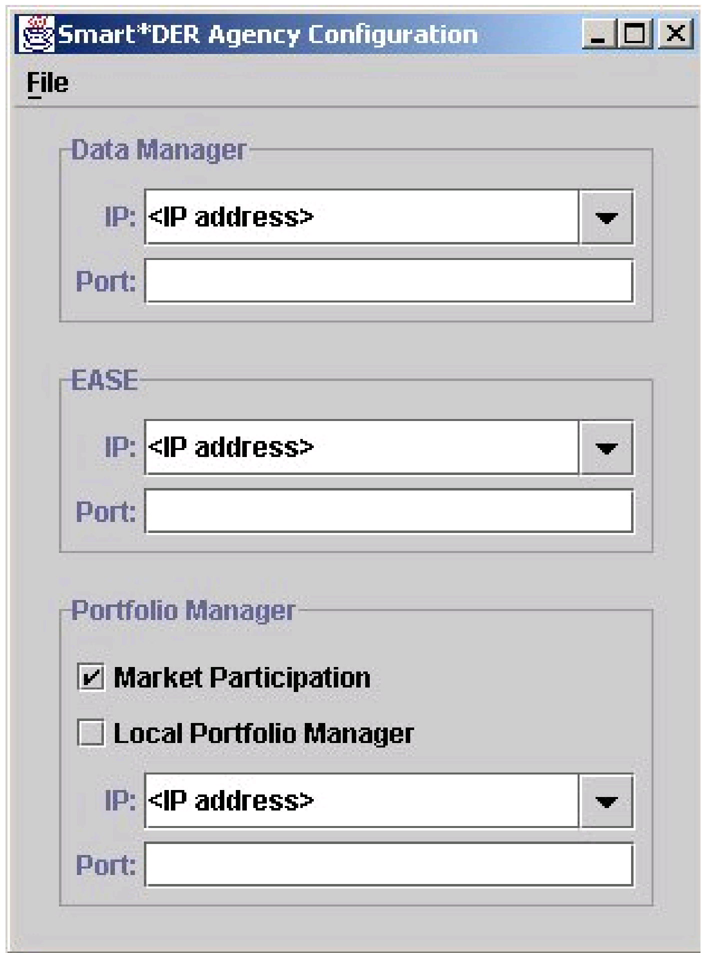


Figure 6. EASE Configuration Tool Input Screen

<u>EASE Web Emulation Services</u>

The EASE web server is hosted by Reticular Systems and provides emulation services for the external entities that a *Smart**DER agency communicates with during normal operation. The EASE web server provides two basic services.

<u>Data Retrieval</u> - The *Smart**DER agency requires pricing and weather information to develop cost effective operating schedules for the various DER assets. In a commercial environment the Internet Agent (IA) would obtain this information on a daily basis from websites maintained by the CalPX and CAISO (pricing) and from a commercial weather data website. Providing these services on a consolidated web server ensures availability of these resources during testing and demonstration of *Smart**DER agencies. The EASE

web server mimics the weather, CalPX and CAISO web sites using 1999 historical data for the San Diego region. Use of historical data provides a controlled and known environment for *Smart**DER testing and demonstration. The web server provides:

Auction Interaction - When market participation is desired it is the responsibility of the PM / OIA to represent one or more *Smart**DER equipped sites in both the CalPX (day-ahead energy spot market) and CAISO (ancillary services) markets. The EASE web server emulates this interaction by accepting, processing and returning auction results to the PM / OIA via the Internet Agent. These actions are handled via a servelet on the EASE web server. Note that no attempt was made to emulate the CAISO and CalPX auction protocols since *Smart**DER would not communicate directly with these entities in a commercial environment but would instead communicate via a Schedule Coordinator.

EASE Simulation Control

EASE control of a *Smart**DER simulation run is accomplished using a separate EASE agent with a graphical user interface (GUI). The various parameters for a simulation that are controlled with this GUI include:

- 1999 Date for Simulation,
- Time base acceleration constant for running the simulations faster than real-time,
- Probability of Ancillary Services (Non-Spinning and Replacement Reserves) capacity being called during the simulation, and
- Simulation start / stop control.

The EASE simulation control agent monitors and communicates with *Smart**DER agents across all agencies during a simulation run. One of the main functions of this agent will be to generate CAISO requests for Ancillary Services (AS) capacity during a simulation run. These requests are communicated directly to the PM / OIA for action.

***Smart*DER Test Bed Capabilities**

Other interactions between *Smart**DER agents and EASE are accomplished with Personal Action Classes (PACs) that are incorporated into each *Smart**DER agent. The following sections briefly summarize the interaction that each *Smart**DER agent has with EASE, via these PACs during a simulation run.

Common Agent Capabilities - Time Base Control - EASE provides a time base control PAC that is integrated into each *Smart**DER agent. Two types of time control are required. First, the user needs a mechanism for setting the current time to an arbitrary value, which allows simulations to be performed for defined timeframes independent of the current wall clock time. This ability is especially useful when simulations are run using historical data. Second, control of simulation speed is required to allow extended timeframe simulations to be performed faster than real-time. In a real word environment, the time base PAC can be easily swapped out with one that provides a simple pass through of wall clock time. The EASE simulation control agent and GUI are used to communicate with the time base control PACs contained in each *Smart**DER agent. Note that the *Smart**DER agency is the first AgentBuilder agency to incorporate continuous simulation time and timer functionality across multiple agents under control of a single GUI.

Agent Specific Capabilities - As noted previously, EASE emulates the environment that a *Smart**DER agency would encounter during normal operation. As autonomous entities, each *Smart**DER agent interacts with this environment individually and as such EASE must accommodate the needs of each agent. Table 1 summarizes the agent specific interaction.

Table 1. EASE Agent Specific Capabilities

Agent	EASE Capabilities
Owner Interface Agent (OIA)	EASE does not interact directly with the OIA but instead generates OIA activity via responses to data that EASE initially supplies to other *Smart**DER agents (i.e., weather data, etc.), which results in actions and communications that involve the OIA.
Portfolio Manager (PM/OIA)	EASE interacts with the PM/OIA to emulate: 1) the interaction associated with participation in the CalPX and CAISO auctions and 2) the CAISO call for ancillary services capacity.
Event Manager (EM)	There are no EASE components specific to the EM agent, however the EM relies heavily on the EASE time base functionality described previously.
Data Manager (DM)	The EASE simulation control agent uses the data supplied by each DM: 1) for monitoring and logging of activities/events associated with simulation runs, 2) to display agency configuration information for the simulation user.
Facility Interface Agent (FIA)	A special purpose EASE PAC provides site sensor and DER operating parameters to the FIA on one minute simulated time intervals using template files installed with each agency by the configuration tool control. A second PAC interprets the schedule commands sent by the EM to the FIA and modifies the sensor data accordingly (i.e., change a kW reading if a generator is turned on, etc.).
Internet Agent (IA)	The EASE web server emulates the CalPX and CAISO and responds to IA requests for information and provides auction support. The EASE web server also provides weather data upon request.
Data Analyst (DA)	The DA makes extensive use of data provided by EASE via other *Smart**DER agents (FIA, IA) but does not have any EASE components specific to the DA agent itself.

2.4 Task 4 DER*S – EASE Integration and Testing

The purpose of this task was to integrate the previously developed *Smart**DER agency with EASE. The purpose of this integration and subsequent testing was to verify that EASE and *Smart**DER agency protocols are compatible. During this effort it was necessary to modify EASE, and various *Smart**DER agents. Testing of fully integrated system in both single and multiple site (multiple agency) configurations was conducted. Results of this testing effort was summarized in the DER*S Final Integration Test Report.

As part of this effort, AESC also provided a demonstration of *Smart**DER agent technology for members of the Virtual Evaluation Group of market participants so that their feedback could also be included in the Final Integration Report.

AESC and its principal subcontractor, Reticular Systems, Inc. provided the following deliverables prior to completion of the Task 4 effort:

- DER*S Final Integration Test Report
- Demonstration of the Integrated Package

2.4.1 Task 4 Results

As noted above, EASE enables realistic operation/testing of the *Smart**DER agents/agency by providing software simulation of real-world resources and assets (sensors, generators, etc.) as well as emulation of communications between *Smart**DER and external entities (weather services, CalPX/CAISO, etc.). In addition, EASE provides services specific to the simulation environment including configuration assistance in setting up a *Smart**DER agency and time base control for performing simulations faster than real-time. Once the agent software is installed, operation of a *Smart**DER simulation/test is a three step process where the:

- Simulation environment is established and then initiated using EASE (EnerAgent Simulation Environment),
- Simulation progress is observed using screens provided in EASE, the Site OIA and the Portfolio Manager GUIs, and
- Final results, in the form of DER schedules and associated financial and operations information, are summarized in reports provided in both the Site OIA and Portfolio Manager GUIs.

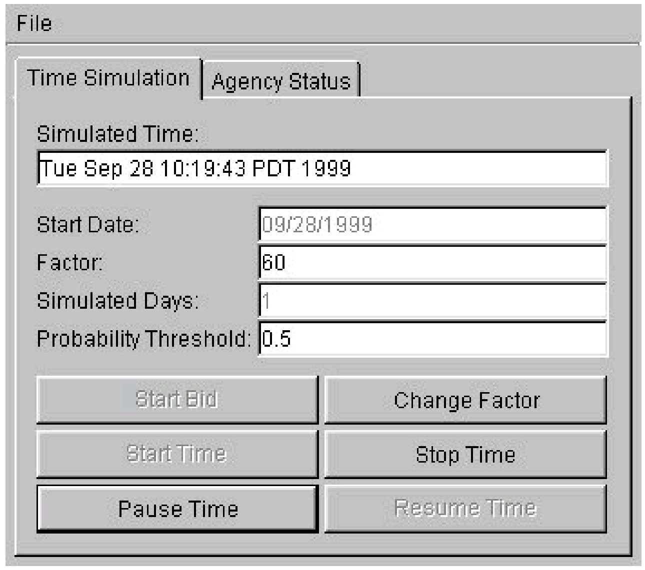
2.4.1.1 Simulation Setup

EASE provides the *Smart**DER agents with an operating environment that:

- Emulates the external entities (CAISO, CalPX, etc.) that a *Smart**DER agency would communicate with,
- Allows selection of a test day,
- Provides for time base control (i.e., accelerated system operation, starting/pausing/stopping a simulation), and
- Displays information on agent status during execution.

The EASE GUI consists of two screens, which are shown in Figure 7. The first screen provides for test date selection, and specification of time base acceleration “Factor”. In addition, the user can start, pause / resume and stop the simulation using buttons located on this screen. In addition, the user may specify a “Probability Threshold”, which is the probability that the CAISO will call for any capacity that was successfully bid into one of the ancillary services markets. The second screen displays the status of each agent in any agency that is participating in the simulation.

