Distributed Energy Neural Network Integration System (DENNIS) Quarterly Review

Orion Engineering Corporation

By:

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at the October Quarterly Review Meeting

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How Can Distributed Generation Get Full-Value Pricing?

- Avoided cost and net metering models are not viable for providing the first cost recovery rates needed to make distributed resources economical for household and small commercial applications.
- A solution to economically integrate distributed resources onto grid is needed. This solution should capture the full-value of the distributed resource.
- Solution will need to be adaptable, knowing when to sell and when to store energy (if site has ability).
- Solution will also need capacity to aggregate small blocks of power production into blocks large enough to make and place bids to the ISO.

Distributed Energy Neural Network Integration System (DENNIS)

- Distributed generation and storage systems need an adaptive mechanism that allows for the resources to predict the site specific energy generation capacity and power consumption.
- DENNIS is optimization system that uses neural networks and fuzzy logic to determine where, when and which distributed generation resources are utilized.
- Solution predicts and meets demand of a particular user instead of curtailing that user's demand.
- Our system will be capable of optimizing to a single user or to a larger group of users. Year II and III expand this aspect of development to a “neighborhood controller”.

How Does DENNIS Work?

- A Neural Pattern Database monitors and learns load, weather, price and available power data streams.
- Incoming signals are compared with patterns stored in Neural Pattern Database to select appropriate operating conditions.
- Optimization algorithm selects control strategy for power storage, power export/import and generation dispatch.

Program Goals (Overall)

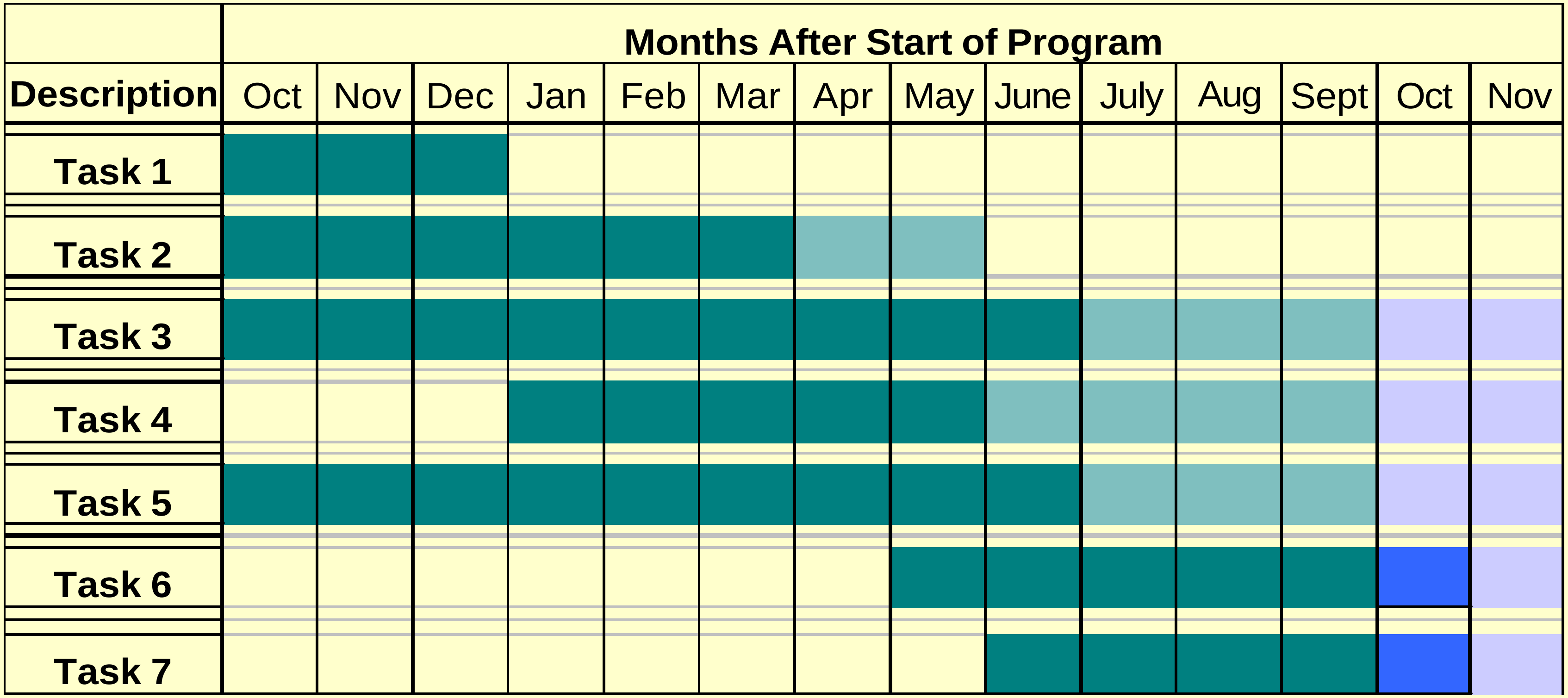
- Prototype, test and evaluate the system utilizing the facilities at the University of Massachusetts Lowell (UML) Center for Energy Conversion (CEC).
- Develop an economic model/analysis of the potential impact of our method for aggregating and managing distributed power.
- Deploy units to customer sites in two phases. First phase provides geographic dispersal during debugging and analysis. Second phase will be a beta product release.
- Establish industrial contacts and relationships to allow effective transfer of product into residential and business sectors.
- Inform and demonstrate to the electric power community the potential of a new business in generation communities.

