Long Island Power Authority

FINAL REPORT

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Name of Recipient: Long Island Power Authority

Project Title: Long Island Smart Energy Corridor

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EXECUTIVE SUMMARY

The Long Island Power Authority (LIPA) has teamed with Stony Brook University (Stony Brook or SBU) and Farmingdale State College (Farmingdale or FSC), two branches of the State University of New York (SUNY), to create a "Smart Energy Corridor." The project, located along the Route 110 business corridor on Long Island, New York, demonstrated the integration of a suite of Smart Grid technologies from substations to end-use loads. The Smart Energy Corridor Project included the following key features:

- TECHNOLOGY: Demonstrated a full range of smart energy technologies, including substations and distribution feeder automation, fiber and radio communications backbone, advanced metering infrastructure (AM"), meter data management (MDM) system (which LIPA implemented outside of this project), field tools automation, customer-level energy management including automated energy management systems, and integration with distributed generation and plug-in hybrid electric vehicles.
- MARKETING: A rigorous market test that identified customer response to an alternative time-of-use pricing plan and varying levels of information and analytical support.
- CYBER SECURITY: Tested cyber security vulnerabilities in Smart Grid hardware, network, and application layers. Developed recommendations for policies, procedures, and technical controls to prevent or foil cyber-attacks and to harden the Smart Grid infrastructure.
- RELIABILITY: Leveraged new Smart Grid-enabled data to increase system efficiency and reliability. Developed enhanced load forecasting, phase balancing, and voltage control techniques designed to work hand-in-hand with the Smart Grid technologies.
- OUTREACH: Implemented public outreach and educational initiatives that were linked directly to the demonstration of Smart Grid technologies, tools, techniques, and system configurations. This included creation of full-scale operating models demonstrating application of Smart Grid technologies in business and residential settings. Farmingdale State College held three international conferences on energy and sustainability and Smart Grid related technologies and policies. These conferences, in addition to public seminars increased understanding and acceptance of Smart Grid transformation by the general public, business, industry, and municipalities in the Long Island and greater New York region.
- JOB CREATION: Provided training for the Smart Grid and clean energy jobs of the future at both Farmingdale and Stony Brook. Stony Brook focused its "Cradle to Fortune 500" suite of economic development resources on the opportunities emerging from the project, helping to create new technologies, new businesses, and new jobs.

To achieve these features, LIPA and its sub-recipients, FSC and SBU, each have separate but complementary objectives. At LIPA, the Smart Energy Corridor (1) meant validating Smart Grid technologies; (2) quantifying Smart Grid costs and benefits; and (3) providing insights into how Smart Grid applications can be better implemented, readily adapted, and replicated in individual homes and businesses. LIPA installed 2,550 AMI meters (exceeding the 500 AMI meters in the original plan), created three "smart" substations serving the Corridor, and installed additional distribution automation elements including two-way communications and digital controls over various feeders and capacitor banks. It gathered and analyzed customer behavior information on how they responded to a new "smart" TOU rate and to various levels of information and analytical tools.

Farmingdale State College demonstrated the integration of various electric applications and distributed renewable generation technologies including solar car charging station, small scale wind, photovoltaics, and solar thermal with the existing grid. It created full scale operating models demonstrating Smart Grid applications in both residential and commercial settings to increase public awareness. It deployed customer side controls on the smart campus managing electricity consumption. FSC created occupational training for the emerging jobs in Smart Grid and renewable energy business. It also retrofitted an existing facility to serve as a training and repair facility and laboratory for Plug-in Hybrid Electric Vehicles (PHEV). It outreached the community and students as well as energy professionals with new smart grid related training and workshops.

Stony Brook University leveraged its Center of Excellence in Wireless and Information Technology and researched cybersecurity issues arising from smart meters. It utilized the interval data collected by LIPA's AMI meters to help LIPA improve load forecasting, phase balancing, and voltage control techniques and enhanced reliability. It developed visualization components of customer interfaces to help gain customer acceptance and behavior change

RECIPIENT TEAM OVERVIEW

The Long Island Power Authority (LIPA) is the second largest public power utility in the United States, in terms of revenue. LIPA has teamed with two branches of the State University of New York (SUNY) through The Research Foundation of SUNY Stony Brook University ("Stony Brook") and The Foundation of SUNY on Behalf of Farmingdale State College (Farmingdale) to deliver a demonstration of Smart Grid technology and benefits that have specific applicability to the greater New York and Northeast region, as well as significant benefits to the industry as a whole.

Long Island Power Authority

The LIPA Service Area encompasses Nassau and Suffolk Counties and the Rockaway Peninsula of Queens County, an area of approximately 1,230 square miles, excluding areas served by three municipal utilities: the villages of Freeport, Greenport, and Rockville Centre. Suffolk County is the easternmost county within the Service Area and covers an area of approximately 911 square miles, followed by Nassau County with a 287 square mile area, and the Rockaway Peninsula with an area of approximately 32 square miles. The Service Area is bounded by the Atlantic Ocean on the south and east, by the Long Island Sound on the north, and by portions of New York City on the west. LIPA had a contract with National Grid to manage its transmission and delivery system that ended in December 31, 2013. The system manager's role has been awarded to PSEG Long Island, a subsidiary of Public Service Enterprise Group, since January 1, 2014.

LIPA's Service Territory	
Total number of customers:	
Residential	1,001,715
Commercial	114,729
Peak load:	

Summer	5,915 MW
Winter	3,759 MW
Total MWh sales (in a 24-hour period includes: residential & commercial and line losses)	113,951 MWH
Total number of substations providing distribution load	150
Total number of distribution feeders	903
Total miles of distribution line	13,808

Table 1 - LIPA's Service Territory

Farmingdale State College

Farmingdale State College (FSC) is the largest College of Applied Science and Technology in the 64-institution SUNY system. FSC is located in the Route 110 Corridor. It offers a state-funded, campus-based business incubation facility, located at the Broadhollow Bioscience Park. The College's four Schools, Engineering Technology, Arts and Sciences, Health Sciences, and Business, offer 25 baccalaureate degree programs and 10 associate degree programs, enrolling over 6,800 undergraduate students. The Engineering School offers bachelor degrees and associate degrees in many disciplines including Aeronautical Science, Architectural Engineering Technology, Construction Management Engineering Technology, Computer Engineering Technology, Electrical Engineering Technology, Mechanical Engineering Technology, Manufacturing Engineering Technology, Facility Management, Software Technology, and Automotive Technology. The College – and especially the School of Engineering Technology – has long been recognized as a leader in energy management and sustainability. The College established the first accredited photovoltaic (PV) solar installation in the Northeast in 2000. FSC has created a Green Building Institute in partnership with industry and municipalities. Most recently, FSC created their Renewable Energy and Sustainability Center (RESC) as an umbrella center to lead all workforce training programs, public outreach, and K-16 Science, Technology, Engineering, and Mathematics (STEM) programs in collaboration with other higher educational institutions, high schools, and the Brookhaven National Laboratory on Long Island. The overall objective of the center is promoting sustainability through education and research in areas such as solar and wind energy, architecture and building design, green roofs and sustainable gardens, and energy efficiency audits and monitoring.

SUNY Stony Brook

Stony Brook is also located within LIPA's service territory. Stony Brook is SUNY's flagship research campus and collaborates with Brookhaven National Laboratory, which it now co-manages with Battelle for the US Department of Energy. Its growing research capacity is exemplified by its newest research facilities, the recently opened Advanced Energy Research and Technology Center (AERTC) and the New York State Center of Excellence in Wireless and Information Technology (CEWIT).

The AERTC's mission is to deliver IT and nano-science and technology-based means of accelerating the transfer of alternative energy technologies from the laboratory to the marketplace. CEWIT is one of only two wireless and IT centers in the nation and among a handful around the world. CEWIT's affiliated laboratories include the

Center for Cyber Security, a National Security Agency-designated Center of Excellence, and its affiliated labs including the Security, Programming Languages and Theory ("SPLAT") Lab, specializing in Software Security, System and Network Security and Cryptography; the Network Security and Applied Cryptography Lab, the File Systems and Storage Lab. Another major CEWIT affiliate is the Center for Visual Computing.

Stony Brook's management development and workforce training programs, offered through the College of Business, the School for Professional Development and the College of Engineering and Applied Sciences, assists 2,000 professionals a year. These programs range from the Executive MBA program through specialized master's degree programs in business and engineering specialties, graduate certificate programs in management and technical areas, and non-credit programs, workshops, seminars, and distance learning offerings across information technology, engineering and basic and advanced management topics, customizable based on a needs assessment climate survey and deliverable on-campus or on-site.

As SUNY's most successful technology transfer and economic development campus, Stony Brook will leverage its existing, comprehensive suite of "Cradle to Fortune 500" economic development programs to commercialize new technologies emerging from this project to strengthen established companies, created new ventures and retain and create new quality jobs.

PROJECT OVERVIEW

The LIPA Smart Grid Demonstration Project included the installation of AMI, distribution automation and substation automation, as well as the installation of residential load control devices. The AMI deployment installed 1,620 smart meters at residential locations and 930 smart meters at commercial locations. The distribution automation work involved the deployment of 24 smart switches on more than 18 circuits across three substations, as well as the installation of 51 automated capacitor bank controllers. The substation automation work upgraded the five existing RTUs and installed 26 new digital meters across the three substations.

The Long Island Smart Energy Corridor Project has seven objectives:

1. Demonstrate and validate how Smart Grid technologies can reduce customer costs for electricity and decrease peak loads and system demand;
2. Demonstrate how Smart Grid technologies can enhance reliability by reducing the frequency and duration of outages;
3. Demonstrate how distributed generation can be integrated with Smart Grid technologies to reduce system demand and defer utility investments;
4. Anticipate and address emerging cyber security concerns with Smart Grid technologies (especially AMI), while leveraging the potential for enhanced data collection and analysis enabled by smart devices;
5. Facilitate the development and commercialization of new Smart Grid technologies and tools;
6. Develop relevant curricula to train the workforce that will be needed for significant expansion of Smart Grid, renewable and photovoltaic hybrid electric vehicle (PHEV) technology deployment; and
7. Engage customers by performing outreach and informational activities, and by providing a platform for customer understanding, acceptance and use of Smart Grid technologies and dynamic pricing to reduce customer costs for energy and to reduce demand during system peak.

The Long Island Smart Energy Corridor Project integrated Advanced Metering Infrastructure (AMI) technology with the distribution automation system, implemented advanced substation automation technologies, and other features to demonstrate how customers and utilities can work together to give residential, industrial and commercial customers more information and choices, enabling them to reduce their energy costs while reducing peak demand and increasing the utility's ability to identify and respond to outages on an expedited basis. AMI was installed at approximately 2,550 customer locations, of which 1,620 are residential.

This demonstration project evaluated the impact of a range of variables on customer behavior and consumption, including an alternate Time of Use tariff structure, provision of varying levels of information and analytical tools, a range of outreach and educational support and energy automation for a sample of participating customers. In addition, the Smart Energy Corridor included demonstrations of how distributed generation (in this case, wind and solar at Farmingdale State College) can be integrated into a local distribution network with AMI technologies to serve customers while maintaining reliability. On occasions when certain project deliverables could not be met due to unforeseen technology, timing, or cost constraints or when cost avoidance arise, the project team consulted with the Department of Energy to find new opportunities for investment and enhanced demonstration. As the result, the project was able to strengthen the mesh from 500 AMI meters to 2,550 AMI meters, increase the mix of AMI meters for commercial customers where more benefits are expected per installation, add JMUX cable to increase data quality and communications reliability, improve smart grid restoration efforts with mobile data capture, and expand the AMI footprint westward to serve more commercial customers.

The Farmingdale State College portion of the project included "live" residential and commercial models showing how intelligent devices can enable customers to understand and control their usage and respond to price signals, as well as integrating distributed renewable energy. Farmingdale also developed a curriculum and implemented training relating to AMI infrastructure, integration of distributed renewable generation, and PHEV systems to provide for a trained workforce. Over 1,250 people from private, public, and educational sectors attended the various training sessions and seminars. The University of Applied Sciences from Germany visited the demonstration at Farmingdale which led to a trip to the University by Farmingdale's staff and the development of a beneficial partnership that broaden the way smart grid and renewable energy technologies are taught at Farmingdale. The electric generation equipment demonstrated at Farmingdale totaled 209 MWh of output.

Stony Brook University's portion of the project included the development of mechanisms to leverage the data available from smart meters for utility and customer purposes. Stony Brook University has filed a patent on its forecasting and modeling developments and is pursuing commercialization of its visualization techniques with the intent of furthering economic development and job creation. In addition, Stony Brook University utilized its existing Center of Excellence in Wireless and Information Technology (CEWIT) to provide research into cyber security as it relates to intelligent devices used for Smart Grid applications, focusing on AMI.

Both Stony Brook and Farmingdale have engaged in extensive public education and outreach.

TECHNOLOGIES AND SYSTEMS DEMONSTRATED

LIPA deployed AMI, distribution automation and substation automation, as described below.[1] In addition, Farmingdale State College installed small-scale wind generation (three (3) nominal 2.4 kW grid-connected monopole wind turbines), as well as a solar parking lot that included PV as well as charging stations (100 kW solar panels over 42 parking spaces which includes 10 double pedestal EV charging stations). Farmingdale also included additional solar generation and solar thermal in its model home to demonstrate residential smart grid applications. Although Farmingdale purchased hydrogen fuel cell equipment, it was not successful in soliciting a qualified installer. Farmingdale is showcasing the equipment as part of the demonstration and intends to fund the installation on its own once it can find a qualified installer. As noted above, the primary purpose of these installations is education and training.

AMI ASSETS

1,620 residential smart meters and 930 commercial meters have been deployed. The smart meters supported the recording of 5-, 15-, 30-, and 60-minute interval lengths, 4 channels of data capable of measuring reactive energy quantities, net metering, time of use, perpetual calendar, interval demand values, kVA recording, power factor recording, outage detection reporting, power quality monitoring, and tamper detection. Additionally, a small sample of meters has remote connection/disconnection capability that allows control of the switch status. The AMI system selected utilizes an RF mesh network with wireless carrier backhaul or fiber-optic to the three substations. The RF mesh network can be supplemented by wireless carrier enable meters for locations that are not near any AMI routers and collectors but the supplier, L+G, has not yet fully evolved this aspect thus was not demonstrated. A field inventory system that was originally contemplated was not installed because the cost was found to exceed the project budget by several multiples.

The deployment of AMI used a Vendor Hosted AMI Head-End that depended on a Cellular Backhaul (Verizon (EVDO)) which communicated from the AMI Collector to AMI Hosted Head-End system. This AMI Head-End System has been transitioned to a LIPA facility. A separately funded Fiber Communications Project not associated with the Demonstration Project enabled communications from the collectors to the Substation and then back to the AMI Head-End.

The primary functions of the head end system included performing scheduled reads on billing cycle, provide outage information, detect tampering and provide various reporting tools. LIPA has implemented an e-Meter Meter Data Management System outside of the Smart Grid Demonstration Project. The e-Meter system performs auto-provisioning, data validation, and estimation, and creates billing determinants.

The AMI assets were supported by mobile data capture tools which are computer tablets used in the field to record storm damage assessments. Approximately fifty computer tablets (iPads) were deployed in the AMI footprint replacing the card forms that were required to be completed during storm damage assessments. The tablets not only record data about the damages and replacement parts needed but also can take photographs for further analysis by the appropriate management or technical personnel. This information can be uploaded

[1] The AMI and pilot OMS/DMS Integration (project simulation) was eliminated with approval from the DOE as a result of LIPA's decision to deploy a full-scale OMS/DMS outside of the project and followed a year later by a decision to change OMS vendors and defer a full DMS deployment. In any case, because this portion of the project was a simulation, none of the impact metrics to be reported relate to it.

remotely to reduce the cycle time for damage assessments and increase the quality of information transmitted resulting in better and timelier decision making.

LIPA decided to change its Outage Management System (OMS) provider which caused a detrimental delay in the implementation of the linkage between AMI and OMS. The linkage had to be abandoned.

Asset Summary:

- 1620 residential meters
- 930 commercial meters
- 50 mobile data tablets

CUSTOMER SYSTEMS ASSETS

LIPA deployed smart meters that can interface with customer communication networks for the eventual adoption of home area networks ("HAN") by customers (in other words, LIPA did not purchase or offer a HAN as part of this project). While LIPA anticipated some customers will eventually purchase smart appliances when they become available, LIPA did not deploy any of these products at Farmingdale State College as part of this project. A major appliance manufacturer withdrew from smart appliances and other market ready smart appliances did not materialize. LIPA provided a web-portal that is available for all customers receiving AMI meters, excluding the control and test groups. Most customers can enroll in the web-portal services and receive information related to energy usage, including consumption and cost data, and recommendations for better ways to manage their energy usage. A small number of commercial customers received consumption data but not cost data due to the complex pricing formulas that the system cannot easily handle.

LIPA deployed Direct Load Control (DLC) technology to 38 residential customers and 6 friendlies. Friendlies were employees who volunteered to test the technology prior to executing a command or task globally on customers. Residential customers have thermostats installed to control each zone in their house, as well as load control devices, as applicable, on other loads such as pool pumps. In addition, they each received two smart plugs. LIPA also deployed a mobile application for customer use.