Simulation results consist of the DER schedules and associated savings. Individual site results are observed using screens provided in the Site OIA GUI, while multiple site or portfolio results are observed using displays associated with an individual site or income and expense that result.



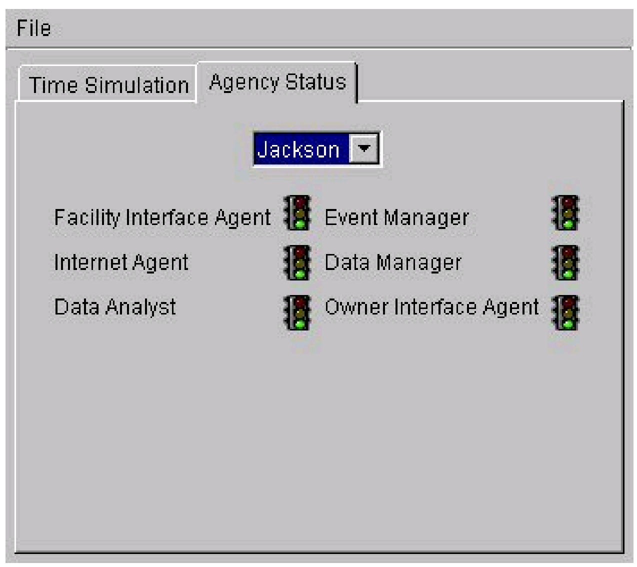


Figure 7. EASE User Interface Screens

2.4.1.2 Operating Environment

Testing was conducted on a variety of platforms and operating systems. During the course of development *Smart**DER agents / agencies were run on personal computers under the Windows ME, Windows NT and Windows 98 operating systems as well as computers[3] operating the Solaris operating system.

2.4.1.3 Test Description

Testing was conducted to confirm *Smart**DER operation in a variety of configurations and with a number of different test days. As noted previously, test days were confined to the 1999 calendar year. Testing confirmed that the *Smart**DER agencies successfully scheduled the operation of the DER assets involved. Two of the basic test cases, one case for a single site having multiple assets and a second case with two sites, each with multiple assets are presented in the following subsections. The single site test case will be described for September 27, 1999 and the dual site test case will be illustrated under operating conditions that existed on September 28, 1999. These dates were selected in order to illustrate both bidding into and subsequently providing capacity into the California energy markets.

For testing purposes, we assumed that *Smart**DER operation would provide DER operation to:

- Reduce site utility energy costs
- Participate in the CalPX energy auction,
- Participate in the Day Ahead CAISO Non-Spinning and Replacement Reserve ancillary services (AS) markets,

Furthermore, in order to enhance site participation in the various markets we used a minimum bid size requirement of only 10 kW compared with the actual 1 MW requirement used by the CAISO. In addition, we assumed that a bid into the CAISO AS markets would be accepted as long as it occurred on a weekday between the hours of 10 a.m. and 8 p.m. The probability of subsequently providing AS capacity that was successfully bid in any given hour was set for 0.5.

2.4.1.4 Site Descriptions

Weather, market pricing and building load profile information was confined to the San Diego area so all tests were conducted for sites located in the San Diego area. Fuel (natural gas) prices were taken from 1999 EIA data for California.

Single site test cases were run using a site with the following characteristics:

- Large commercial load profile,

---

[3] Operation on Unix based machines did not include the Data Manager agent, which uses the Microsoft Access DB and is therefore limited at this time to Windows based machines.

- Peak annual demand of 300 kW,
- SDG&E Time of Use electric rate tariff for secondary distribution customers (AL-TOU Secondary),
- DER assets consisting of a natural gas fueled 200 kW recuperated gas turbine with a nominal electric efficiency of 42 percent and a second 200 kW reciprocating type generator with a nominal efficiency of 35 percent.

For test cases where a second site participated, a test site was added with the following characteristics:

- Small commercial load profile,
- Peak annual demand of 150 kW,
- SDG&E Time of Use electric tariff for secondary distribution customers (AL-TOU Secondary),
- DER assets consisting of a natural gas fueled 100 kW reciprocating type generator with a nominal electric efficiency of 35 percent and a second 75 kW reciprocating type generator with a nominal efficiency of 33 percent.

2.4.1.5 Test Day Market Prices

Ancillary services and unconstrained market clearing price (UMCP) data are shown in Figures 3 through 6 for the two test days, September 27th and September 28th, 1999. These two days were selected based on the variety of pricing that was evident. On the 27th the Non-Spinning Reserve AS market pricing was higher while on the 28th the Replacement Reserve market pricing provided the best opportunity. UMCP values also varied significantly for each day.

2.4.1.6 Test Results – *Smart**DER Operation

*Smart**DER operation is dynamic in the sense that multiple agents operate independently and communicate continuously with other agents within the *Smart**DER agency to accomplish the DER scheduling and dispatching functions. This dynamic agent/agency characteristic is difficult to illustrate in a report format. However, the fact that test results are offered for this and the dual site test cases indicates that *Smart**DER successfully:

- Operated multiple agents at one or more sites to achieve the *Smart**DER scheduling and dispatch functions,
- Established communications with the DER*S demonstration website to retrieve weather and pricing information and to interact with CalPX and CAISO auctions,
- Conducted an intrasite auction to establish a portfolio response to one or more of the California markets (CalPX, CAISO), and
- Implemented CAISO calls for capacity, when needed.

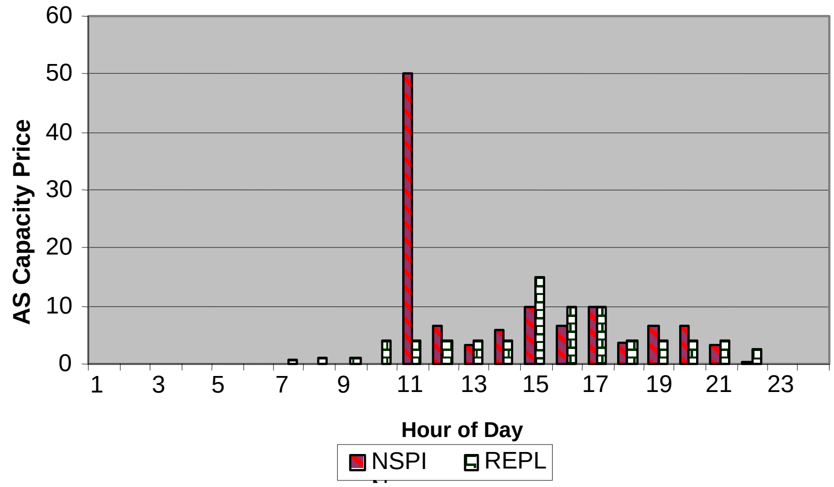


Figure 8. Ancillary Service Capacity Prices – 9/27/99

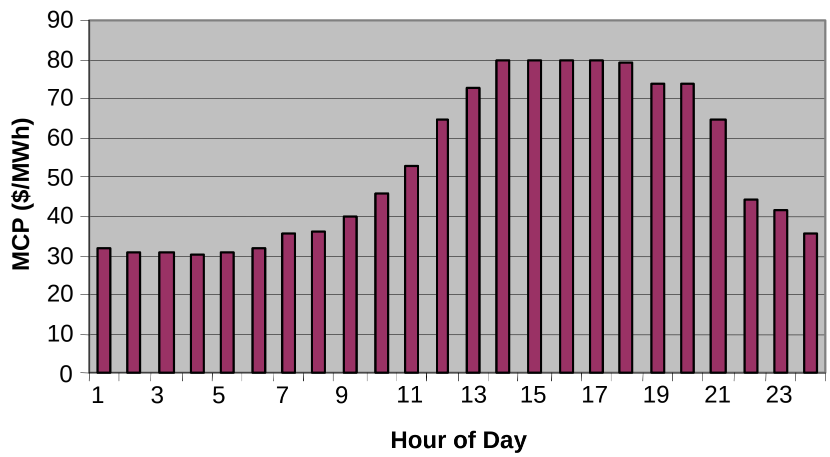


Figure 9. Unconstrained Market Clearing Price – 9/27/99

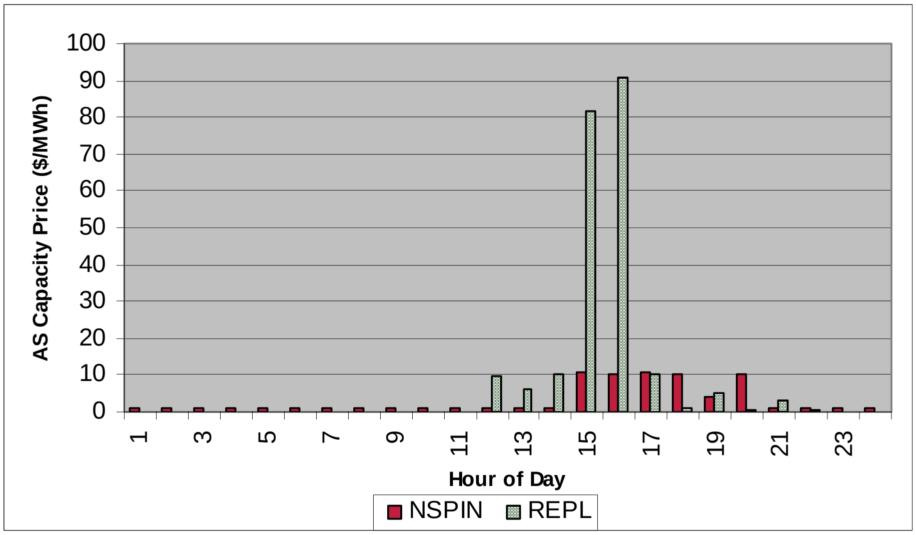


Figure 10. Ancillary Service Capacity Prices – 9/28/99

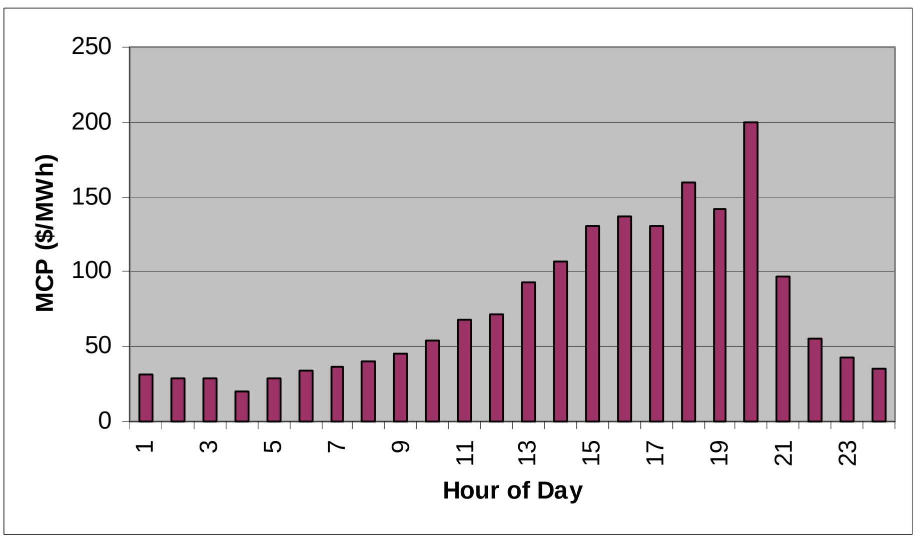


Figure 11. Unconstrained Market Clearing Price – 9/28/99

2.4.1.7 Test Results - Single Site, Multiple DER Assets

Results of *Smart**DER agency operation under operating conditions (weather, site load and pricing) that existed on September 27, 1999 are illustrated in the Site OIA screens show in Figures 12, 13 and 14. Figure 12 graphically depicts the DER operating schedule that was planned and subsequently implemented. The schedule shows continuous operation (shown as green) of the more efficient regenerative gas turbine to offset site load with operation of the less efficient reciprocating unit beginning at 10 a.m. to offset the midday peak and continuing until 4 p.m. (hour 16). In addition, *Smart**DER committed the remainder of the second asset's capacity to the AS market (shown as blue) to take advantage of the AS price spike (see previous Figure 8). *Smart**DER continued to commit all of the second asset's capacity to the AS market even after it ceased to operate to offset site load at 4 p.m.