Year One Program Tasks

Task 1 – Data Reduction and Analysis (Completed)
Task 2 – Power Electronics (Completed)
Task 3 – Fuel Cell Characterization and Integration (Underway)
Task 4 – Power Quality Study (Complete - except for Fuel Cell)
Task 5 – Pattern Database & Pattern Recognition (Underway)
Task 6 – Control Law Generator (Underway)
Task 7 – Preliminary Economic Analysis and Market Assessment (Underway)

GOALS – Make infrastructure investments, develop neural network systems, and validate savings potentials.

Year One Program Schedule



Task 1 – Data Reduction and Analysis

- UML Facility data for last 3 years input into database (partial for 2 other years). Data includes: insolation, wind speed, system generation via voltage and current.
- Data utilized extensively in Tasks 5 and 7
- Weather data from local airports used to augment facility weather data and fill in gaps in UML weather data. This data includes wet/dry bulb temperature, wind direction & character, barometric pressure, sky cover, visibility and precipitation.
- ISO data has also been added for hourly clearing prices, and natural gas prices has been added from EIA reports.

100% Complete

Task 2 - Power Electronics

- Current inverter system upgraded to allow for computer control of load switching.
- Machine Communications Modules (MCMs) and Status Reporting Modules (SRMs) built.

100% Complete

Task 3 - Fuel Cell Characterization and Integration

- Hydrogen PEM Cell - Temporary unit received and permanent unit received awaiting fume hood installation.
- Problem - Fundamental lack hydrogen infrastructure and knowledge of hydrogen systems (safety).
- Environmental Health and Safety had concerns about having large quantities of hydrogen in building.
- Current ventilation system not rated for H_2 operation. Major facility refit was needed to correct system.

90% Complete

Task 3 - Fuel Cell Characterization and Integration

- $250W_e$ PEM and $500W_e$ PEM in house
- DC Output
- Hydrogen fueled

<u>Challenges</u>:
- Hydrogen safety concerns and infrastructure
- Completing sales and delivery transaction

Task 3 - Fuel Cell Characterization and Integration

- Safety procedures and SOPs (Completed)
- Fuel cell DAQ system (Completed)
- Fuel cell DC/DC converter (Completed)
- Fuel cell installation and commissioning (Completed 11/08)
- Theoretical fuzzy model (Completed)
- Fuzzy model verification plan (Completed)
- Fuzzy model parameter measurement (Completed 11/15)
- Fuzzy model verification (Completed 11/31)