Our implemented configuration included data collection and control through an installed "gateway" that interfaced with the home devices via ZigBee. The gateway utilized an internet connection to communicate with the utility. Due to privacy concerns from customer feedback and operational concerns relating to provisioning devices, we did not deploy a configuration where the meter served as the communications path to the utility for data and control. LIPA was not successful in recruiting commercial customers to participate in the commercial direct load control demonstration. LIPA did not have a dispatchable demand response program according to price or emergency demand response as a reliability resource at this time and could not assure customers that it would develop one that would sustain beyond the pilot period.

Asset Summary:

- Web-portal access for all commercial and residential customers
- Mobile application Load control devices (approximately). Since this equipment is given to customers, they are treated as expense from an accounting standpoint.

ELECTRIC DISTRIBUTION AND SUBSTATION ASSETS

LIPA deployed distribution automation and substation automation in the Route 110 Corridor. A pilot scale OMS/DMS system (project simulation) was to be deployed but has been removed from the scope due to a change in the vendor for OMS/DMS system. LIPA's move to a different vendor than originally intended coupled with the transition of all its systems from National Grid, LIPA's former operating agent, to PSEG Long Island drained the necessary time and resources needed to support a linkage from AMI to OMS/DMS. Eighteen of the 32 feeders from three substations became "smart feeders," with additional switches being installed on certain other feeders as well. LIPA enabled automatic feeder switching and coordinated voltage management as part of this distribution automation implementation. LIPA demonstrated improved reliability for customers and reduced distribution line-loses utilizing this new functionality.

Asset Summary:

- 18 overhead switches at three substations
- 6 underground pad mounts with supervisory controls monitoring analogs such as voltage, current, and phase angle
- 51 two-way capacitor bank controllers over all of the circuits fed from the three substations.
- 5 substation RTU upgrades to enable an increase in the quantity of data brought back
- 26 digital meters at substations (4 at South Farmingdale and 22 at Ruland Road)

DOE SMART GRID FUNCTIONS AND ENERGY STORAGE APPLICATION

SMART GRID FUNCTIONS

Function	Provided by Project
Fault Current Limiting	NO
Wide Area Monitoring, Visualization, & Control	NO
Dynamic Capability Rating	NO
Power Flow Control	NO
Adaptive Protection	NO
Automated Feeder Switching	YES
Automated Islanding and Reconnection	NO
Automated Voltage & VAR Control	YES
Diagnosis & Notification of Equipment Condition	YES
Enhanced Fault Protection	NO
Real-time Load Measurement & Management	YES
Real-time Load Transfer	YES

Customer Electricity Use Optimization	YES

Table 2 – DOE Smart Grid Functions

ENERGY STORAGE APPLICATIONS

Twelve sealed absorbed glass mat (AGM) lead acid batteries were to be installed for demonstration of storage in the residential demonstration model at Farmingdale; 60 Amp, 720W, 12V. This portion of the project was not demonstrated due to the inability of Farmingdale State College to solicit an installer for their hydrogen generator and associated battery storage. Farmingdale will pursue the completion on its own.

GRID OR NON-GRID CONNECTED BENEFITS

Benefit Category	Benefit	Provided by Project	Remarks / Estimates
Economic	Arbitrage Revenue (consumer)	NO	
	Capacity Revenue (consumer)	NO	
	Ancillary Service Revenue (consumer)	NO	
	Optimized Generator Operation (utility/ratepayer)	NO	
	Deferred Generation Capacity Investments (utility/ratepayer)	NO	
	Reduced Ancillary Service Cost (utility/ratepayer)	NO	
	Reduced Congestion Cost (utility/ratepayer)	NO	
	Deferred Transmission Capacity Investments (utility/ratepayer)	NO	Deferral of distribution capacity investments, if any, will be minimal given size and scope of project.
	Deferred Distribution Capacity Investments (utility/ratepayer)	**YES**	
	Reduced Equipment Failures (utility/ratepayer)	**YES**	Reduced equipment failures may be able to be achieved over time from the collection of data to support investment decision, but the immediate impact will be minimal.
	Reduced Distribution Equipment Maintenance Cost (utility/ratepayer)	NO	
	Reduced Distribution Operations Cost (utility/ratepayer)	NO	
	Reduced Meter Reading Cost (utility/ratepayer)	**YES**	Reduction of Meter Reading Cost, if any, will be minimal given the size and scope of the project
	Reduced Electricity Theft (utility/ratepayer)	**YES**	Reduction of Electricity Theft, if any, will be minimal given the size and scope of the project
	Reduced Electricity Losses (utility/ratepayer)	**YES**	Electric Losses specific to the Project Area may be reduced, but minimal impact will be achieved due to the

			size and scope of the project.
	Reduced Electricity Cost (consumer)	NO	
	Reduced Electricity Cost (utility/ratepayer)*	**YES**	Overall reduction of Electricity Cost will be a direct result of ratepayer response to information available to them. Minimal effect is expected as part of this project
Reliability	Reduced Sustained Outages (consumer)	**YES**	Automation will be used to reduce outage duration due to more rapid identification of outages and use of remote and centralized switching
	Reduced Major Outages (consumer)	NO	
	Reduced Restoration Cost (utility/ratepayer)	NO	
	Reduced Momentary Outages (consumer)	**YES**	Ability to measure power quality and reduce outages and sags and swells in voltage will be enhanced
	Reduced Sags and Swells (consumer)	**YES**	
Environmental	Reduced carbon dioxide Emissions (society)	**YES**	Immediate impact will be minimal
	Reduced SO_X, NO_X, and PM-2.5 Emissions (society)	**YES**	Impact will be minimal as LIPA's generation mix is weighted toward natural gas and nuclear
Energy Security	Reduced Oil Usage (society)	**NO**	Impact will be minimal due to small number of customers in project; few if any truck rolls avoided by automation of switching
	Reduced Wide-scale Blackouts (society)	NO	

Table 3 - Smart Grid Benefits for LIPA's Smart Grid Demonstration Project

TECHNICAL APPROACH FOR ACHIEVING INTEROPERABILITY AND CYBER SECURITY

In the Amended and Updated Interoperability & Cybersecurity Plan (ICP) dated December 7, 2012, LIPA recognized that a critical component was to create a framework within which interoperability between the multiple domains in an electric system could be maintained. This framework included Technical Architecture and Approach, an Enterprise Semantic Model and Approach, and a System Development Life Cycle and Documentation.

As prescribed by the ICP, LIPA deployed SONET JMUX for NERC-specific applications and an Ethernet network for non-NERC data communications at substations and the backbone. LIPA deployed a DNP Protocol over licensed and unlicensed radio communications frequencies and distributed data via Ethernet TCP/IP with the GE ENMAC distribution management system. For Advanced Metering Infrastructure, LIPA used Landis+Gyr Gridstream, a secured encrypted wireless link to gather data from the front-end communication server to a hosted Command Center. The data is routed within the LIPA network using TCP/IP.

All new systems deployed in this demonstration project within LIPA followed the Technical Architecture and were modeled to a common semantic model to enable ease of integration. Project implementations also adhered to IEC 61970, IEC61968, IEC 61850, IEC 60870-6, and IEC 62351 as describe in the ICP and to LIPA's System Development Life Cycle where applicable.

INTERACTIONS WITH PROJECT STAKEHOLDERS

LIPA strived to have extensive interaction with customers in the project area. In addition, LIPA engaged in general customer education and outreach efforts in order to familiarize customers and public officials with the anticipated benefits of smart grid technologies. LIPA's two sub-recipients, Farmingdale State College and Stony Brook University, also engaged in public outreach in coordination with LIPA, including town hall meetings, public forums and other outlets. In addition, as described above, Farmingdale's portion of the project included "live" demonstration models that enabled residential and business owners to gain a better understanding of AMI and other technologies as well as time of use pricing. Farmingdale also conducted training programs and courses relating to smart grid and renewable energy, and Stony Brook offered courses relating to cyber security and other areas.

With respect to AMI, LIPA implemented a detailed marketing and outreach plan to engage customers in the project area. Because LIPA is assessing the impacts of several different factors, LIPA used different groups of customers, some of which served as control groups to isolate the impacts. The test groups and the control groups are described below. LIPA took a number of factors into consideration in determining the size of the groups in order to ensure that the results would be meaningful. To ensure the ability to replicate the Smart Grid beyond the pilot area and ultimately throughout LIPA's service territory, Load Research provided sample sizes for each customer segment that are representative of the entire Long Island population. Samples were designed by using the same model based statistical sampling techniques used for conducting load research studies.

The ***Control Group*** (circuit 6U-876) consisted of 200 residential and 107 commercial customers, totaling 307 customers. All customers received Smart Meters. This circuit served as a control circuit for both Operations and Marketing and to which no system changes will occur. Customers in this group received communications pertaining to Smart Grid education and Smart meter deployment only and to ensure that they allow LIPA to install the Smart Meters. They did not receive special marketing communications or information on their usage, devices, or rate offerings. Otherwise these customers received the same marketing communications as all other LIPA customers. Metering was installed at the substation to measure three phase and power factor to capture aggregate feeder data per the project plan for that element of the Route 110 Corridor project.

The ***Operations Test Group*** (circuit 6K-447) consisted of 197 residential customers and 85 commercial customers, for a total of 282 customers. All customers received Smart Meters. System changes such as voltage fluctuations occurred on this circuit; however, customers were not informed of these system changes. As with the Control Group, these customers received communications pertaining to Smart Grid education and Smart Meter deployment only. They did not receive information on their usage, devices, or rate offerings. Otherwise these customers received the same marketing communications as all other LIPA customers. Metering was installed at the substation to measure three phase and power factor to capture aggregate feeder data as per the project plan for that element of the Route 110 Corridor Project.

The ***Marketing Group*** was a representative sample of the entire Long Island population, both residential, and commercial and consisted of 1,091 residential customers and 658 commercial customers, totaling 1,749 customers. The *Marketing Group* received marketing communications pertaining to Smart Grid education, Smart Meter deployment, usage information, devices, rate offerings, as well as a series of seasonal ongoing communications. The residential customers were also segmented based on potential to save under the alternative rate offering.

The impact of automated energy management devices were tested for residential customers. This ***Direct Load Control (DLC) Group*** received smart meters and was provided with standard automation devices that receive signals from the meter to control high load devices, such as HVAC equipment and pool pumps without the need for direct customer intervention.

After a rigorous bidding process, Schneider Electric was selected as the DLC technology provider. During the time between the award of the bid and the implementation, customer concerns for privacy became one of the utility industry's customer satisfaction challenges. The project team came to the conclusion that direct load control programs and technology would be more widely accepted, economical, and marketable and would evolve more quickly if the utility allowed customer to choose and purchase their own equipment and choose to participate into one or many of the utility's direct load control programs.

To realize this vision, direct load control devices would not be provisioned by the utility's meter as LIPA had once required but instead, the meter would be an appliance feeding its information into the technology chosen by the customer. Customers may elect to purchase their own load control devices and opt into one or many of the utility's load control programs according to their life style, preference, and experience.

LIPA directed Schneider to re-design and re-program their communications architecture to achieve this vision. Schneider reconfigured their internet connected gateway which became the communications hub for the load control devices including a thermostat, 2 smart plugs which can turn off and on connected appliances remotely and report their consumption, a pool switch, and the smart meter. The smart meter would still communicate with the utility on whole house electric consumption while the gateway provided near real-time device consumption reporting and controlling of the thermostat, plugs, and pool switch to the customer via the internet. The curtailment event can be opted out by the customer thus providing the choice, control, and privacy that customers want. This re-design delayed the schedule launch by 6 months but helped LIPA envision how future DLC program would be designed and operated.

CUSTOMER OUTREACH

Phase 1– Smart Grid/Smart Meter Education:

This phase ran throughout the demonstration phase of the project. It focused on educating customers about Smart Grid and Smart Meters and the potential benefits for customers. Most customers are not familiar with or do not fully understand the Smart Grid and its benefits. The goal of these communication efforts is to minimize possible customer resistance to Smart Meter installation by educating the population within the Route 110 Corridor (other than the control groups) about Smart Grid and the potential benefits for customers. High level information about the benefits of time of use rates was described, but not specifics about rate offerings or options. During this period, LIPA addressed possible customer concerns surrounding this new technology, including security, health, privacy, and accuracy/ bill impact issues.

The Education phase provided customers with a level of understanding that allows them to feel comfortable with the installation of AMI Meters. Phase 1 also included sustained Smart Grid education throughout the duration of the project to ensure consistent information is available for Route 110 Corridor customers.

The success of Phase 1 was critical and set the tone for the remainder of the pilot as well as ensured maximum customer participation. Proactive education was a key component in addressing customer concerns about the technology, time of use pricing, privacy, and load control programs.

Phase 2 – Smart Meter Rollout

The objective of the communications campaign around the overall meter deployment is to set customer expectations while addressing customer concerns. Communications reinforced the benefits and addressed customer concerns as well as provide a process overview and timing of the rollout. Setting the customer's expectations at this point was critical to the success of actual meter deployment. The goal was to give customers an understanding of the process, the timeframe for deployment, and a means of providing feedback or obtaining additional information. Communications were specific in addressing the how, what, when and why of the actual meter installation, and provided FAQs to take the mystery out of the meter installation.

Resistance and negative exposure was dealt with immediately. Tight monitoring of customer questions into the Call Center and walk-in offices was done on a daily basis. Updates were given to the staff of the Marketing Department who was responsible for the management of customer issues that were uncovered throughout the program.

After the smart meters were installed, LIPA started receiving written demands from customers requesting to be excluded from the installation of smart meters. Smart meter opponents had sponsored viewings of the film "Take Back Your Power" in local libraries and theaters. A majority of the demand notices was from download forms that one can download from a variety of websites opposing smart meters. Fortunately, none of the over 90 "opt-out" requests included premises where smart meters were deployed. This was a visible reminder that utilities and stakeholders have much to do to educate the public on the magnitude of the benefits and risks of smart meters.

Phase 3 – Tools & TOU Rate Option Enrollment:

Residential customers within the Route 110 Corridor Project Marketing Group were segmented for the purpose of measuring customer response under the two treatment scenarios (web tool access and web tool access/TOU offer). Three stratified random samples were chosen to be representative of the Route 110 Residential population. The study employed a random encouragement design for the two treatment groups.

Residential Marketing Group Segments

Control - Customers received little or no marketing materials. This represents the counterfactual (how customers would have behaved absent the treatment).

Tools - Customers received access to the web tool and marketing materials to encourage use of the web tool. The objective of the Smart Web Tool was to provide customers with detailed usage, cost, and environmental impact data. The tool displayed 15 minute interval data which correlates to customer's individual energy usage with associated costs and carbon footprint. The tool has the ability to display data in as it relates to PSEG Long Island's rate design.

Rate - Customers received access to the web tool and were actively encouraged to use the web tool and to opt in to the M188 TOU rate. Time of Use rates were displayed in peak, off-peak and intermediate periods for each day. This enabled the customer to understand how much electricity is being used in each period and helped them to shift their usage to periods where the cost of electricity is lower.

Immediately following the end of the summer season 2012, this phase focused on ensuring that customers received information on tools and were given necessary information to ensure they knew how to take advantage of the opportunities available to them. Residential customers were provided with a new Time of Use (TOU) option where Peak hours are defined as between 2 p.m. and 7 p.m. Monday through Friday. All remaining hours are Off-Peak. The costs for Peak and Off-Peak changed seasonally resulting in a substantial increase in cost during the Peak time period in the summer beginning June 1st and ending September 31st. Rate enrollment began after the summer 2012, once the baseline data had been gathered and analyzed. The results were used to identify customers who are more likely to enroll into an alternative Time of Use Pricing plan and shift usage to maximize savings. The enrollment timeframe was interrupted by Superstorm Sandy and was not completed until after the summer of 2013.

Customers did not receive an in home device as originally proposed. The synchronization process between the in home device and the meter was cumbersome. Customer feedback suggested that an application (app) to be used on a smart phone is preferable and more effective. The meter data management and web tool provider did not have a phone app in their tool box at the time. The solution was to have the phone app as part of the direct load control deliverables.

Phase 4 – TOU Rate Option Demonstration:

At the customer's one-year mark on the TOU Rate, he/she received a cost comparison showing what they would have paid on their original rate versus the Smart TOU rate. If the customer incurred increased costs due to the TOU rate, the "Cost Guarantee" was invoked and a refund in the form of a bill credit was issued for the difference in costs.

ON GOING CUSTOMER ENGAGEMENT

In addition to those specific, phased messages, customers received a series of communications at different intervals throughout the pilot regarding:

- Seasonal Changes – Peak Cost Changes
- Energy Savings Tips
- Energy Efficiency Programs
- Tips & Tricks (Web and IHD)

The purpose of these communications was to continue to grow the targeted consumer's knowledge about the Smart Grid, the benefits of the rate options, and how to optimize their savings opportunities with the rate options throughout the program.