The resulting site load (net demand after asset operation) is depicted in Figure 13. As the figure shows site load exceeded the capacity of the first generation asset after 5 a.m., which could have signaled a need to operate the second asset. Yet *Smart**DER did not schedule operation of the less efficient asset until 10 a.m. In this case, the operating costs (i.e., fuel and O&M costs) associated with part-load operation of the second asset exceeded the benefit associated with operation of the unit to offset site load. Operation could not be justified until higher energy prices, higher site load and the availability of income associated with the AS market provided sufficient additional income to justify unit operation at the later time. Note that this screen updates continuously during operation with green values depicting measured values and gold values showing predicted values. This particular screen shot was taken at 7:15 a.m. (simulated time).

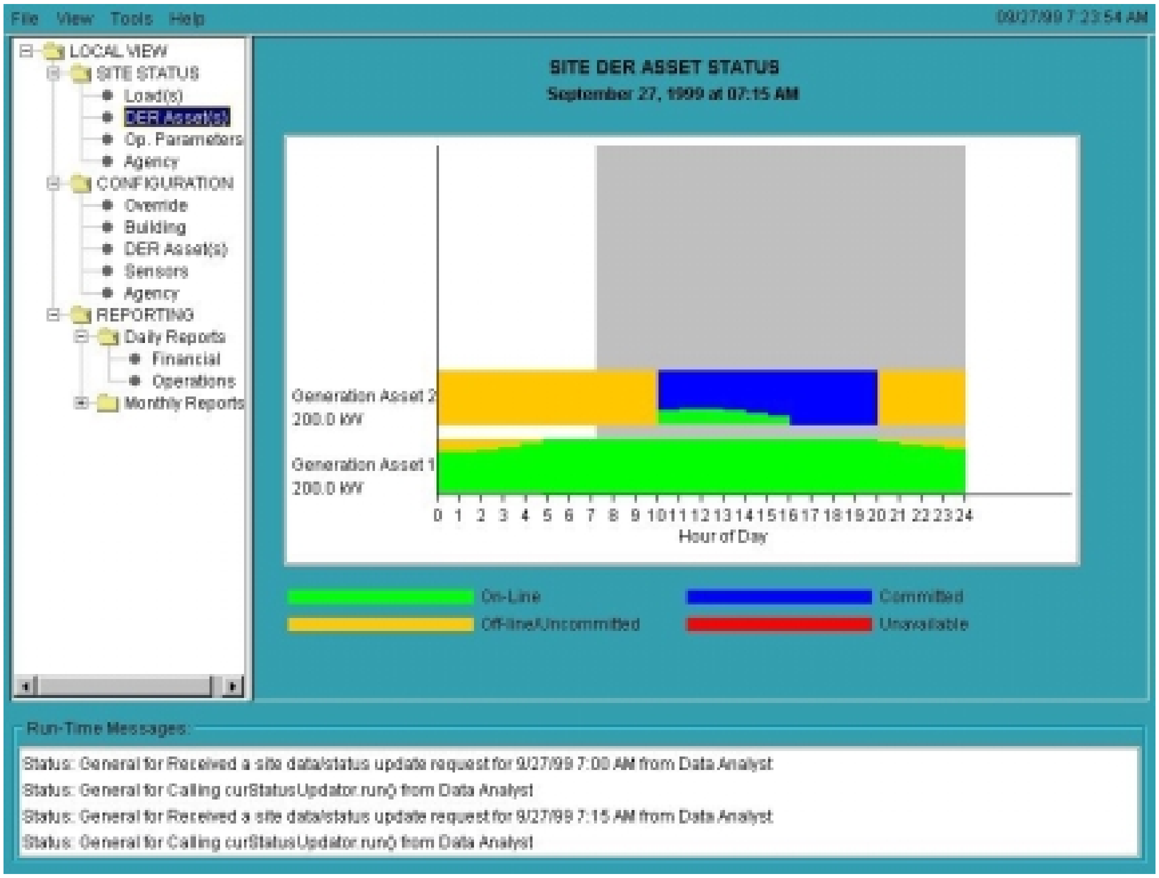


Figure 12. Single Site Operating Schedule for 9/27/99

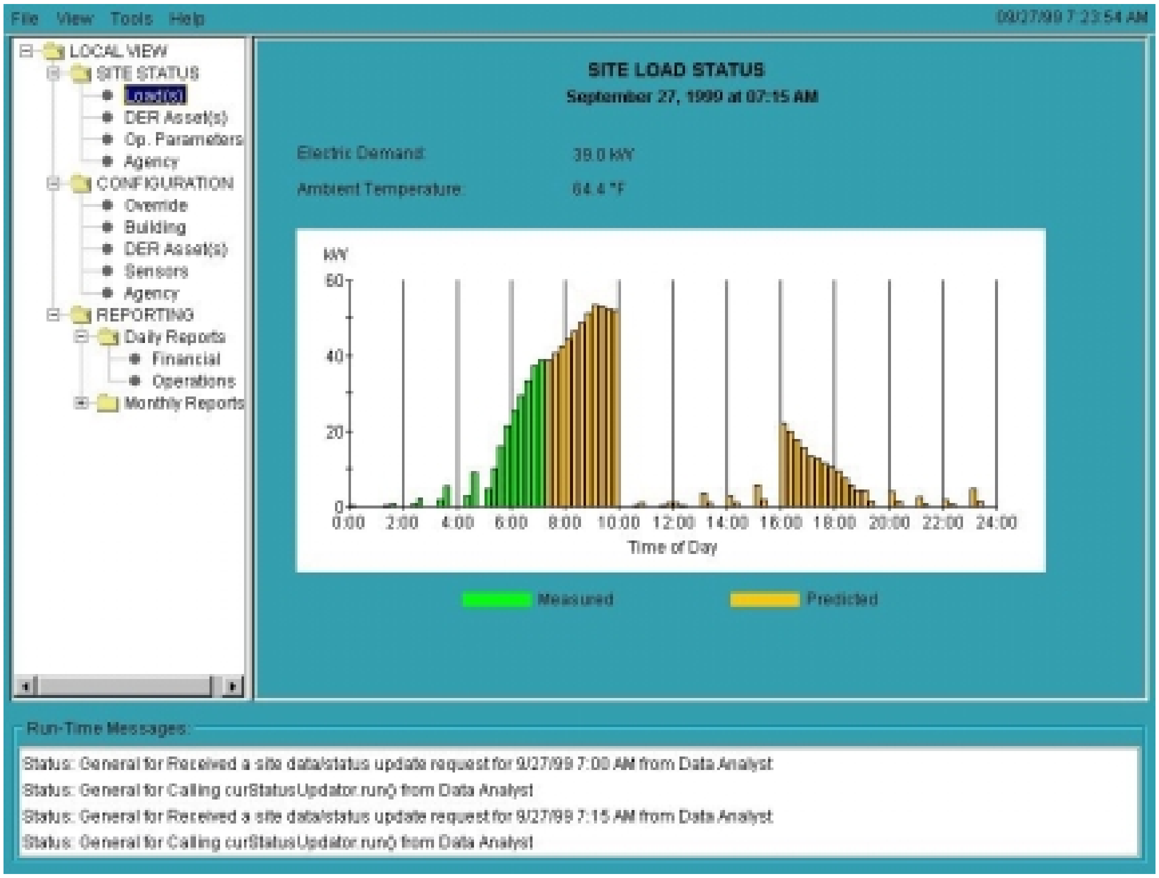


Figure 13. Single Site Load Status for 9/27/99

The economic results for operation of the single site on September 27th are shown in the OIA GUI, Site Daily DER Financial Summary screen depicted in Figure 14. From a financial perspective the additional income associated with participation in the AS market was modest. An additional $17.55 was obtained from the sale of the second asset's capacity and an additional $19.61 was obtained from the eventual sale of energy to the CAISO. Note that operation of the second asset in response to a CAISO call for capacity does not appear on the operating schedule previously shown in Figure 12 since the call for capacity occurred after the 7:15 a.m. snapshot of the OIA DER Status Screen was taken.