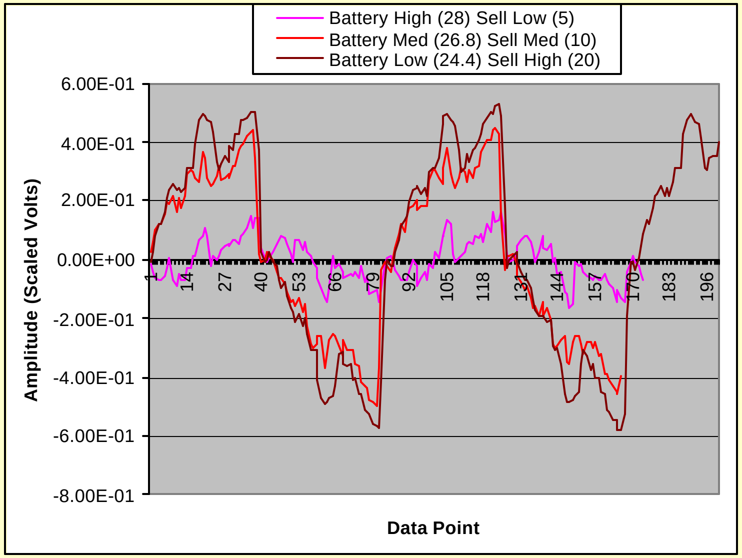
Task 4 – Power Quality Study

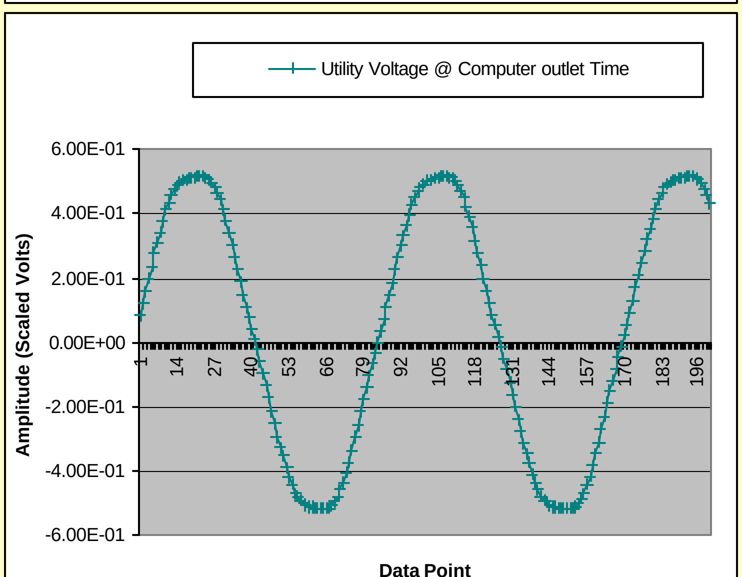
- Characterize harmonic content of facility. Measure total harmonic distortion (THD) from individual resources and from the utility interconnect (IEEE 519 and P1547)
  - Individual DC/DC converters, rectifiers, and maximum power point tracker (Completed)
  - Inverter output under different loadings (Completed)
  - Fuel cell DC/DC converter (Completed 11/15)