During the implementation of the Route 110 Corridor Project, there were issues that arise from partners, employees, customers, and potentially community and the media. The front-line for questions and issues were the customer service representatives (CSRs) at the Call Center. A group of seasoned CSRs were trained and they answered questions and resolved issues from customers using a special phone number set up for the project. The following process was utilized for issues that the CSRs needed assistance to resolve:

- Issues that were unable to be resolved by the CSRs from a community leader were referred to the LIPA Government Relations Team
- All other issues were raised to designated Marketing representatives

An issues log was maintained to ensure resolution and gather learnings. Baseline customer data was collected through research that was conducted during the marketing campaign for Time of Use Rate Enrollment. Surveys focused on demographic and firmographic information, including appliance or equipment inventories and type of home or business. Included with this survey were questions around Customer Satisfaction with educational messaging. The process of meter deployment, Email and additional contact data were also obtained. This information was utilized during baseline data analysis to provide a deeper understanding of energy use per customer as well as providing recommendations as to how customers can reduce their costs by shifting their consumption.

Additional research was conducted at the customer's one-year anniversary. Surveys focused on the ability to shift energy usage, modifications made, success of the modifications, any challenges the customer faced, and satisfaction with the rate and communications throughout the year.

TECHNICAL APPROACH

PROJECT PLAN

The overall plan was to deploy an AMI System, Distribution Automation Devices such as Automatic Sectionalizing Units (ASUs) for overhead, Pad Mounted Housings (PMHs) for underground, 2-way Capacitor Controllers, and Substation Remote Terminal Units (RTUs) for 3 phase monitoring. The implementation involved the installation and configuration of the devices in the field, modes of communication to the devices, integration of the data received and exported to our PI System, Lodestar, CYME and other databases for analysis.

One of the lessons we have learned to make this a successful deployment is to be cognizant that the technology is always changing and evolving. We need to be open to exploring new options such as new types of communications for AMI meters and DA devices, new 2 way capacitor controllers, and new RTUs that give far more information in balancing loads and controlling levels of voltage.

STEPS TO ACHIEVE EFFECTIVE DEPLOYMENT

MODEL OR SIMULATION DESIGN AND DEVELOPMENT

The model developed by Stony Brook was used to improve the ability of the utility supplying energy to its customers by making system improvements, reducing costs, improving power factor and delivering energy. The model gathered the data from the appropriate systems (PI Historian, MDM, AMI Head-End, Lodestar) capturing 3 phase voltage, current, kVar, KVA, power factor at the substation and distribution devices. It utilized the kWh delivered and received, voltage, kVar, and power factor from the meter as input. Meter data, billing data, and circuit data were used in load balancing, feeder optimization, voltage optimization and forecasting.

COMMUNICATIONS SYSTEM DESIGN AND DEVELOPMENT

Advanced Metering Infrastructure (AMI)

LIPA's application used a number of additional open standards and protocols including DNP3, ANSI C12.22, and ZigBee that work with systems in distribution automation and AMI implementation. These protocols and standards were included in the 'low hanging fruit' identified in the NIST standards process.

The smart meters communicated over a secure encrypted wireless link between the Landis+Gyr (L+G) Gridstream Network from the meter to the Hosted L+G Head-end System Command Center and then routed the meter data via TCP/IP to e-Meter Meter Data Management System, the Data Warehouse, and the Load Research System.

The AMI Mesh technology (L+G Command Center) supported data encryption to and from the electric meter. The vendor's electric meters have three levels of password access: (1) Read Only; (2) Read/Write; and (3) Admin/Programming. The software used to locally interrogate the meters also requires additional login security.

All electric metering risks have been mitigated by creating a redundant design concept. Each energy device was supported by the RF mesh network capable of reading every end point on schedule or on demand. In addition, each meter displayed a standard cumulative energy index value and internally stored load profile data for manual read process when required.

Distribution Automation (DA)

The Distributed Network Protocol ("DNP") was developed for use in process industries. In the electric utility industry, DNP is typically used to enable interoperability between substation computers, remote terminal units, and intelligent electronic devices. The Automatic Sectionalizing Units (overhead switches), Pad Mounted Housing (underground switches) and capacitor bank controllers used DNP. The current version, DNP3, runs on the distribution automation system solution that has been installed by LIPA. The ownership of the specification resides in the DNP3 Users Group comprised of users and vendors.

The ASUs, PMHs, and capacitor bank controllers security was provided from the front end ENMAC system. The ENMAC system recognized four regions, and operators were required to use sign-on-passwords to monitor and control the field devices in their respective regional operating areas. The ENMAC system has been set up on a Virtual Private Network (VPN) in which all workstations are physically connected to a network that is not directly connected to the corporate network. The communications to these devices was over a private radio network which uses licensed and unlicensed frequencies as well as a changing hop pattern.

Substation Automation (SA)

The RTU retrofits were connected to existing communications systems using fiber. The Supervisory Control and Data Acquisition (SCADA) data from these RTUs utilizes a secure private communication network. A cut in the communication fiber ring or lease line network maintained connectivity through rerouting traffic (traffic goes around the ring in the opposite direction or follows a different redundant path).

The RTU communications used Jungle Multiplex (JMUX) fiber communications. The ASUs, PMHs and capacitor bank controllers utilized radio communication to support SCADA. The radio communication with field devices used unlicensed spread spectrum through the appropriate repeater hierarchy that brings the information to the CG Automation Concentrator and to GE ENMAC. If a communication repeater or communications with a device was affected by weather, antenna orientation or interference, personnel was dispatched to resolve these issues.

Interoperability Considerations

Interoperability was accomplished in several ways. Data communication across the automation devices were broken down into three distinct types of communications to the smart devices that are used for this project, including a (1) Sonet JMUX network over fiber for non-TCP/IP applications; (2) DNP Protocol over unlicensed spread spectrum; and (3) secure encrypted wireless transmission.

The retrofitted substation RTUs used non-TCP/IP applications to carry data via Verizon leased-lines or Sonet JMUX fiber to the Energy Management System (EMS) Network or the Corporate Network. The Sonet JMUX network used different channels of bandwidth that can be separated from each other. These channels were used in a point-to-point scheme. Because they do not rely on TCP/IP, their native communications protocols were maintained from one end point to another.

The ASUs, PMHs and capacitor bank controllers were monitored and controlled using DNP Protocol over unlicensed spread spectrum radio communication utilizing frequency hopping. A CG Automation Concentrator distributed the data via Ethernet TCP/IP communications to and from the GE ENMAC distribution operation Control System.

LIPA has already made investment to set up an Enterprise Data Management (EDM) policy, processes and program that is being used as a basis for all LIPA systems development and integration efforts going forward. The methodology included a requirement that any new systems development and implementation project must follow certain work steps including assessing where data elements exist in LIPA's semantic language framework in relationship to industry model standards (currently modeled to CIM, IEC 61850). All systems integration projects were required to go through the modeling, development and implementation processes using LIPA standards that have been based on, and will continue to be shared with industry standards groups.

Data Management Considerations

The meter data management system has standards-based open architecture. The system architecture included smart, flexible adapters to enterprise software applications and AMI and meter data collection systems. The databases stored relationship, interval, event and other data for use by meter data management applications to manage the AMI systems and processes and for use by other applications throughout the enterprise. It provided two-way communication for meter data collection and other communications, such as load control or sending data to in-home displays. Communication processes included retrieving meter reads, sending configuration data to meters, issuing control commands to appliances or equipment linked to a variety of networks, and sending price signals and other information over a network to in-home or in-premise devices.

The communication systems supporting the smart grid devices transferred data to the operating centers. Legacy systems such as GE ENMAC, GE Harris EMS, and OSI PI Historian data warehouse interfaced with the Smart Grid devices or associated servers. The PI Historian system has an open architecture design to enable connectivity to enterprise systems supporting common modeling techniques to better support the user population managing assets and system operation. This system not only required security access but also resided on a separate network.

The connection to the smart grid devices provided monitoring of system health for the distribution electric meters through use of unsolicited messages and response of control commands. Automated polling algorithms used to monitor the smart grid infrastructure devices determined hardware failures and alerted the operator alternative system solutions. The monitoring also provided an efficient and effective way to manage the maintenance / replacement of system assets for positive system reliability results.

Cyber Security Considerations

The deployment of the AMI can be broken up into two major areas such as security in the meter and security in the collector.

- Security in the Meter
  Devices can be accessed locally via the optical port or remotely via the 900 MHz radio system. Access to the devices via the optical port requires an optical port password. A valid password is necessary to read data from or write data to the meter. The optical port password is set per the customer’s factory configuration and can only be changed by the utility using the meter vendor configuration software. Recommended policy for the utility is that passwords for meter access be disclosed on an as-needed basis.
- Security in the Collector
  The collector can be accessed locally via the optical port or remotely via the wide area network (WAN). Access to the collector via the optical port requires an optical port password. A valid password is necessary to read data from or write data to the collector. The optical port password is set per the customer’s factory configuration and can only be changed by the utility using meter vendor’s configuration software. Recommended policy for the utility is that passwords for collector access be disclosed on an as-needed basis.

The substation RTUs used the existing General Electric SONET JMUX System as the data transport mechanism between sites. The security layer rides over this transport mechanism. The JMUX used individual dedicated channels of the SONET to isolate one path from another. For non-TCP/IP applications such as bringing back RTU data, these paths were not shared.

The distribution automation devices used the 900MHz Spread Spectrum Communications Network to encapsulate DNP messages from the end-device (ASUs, PMHs and capacitor bank controllers) to the CG Concentrator and then passed the data to a private VPN Network that feeds information to/from the GE ENMAC.

LIPA's information security policy ensured that the business benefits of sharing information and ideas are maximized while the information assets are protected from security risks. To control access to information assets according to business need, business risks and any legal or contractual requirements, LIPA followed the NERC Critical Infrastructure Protection reliability standards CIP-002 and CIP-003 to identify those assets to which the NERC CIP standards apply. These standards require that LIPA use a methodology that includes risk assessment to identify critical assets (002) and the critical cyber assets (003) that support those critical assets. All CCA data resided within a secure physical and electronic perimeter as required in NERC CIP-005 and CIP-006. Employee awareness of security policies and the access to any CCA data followed the requirements of NERC CIP-004. Management of the configuration of the firewalls and routers was administered in compliance with NERC CIP-007.

The following restrictions were and are in place at LIPA:

- Access to LIPA's information assets and services shall be controlled by the security requirements.
- Information access rights to information assets and services shall be authorized, consistent with a user's job requirements and shall be modified when their job requirements change.
- LIPA shall establish and maintain access controls that meet or exceed legal and regulatory requirements for the standards of due care.
- Formal procedures shall be in place to control and review the allocation of access rights to information assets and services.
- Access to information systems shall be controlled, and each user will maintain an individual user id and password.
- Business owners are responsible for ensuring contractual controls are implemented by third party service providers when LIPA information assets are accessed, stored or processed at a third party site.
- Users shall be made aware of their responsibilities for maintaining effective access controls, particularly regarding the use of identification and authentication mechanisms and the protection of both hard-copy and soft-copy information.
- A clear desk and clear screen policy shall be implemented to reduce the risk of unauthorized access or damage to papers, media and information processing facilities.

The Smart Energy Corridor Project included firewalls, routers, switches, access points, repeaters, radios, In-Home Displays/gateways, internal network servers and clients on private networks allowed for the data to be transferred to the front-end systems as well as the internet. The use of DNP Protocol, Non-TCP/IP Applications and Data Encryption supported the smart grid cyber security standards.

Stony Brook tested smart grid devices to determine their vulnerability to physical and cyber-attacks.

TEST PLAN

There were 3 major areas where we have installed equipment to support the building of the Smart Grid in the Route 110 Corridor. The equipment for each of these areas was procured, configured and tested prior to actual implementation. Below is an outline of the testing in each of the areas.

ADVANCED METER INFRASTRUCTURE (AMI)

There were 2 hosted systems (test and production) that L+G had provided. The test system consisted of the hosted server and collector for communications to the meters within the company facility. The various AMI meter types (L+G Focus RXR – residential and L+G S4e RXR - commercial) were programmed and tested to communicate with the Test System. The testing included communications (mesh network) to the meter via routers and collectors, data flow to the Meter Data Management System (MDMS), and connectivity to Home Area Networks (HANs) and In Home Displays (IHDs). This is in addition to the normal meter calibration and accuracy testing, meter firmware updates, programming of different rates and quantities measured in the meter, and various alarming features. Meter Engineering and Shop personnel performed trials on the test system prior to implementation into the production environment.

DISTRIBUTION AUTOMATION (DA)

There were three distinct distribution automation devices that were installed for the Route 110 Corridor. They were ASUs, PMHs, and capacitor bank controllers. The ASUs and PMHs were devices that already exist on our distribution system. There were approximately 1300 of these devices on the system and the equipment was directly installed and tested when it is put into production. The configuration of how these devices communicate and integrate to the distribution automation system was performed in the DA Lab. There were three primary components of the distribution automation system that were configured which is the radio communication, CG Concentrator and GE ENMAC. There was a redundant test system which all configurations were tested for new devices prior to being deployed in the production environment.

The capacitor bank controller was a new device type that did not exist on LIPA's distribution automation system prior to the Demonstration Project. The following had to be completed or determined: development of the DNP points to be retrieved from the device, configuration of the control parameters, type of communications, integration to ENMAC (device screen development and tele-control parameters), and CG Concentrator Configuration. Whenever a new device (CBC8000 Capacitor Bank Controller) was integrated, we installed it first within our DA LAB. This allowed for testing of the installation, configuration, and control to be completed within the test system prior to implementation to the production environment.

SUBSTATION AUTOMATION (SA)

Substation Automation has installed substation RTUs and digital meters that are tested when they are commissioned in the field. The commissioning included communications to the Energy Management System (EMS), testing of the inflow quantities being measured (such as Voltage, Current, kVar, kWh etc.) and connectivity of data flow to the PI Historian. In the event there are problems with the new equipment, the old equipment is put back in place reducing the amount of any downtime.

DATA COLLECTION AND BENEFITS ANALYSIS

As stated previously, the data gathered was imported into the CYME Load Flow Analysis Tool to specifically perform the following:

Feeder Loss Estimation
We met DOE metric reporting requirement for yearly distribution feeder losses. Initially, we used commercial and residential AMI data spreadsheet analysis and later used CYME load flow analysis to determine average feeder losses as percent of load and total feeder cumulative MWh losses.

Capacitor Control Optimization
We used CYME load flow analyses to assess alternative capacitor control methods and settings with the present time-clock method and setting as a baseline. We leverage AMI data and historical time clock and pager log database to enable setting of capacitor banks to on or off position depending on day and hour simulated. We also used CYME load flow analyses to determine the automatic voltage settings to open and close the capacitor bank leveraging data captured from the sensors at the capacitor bank location.

TLM Enhancement
We used AMI residential customer meter data to study customer load diversity (as a function of customer count, KW, KVAR, etc.) at the distribution transformer level. This enabled better sizing of the transformer.

Customer Voltage Assessment
We deployed AMI residential customer meter data to assess feeder voltage regulation. We developed a report showing min/avg/max volts by transformer/customer/meter. We enhanced the report later to include commercial customer AMI data.

Feeder Optimization (Phase Balance, Voltage Regulation)
We built an advanced CYME Corridor network model using the database incorporating feeder breaker, ASU, and capacitor bank metering points. We also built a CYME EPM (Energy Profile Manager) database to enable CYME Load Flow with Profiles (LFP) analyses. This database included information from SCADA and PI.

- Feeder breaker amps and power factor for the annual peak day (7/18/13);
- ASU amps and power factor for the annual peak day;
- Capacitor bank amps and power factor for annual.

We performed enhanced CYME Load Allocation and assess feeder optimization using 24 hour and seasonal LFP analyses.

RESULTS

OPERATION OF SMART GRID TECHNOLOGIES AND SYSTEMS

There were three distinct areas that the Smart Grid Technologies were deployed to address, including Advanced Metering Infrastructure, Distribution Automation, and Substation Automation. The Advanced Metering infrastructure consisted of the installation 2,550 AMI meters, supporting collectors, and L+G Gridstream Command Center, a separate L+G Test System, a web portal tool for customers, and interface to MDM for customer billing. Distribution automation included the procurement and installation of six (6) Underground Pad Mounted Housings (PMHs), 18 Automatic Sectionalizing Switches (ASUs,) and 51 2-way capacitor bank controllers with 3 phase sensing of voltage and current. The capacitor bank controllers have connectivity to the existing front-end DA System and PI using an enhanced fiber link to radio communications to all the existing DA devices in the Smart 110 Corridor. Substation Automation involved the procurement and installation of 5 RTU Retrofit Upgrades and 26 digital meters which improve from single phase monitoring of the voltage to 3-phase monitoring of voltage, current, power factor, kVar, target, and other information that are sent to the EMS System and PI.

Below are the major items that have been completed:

Automated Billing for AMI Customers

- The L+G Gridstream Command Center sends the relevant metering data to the e-Meter Meter Data Management System Energy IP that successfully produced billing determinants for several rates (both Residential and Commercial) used by the Customer Accounting System to send out bills automatically to the customers. We achieved near 100% register read rate via AMI as compared to our manual register read rate of 97.1% for billing. Our AMI interval read access rate (non-billing) was at 99.7%.

Implementation of Cost Information to eMeter Web Tool

- This improvement to the existing web tool allows us to go to a non-custom version of the tool which simplifies upgrades and the inclusion of rate information. Cost information can then be provided to the customer based on his energy usage.