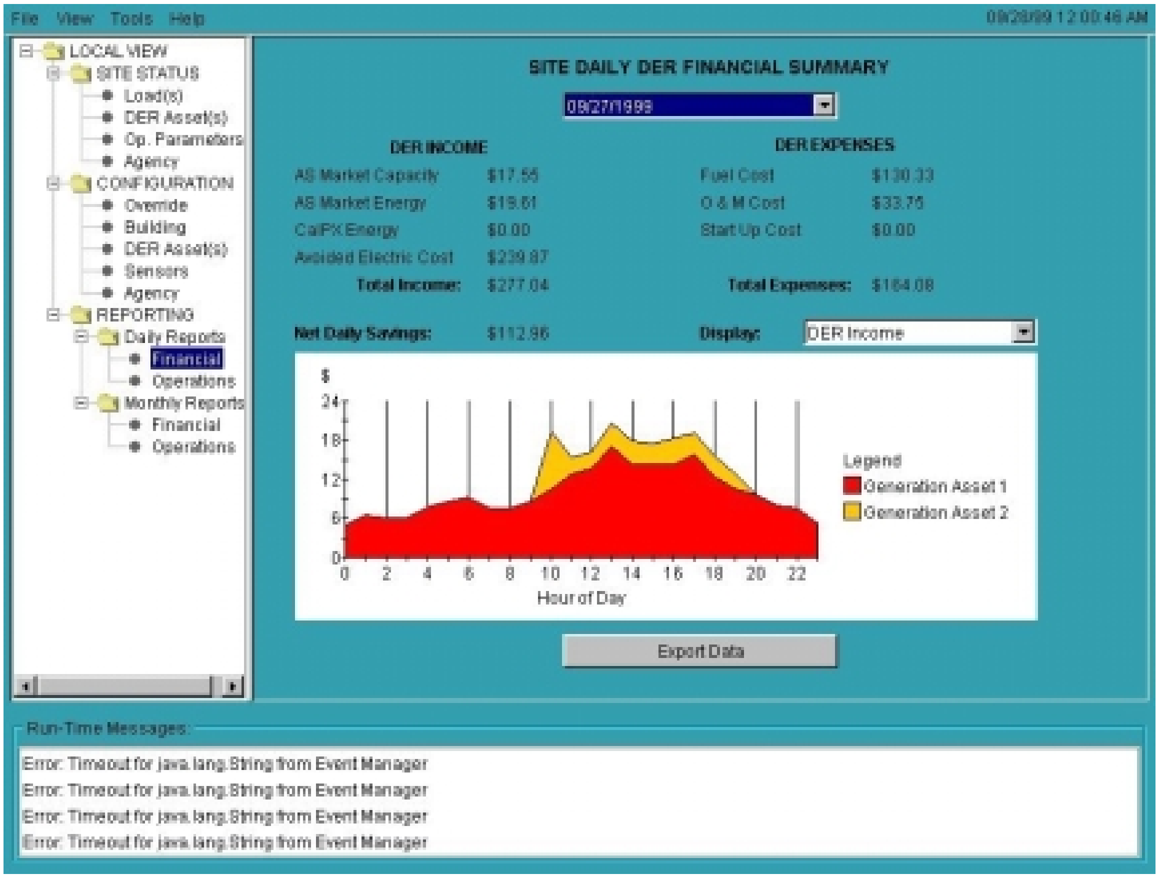


Figure 14. Single Site Financial Results for 9/27/99

While the financial benefits to the site were minimal for this particular day, it is important to note that *Smart**DER operation in this case resulted in additional capacity being made available to the California marketplace. In the absence of *Smart**DER it is likely that this capacity would have either operated at low loads to offset site load or not operated at all.

2.4.1.8 Test Results - Dual Site, Multiple DER Assets

For the dual site test example we retained the large commercial site with its two 200 kW generators and added a second site with a small commercial load profile and two smaller generators totaling 175 kW in capacity. Each site was represented by a *Smart**DER agency operating on separate personal computers. As noted previously, the example test day was September 28, 1999 with sites assumed to be located in San Diego.

Test results are presented for each individual site and then for the portfolio of assets that were offered for participation in the California market(s).

Large Commercial Site Results – 9/28/99

Results of *Smart**DER agency operation under operating conditions (weather, site load and pricing) that existed on September 28, 1999 are illustrated in the Site OIA screens show in Figures 15, 16 and 17. Figure 15 graphically depicts the DER operating schedule that was planned and subsequently implemented.

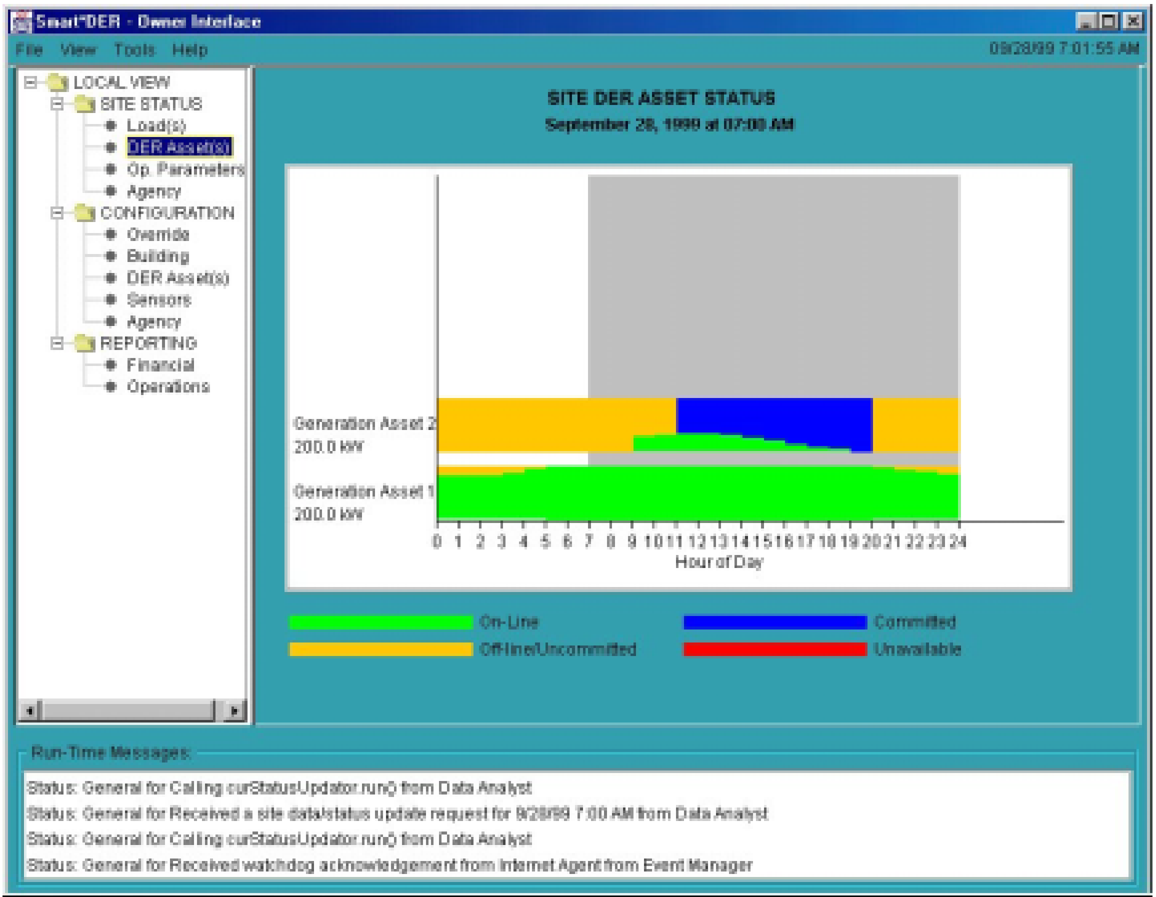


Figure 15. Large Commercial Site DER Operating Schedule for 9/28/99

The schedule is similar to the one developed for September 27th in that it shows continuous operation (shown as green) of the more efficient generator (Generation Asset 1) to satisfy site load. Operation of the second asset begins at 9 a.m. and continues until 7 p.m. In this case the second asset operates earlier and longer due to the higher energy costs (Figures 8-11) that existed on the 28th relative to the 27th. The resulting site load (net after generation) for the 28th is shown in Figure 16. Note the absence of any site load after 9 a.m. when the second generating asset was brought on-line.

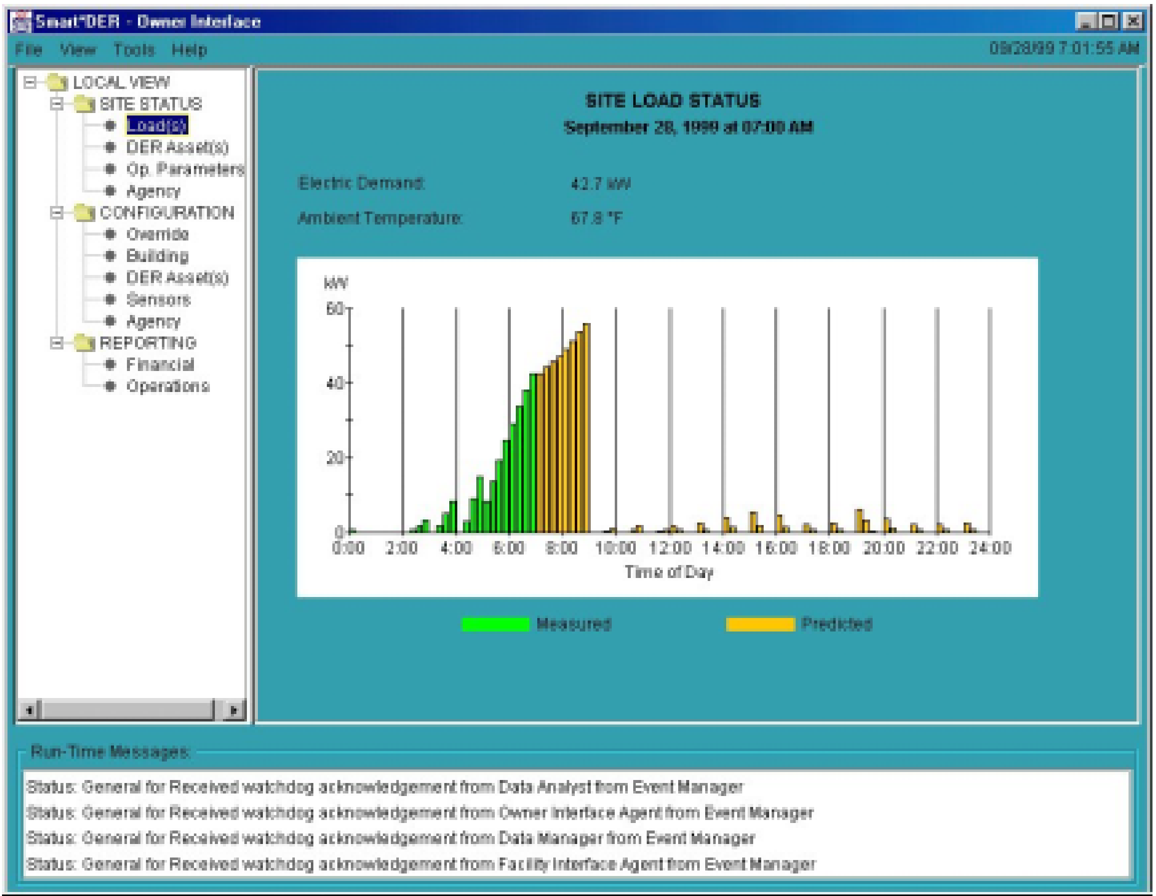


Figure 16. Large Commercial Site Load Status for 9/28/99

The financial results for operation of the large commercial site on September 28th are shown in the OIA GUI, Site Daily DER Financial Summary screen depicted in Figure 17. A net saving of $508 was achieved for the day, which is significantly higher than the $113 reported for the 27th (see previous Figure 14). The majority of the income is derived from avoided electric costs but income due to participation in the AS market increased to $212 from the $37 reported for the 27th.