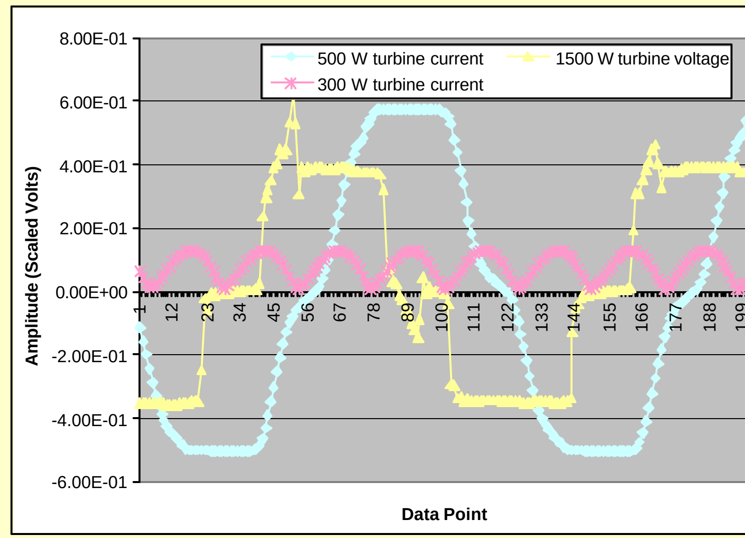
90% Complete

Task 4 – Power Quality Study

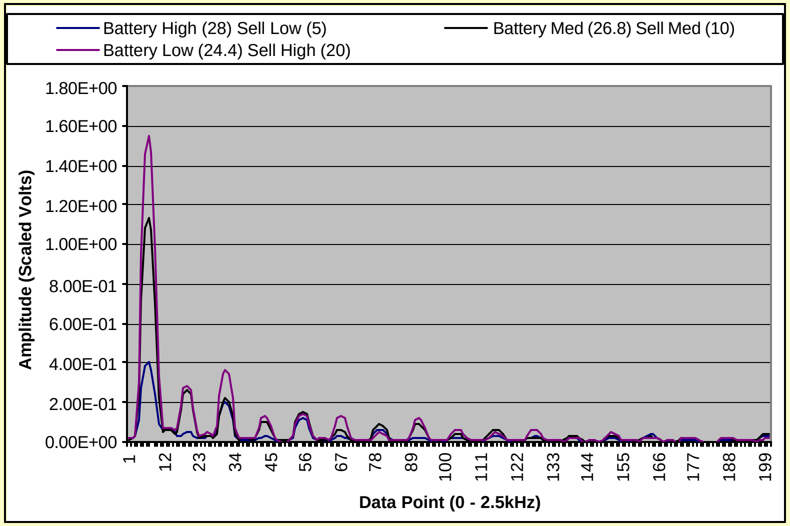
Time Domain Signals



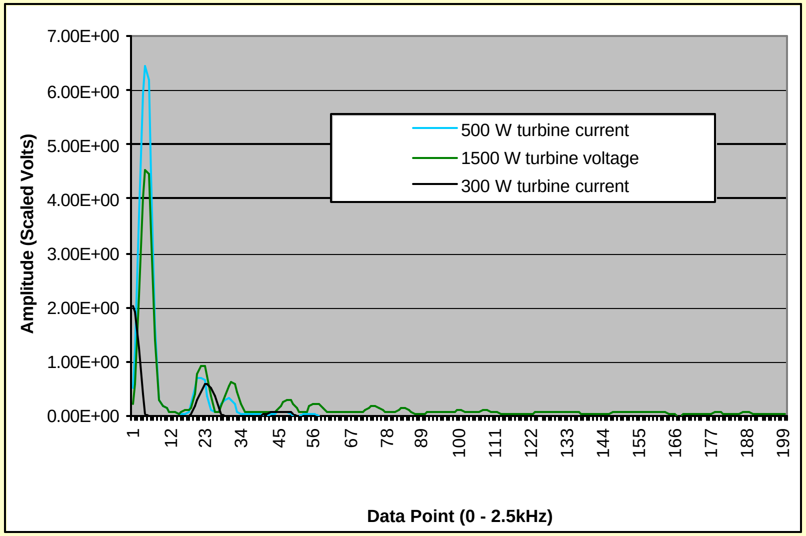


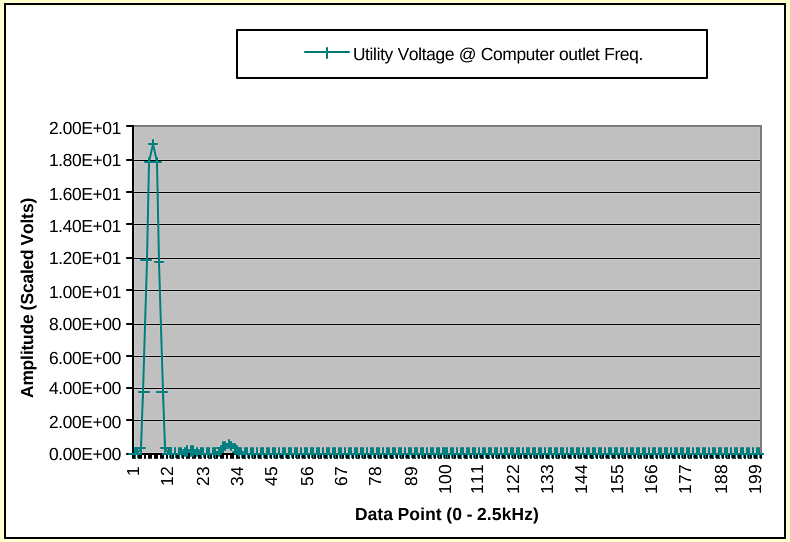


Task 4 – Power Quality Study



Frequency Content





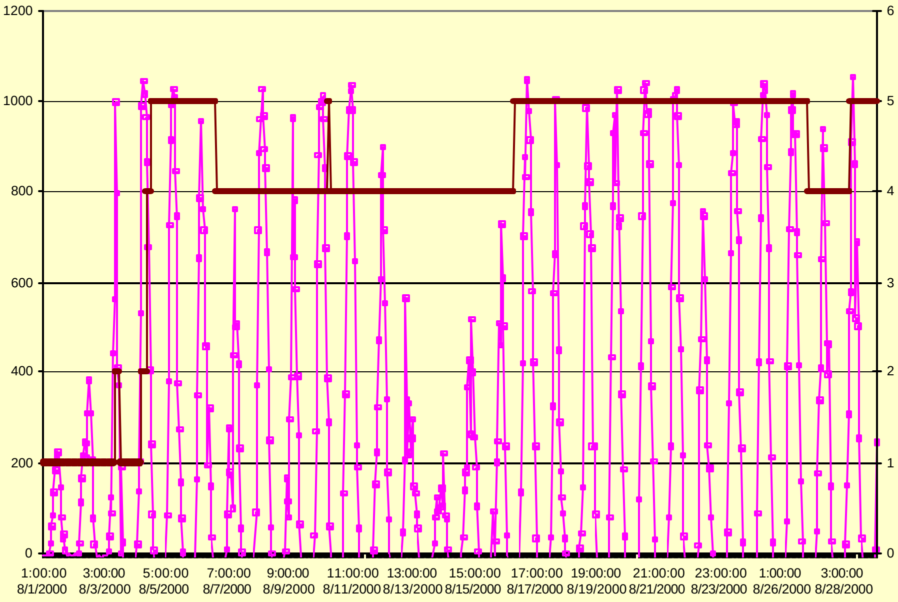
Task 5 – Pattern Database Development

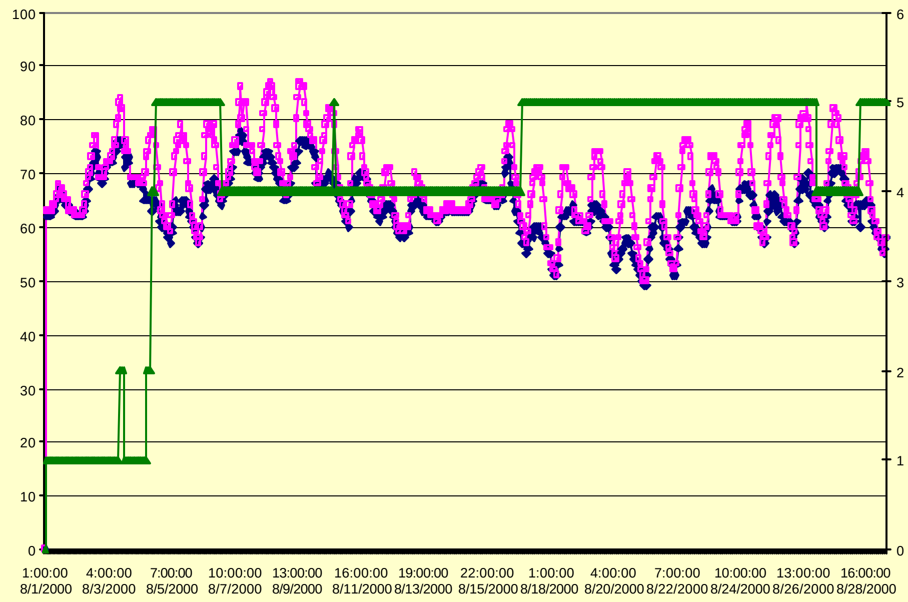
- Correlate weather data parameters with day types to determine best set of input signals (Completed)
- Manually separate day types into bins using input parameters (Completed)
- Build simple perceptron-type network to test general ability to automatically distinguish day types (Completed)
- Code ART neural network using input signal basis from previous 3 steps (Underway, Completed 11/8)
- Test stability and plasticity of ART network, revise as necessary to assure flexible automatic learning (Completed by 11/15)

70% Complete

Task 5 – Pattern Database Development

Build simple perceptron-type network to test general ability to automatically distinguish day types