DA Implementation of JMUX Fiber Link to Ruland Road Substation

- The communications path used to monitor and control the DA devices in the Route 110 Smart Grid Corridor was changed from 4 radio hops to a fiber link from Brentwood to the Ruland Road Substation with 1 radio hop, improving communications to nearly 100%.

Programmed Cap Bank Controllers as Time Clocks changed over to Voltage Control

- The capacitor bank controllers on the Distribution System that are programmed as time clocks operate to support the local conditions of the circuit. In order to operate them more efficiently, we gathered data for approximately 6 – 12 months with the normal time clock settings for all the devices and then converted them to operate on voltage, which was determined by our planning department.

Programmed Cap Controllers with New Firmware

- We upgraded the firmware on all capacitor bank controllers which enabled additional DNP data to be brought back including 3 phase kVAR Delta on operations, Phase Unbalance Alarm, Neutral Fault Current Alarming, and Bank Confirmation Status. These values have helped in isolating and detecting problems with capacitor banks which was not possible before.

Mobile Data Capture – Storm Damage Assessment Tool

- This project involved using iPads that are configured to bring up forms to be completed by survey personnel and enabled the information to be transmitted over the air to a hosted system (ArcGIS Online) which resulted in faster response in taking care of hazardous conditions and restoring power.

Desired vs. Actual Performance

The added feature of voltage control allowed the capacitor to respond to abnormal conditions that a normal time controlled capacitor cannot. For example, on cooler days during the summer when the load may be lower than typical summer loading and the voltages could be higher on a particular section of the circuit, a capacitor can respond to the higher voltage by turning itself off (and vice versa for lower voltages).

Voltage control on the feeder provided benefit to customers with PV who have inverters to supply power back into the grid. Sometimes, time-based capacitors are on when they don't need to be. This causes inverters to max out and trip off. This leads to complaints and may lead to a serviceman disconnecting the capacitor.

SCADA data recorded by the new controllers was found to be extremely useful for planning and service purposes. Voltage complaints are addressed much quicker when loading can be seen at more points along the feeder. This information is crucial to feeder modeling and allowed operations/planning personnel see what transfers can be made without causing overloads (similar to the data gathered by ASUs).

Extra monitoring points confirmed feeder imbalance between phases (a balanced feeder leads to better voltages and less load loss in most cases). Without 3-phase SCADA in most substations, planning personnel relied heavily on estimated loading on the B and C phases. Monitoring on field equipment greatly increased the accuracy of these estimates.

We found that accurate knowledge of where the concentration of load is on a feeder helped justify planning projects. Multiple points of monitoring along the feeder enabled accurate load allocations in planning models and helped determine where support is needed in proposing Conversion and Reinforcement projects. Reinforcement becomes more precise and can potentially help defer more costly major capital projects.

From a maintenance perspective, additional data provided the ability to confirm that equipment functioned properly. With multiple monitoring points, it was easier to identify when equipment is faulty or is not installed correctly, since data from one point may not coincide with data from another point. This made inspections and servicing easier for capacitors and other equipment all along the feeder. This has already proven to be a useful tool with ASUs. The capacitors in the Route 110 corridor have helped to identify equipment issues at the substation.

Lessons Learned

1. The current system configuration does not support the installation of AMI meters on Totalized Accounts.
2. AMI installation must be supported by field tools to increase administrative accuracy that should include bar-coding and field imaging of old meter to show meter number.

3. Numerous refinements are needed in the process of changing out a non-AMI meter to an AMI meter and then enabling it to be automatically read and billed accurately. A successful deployment must have commitment from metering, billing, operations, planning, and IS areas to make the appropriate changes in systems and processes.
4. Substation RTU, ASU and capacitor bank data can be used successfully to enable phase balancing.
5. Individual feeder power factor data can be used to determine voltage levels.
6. Analyzing voltages provided by cap bank and ASUs and tightening feeder voltage bandwidths through the use of voltage-regulated controllers enhance the utility's ability to address customer voltage complaints.
7. 3-phase data allowed operators to identify a potential phase overload in summer 2013. Emergency load transfer was made and the feeder was balanced to prevent further phase overload.
8. Cap data allowed planners to identify equipment issues related to substation 13kV bus voltage and the bank's LTC at 6U and 7UM.
9. The fiber backbone to Ruland Road Substation has been in place since September 2013 and the connectivity is at near 100%. The fiber backbone eliminated hops on the communications path and increased communications reliability to and from end devices. The resultant one hop to fiber enabled more information to be solicited while reducing the overall air traffic time. Fiber optic communication to a radio hop for the last mile to the supervisory controlled DA device enables a much more reliable method of communication.
10. Implementation of 2-way capacitor bank controllers has eliminated the need for manual inspections and provided more accurate identification of phase imbalances resulting in faster resolution of problems with the bank and more overall control.
11. When cap bank controllers operate on voltage control, the transmission support of kVars is reduced by approximately 50%.
12. The Mobile Data Capture iPads have enabled planners and tree trim personnel to identify distribution system problems with greater speed and accuracy. Digital photographs of damages, their GPS locations, and associated reporting were uploaded, transmitted, and analyzed. This resulted in dispatching the appropriate resources and more efficient and faster restoration of services.

Recommendations

1. The use of fiber communications should be increased system-wide to enable better communications to the DA supervisory controlled devices.
2. Capacitor banks should be deployed to support the distribution system and not be used to support the transmission system.
3. We should be encouraging vendors to support AMI using common carrier for hard to access customers not able to be reached by the fixed network.
4. Mobile Data Capture iPad tool is highly effective in eliminating paper and providing information for restoration but needs to have a direct link into new CGI Outage Management System (OMS) to enable for the information to be used more effectively.
5. Capacitor bank controllers have firmware upgrades to enable more functionality however, field visits were necessary in order to download them. We should pursue the capability of over the air updates with the vendors, similar to the AMI meters.
6. SCADA data could be used in the new OMS and allows for real-time study and diagnostics.

ENERGY STORAGE SYSTEM PERFORMANCE PARAMETERS

- Farmingdale State College did not receive contractor interest in the first bidding process for the installation of the hydrogen fuel cell and associated energy storage. After the second RFP, the lone bidder later withdrew. Farmingdale is in the process of a third RFP attempt and is pursuing installation outside this project. No results can be reported at this time.

IMPACT METRICS AND BENEFITS ANALYSIS

- Fault Location and Isolation and Feeder Peak Load Management demonstration was abandoned primarily due to the fact that the OMS System upgrade provider was changed from ACS to CGI as a result of LIPA's system management company changing from National Grid to PSEG Long Island. The new CGI OMS System came on line in September 2014 and required settling and debugging time of six months.

- In home displays have been eliminated due to the fast pace in technology change. The new edict as part of this project is a Mobile Web App as part of Direct Load Control technology that was installed on a tablet or smart phone. It enabled the functionality of the in home display from anywhere.
- LIPA integrated AMI data with its billing and MDM systems and provided residential and commercial customers on various rates with the ability to view their consumption and cost information over the web.
- The installation of 2 way capacitor bank controllers with sensors enabled the ability to remotely detect problems with the cap bank and drastically reduced field inspections needed to check the health of the units. This is a more proactive approach for maintenance and troubleshooting for distribution switches. Additionally, the sensors provided data for voltage, current, power factor, etc. and served as a superior input to model circuits in CYME-DIST.
- The availability and utilization of 3-phase SCADA information at the feeder breakers with downstream monitoring via capacitors and ASUs, have led to the proper balancing of the corridor's feeders to be within the distribution planning criteria of less than 15% imbalance per phase from the feeder's 3-phase load, at peak loading. This balancing is achieved not only on the total feeder load, but also at downstream points without the addition of extra phases to various taps.
- Periodic evaluation of data extracted from the field and comparison against simulation profiles, in particular voltage profiles and current profiles, have led to improved equipment calibration and malfunction identification as well as triggering more in-depth studies when abnormalities appear. Such observations include sensors not being properly calibrated, phase mislabeling, abnormally low voltage, etc. Attached are an expected voltage profile (Figure 1) and actual voltage profile (Figure 2) for feeder 6K-448 showing an ASU that possibly has not been calibrated (low voltage dip).

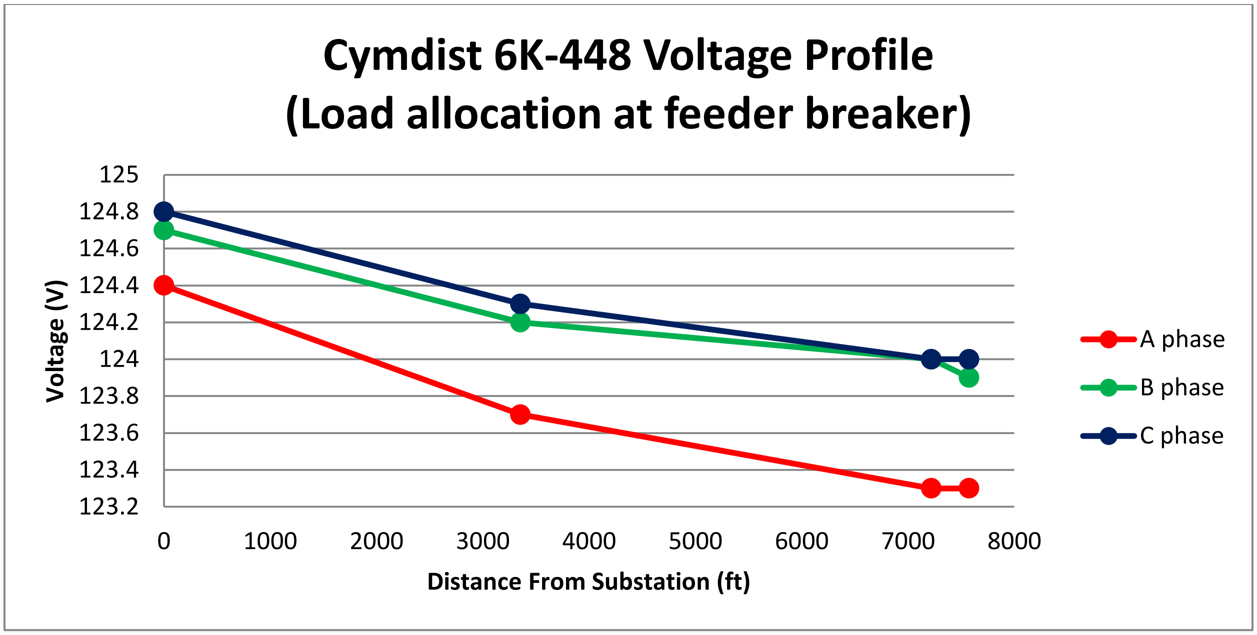


Figure 1 - Voltage Profile

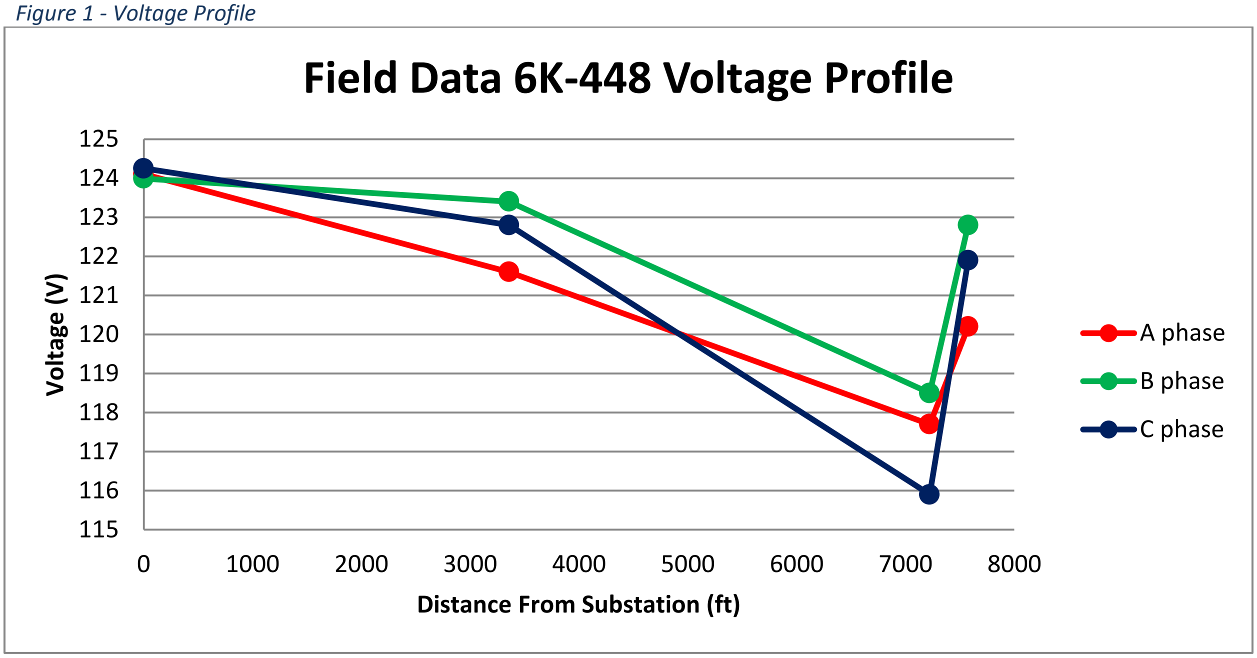


Figure 2 – Voltage Profile

- Shown in the Figures 3 and 4 is an instance where the phases on a particular capacitor seem to be mislabeled on feeder 6K-446. In the last set of data points, A and C phases appear swapped from the simulation to actual field readings.

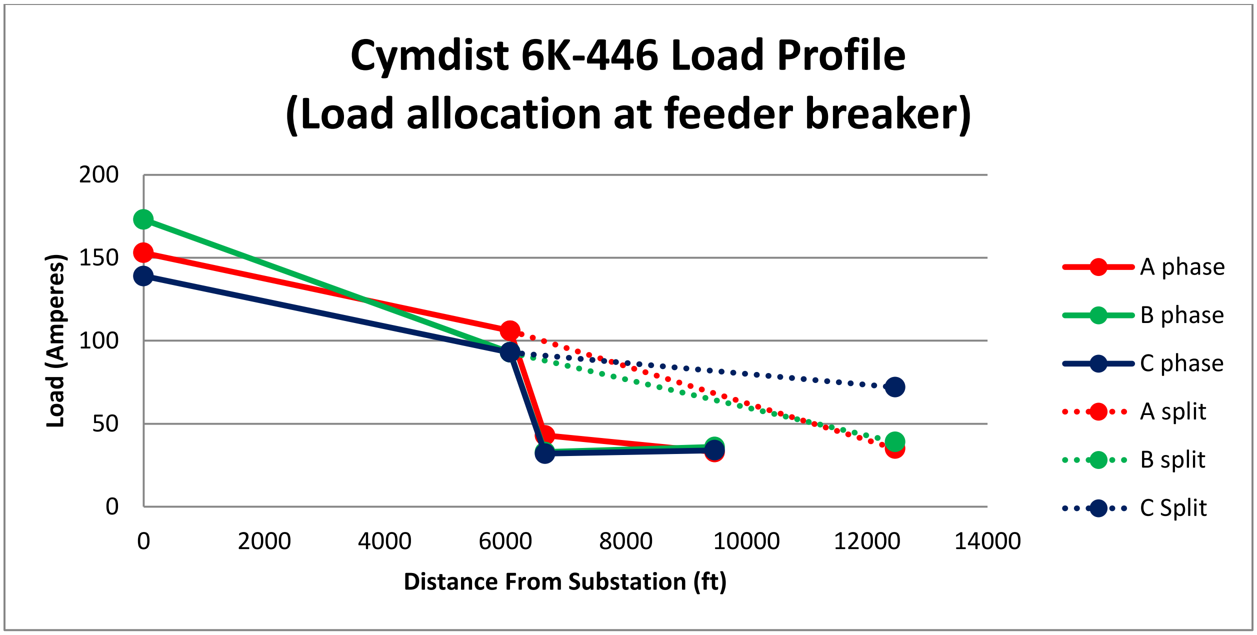


Figure 3 – Load Profile

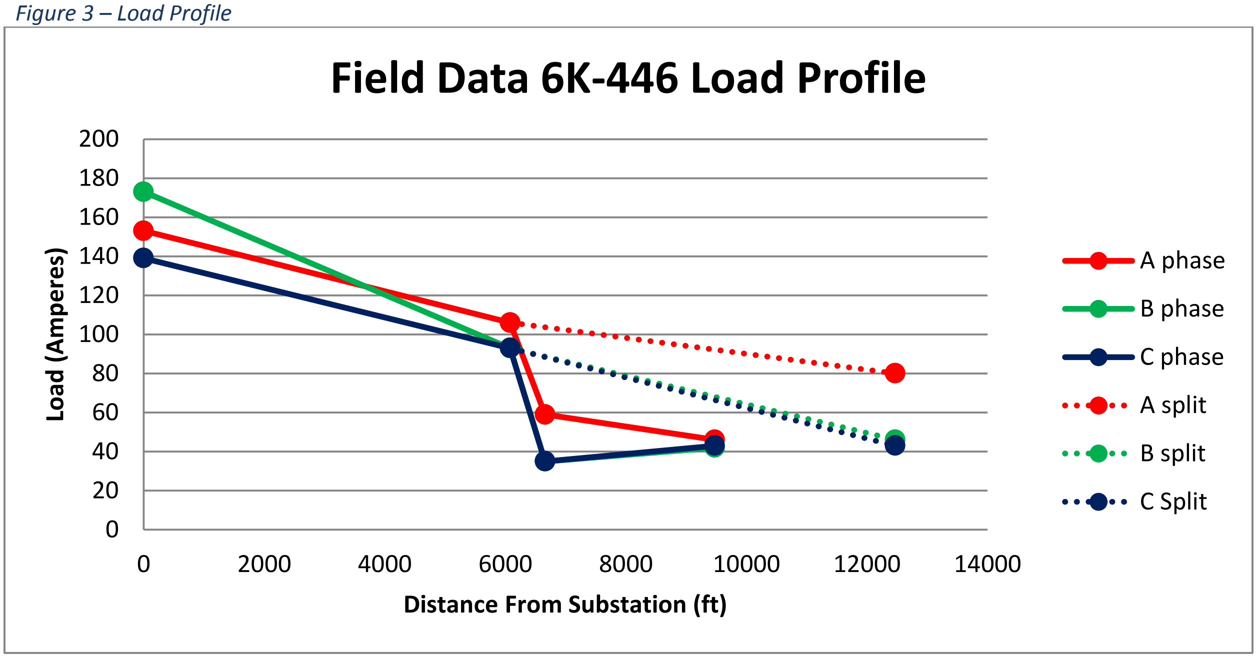


Figure 4 – Load Profile

- We are using the data to perform further analyses including studies on the potential reduction of load loss from phase balancing, voltage regulation benefits based on the type of controller, and interaction between capacitors with different control methods.
- The addition of 3 phase monitoring at several points along the feeders has helped to address customer power quality issues. In one case, a high voltage complaint from a customer with voltage sensitive equipment led to an analysis of voltage profiles via SCADA data and the determination of troublesome "CMV, R, & X" voltage compensation settings in the on-load tap changer at the substation.