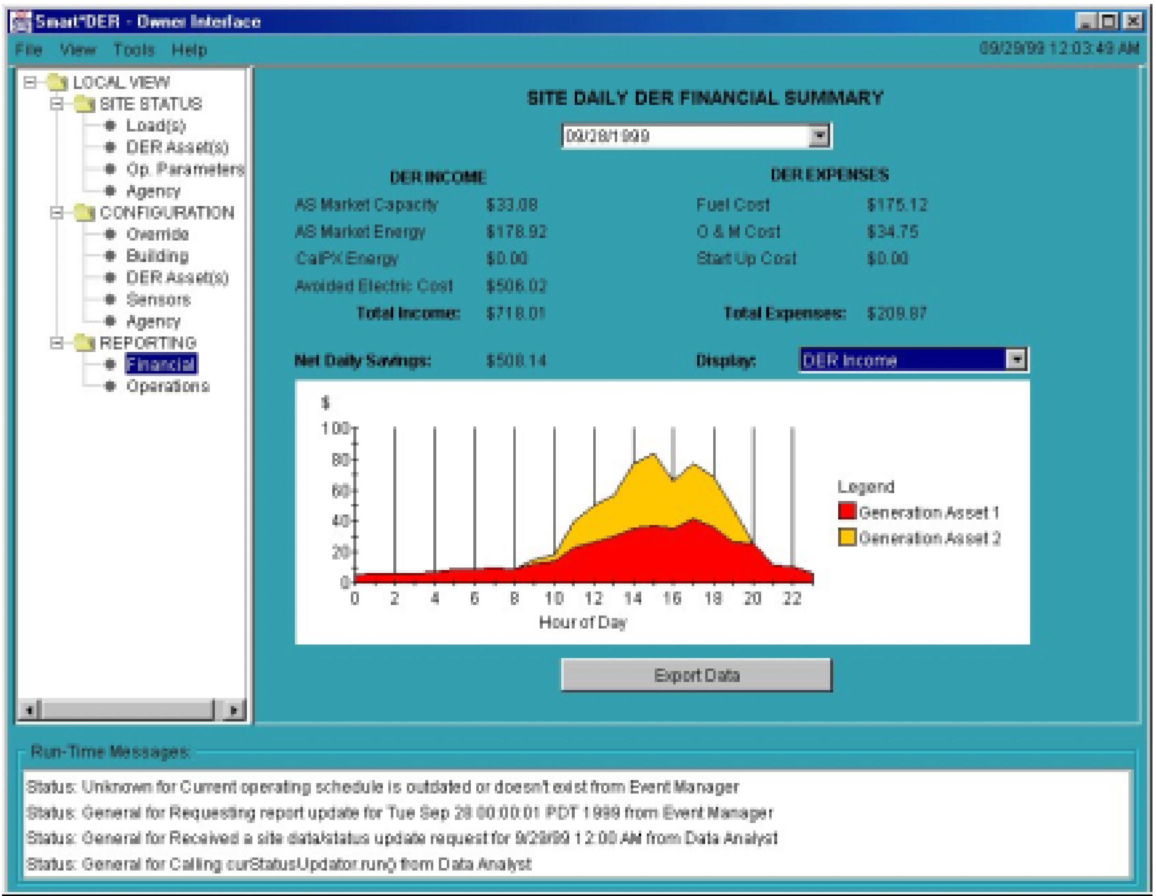


Figure 17. Large Commercial Site Financial Results for 9/28/99

Small Commercial Site Results – 9/28/99

Results of *Smart**DER agency operation for the small commercial site under operating conditions (weather, site load and pricing) that existed on September 28, 1999 are illustrated in the Site OIA screens show in Figures 18, 19 and 20. Figure 18 graphically depicts the DER operating schedule that was implemented and Figure 19 shows the resulting net site electric demand. The DER operating schedule shows that *Smart**DER did not schedule any unit operation prior to 7 a.m nor after 11 p.m. Operation of either unit during these periods would not have provided sufficient income to offset the operating costs. Operation (shown as green) of the first, more efficient, reciprocating type generator to offset site load began at 7 a.m. with operation of the less efficient generation asset beginning at 11 a.m. to offset the midday peak. *Smart**DER committed the remainder of the second asset's capacity to the AS market (shown as blue) beginning at 1 p.m. and continued to do so until 8 p.m. to take advantage of elevated AS prices occurring in the afternoon. (Figure 9). In addition, *Smart**DER committed excess capacity from Generation Asset 1 during the hours of 5 p.m. to 8 p.m., again to take advantage of high AS market prices.

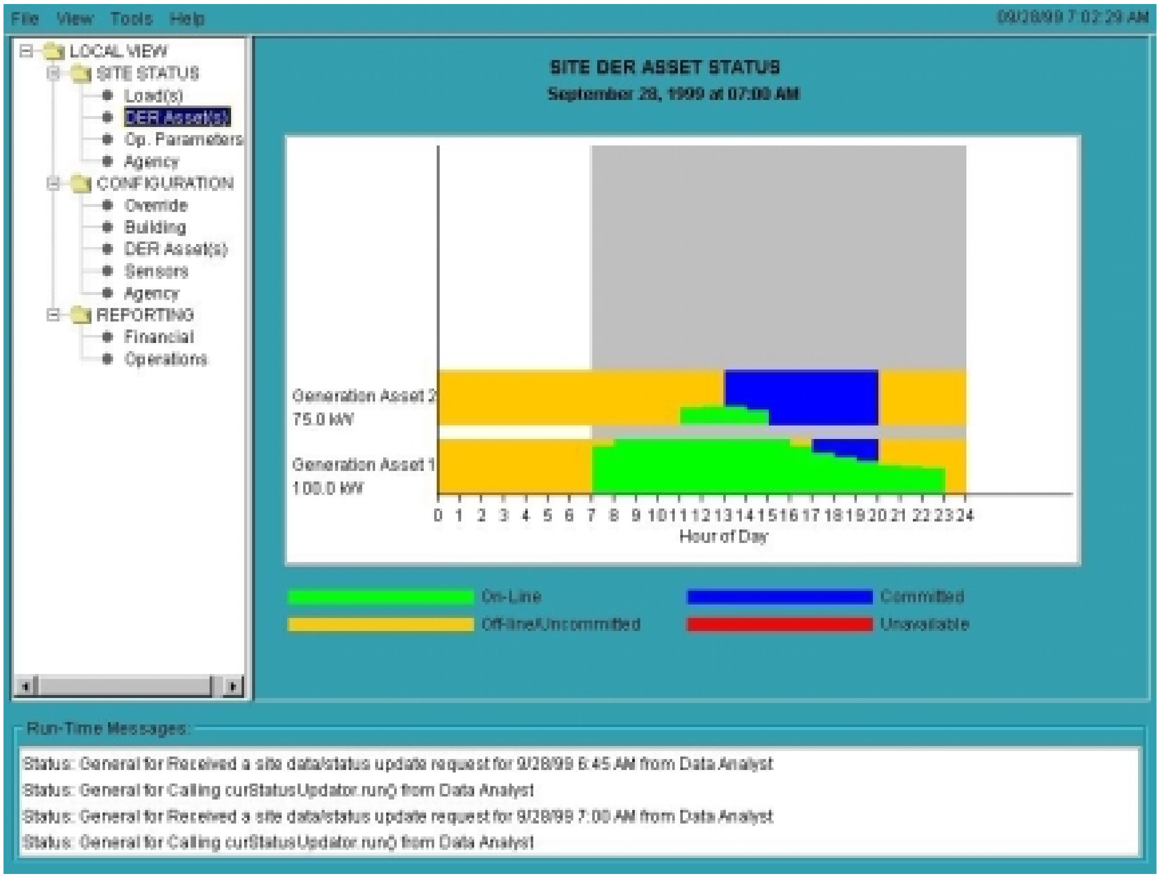


Figure 18. Small Commercial Site DER Operating Schedule for 9/28/99

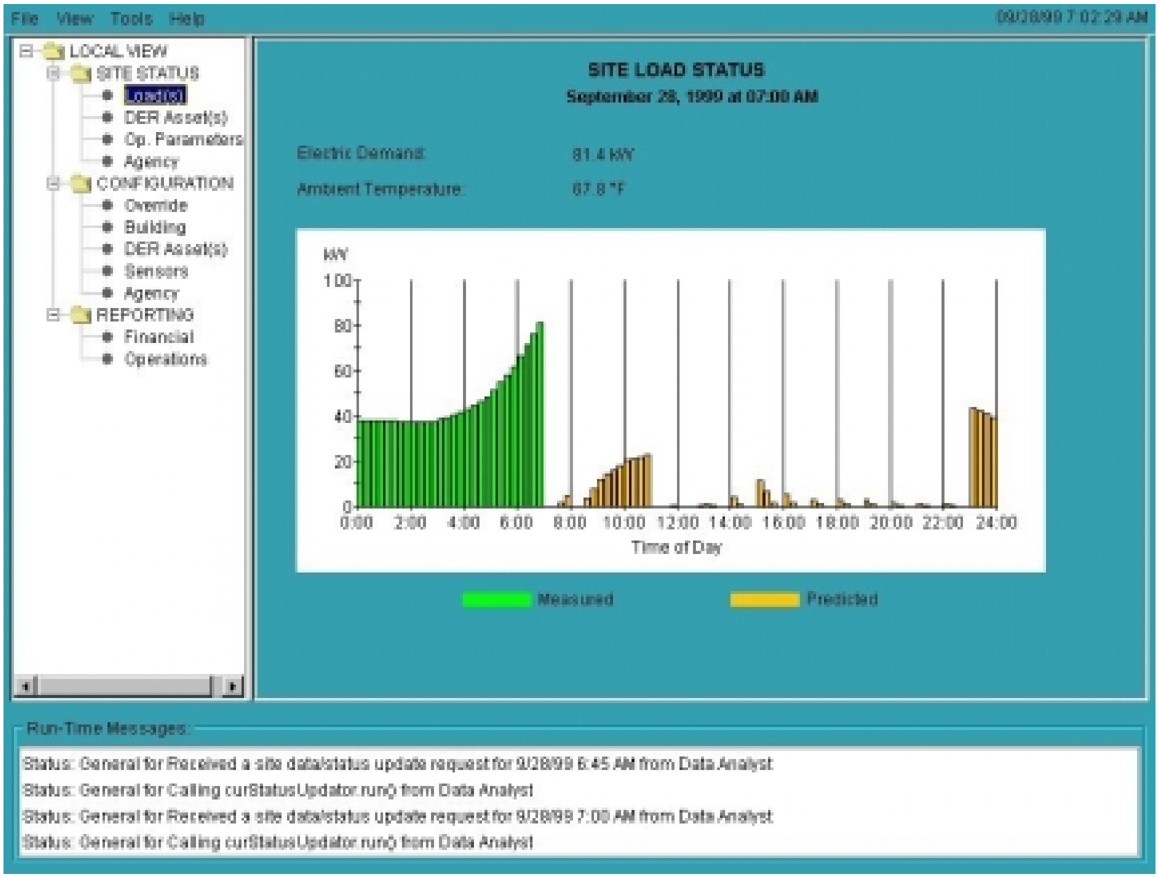


Figure 19. Small Commercial Site Load Status for 9/28/99

The financial results for operation of the small commercial site on September 28th are shown in the OIA GUI, Site Daily DER Financial Summary screen depicted in Figure 19. A net saving of $186 was achieved for the day with a significant portion of the $275 income for the day derived from participation in the AS market.