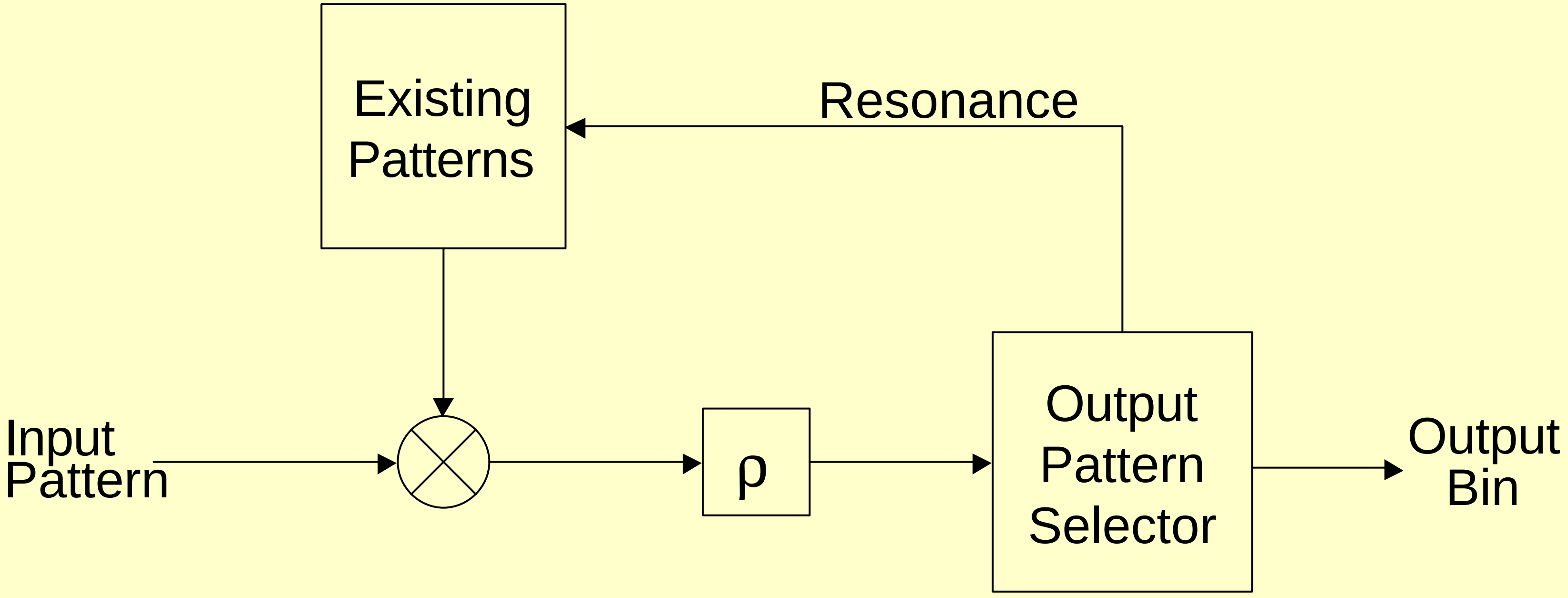


1=Rainy 2=Hazy 3=Hazy/Partly Sunny to Sunny

4=Partly Sunny 5=Sunny

Task 5 – Pattern Database Development

ART Network Block Diagram



Task 6 – Control Law Generator

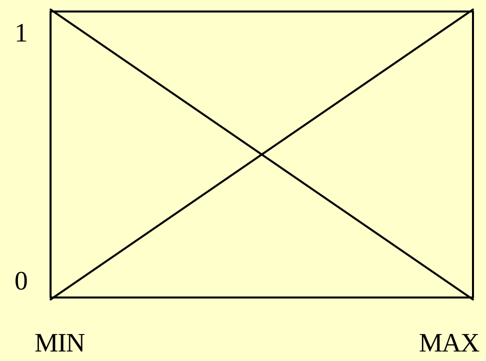
- Identify a set of possible fuzzy constraints based on input sets for available generation, load, and demand. Some of these constraints will be hardware specific and would be analogous to device drivers on a PC. (Completed)
- Develop a mathematical description of the cost function, and constraints to describe the optimization system (Completed)
- Design and program algorithm for finding the optimal operating point within the fuzzy constraint structure (Completed by 11/31)
- Move fuzzy constraint boundaries to shift optimal operating point and measure change in cost function (Completed by 11/31)

70% Complete

Task 6 – Control Law Generator

- Constraint rules developed:
  - Internal/External Pricing Mechanism based on Load, Demand and Available Generation
  - Storage Sizing and Allocation

Future Load	Future Price	Future Generation	Storage Capacity Required
H	H	L	H
H	H	H	M
H	L	L	M
H	L	H	M
L	H	L	M
L	H	H	M
L	L	L	M
L	L	H	L



Task 6 – Control Law Generator

24 hour optimization:

$$C_{opt} = \max_{U_k, D_k} \left[\sum_{k=1}^{N} \left(D_k \times Q_k \right) - \left(P_k \times U_k \right) \right]$$

where U is electricity consumption, D is external demand, Q is market sell price, P is market buy price

Energy in and out of storage is balanced over 24 hours between purchases and sales/use.

Optimization requires choosing a set of values for k = 1 to 24 that satisfies the optimal cost function based on predicted market price, load, external demand and available storage. Technique exists in public literature.