- 3-phase SCADA has helped to measure the accuracy of load allocation methods used to model the distribution system, and in some cases has been able to identify field/model discrepancies. For example, this plot shows a load profile along the feeder 6K-447. At the 4th data point, CAP-8033, there is an A and C phase discrepancy between the model and actual field. This type of discrepancy has been used to identify mislabeled maps (taps on an incorrect phase) and equipment issues.

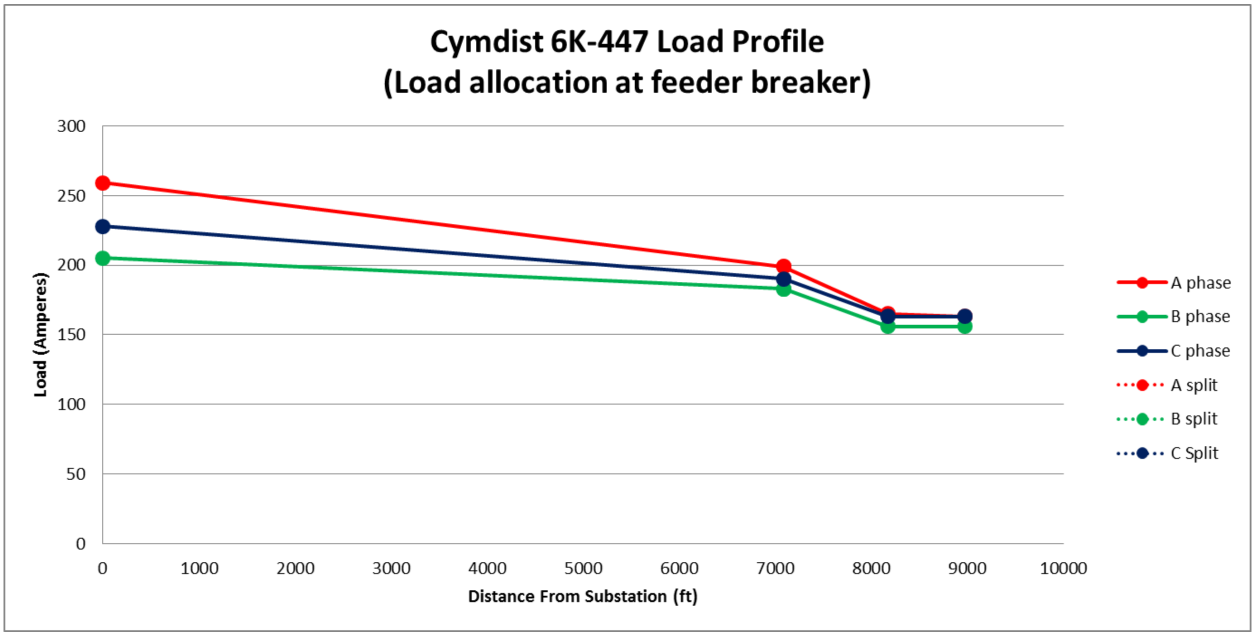


Figure 5 - Points of Measurement: 1. Feeder breaker, 2. CAP-8005, 3. ASU-1181, 4. CAP-8033

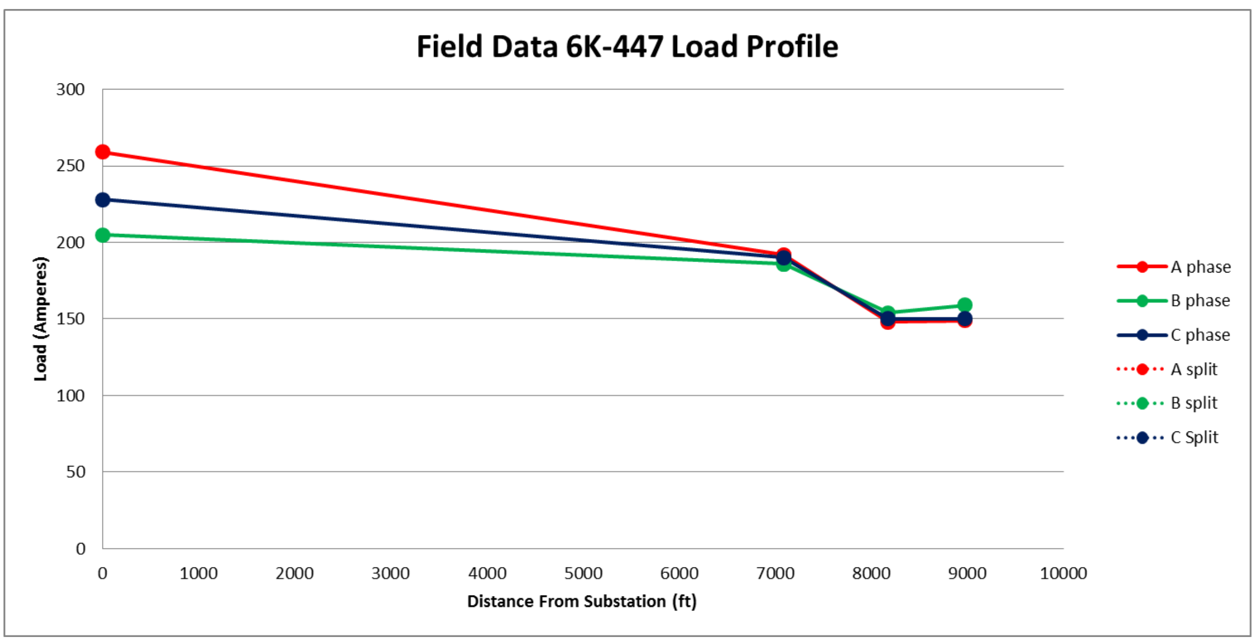


Figure 6 - Comparative Analysis on the Voltage Control Cap Banks vs. Time Controlled Cap Banks

On the distribution system, there are pager-signaled capacitor banks that are utilized in the summer months to provide additional VAR support to the transmission system. Concern was raised over whether the voltage controlled (VC) capacitors would still help contribute to transmission VARs. (Note that time-controlled, "TC", caps are on during peak hours to maximize VAR contribution.) Tying to this was the interaction between a VC cap and pager controlled cap, if both are present on the same feeder. 18 voltage controlled capacitors were analyzed during hours that a TC cap would normally be on (10:00 to 21:00) over a time period from 7/1/2014 to 10/1/2014. This period encompasses 2929 hours, of which 1342 hours were designated as "peak loading" hours. During this time period, there were 787.5 peak hours where pager zones were on and 554.5 hour where pager zones were off.

One concern was VC capacitors simply turning off when pagers were on, due to already satisfactory voltage requirements. In the analysis, LIPA found that VC caps were on an average of 53% of the time the pagers were on. Similarly, VC caps were on an average 57% of the time the pagers were off. Therefore, a rough conclusion is that the pager controlled capacitors being on does not have significant impact on the on/off state of the VC caps.

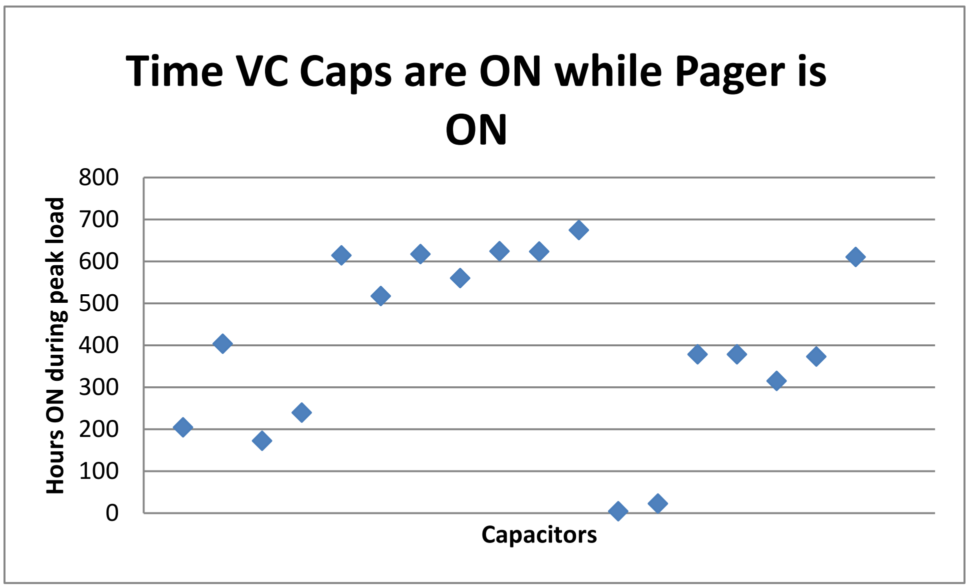


Figure 7 - Time VC Caps On while Pager is On

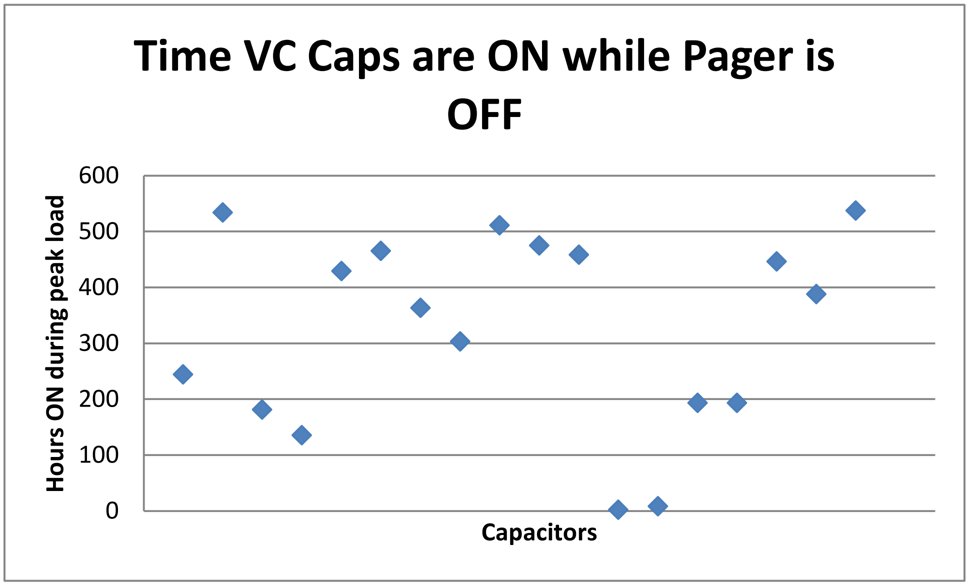


Figure 8 - Time VC Caps On while Pager is Off

The other half of the study was to assess the length of time VC caps are on compared to a time clock (again, to analyze how much VAR support is being provided to the transmission system). During this 1342 hour peak time period, time controlled capacitors would have been on for an average 787.5 hours that the pagers were also on (on 100% of the time that pagers are on). VC capacitors were on for an average 407 hours that the pagers were also on (51.7% of the time that pagers are on). The conclusion is that approximately 48% VAR support capability to the transmission was lost by placing capacitors on voltage control. It is determined that VC caps are a benefit to the distribution system only, and if a transmission benefit is needed there needs to be a voltage control override to force caps to stay closed in, in the event that transmission VAR support is needed.

STAKEHOLDER FEEDBACK

SMART WEB TOOL AND TIME OF USE

Of the 620 customers who were actively marketed to, 194 of them access the web tool on a regular basis. In speaking with customers who used the web tool, they found it valuable as it provides them with usage data as well as cost data. The data allowed them to make better decisions on how they use energy and provided an educational opportunity to understand how kilowatt hours relate to cost.

In addition to the web tool, 310 customers or half of the 620 customers were given the option to participate in a time of use rate. 70 of these residential customers elected to participate in the TOU experiment. LIPA also solicited 127 residential customers in Bethpage and Hauppauge who have AMI meters installed from previous pilots into the sampling. They were provided access to the web tool and 66 of these customers elected to participate in the TOU experiment. In total, we have 136 residential customers on the TOU rate and we have 611 residential customers who remained on a general rate.

Once reaching their 1-year anniversary date, cost comparisons were conducted as part of the "cost guarantee". Letters were sent to let each customer know if their behavioral changes regarding their energy usage over the past year resulted in any cost saving. If they were not successful, a refund of any additional monies paid was returned to them in the form of a bill credit. (The bill credit was absorbed by LIPA and did not impact the Demonstration Project budget.) Customers then had the opportunity to remain on the rate, or revert back to their prior rate. After the first year, it became the customer's responsibility for any bills they incurred as the "cost guarantee" expired.

Design and Methodology

The original design of the Smart Web Tool was a multiple sign on process. Customer's needed to access and log into the utility website (www.psegliny.com) then click a link that brought them to a separate site where they needed to log in again with a unique username and password that was maintained by the utility. It was found that trying to maintain multiple user names, passwords and PIN numbers (in case customers forgot their password) was difficult.

We developed a single sign on process within the utility's website (through "My Account") which allowed the customer to log in only once. They then had access to all their account information offered by PSEG Long Island including past and current bills, to pay their bill on line, to enter a meter reading, to check balances, to start, stop or transfer service, and to view their AMI meter data.

Once signed into "My Account", the customer has access to their AMI Meter data by clicking on the tab marked "Smart Meter". The Dashboard of the Smart Web Tool (Figure 9) is displayed and allowed the customer to choose a particular view based upon what data they want to review such as usage (Figure 10), cost (Figure 11), or environmental impacts (Figure 12).

The data from each display can be viewed in several drill down versions – by bill period, by a single day, or by a one year period. The data can also be downloaded into a spreadsheet with the Green Button function for further analysis by the customer.