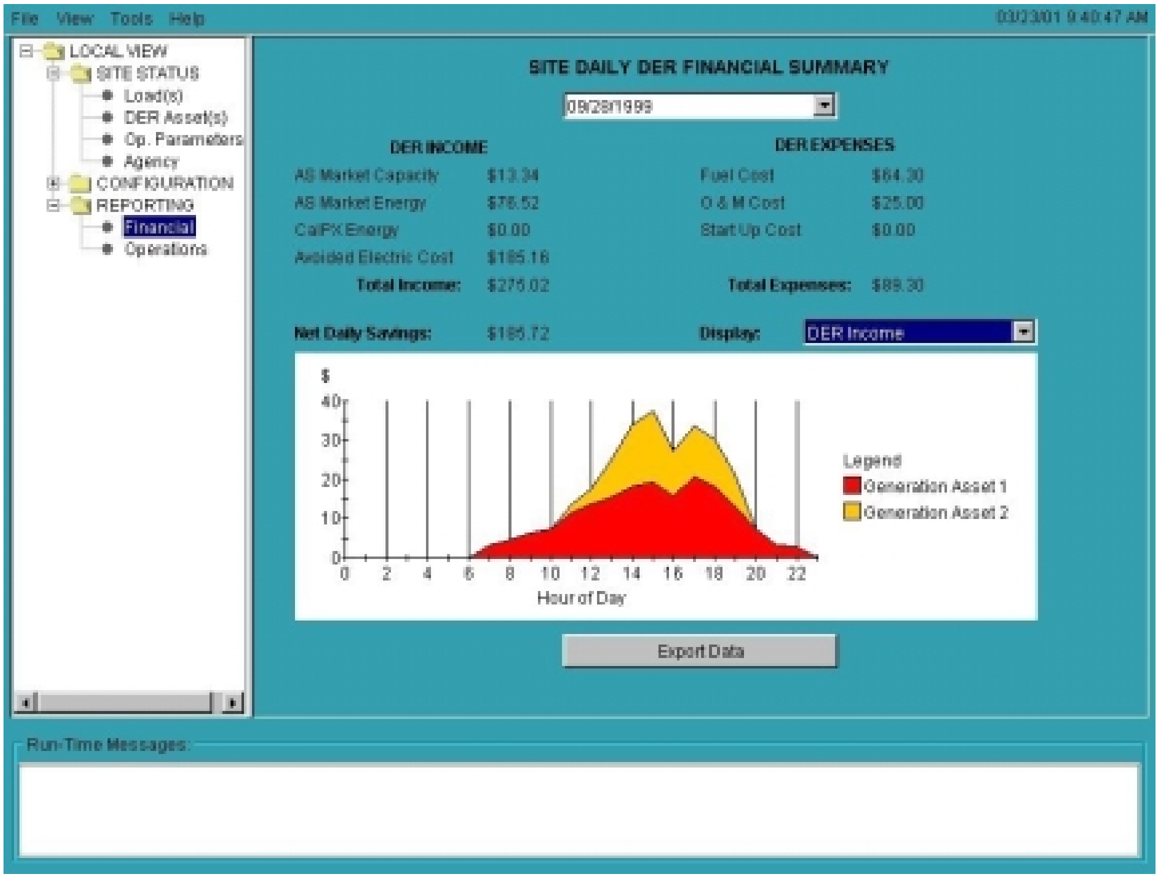


Figure 20. Small Commercial Site Financial Results for 9/28/99

It should be reiterated that operation of Generation Asset 2 would have been minimal in the absence of *Smart**DER. The capacity of this asset as well as a portion of the first generation asset's capacity became available to the California marketplace as a result of *Smart**DER operation.

Portfolio Results – 9/28/99

The Portfolio Manager OIA screens, shown in Figures 21, 22 and 23, illustrates portfolio results for operation on the September 28, 1999. The Generation Status Screen shown in Figure 21 graphically depicts the status of the generation asset contribution (both committed and generated) of each site to the portfolio. In this case, the graph shows that the large commercial site (designated as SDGE_Lead) has committed between 125 kW and 200 kW of capacity between the hours of 11 a.m. and 7 p.m. in support of portfolio commitments. The small commercial site (designated as Small_Commercial) is also shown to provide generation capacity in support of portfolio operations between 1 p.m. and 7 p.m. Note that this screen shot was taken at the beginning of the day immediately following the initial bidding cycle (see time stamp of "September 28, 1999 at 12:00 AM" located below the screen title). As such this screen would only show commitment of capacity since at that point in time no unit operation would have occurred. Actual operations that occurred during the day are summarized in the Portfolio Daily

Operations Summary screen shown in Figure 22. This figure shows that both sites generated power in support of the AS market between the hours of 1 p.m. and 7 p.m. with a peak contribution of 316 kW of generation (200 kW for SDGE_Lead and 116 kW for Small_Commercial) at 7 p.m.

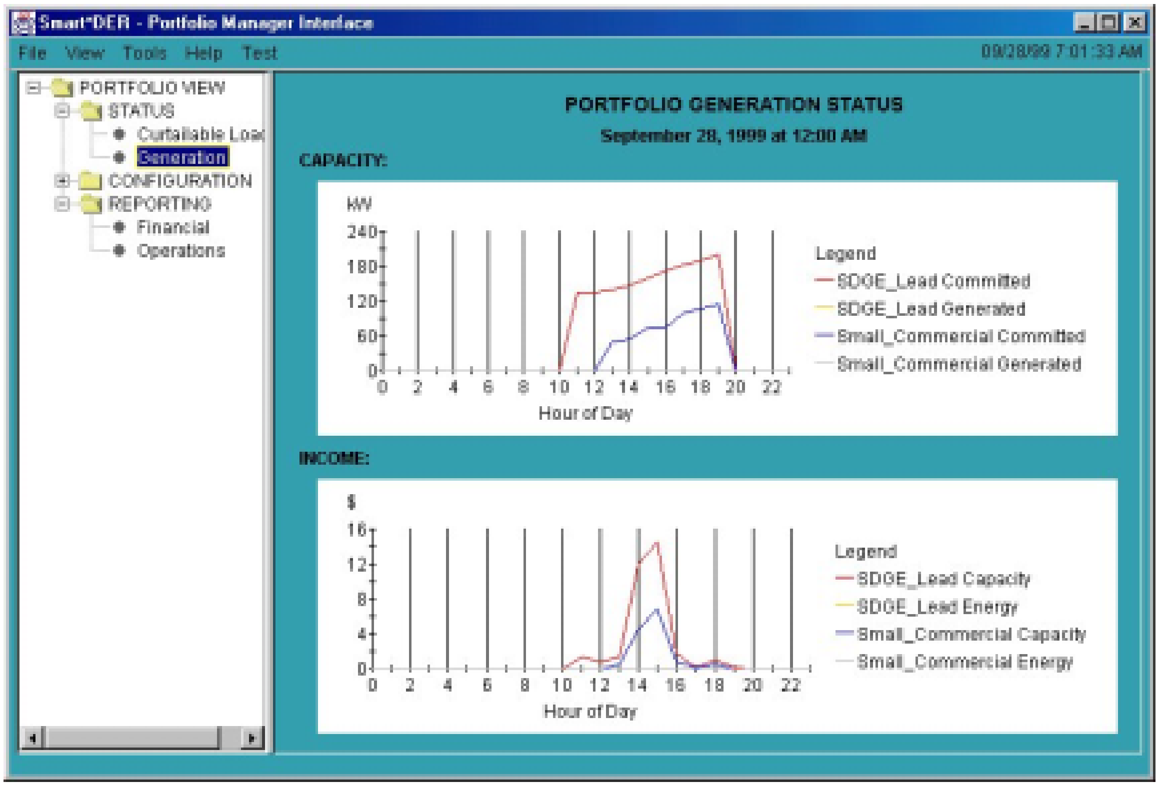


Figure 21. Portfolio Generation Status for 9/28/99

The Portfolio Daily Financial Summary screen (Figure 23) summarizes the income associated with portfolio operations and graphically shows the income attributable to each site. Additional detail (not shown) in the form of a tabulated site breakdown for a given hour is provided by clicking on an individual hour in the graph. For this date, the portfolio earned income associated with both the sale of generating capacity and energy (after the call for capacity was received) into the AS Replacement Reserve market.

The financial results of this particular day and for these individual sites were modest. However, it is clear that the magnitude of the financial results is simply a function of the size and number of the assets involved. The truly important result is that *Smart**DER agencies successfully collaborated to schedule and aggregate the assets at multiple sites, which allowed assets to participate in the marketplace that would otherwise have been excluded.