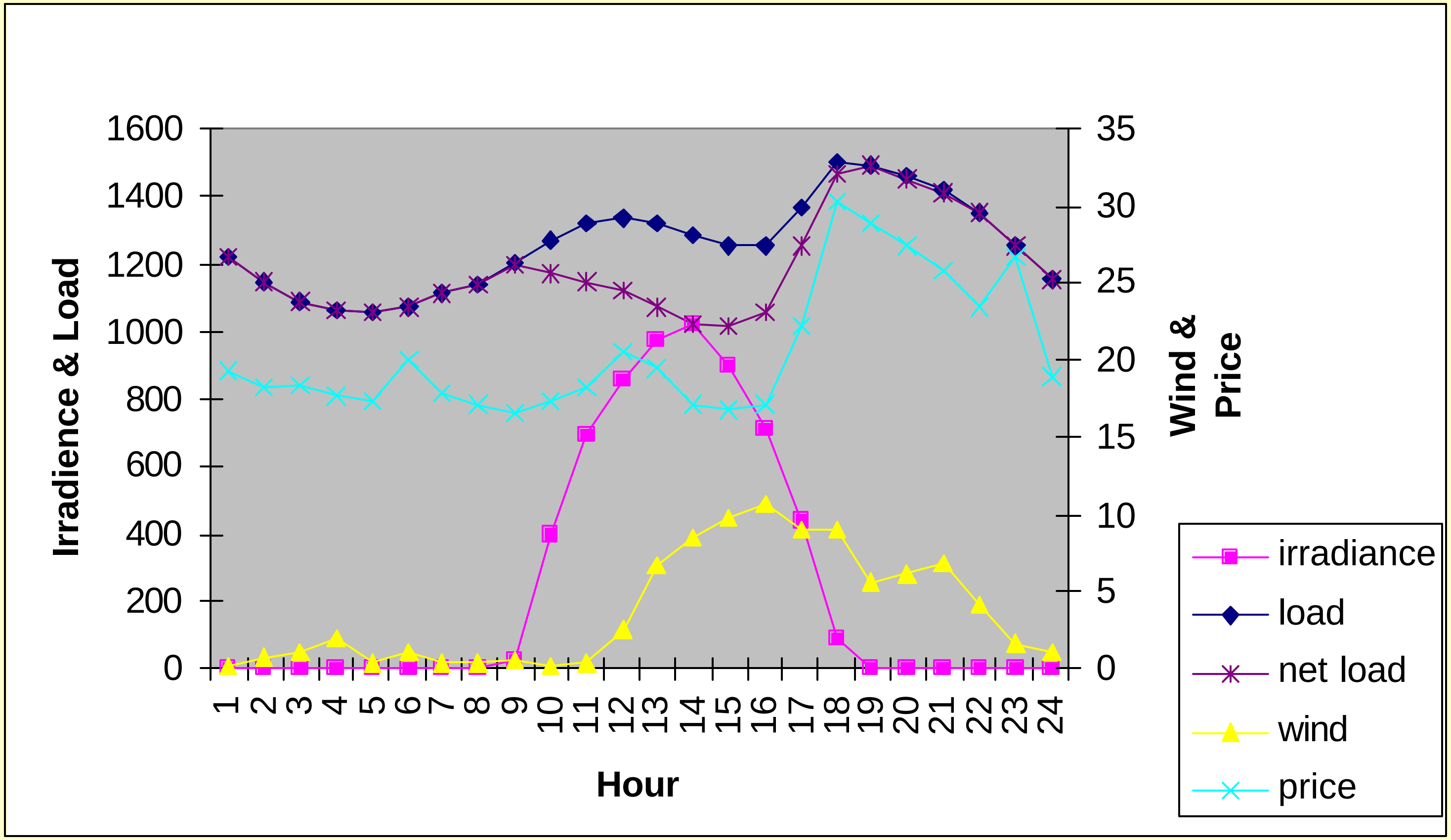
Task 7 – Preliminary Economic Analysis and Market Assessment

- Evaluate effectiveness of a DENNIS controller running residential DG with single connection to the grid. (Simple control analysis completed 10/31, Optimal control completed 12/7)
- Develop our relationship with building automation technology companies to provide a distribution infrastructure for DENNIS to be installed at commercial early adopter sites. (Ongoing)
- Pursue a broader market impact with the Zero Net Energy Alliance of Lowell (Z_NEAL) in Lowell, Massachusetts and are pursuing development of a distributed generation education facility for the state of Massachusetts at the University of Massachusetts Lowell (Ongoing)