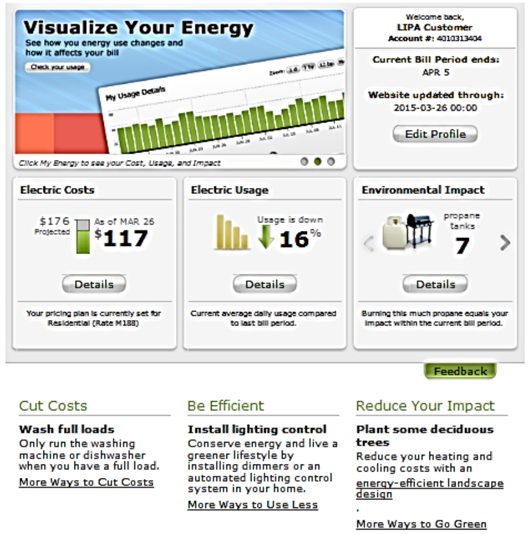


Figure 9 – PSEG Long Island Smart Web Tool – Dashboard

Figure 10 – PSEG Long Island Smart Web Tool – Usage Tab

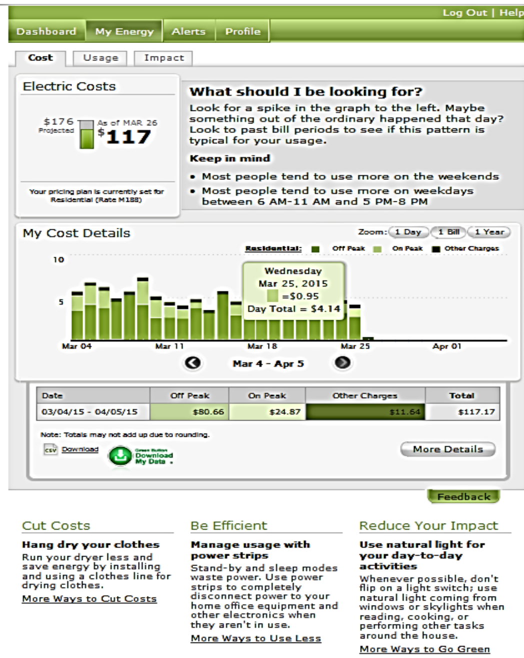


Figure 11 – PSEG Long Island Smart Web Tool – Cost Tab

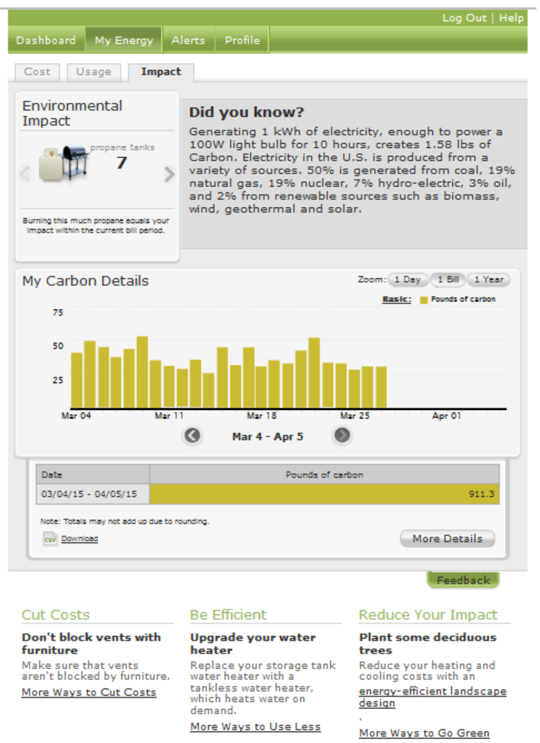


Figure 12 – PSEG Long Island Smart Web Tool – Environmental Impact Tab

Findings, Observations and Lessons Learned

Customer participation and engagement were a large part of the observations and lessons learned over the years of the study. LIPA found that those customers who participated in the Smart Time of Use Rate (TOU) had a higher propensity to access the tool and stay engaged. This segment used the tool to better understand their energy use and used the data to help change their behavior in shifting usage to off-peak times. The more the customer stayed engaged, the more effective they became in shifting and saving. This segment was also more educated in all aspects of Smart Grid technologies and had higher levels of customer satisfaction.

For the segment that remained on a general rate, LIPA found that their engagement was notably lower than those from the Smart TOU Segment. During communications throughout the years with this General Segment, it was found that some had forgotten they had a smart meter and were not aware of any additional Smart Grid technologies even though marketing efforts were identical to those in the TOU Segment.

Of the 70 customers enrolled in this TOU Rate, 49% were successful in "shifting and saving" while 44% were not. 7% were excluded from the program due to customers opting for net metering resulting in a rate change which made them no longer eligible to participate in the Smart TOU Rate. For the 44% that were not successful in "shifting & saving", it was extremely difficult to keep these customers as engaged as the 49% that did save. Marketing efforts were the same for all TOU customers. Participants who didn't save were more likely to not change their behavior or respond to direct communication. Our hypothesis about this phenomenon is the offer of the "Cost Guarantee". The "Cost Guarantee" may have allowed these customers not to be as rigorous or dedicated in their ability to shift their usage. This becomes evident in the load shapes for the TOU Group.

Load Research Observations

The summer of 2014 was chosen as the test period because at that point all customers had been fully treated. However, the only available baseline period was June-July of 2013 due to the fact that treatment for the TOU rate started in August 2013. The summer of 2012 did not contain adequate data for analysis.

For the three Marketing Group segments (Control, Tools, and Rate) the average weekday load profiles were constructed for the baseline (June-July 2013) and test (June-July 2014) periods. The treatment groups (Tools and Rate) were compared against the Control group for both the baseline and test period.

During baseline June-July 2013 weekdays, the three group's behavior were indistinguishable. All three groups had similar daily energy consumption (Table 4) and the two treatment groups (Tools, Rate) showed no observable differences in their load profiles when compared to the Control group (Figure 13).

During test June-July 2014 weekdays, the Tools group showed a small difference in their daily energy consumption as compared to the Control group but the Rate group exhibited a distinguishable difference in their daily energy consumption as compared to the Control group (Table 4). However the load profiles for the Tools or Rate group do not illustrate any distinguishable differences in the way customers used energy throughout the day when compared to the Control group (Figure 14).

In conclusion, the study showed a reduction in energy for the Rate group but not a distinguishable shift in their consumption pattern for weekdays. We also concluded that frequent and creative reminders of the benefits to customers about smart meters and smart grid technologies along with specific recommendations on ways to save energy and money are necessary for customers to participate and remain engaged.

Group	June-July 2013	Difference from Control	June-July 2014	Difference from Control
Control	40.33		37.25	
Tools	40.26	-0.17%	36.26	-2.66%
Rate	40.15	-0.43%	35.27	-5.33%

Table 4 – Load Analysis Comparison

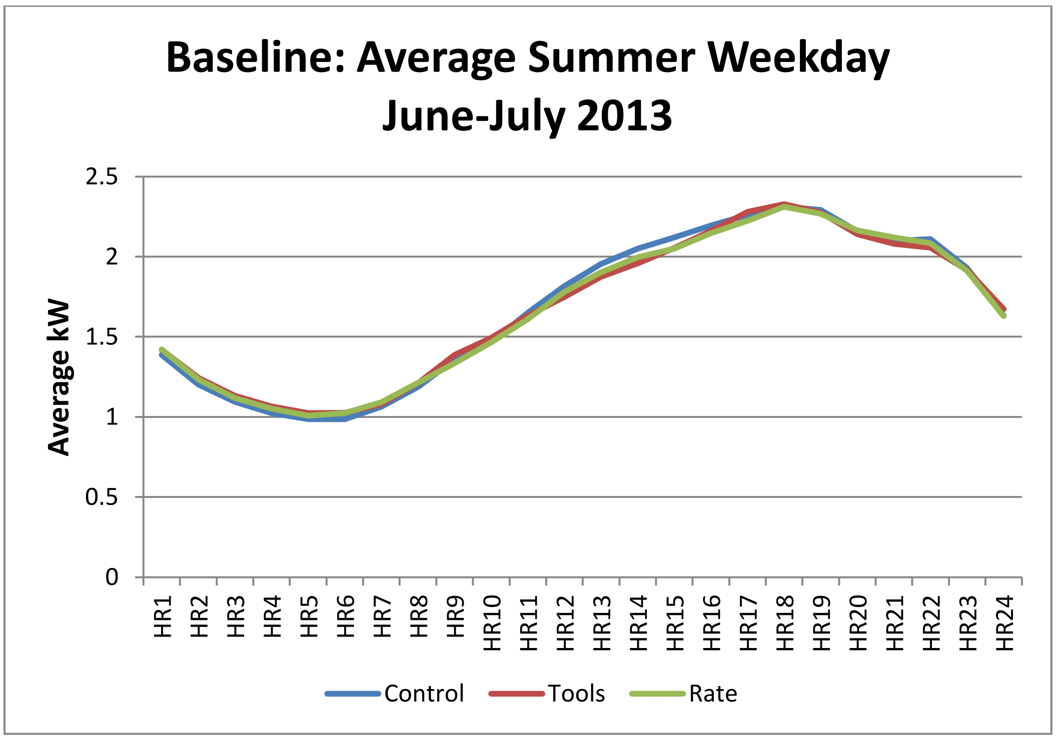


Figure 13 - Baseline Study of Customer Load by Group

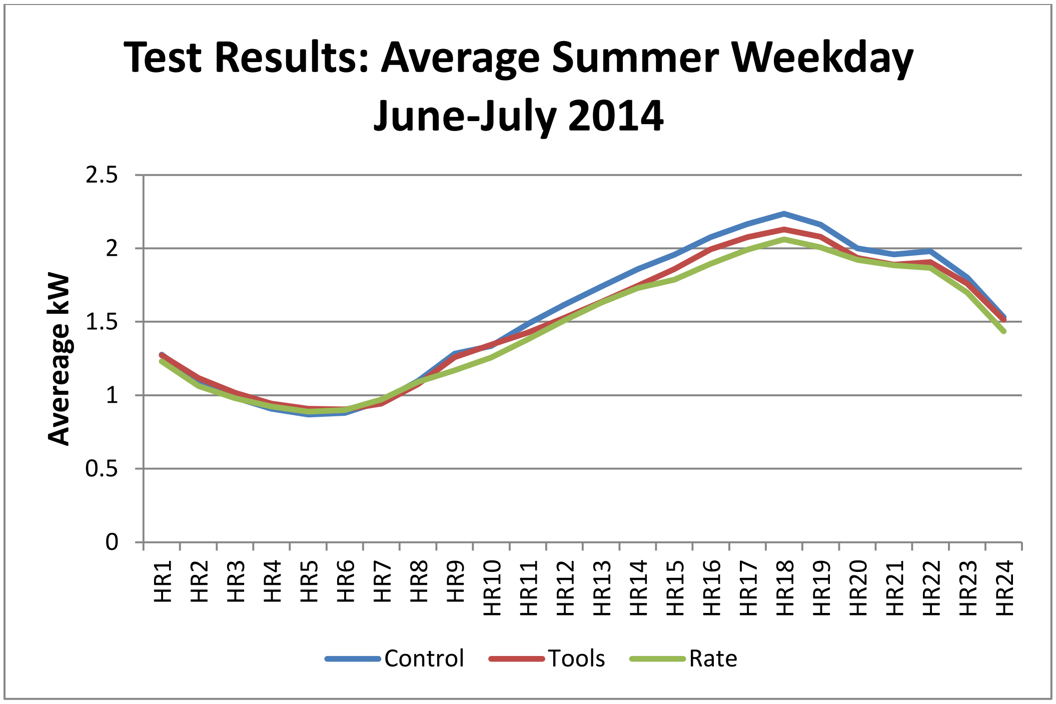


Figure 14 - Results Study of Customer Load by Group

Recommendations/Best Practices

Customer education and communication regarding any smart tools is vital. Clear and concise information targeting the benefits and what it means to the customer will improve the customer's experience, satisfaction and overall the success of a project. Tools should be easy to use, the language should be simple, and accessing any tool should be stress-free.

We also should note that we have received approximately 90 complaints from concerned customers who have not had AMI meters installed and are objecting to the installation of AMI meters for fear of EMF's alleged adverse impact on health and concerns about privacy. All are expressing their refusal to have any RF equipment on their homes and some are challenging the utility's right to install RF and EMF emitting equipment in general. They are stirred by local and internet based opponents of AMI meters citing invasion of privacy and increased health risks associated with RF and EMF. Most submitted form letters that are readily available on the internet and many cited that the World Health Organization has classified AMR meters and other wireless devices as a Group 2B carcinogen. More definitive research and public communications by disinterested parties are needed to address these public concerns that are hampering the rollout of this technology.

DIRECT LOAD CONTROL

The objective of the Direct Load Control (DLC) project was to select residential customers within the *Smart Grid Demonstration* project area with large controllable loads (e.g. central air conditioning, pool pumps and other appliances) and allow these customers to control and monitor the load usage of these devices. In addition, the utility would have oversight into initiating voluntary load reduction events.

Design and Methodology

The initial design proposed by Schneider Electric through a bidding process was the Single Architecture Configuration (*Figure 15*), where all the devices were connected to the meter and the Router Gateway was connected to the Wiser Home Energy Portal through the customer's internet.

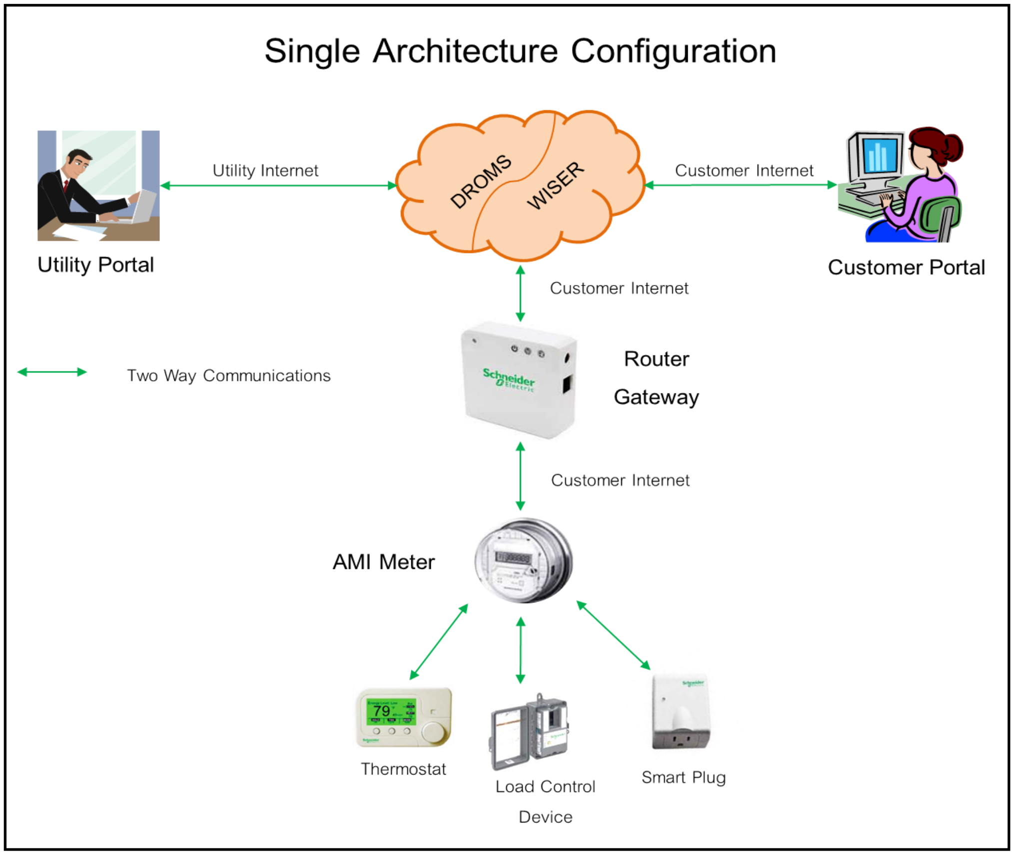


Figure 15 – PSEG Long Island DLC System Single Architecture

After review of other DLC implementations, LIPA came to the conclusion that the best practice model would be one that protected the customer's privacy and allowed customers to opt in with devices they can purchase on their own or obtain from the utility. To counter the claim that the utility and the government through DLC devices would obtain details on the customer's behavior through the collection and analysis of individual appliance data, the project team concluded that third party devices should not communicate to or be directed by the utility meter. This initial design was not acceptable and had to be re-engineered.

The second design proposed by the vendor was to have a panel meter installed the resident's circuit breaker panel (*Figure 16*). This allowed all the devices to be connected to the panel meter rather than the utility meter.

The panel meter was a component of the Wiser home management system. It allowed the homeowners to monitor and improve use and efficiency as well as coordinate load control events. The panel meter was used for monitoring the main power coming into the house through the meter to show whole house consumption. However, this was not acceptable to the utility because the contractor installing the Direct Load Control devices would have to go into the customer's circuit breaker panel. That was a liability that the utility did not want to assume.

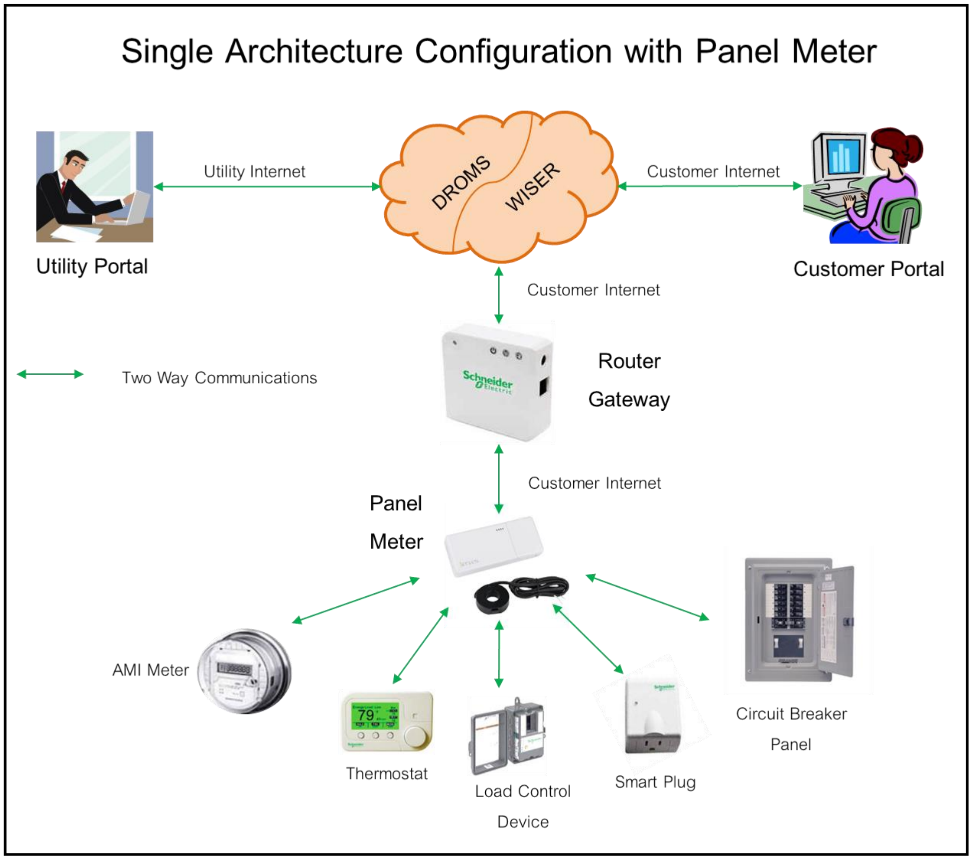


Figure 16 – PSEG Long Island DLC System Single Architecture with Panel Meter

The final design (*Figure 17*) that was utilized for the DLC program is a dual architecture configuration. This configuration has two gateways (a router and a coordinator) that are installed at the customer's house. The router gateway was provisioned to the meter using L+G Command Center software and the Home Area Network (HAN) protocol. It is then connected to the Wiser Home Energy Portal through the customer's internet which will only pass the consumption (kW) information from the meter to the portal. This provided an additional layer of security by isolating the meter as much as possible from the system architecture.