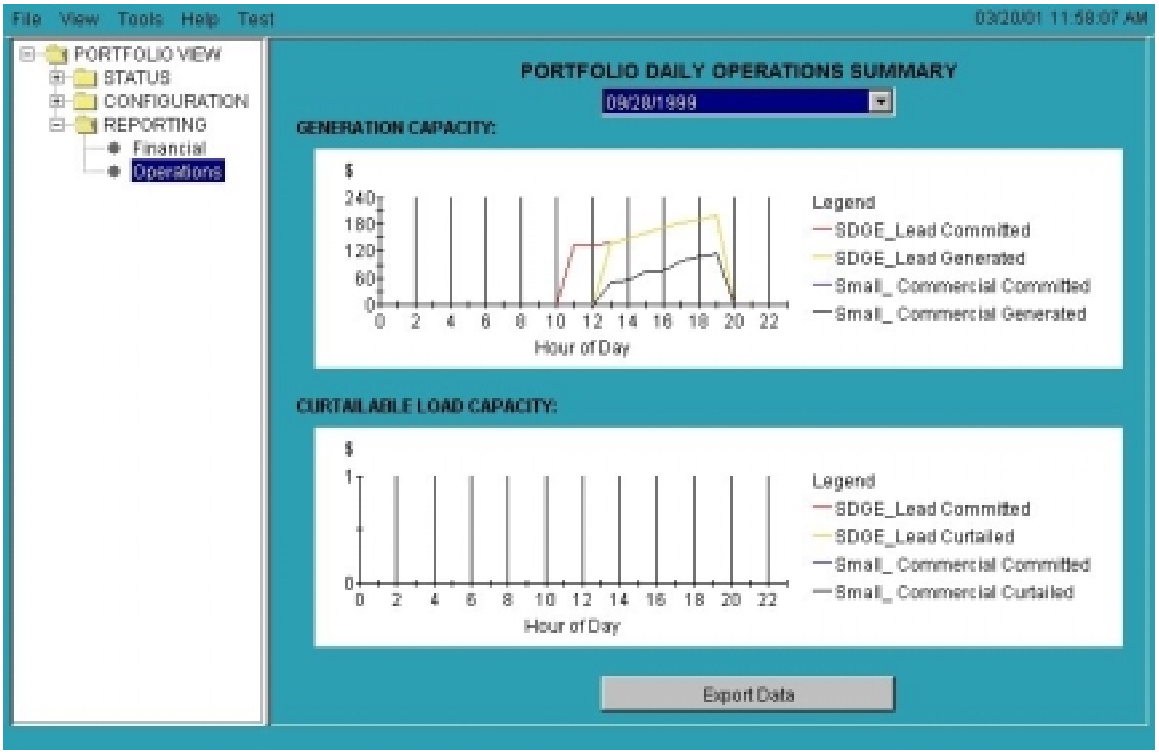


Figure 22. Portfolio Daily Operations Summary for 9/28/99

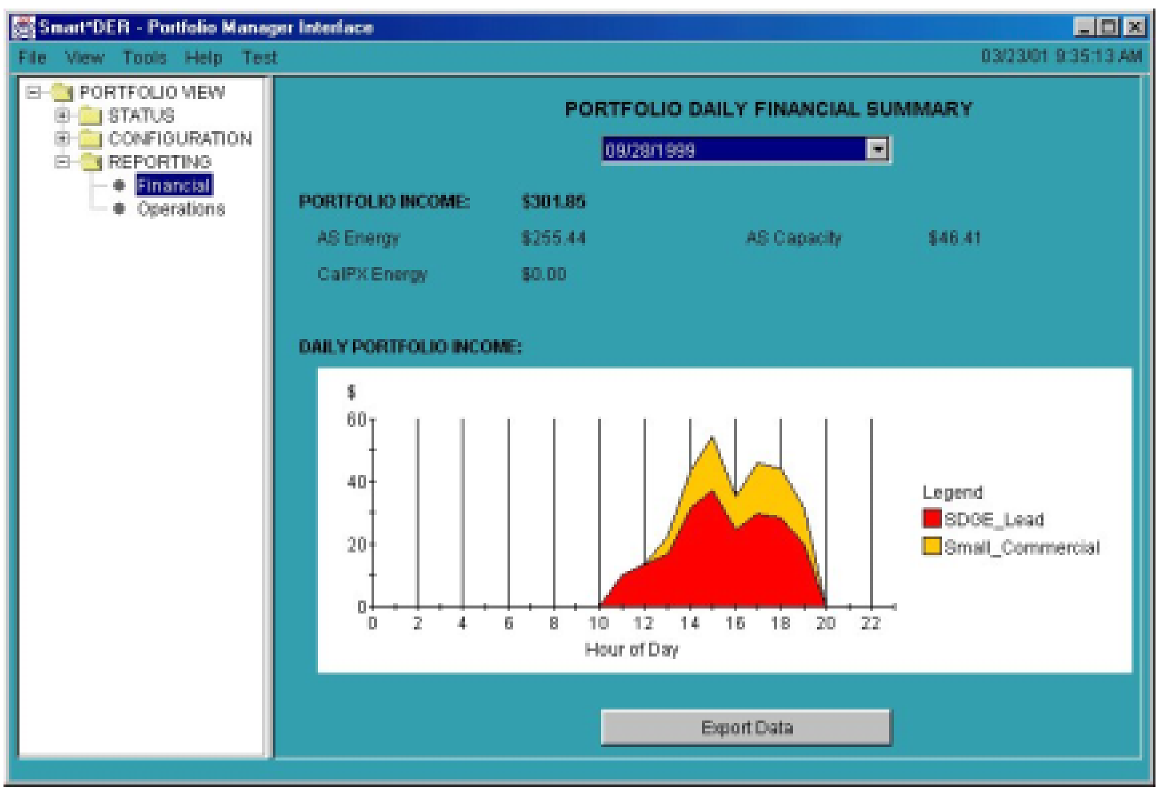


Figure 23. Portfolio Daily Financial Summary for 9/28/99

2.4.1.9 Integration Testing Summary

*Smart**DER agency operation is both simple and complex. It is simple in that each individual agent is designed to have a relatively small number of functions and tasks. It is complex in that each agent communicates with one or more other agents in order to carry out its tasks. In turn, an agency of agents must communicate with other agencies to represent the interests of an individual site. Testing was therefore carried out as a three part process where:

- Basic functionality of each agent was checked and confirmed,
- Inter-Agent communications were checked and confirmed, and
- Agents were combined into agencies and operated in a simulated environment (EASE) to verify that agencies could function independently yet collaborate to schedule DER asset operation in response to dynamic price and weather conditions.

At each of these steps AESC and its principal subcontractor, Reticular Systems were able to confirm that agents and agencies were operating correctly.

Ultimately, testing confirmed that *Smart**DER agents, operating in response to 1999 AS and energy market pricing, were able to collaborate and therefore aggregate the capacity of DER assets into a portfolio of assets that could in turn participate in the marketplace.

2.5 Task 5 DER*S Documentation and Demonstration Development

The purpose of this task was develop a technology transfer tool that would assist us in moving *Smart**DER agent technology beyond the proof of concept stage. To accomplish this we needed to develop demonstration software suitable for approaching and informing end-users and equipment manufacturers about *Smart**DER agent technology. This task also provided for development of a demonstration software user's manual suitable for use by industry personnel. This demonstration software and manual would be provided to the both the Commission Contract Manager and virtual evaluation group for their review and comment.

AESC and its principal subcontractor, Reticular Systems, Inc. provided the following deliverables prior to completion of the Task 5 effort:

- Copy of the demonstration software
- User’s manual for the demonstration software

2.5.1 Task 5 Results

Under this task AESC was to develop demonstration software and associated documentation that would facilitate transfer of intelligent agent technology into the private sector. This software would then be demonstrated and subsequently provided to the market participants for their review and feedback.

2.5.1.1 *Smart**DER Software Demonstration

AESC developed a PowerPoint presentation (Appendix IV) and associated *Smart**DER software demonstration, which were presented to the Commission at a March 13, 1999 meeting held at the Commission's offices in Sacramento, California. Commission staff members as well as a number of the market participants were in attendance.

Market Participant Feedback

Valuable feedback on the *Smart**DER interface screens as well as feedback on the major issues facing *Smart**DER implementation was obtained during the meeting. Participant feedback is briefly summarized below.

1. OIA GUI screens that display DER asset status didn't provide sufficient information. This screen displayed either commitment of capacity or operation but could not provide an indication when both conditions applied during the same hour of operation. DER asset status would appear as green (on-line) if any portion of the generator's capacity was on-line. Therefore, information on partial commitment of capacity to the AS market was not displayed if the unit was also on-line to offset site load during a given hour. This screen (see previous figures 12,15,18) was subsequently modified to show both on-line and AS market commitments during any hour.

2. OIA GUI screens that display load status didn't provide sufficient information on the contribution of the various generating assets. This screen (see previous figures 13, 16, 19) displayed the net site load after generation was subtracted and as such did not display any information on the output of individual generating units. Conversion of this screen to a stacked bar graph showing the contribution of the various assets is planned.

3. The benefit of *Smart**DER use of JAVA code and the platform independence that this provides was questioned. The response was that one of the primary strengths of the agent-based approach is the ability to locate agents on separate platforms. For instance, it is conceivable that the OIA would be located on a personal computer located in the Facilities Department of a large complex while the Data Manager (DM) could be located on a Unix server located in the Information Systems department. This multi-platform capability was fact confirmed by AESC and Reticular Systems during testing.

4. It was observed that reliance on a single Portfolio Manager (PM) agent to represent the interests of multiple sites makes the system vulnerable in the event that this agent were to go off-line. The question was raised if it was possible to have more than one PM agent so that an alternative would be available in the event that the primary PM crashed. The response was that this is entirely possible. Communications between agents could easily accommodate multiple PM agents and if fact AESC had proposed a similar system as part of a 1997 Army Small Business Innovative Research (SBIR) grant proposal.

5. The question was raised as to the maximum number of sites that an individual PM agent could handle. The response was that the data analysis performed by the PM was relatively simple and would not be limited to any particular number of sites. The computational burden is handled at each site with the PM simply processing the intrasite bid information. In addition, it was explained that the system was envisioned as having a separate PM agent for each CAISO zone since the CAISO had indicated that portfolio bids involving multiple zones would not be permitted. This restriction would help to limit the number of sites handled by a single PM.

   The question was clarified to state that the number of transactions and data storage needed for billing true up and settlement could prove burdensome for the PM as additional sites were added (especially in light of CAISO data requirements). One of the market participants observed that settlement and true-up are not done in real-time and could therefore be handled as separate data processing streams. An agent-based technology easily accommodates this approach since the DM agent could readily be attached to an existing legacy system that would perform the needed data storage and processing.

6. The issue of network security was raised. An observation was made that it was not clear how an intelligent agent based system would prevent intrusion by unauthorized personnel. The response was that security is handled at two levels. The AgentBuilder® software that serves as the basis for the agents themselves handles security at the agent communication level while higher level security is handled by the network infrastructure software such as that offered by Enflex, Encorp or Sixth Dimension. It was reiterated that *Smart**DER technology is envisioned as a supervisory software layer that would ultimately reside with the infrastructure networking software produced by others. One of the market participants offered that networking software routinely handles higher level security.

2.5.1.2 *Smart**DER Demonstration Software Distribution

Based on discussions with the Commission Program Manager a decision was made to temporarily withhold distribution of the demonstration software. While the demonstration software could have been made available for participant use it was decided that distribution of the software would risk the loss of valuable intellectual property. The JAVA based demonstration software could too easily be disassembled and the risk of loss was too great. Therefore a decision was made to provide demonstrations of the software on a company by company basis with AESC providing software for use at a later date once steps could be taken to protect both AESC's and the Commission's investments.

2.6 Reporting Tasks

The following reporting tasks were undertaken by AESC in accordance with PIER project requirements.

2.6.1 Task 3.1 Monthly Progress Reports

AESC prepared and submitted written Monthly Progress Reports to the Commission Contract Manager by the 30th of each month during the course of the project.

2.6.2 Task 3.2 Final Report

AESC prepared and submitted to the Commission Contract Manager for review an outline of the Final Report describing the original purpose, approach and results of the project. Upon receipt of outline approval AESC prepared and submitted to the Commission Contract Manager a draft Final Report on the project. Upon finding the revised draft to be satisfactory, the Commission Contract Manager provided a written notice of draft approval. AESC then prepared and submitted the Project Final Report.

2.6.3 Task 3.3 Final Meeting

At the conclusion of the project AESC met with the Commission Contract Manager to present findings, conclusions, and make recommendations for next steps.

3.0 Project Outcomes

The discussion of project outcomes is divided into two areas. First, project outcomes will be summarized relative to the various project tasks described previously in the Project Approach section. Second, a discussion of project outcomes as they relate to the project's technical and economic objectives is provided.