70% Complete

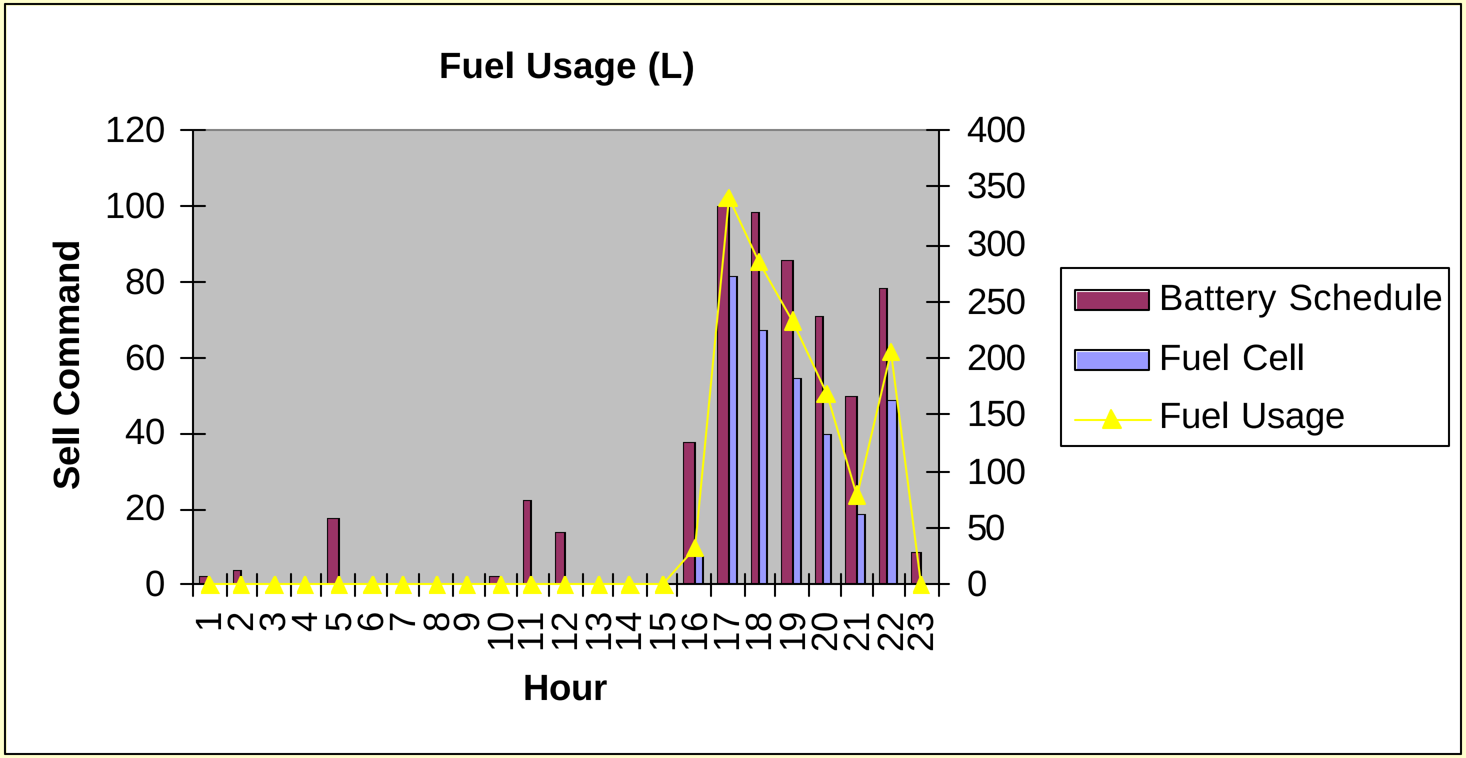
Task 7 – Preliminary Economic Analysis and Market Assessment

DENNIS™ Control



Task 7 – Preliminary Economic Analysis and Market Assessment

DENNIS™ Control



Final Report

- We are currently compiling information from our investigations for the final report.

- Final report targeted for completion in December 2001

Year One Project Summary

At the end of Year One, the following activities will be completed:

- Facilities upgrades at UMLCEC
- Development of the neural networks
- Fuel Cell logic model and characterization
- Power quality studies of facilities and equipment
- Economic models demonstrating that DENNIS is a cost effective solution for distributed generation systems
- Market segmentation and commercialization planning
- Year One sets the stage for field testing and debugging in year 2

Year II Program Tasks

- Task 8 - Control Site Development and Monitoring
- Task 9 - External Site Deployment and Monitoring
- Task 10 - Data Reduction and Economic Analysis
- Task 11 - Utility Integration and Market Development
- Task 12 - Neighborhood Controller Technology Assessment