The coordinator gateway was installed at the customer's house. Using the customer's internet, it was connected to the Wiser Home Energy Portal. All the devices other than the meter were then connected to the coordinator gateway. The customer can view near real-time consumption (kW) and pricing using the Wiser Home Energy Portal or on a mobile app. The customer has the ability to program and operate the devices and participate in demand response events through the customer portal and the mobile app. He can also opt in or opt out of demand response events locally at the Wiser thermostat.

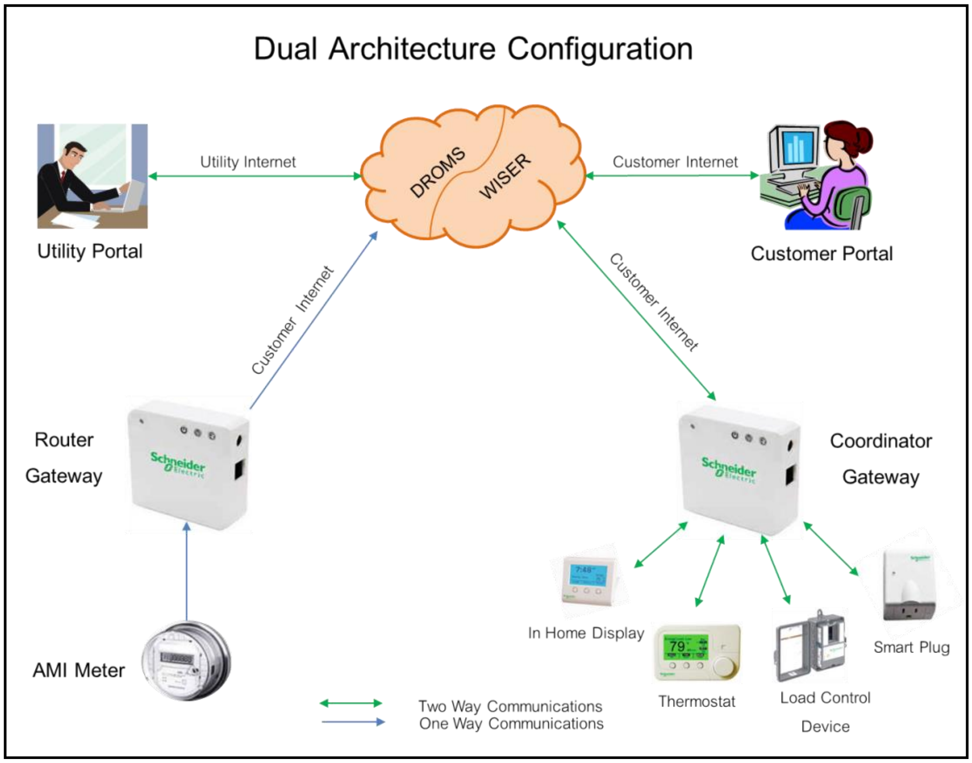


Figure 17 – PSEG Long Island DLC Dual System Architecture

The devices that were used in the DLC project are listed below:

1. Wiser Gateway (Router and Coordinator)
    a. ZigBee compliant
    b. Provides a secure two-way bridge on the customer side of the network.
    c. Provides a communication path to the Wiser Home Energy Platform.
    d. Provides real-time home energy management.
    e. Provides remote access to home energy use and controls.
2. Wiser Programmable Communicating Thermostat (PCT)
    a. Seven (7) day, four (4) periods per day programmable thermostat that is capable of performing two-way communications between the unit and a central control system via ZigBee network.
    b. The thermostat is capable of receiving curtailment signals and able to confirm receipt of signal.
    c. The thermostat is capable of overriding a curtailment event.
3. Wiser Load Control Relay
    a. ZigBee compliant
    b. Provides direct load control
    c. Provides consumption data for the connected load
    d. Capable of remote On/Off operation by the utility

   e. Capable of being controlled locally by the customer either through a local button on the device or by the website
4. Wiser Smart Plug
   a. ZigBee compliant
   b. Provides remote On/Off and timer function capabilities
   c. Provides energy usage to Wiser Platform
   d. Plugs into standard outlet

The Wiser Home Energy Portal (www.wiserenergy.com) allowed the customer to view both their consumption for total home energy from the meter and consumption breakdown per smart plug. Through the wiser dashboard the customer can create energy goals for a selected billing period visually. (*Figure 18*) and monitor day to day usage (*Figure 19*).

Figure 18 - Wiser Customer Dashboard

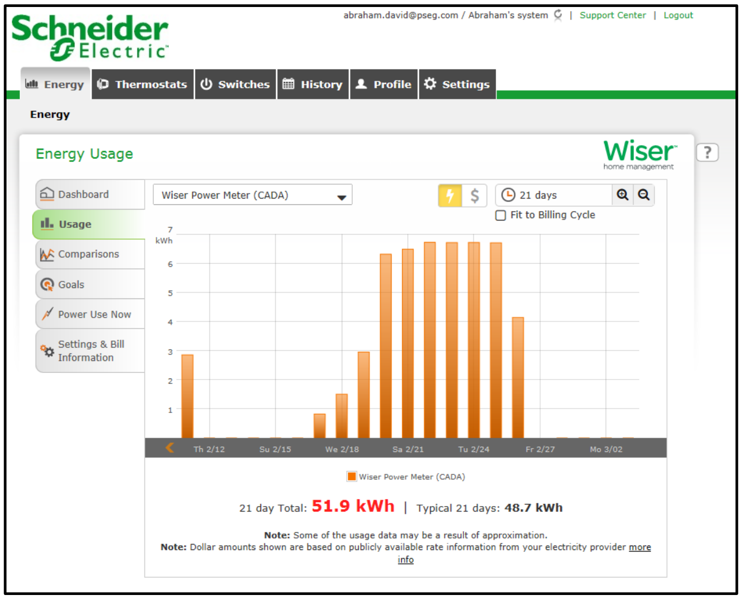


Figure 19 - Wiser Usage Dashboard

The website also allowed the customer to check on their usage for any time period, compare their current usage to previous time frames, and allowed them to see their near real-time power usage. Through third party software called DROMS (Demand Response Optimization and Management System), the utility has the ability to control and manage customer loads during high load events. Load curtailment events can be scheduled in advance and can be customized to include certain customer groups or certain devices only. Once initiated, the customers can be notified by email, automated phone call, and text in advance of the date and time of the load curtailment. They can choose to opt-out via email or at their local device. DROMS tracked customer participation during a demand response event and calculate load reductions results. This software allowed the utility to forecast load curtailments, communicate load-shed events, and execute a load curtailment event..

<u>Findings, Observations, and Lessons Learned</u>

Customer participation, engagement and safety were a large portion of the observations and subsequent lessons learned. When LIPA first came to be, one of the very first energy efficiency programs was LIPAedge, a pager based, residential direct load curtailment program with programmable central air thermostats. The program provided customers with a one-time $25 incentive and a free thermostat for participating. LIPA had a third party contractor install the thermostat as well as the curtailment device on the customer's air handler which was located either in the attic or the basement of the home.

Within the footprint of the current project, there were 163 existing LIPAedge customers. We began recruiting participants for the new project by marketing the Smart DLC Project as a complimentary upgrade service to replace the customer's legacy system. However, the process of recruiting these existing customers at the beginning of the program was difficult. In many cases customers did not understand the benefit of having this new equipment. Their old equipment was working fine and didn't want the burden of another installation. With such a high rejection rate among those customers who were already participating in the existing DLC program, we decided to try to recruit new customers into the program and added a $50 bill credit incentive that was funded outside the Demonstration Project budget. With a sample total of 302 customers, each customer was called as various times throughout the day by PSEG Long Island staff. At least 5attempts for each customer was made. 61 of the 302 eligible customers followed through to schedule an appointment or about 20 percent. The final installation figures total to 44 installations performed and 17 walk-aways. Many customers that initially expressed interest in the program did not follow through when asked to schedule an appointment. In17 cases, the installation was not able to be completed, typically because of difficulty in pulling new control wires from the energy appliance to the thermostat.

Customer and installer safety was paramount when executing the installation portion of this project. Field conditions can vary greatly and customer homes are no exception to this. Having the power consumption read off the AMI Meter was the only safe way to provide data to the WISER & DROMS platform. The secondary option for non-AMI meters would have been to install current transformers and voltage wiring within the customer's main circuit breaker. This was not a viable option because of safety concerns and because the line of demarcation ends at the meter for our utility.

The smart plugs have a 15 amp load rating to accommodate large appliances with higher current rating that would utilize the load controller. Typically, the load controllers would be installed on the load side for pool pumps. Refrigerators were too heavy at times to move to install the smart plugs. Often time, we were afraid that moving may break an existing water line the connected to the refrigerator. We could not wire the load control box into the standalone air conditioning unit without causing a safety hazard and could not use a smart plug because its current rating was not sufficient to handle the demanding current loads of an air condition unit.

<u>Recommendations/Best Practices</u>

Recruiting customers to participate in the program is a difficult task. Incentives need to be offered and the technological benefits to the customer must be stated and reinforced. Larger than normal (10:1) samples need to be utilized to obtain desired results.

Customer communication during this process is paramount. Clear, concise and open information regarding the background and progress of the project improves the customer experience and overall the success of a project. This affects ease of installation and also customer interaction with the technology. The easier we make the setup and use of these tools, the less a customer has to do to enjoy the benefits. Customer communications on the purpose of DLC will be needed to alleviate customer concerns regarding privacy and the use of customer data by the utility.

Security also is an aspect of this project that should be approached carefully and thoroughly. The specifications for the WISER system are designed for best-in-class security. Redundant encryption and firewalls provide robust compliance and security testing is a must for assuring safe and reliable performance of this system.

Future DLC cannot solely rely on a utility installation model but needs to be flexible to accommodate customer preferences for their purchased equipment. The utility installation model will need to co-exist with a "Bring Your Own Thermostat" or BYOT model and be adaptable to work with a 2 and a 3 control wire configuration found in the customer's home to obtain the broadest enrollments. The DLC program could also be bundled and marketed with new major appliance or upgrade incentive programs such as refrigerators, central air conditioning, swimming pools, and air conditioners.

CUSTOMER FEEDBACK

The objective to obtaining customer feedback throughout the Pilot Study was to ensure customer satisfaction, process improvement, increased participation, and sustained customer engagement. Feedback was obtained through various channels – tracking customer calls through the call center, direct contact with customers by AMI Project Team staff, email communications, through the "Feedback" function on the Smart Web Tool, and qualitative and quantitative research studies.

Design and Methodology

LIPA designated a separate phone number, the *"Smart Line"* for specialized customer support for those customers participating in the Pilot. A group of Customer Service Representatives in our Call Center were trained in smart grid technologies throughout each phase of the Pilot. This select group handled and tracked customer calls that were received through the "*Smart Line".* The intent of the calls was passed on to the AMI Project Team.

Customer Engagement AMI Project Team staff often corresponded with customers through email and direct mail campaigns and were designated as a single point of contact. This served as a means of immediate feedback for various stages of the Study.

Qualitative research was conducted through in-depth interviews with customers usually be phone, sometimes in-person, to obtain customer understanding of the initial educational material, customer communications, meter installation practices, Time of Use Rates, how to use the Web Tool, interpret data, etc. The data obtained through these interviews lead to better communications, process improvements, clear and concise educational materials and the development of quantitative research.

Quantitative studies were administered through direct email communications containing links to surveys such as appliance inventories, TOU Rate and the effect on behavior, meter installation and process satisfaction, Web Tool effectiveness, overall customer satisfaction, to name a few.

LIPA and later the PSEG Long Island's web site contained a section on Smart Grid and Smart Meters. The section contained general information about the Pilot and a list of Frequently Asked Questions. Customers can access the site and obtain information about the Smart Grid, Smart Meters, benefits of Smart Meters, understand why PSEG Long Island is investing in Smart Meters, privacy, cyber security, opt-out policy, etc.

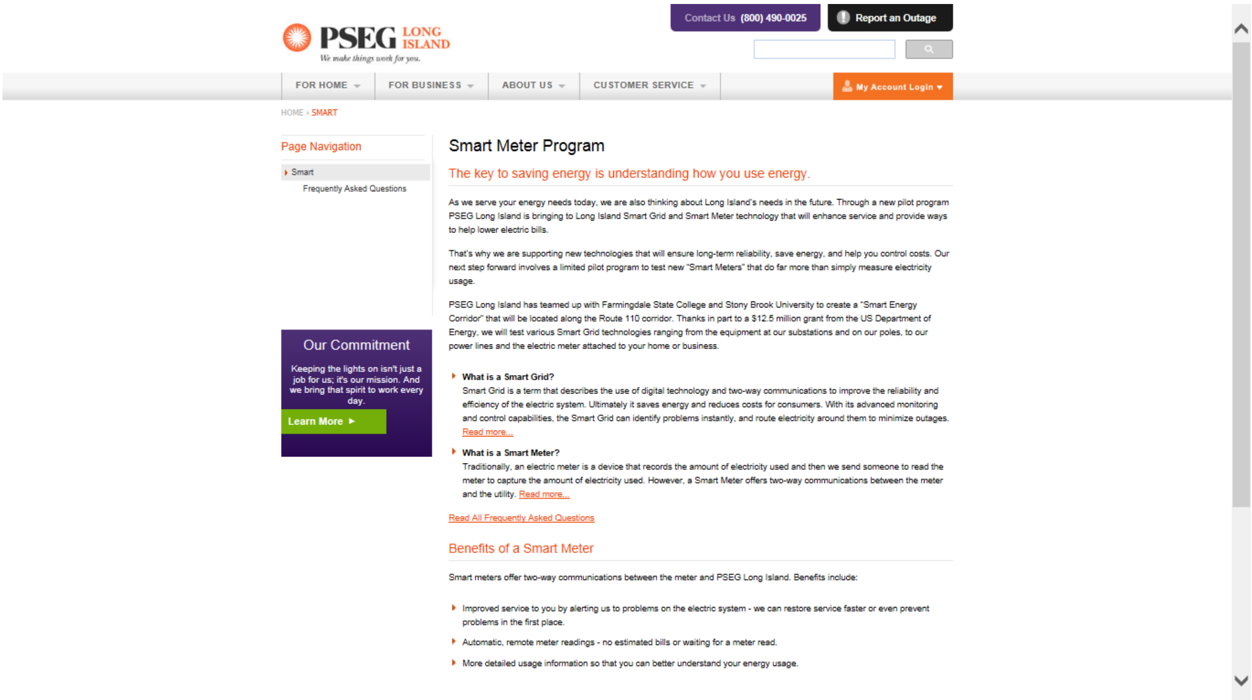


Figure 20 – PSEG Long Island Web Site - Smart Section

Figure 21 – PSEG Long Island Web Site - Smart Section FAQs

Findings, Observations and Lessons Learned

Through studies and feedback obtained from customers throughout the Pilot, the findings, observations and lessons learned are extremely valuable in moving forward with future implementations. Towards the beginning of the Project, LIPA conducted a study among residential smart metered customers within the footprint from each of the three designated segments, Control Group, Tools Group, and Tools & Rate Group, to better understand what equipment and appliances customers have in their homes as well as to understand usage behavior. The study was administered by inviting customers via direct mail, including a link and a unique log in with a $15 incentive. Overall, the study had a 19% response rate. Some of the key findings include:

- 64% of smart metered households have central air conditioning units with an average temperature setting of 71.9 degrees
- 25% of smart metered households have electric water heaters
- Average household size = 3.2 individuals
- Average home size (excluding bathrooms) was 8.5 rooms
- Average number of televisions per household was 4
- Average number of computers per household was 2.4
- Average daily hours of longest running appliances:
    - Dehumidifiers/Humidifiers/Air Purifiers was 8 hours per day
    - Room/Window AC was 6.4 hours per day
    - Pool Pumps was 6.3 hours per day
    - Televisions was 5.9 hours per day
    - Computers was 5.8 hours per day