3.1 Project Outcome by Technical Objective(s)

The project technical objectives were achieved during the course of the project. The two technical objectives for this PIER project were to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.

The first project technical objective was achieved during the testing and integration tasks when AESC and Reticular Systems confirmed:

- operation of individual *Smart**DER agents,
- agent-agent communications,
- agency communications with external, web-based entities in order to retrieve pricing and weather data needed for routine *Smart**DER operation, and
- *Smart**DER agency operation to schedule DER assets in response to market and weather conditions for dates in 1999 (see Section 3.1.4).

The second technical objective called for development of a demonstration package that would facilitate transfer of the project results into the private sector. AESC developed a PowerPoint presentation (Appendix IV) and associated *Smart**DER software demonstration, which were presented to the Commission at a March 13, 1999 meeting held at the Commission's offices in Sacramento, California. Commission staff members as well as a number of the market participants were in attendance. During this meeting both single and multiple agency operation were successfully demonstrated. Distribution of demonstration software was deferred until a later date based on discussions with the Commission Program Manager. It was decided that distribution of the software would risk the loss of valuable intellectual property since JAVA based demonstration software could too easily be disassembled and examined. In lieu of providing the software, AESC will demonstrate the software on a company-by-company basis. AESC will provide the demonstration software for use at a later date once steps have been taken to protect both AESC's and the Commission's development investments.

3.2 Project Outcome by Economic Objective(s)

AESC achieved the project's single economic objective, which was to:

- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of the DER*S agency.

During the course of the project AESC engaged a variety of market participants with the potential to assist in further commercialization of *Smart**DER technology. AESC contacted many of these individuals as part of the Market Research and Domain Analysis efforts (see Section 3.1.1). Many of the participants contacted chose to participate in the Virtual Evaluation Group that subsequently provided valuable feedback during the project.

In addition to the market research and domain analysis tasks, AESC attended CAISO meeting(s) as well as three distributed generation conferences. AESC presented the project at the 1999 CADER (California Alliance for Distributed Energy Resources) conference in November 1999 and also attended the 2000 CADER conference. AESC also visited the Distributech conference in February 2001. As a result of these activities AESC established dialogues regarding *Smart**DER development with:

- Distribution generation equipment manufacturers (e.g., Caterpillar, Honeywell), and
- Network infrastructure software/hardware developers (e.g., ASCO, Encorp, Enflex, Engage Networks, Silicon Energy, Sixth Dimension, C3 Communications).

Of those contacted, companies that provide network infrastructure products have expressed the most interest in *Smart**DER technology. These companies represent the best near-term commercialization partners since *Smart**DER technology could be readily integrated with the software/hardware products that they already offer. The current status of discussions with these companies is focused on potential demonstrations that would provide for integration/interface of *Smart**DER technology with their product/technology for installation and testing at one or more sites in California.

4.0 Conclusions and Recommendations

4.1 Conclusions

Overall, this PIER project has been highly successful since all of the technical and economic objectives were achieved. AESC and its principal subcontractor, Reticular Systems successfully developed the Internet-based *Smart**DER intelligent agent software and subsequently confirmed the functionality of the various agents while operating in response to market conditions for dates in 1999. Single and multiple agency testing confirmed that *Smart**DER agents, acting on behalf of individual sites could collaborate to schedule DER asset operation. Testing indicated that *Smart**DER operation enabled sites with excess generating capacity to collaborate for purposes of aggregating this capacity and subsequently participating in the CAISO AS markets. In other words, testing showed that *Smart**DER technology brought generating capacity to the California marketplace that would not otherwise have been able to participate. AESC successfully demonstrated the *Smart**DER intelligent agent software at the Commission's Sacramento offices on March 13, 2001.

As part of the Market Research and Domain Analysis efforts AESC engaged a variety of market participants in a Virtual Evaluation Group that provided valuable feedback on *Smart**DER product requirements and operating scenarios. This information was used to develop a product specification that further guided the product design and development process. In addition to its involvement with the Virtual Evaluation Group AESC also participated in three industry conferences and CAISO meetings related to distributed generation. As a result of these efforts AESC was able to establish dialogues with a variety of companies interested in continued development of *Smart**DER technology. Companies that currently market network infrastructure software such as Encorp, Enflex and Sixth Dimension have expressed an interest in exploring additional efforts where *Smart**DER technology can be used in conjunction with their products.

Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). During the project AESC succeeded in bringing this intelligent-agent technology to a Stage 3 (Bench testing / proof of concept) level of development. In addition, AESC laid the groundwork for further development beyond Stage 3 by developing and demonstrating software that can be used to facilitate the Stage 4, Product Development and Field Experiments as well as establishing dialogues with potential commercialization partners.

4.2 Benefits to California

There is little question that integration of DER assets into the marketplace, the overriding premise behind this PIER project, continues to be of paramount importance. Intelligent software agents with their ability to communicate and collaborate are well suited to the task of scheduling and coordinating the activities of large numbers of DER assets. Use of intelligent software agents in this fashion reduces the level of expertise needed to own and operate distributed energy resources, which in turn, allows greater participation by owners of distributed energy resources in California's competitive energy industry. The benefits of this project are therefore tied to the benefits of increased DER participation in California's deregulated marketplace:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade / construction
- Customer cost reduction by direct displacement of load
- Energy price reduction (as new DER assets displace existing load and / or centralized generation)

4.3 Recommendations

One need only look at the daily newspaper to appreciate the dynamic nature of the California marketplace. There is little question that integration of DER assets into the marketplace, the overriding premise behind this PIER project, continues to be of paramount importance. In 1998, when this project was first proposed there were four basic avenues for DER interaction in the deregulated marketplace. First, DER assets could be used to offset site loads to provide cost savings associated with utility bill reduction. Secondly DER assets could be used in conjunction with UDC sponsored interruptible rates. Third, DER assets, if aggregated in sufficient numbers, could bid into the energy spot market run by the CalPX. And fourth, aggregated DER assets could participate in the ancillary services auction run by the CAISO. Specific procedures and protocols for DER participation in the marketplace did not exist at the time this project was initiated. A great deal of progress has been made in the development of these procedures and protocols since this project officially began in May 1999. The energy spot market and the CalPX itself no longer exists but there are now five separate programs, either in place or pending that will provide for participation by DER assets. These programs now include:

- CAISO ancillary services (AS) auction (Supplemental energy, ancillary services),
- UDC sponsored interruptible rate tariff participation,
- CAISO DRP (demand relief program) (new program for 2001),
- CAISO DLCP (discretionary load curtailment program) (new program for 2001), and
- Energy Commission Electricity Peak Load Efficiency Grant Program (AB970) (new program for 2001).

Each of these programs has different requirements for participation, varying communication procedures and different verification / reporting requirements. Coordination of DER assets, especially in cases where aggregation of large numbers of assets is necessary has increased in importance. Clearly our efforts to facilitate integration of DER assets into the California marketplace are now more important than ever.

The existing project has brought this innovative agent technology to a Stage 3 (Bench testing / proof of concept) level of development and has also laid the groundwork for a successful Stage 4 development and testing effort. Potential commercialization partners have already expressed an interest in such an effort and AESC has developed the software to a level sufficient to move forward with the Stage 4 development effort.

It is for these reasons that AESC recommends that the Commission fund a follow-on PIER effort that would move this technology forward to completion of Stage 4. This effort would involve the following:

- Review and Evaluate the Feedback from the existing project,
- Identify Feasibility Field Test Participants,
- Refine the Smart*DER Technology and Integrate / Interface it with existing network infrastructure software products,
- Conduct a Feasibility Field Test For Control of Actual Loads

For Additional Information

For additional information on application of *Smart**DER technology or the potential benefits of applying intelligent software agents in general contact:

Gerald L. Gibson PE
Vice President
Alternative Energy Systems Consulting, Incorporated
858-560-7182
gibsonj@aesc-inc.com

5.0 Glossary

AESC	Alternative Energy Systems Consulting, Incorporated
AS	Ancillary services markets
CADER	California Alliance for Distributed Energy Resources
CAISO	California Independent System Operator
CalPX	California Power Exchange
Commission	California Energy Commission
DA	Data Analyst
DER	Distributed Energy Resources
DLCP	Discretionary load curtailment program
DM	Data Manager
DRP	Demand relief program
EASE	EnerAgent Simulation Environment
EM	Event Manager
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
FIA	Facility Interface Agent
GUI	Graphical User Interface
I/O	Input/Output
IA	Internet Agent
ISO	Independent System Operator
kW	kilowatt
kWh	Kilowatt-hour

MCP	Market clearing price
NSPIN	Non-spinning reserve capacity
OIA	Owner Interface Agent
PAC	Personal action classes
PBR	Performance based ratemaking
PC	Personal computer
PG&E	Pacific Gas and Electric Company
PIER	Public Interest Energy Research
PM	Portfolio Manager Agent
PX	Power Exchange
Reticular	Reticular Systems Inc.
REPL	Replacement reserve capacity
SBIR	Small Business Innovative Research
SC	Scheduling Coordinator
SDG&E	San Diego Gas and Electric Company
TCP/IP	Transmission Control Protocol / Internet Protocol
UMCP	Unconstrained Market Clearing Price
UDC	Utility Distribution Company

Appendix I
Market Research Report

Appendix II
Final Domain Analysis Report

Appendix III
Virtual Evaluation Group Participants

Type	Name	Association	Position
DG & Control Mfg	Mark Skowronski	Honeywell (formerly Allied Signal Power Systems, Inc.)	
ISO	Dave Hawkins	CAISO	Principal Engineer
DG Mfg	Eric Wong	Caterpillar	Product Consultant
UDC	Carlos Martinez	Southern California Edison	Manager
Ctrl Supplier	Scott Castalaz	Encorp	VP Marketing
Ctrl Supplier	David Wolins	EnFlex	VP Marketing
Researcher	Chris Marnay	Lawrence Berkeley National Laboratory	Staff Scientist
Loc Gov	Kurt Kammerer	San Diego Regional Energy Office	Director
UDC	Vic Romero	SDG&E	
Individuals listed below were approached after formation of the initial evaluation group & expressed an interest			
Ctrl Supplier	Rich Weiss & Ken Brickner	Engage Networks	National Sales Manager
Ctrl Supplier	Charles DeWitt	C3 Communications, Inc.	Manager, New Service Offerings
Ctrl Supplier	Pat McMillan	Sixth Dimension	Director -- Product Marketing
Ctrl Supplier	Mark Czopek	HESI	Sr Consultant - Business Development
Ctrl Supplier	Jim Moeller	Stonewater Software Inc.	Acct Manager
Hardware Supplier	Jay Tucker	ASCO	Sr Field Sales Engr
Ctrl Supplier	David A. Cohen	Silicon Energy	Director -- Business Development
Hardware Supplier	Mark Shiira	Kohler	Director -- Switchgear Systems

Appendix IV
Demonstration Meeting Presentation

Appendix V
Follow-on Effort Summary