The findings from this study helped LIPA understand the average home profile and customers use electricity. It helped LIPA craft customer communications when marketing the Smart Time of Use Rate, providing customers with energy tips, and ways to manage their costs.
Towards the end of the study, surveys were conducted through Survey Monkey (no incentive was given) with two of the marketing segments, the Tools Group and the Tools & Rate Group, to determine customer satisfaction with the Smart Meter Program, the tools (Web Tools, DLC equipment, Apps), and the Smart Time of Use Rate. A reminder email was sent to those who had not completed the survey 7 days after the initial recruitment email. The overall response rate was 12.4%. The key findings from the respondents include:

- 51% have central air conditioning units
- 28% have in/above ground pools
- 47% have Electric Ranges
- 53% have Electric Dryers
- 29% have Humidifier/Dehumidifier/Air Purifiers
- 67% have Dishwashers
- 20% have 5+ Televisions with Cable/Satellite/DVR Boxes
- 39% have 2 full size Refrigerators
- 25% have a separate Stand-Alone Freezer
- 39% have 3+ Computers/Laptops
- 29% have 5+ Personal Electronic Devices (tablet, cell phone)

- Average household size = 3.1 individuals
- 51% of households prefer to access their energy data by Personal Computer
- 28% of households prefer to access their energy data by Smart Phone App
- 21% of households prefer to access their energy data by Tablet

Findings from those respondents participating in the Smart Time of Use Rate include:

- 59% agree participating in the Rate gives them a better understanding of their usage
- 88% know and understand the timeframes and costs for Peak and Off-Peak periods
- 71% agree the Smart TOU Rate gives them the ability to control energy usage
- 76% agree the Smart TOU Rate gives them the ability to control energy cost
- 76% state the Smart TOU Rate has changed the way they use household equipment
- 76% agree that they do their best to use equipment during Off-Peak hours
- 65% say they would recommend Smart Meters and the Smart TOU to friends & family

Findings from those respondents participating in the Direct Load Control Program (DLC) include:

- 75% are satisfied with the Program
- 58% agree participating in the Program gives them a better understanding of their usage
- 58% agree the Smart TOU Rate gives them the ability to control energy usage
- 58% say they would recommend the DLC Program friends and family
- 58% agree remote access of the thermostat to change mode, set points & schedules are helpful
- 58% agree remote access of Smart Plugs to turn on and off is helpful
- 50% agree obtaining instantaneous reads from the Smart App for the meter and plugs are helpful
- 50% agree accessing the Thermostat from the Smart App to change mode, set points & schedules are helpful
- 58% agree accessing Smart Plugs from the Smart App to turn on & off is helpful

The findings from these studies helped to understand Smart Home profiles, customer satisfaction with the overall program, customer preferences and how different segments utilize and manage their energy and costs. It helped us to develop better programs, communications, processes and rates to make future implementation a success.

For the segment of customers participating in the Smart Time of Use Rate, a few interesting observations were found during the 1-year comparative analysis to support the Rate's "Cost Guarantee":

- 49% of participants saved an overall amount of $3,042 with the highest savings realized by one customer of $396 and the lowest savings realized was $9
- Among the 49% that saved, the average savings realized was $89
- Among the customers who saved, 41% saved less than $50 and chose to remain on the rate without the safety of a cost guarantee

- 44% of participants were not successful in shifting and saving which resulted in an overall $2,489 that was incurred due to excess energy usage during peak times. The highest refund to a customer being $274.45 and the lowest at $0.23.
- Among the 44% of unsuccessful participants, the average refund was $80
- All 44% of unsuccessful participants chose to revert back to their old rate.

It was surprising that customers who saved less than $50 still chose to remain on the rate. They were, and continue to be, willing to modify their behavior, especially during the summer time when peak rates are at their highest to realize savings in the amount less than what it costs to go to the movies.

The lessons learned directly related to customers are listed here:

1. Utilities must set ground work and a strong foundation long before implementation begins. Educational material addressing customer concerns regarding privacy, cyber security, health issues and safety must be provided through several channels of communication. Having third party unbiased institutions collaborating on the material will aid in the transparency and help to gain customer trust in the information.
2. Direct customer contact and a single point of contact toward the start of implementation will help with on-boarding and customer satisfaction. With so much inaccurate and negative information surrounding smart meters found in the media, having a single point of contact to answer customer questions, address concerns and provide additional resources will help lessen customer rejection rates and help the customer feel comfortable with the decision to participate. LIPA found that there was a lack of creditable scientific and testimonial information in support of AMI to help counter the fear and uncertainty generated by smart grid and smart meter opponents.
3. The more customers understood the functionality and benefits of smart meters, the various tools that can help them manage their energy use, and the ability to take advantage of specially designed rates, the higher the level of acceptance by the customers of the technology.

Customers who took advantage of available tools, like the Web Tool, Direct Load Control equipment, or the Smart TOU Rate were more likely to remain engaged, shift their usage behavior, save money, effectively manage their energy use, and have higher levels of satisfaction. A small number of these customers found the ability to better manage their usage to realize additional savings year after year.

As noted earlier, we have been receiving complaint letters from residential customers who are concerned about privacy and EMF exposure. We have not received a complaint on privacy and/or EMF from a commercial and industrial customer. In the process of researching to find the appropriate responses to their concerns, we've found much mis-information on the internet and in mass media. Our research also found responses from utilities and the supplier community lacking. Many responses are very technical and hard to understand for non-engineers. These responses are no match against the emotionally charged accusations of the privacy and EMF opponents and conspiracy theorists who deem most utility and supplier community responses as propaganda. The convergence helps fuel skepticism of the AMI technology by the public.

We are learning that utilities and their suppliers need a long term strategy to provide more education and transparency to the public about AMI technologies to gain acceptance. We are engaging Stony Brook

University's assistance in EMF testing that compares AMI meters to other common appliances to provide more understanding to customers. We are publishing our privacy policy on-line to alleviate privacy concerns. In the near term, commercial and industrial customers may be more incline to accept AMI technologies to help their businesses manage energy costs.

Recommendations/Best Practices

Providing seasonal communications, offering customers tips, and reminding them of cost fluctuations will keep customers engaged. Having Smart Grid information, such as information on opt-out policies, privacy, health issues and cyber security concerns on our company web site gives the customers additional resources to access rather than just the World Wide Web where information may be misleading or misconstrued.

Providing a "Cost Guarantee" in Smart TOU rates encourages customer participation, minimizes their risk, and boosts participation. Periodic communications containing data showing the customers the outcome of their efforts to shift and save is important. This provides the customer with another layer of information to allow them to most effectively and efficiently manage their household's usage and cost.

Having specially trained customer service staff that are fluent in smart grid and smart meter technologies and customer concerns will ensure program success and customer satisfaction. Providing project status and updates on the Utility's web site will provide customers a quick reference point, demonstrates the company's commitment to transparency, and increase customer acceptance. Posting customer testimonials in various communication vehicles demonstrates and validates positive experiences with the program.

SUPERSTORM SANDY EXPERIENCE AND LESSONS LEARNED

Due to the devastation and subsequent restoration efforts resulting from Superstorm Sandy in late 2012, the Operations and Demonstration phase of the project was delayed for six months as our resources were channel to restoration and repair. However, Superstorm Sandy also gave us a unique and valuable opportunity to assess some of the deployed technologies under duress. These lessons learned are described below.

Overview

Superstorm Sandy damaged an estimated 100,000 structures in LIPA's service territory. The worse of the damage was near the shoreline and adjacent areas. Fortunately, the Demonstration Project was near the center of Long Island and away from the more severely damaged areas. Almost our entire AMI infrastructure and meters remained intact though power was interrupted to them. Generally, we found that smart grid devices have tremendous benefits on blue sky days and when used in moderate storm events. There are diminished returns with the type of devastation to the electric system experienced in Superstorm Sandy but significant learnings to guide the pursuit of future technology improvements and training and to manage any unrealistic expectation that Smart Grid can overcome massive physical damages and consequences caused by severe storms.

From Superstorm Sandy, we learned that automation could not heal massive physical damage and that we need to advocate with suppliers to improve the operational integrity and longevity of Smart Grid devices so that they can become a more valuable tool for moderate storm restoration. For all storms, we will need to develop protocols and training for our field forces and contractors to restore our Smart Grid equipment as they become more prevalent in our delivery system.

Distribution Automation

Distribution Automation is extremely valuable to improving reliability on a blue sky day or during moderate storms. The benefits of these systems in severe storm events are limited.

As part of the Smart Grid Route 110 Corridor project, Long Island Power Authority installed 17 Automated Switching Units (ASU) Overhead Switches and 6 Pad Mount Housing (PMH) Underground Switches. These devices limit customer outages and support restoration activities by helping to isolate outages where possible. None of the installed equipment suffered any damage and continued to operate within normal operating parameters on those circuits that had power. In the Smart Grid Route 110 Corridor, there were cases where only half of the customers on circuits lost power because of the automatic opening of an ASU which isolated a downstream fault. These switches provided protection that prevented the substation breakers opening and causing a lockout. However, the storm devastation for this particular area was moderate when compared with other locations at the distribution level.

Information collected from these switches includes voltage, current and power factor at circuit midpoints which can be compared to these same parameters at the Substation breaker. During normal operations, this information can be helpful in the control room providing a means to assess damage locations and in directing crews making repairs in a systematic efficient manner. In a major event like Superstorm Sandy, this value is diminished due to the tremendous amount of damage and the decentralized field deployment of equipment and personnel.

During Superstorm Sandy, the length of the outage caused the charge in the battery associated with the remote operation of many of the ASU's to be drained. The devices were no longer able to be used remotely. Once this capability is lost, ASU's must be manually operated. It should be noted that the Smart Grid ASU's were installed on Storm Hardened H1 poles (including adjacent poles, these are more costly than standard poles to install but has been standard practice for new installations for approximately 5 years) which contributed to these switches/poles withstanding the damaging winds associated with the hurricane. The capacitor banks in the area were also undamaged.

Lessons Learned:

1. Distribution Automation devices provide the most valuable on blue sky days or during moderate storm events
2. While the storm-hardened equipment withstood the conditions, Sandy caused prolonged power outages that resulted in the batteries becoming depleted and devices lose remote operation capability. We needed to work with suppliers to increase battery life
3. Training is needed to enable manual operation of ASU's when the battery power is depleted
4. Distribution Automation cannot overcome massive physical damages caused by a severe storm like Sandy

AMI

Prior to Sandy, LIPA had installed 5 Collectors, 42 routers and 2,100 Electric Meters in the Smart Grid 110 Corridor project and other Automated Metering Infrastructure (AMI) Pilots. The installed equipment sustained only minor damage due to the location of our pilot.

During Superstorm Sandy, meter reading personnel were re-assigned to restoration tasks. This workforce was not available to maintain the billing to customers. Our 900 MHz Layered Routing Mesh AMI system would have provided continuity on meter reading. This type of system requires that power be available to a minimum number of meters and routers to provide reliable backhaul of data. However, the customer outages were so wide spread that the majority of the AMI meters did not have power and thus, cannot provide reliable communication of data.

Lessons Learned:

1. Not all of the last gasp messages are received due to communication gaps from loss of power to devices
2. Not all of the power restoration messages are received due to gaps from loss of power to devices
3. AMI mesh communications technology cannot overcome extensive physical damages and outages from a severe storm
4. Need to review meter mesh communication pathways and collection strategies and their costs/benefits to ensure appropriate coverage and redundancy in future AMI deployments for storm restoration
5. New repair protocols are needed to address mesh communications infrastructure as part of the storm recovery process
6. AMI benefits tend to vary inversely with the number of customer outages in a storm (see Figure 22 below)

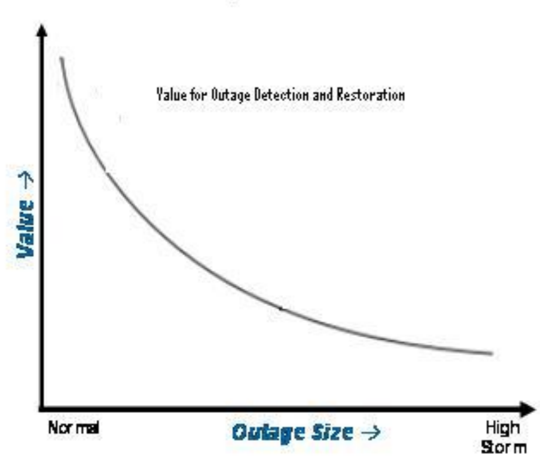


Figure 22 - Relationship between Outage Detection and Outage Size

Substation Automation

Because of the widespread damage, most substations were staffed for the restoration effort. Ruland Road, State School and South Farmingdale substations which were part of the Demonstration Project, were among those that suffered less damage. Substation Automation provides tremendous benefits with data for planning studies, daily operations (particularly during high load periods) and normal restoration up to moderate storms. As expected, substation automation does not provide significant benefit during a major event.

STONY BROOK UNIVERSITY

Stony Brook University is a major technology stakeholder on this project. They are charged with research on feeder loss estimation, capacitor control optimization, transmission loss management, customer voltage assessment, feeder optimization, cyber-security, and visualization as well as curriculum development.

FEEDER LOSS ESTIMATION

Feeder losses play an important role in the economics of a distribution system. The objectives of this task were to determine: 1) average feeder losses as percent of load; and 2) total feeder cumulative MWH losses. More accurate and timely estimation of feeder losses provide utility companies better assessment of their operating performance and opportunities to improve it.

Design and Methodology (equipment)

We used CYMEDIST for load flow analysis. CYMDIST is distribution analysis software composed of a network editor, analysis modules and user-customizable model libraries based on the Component Object Model (COM). The 15-minute AMI data enables a more accurate load model to be developed. AMI data provided real and reactive load, current and voltage readings of customers on the 15-minute interval. From these data, we were able to determine the load at particular distribution transformers and customers. Aggregating the individual customer real and reactive power consumption and subtracting the metered value at the substation feeder monitoring meter would provide the overall feeder losses and uncover any potential theft of service that may exist. Having the reactive power consumption will also support a more effective distribution of capacitors through the feeder and identify customers that are using excessive reactive power as a result of poor power factor conditions. Identifying and correcting conditions of bad power factor benefits the customer by extending the life expectancy of their motors and electronic equipment.

Traditionally, loads are allocated based on connected kVA or historical kWh consumption. Connected kVA are designed data and historical kWh is usually at least one year old and not up-to-date. Having AMI data would enable us to maintain updated usage data and not need to rely on historical values. AMI data provide more accurate and more updated load information. Using AMI data to allocate load would more accurately reflect the most current network conditions. Loss estimation and other calculations based on such models are thus more accurate.

Data and Analysis (graphs and charts)

Table 5 shows the typical CYME load flow analysis. In the bottom of the table it shows the power losses due to various factors. Table 6 gives the annual estimation based on the current load conditions.

Total Summary	**kW**	**kvar**	**kVA**	**PF(%)**
Sources (Swing)	8265.81	3820.23	9105.92	90.77
Generators	0	0	0	0
Total Generation	**8265.81**	**3820.23**	**9105.92**	**90.77**
Load read (Non-adjusted)	8141.79	4053.71	9095.13	89.52
Load used (Adjusted)	8142.14	4053.93	9095.53	89.52
Shunt capacitors (Adjusted)	0	830.59	830.59	0
Shunt reactors (Adjusted)	0	0	0	0
Motors	0	0	0	0
Total Loads	**8142.14**	**3223.34**	**8756.96**	**92.98**
Cable Capacitance	0	70.21	70.21	0
Line Capacitance	0	1.83	1.83	0
Total Shunt Capacitance	**0**	**72.04**	**72.04**	**0**
Line Losses	61.99	136.67	150.07	41.31
Cable Losses	12.5	11.51	16.99	73.56
Transformer Load Losses	-30.21	520.74	521.61	-5.79
Transformer No-Load Losses	79.39	0	79.39	100
Total Losses	**123.67**	**668.92**	**680.25**	**18.18**

Table 5 - Output from CYME Load Flow Analysis

Annual Cost of System Losses	**kW**	**MW-h/year**	**k$/year**
Line Losses	61.99	543.02	16.29
Cable Losses	12.5	109.5	3.28
Transformer Load Losses	-30.21	-264.66	-7.94
Transformer No-Load Losses	79.39	695.46	20.86
Total Losses	123.67	1083.32	32.50

Table 6 - Annual Cost Estimation of System Losses

Findings, Observations, and Lessons Learned (benefits/risks)

Our simulation in CYME indicated that a balanced system achieves significantly lower power losses than the unbalanced case. With the experiment of 6K-447 on June 21, 2012, in the unbalanced case, the average power loss is 40 kW. But in the balanced case, the average power loss is just 24 kW. Assuming a power loss factor of 25%, this translates to an annual saving of 35 MWh.

This finding also has another implication - utility may introduce some program to help some three-phase large customers to balance their loads. If these large customers' loads are well balanced, the overall feeder should be more balanced.

We have also learned the following lessons:

First, it is very important to choose the right platform and software tools. At the beginning of the project we considered Efacec's Advanced Control System (ACS). It was considered because at that time LIPA was piloting its Outage Management System (OMS) on the ACS platform. ACS is a software system developed under the UNIX system. It uses the licensed Oracle database. In order to exchange data between ACS and our software products, we had to obtain the Oracle license first. Also, unlike the COM in CYME, ACS does not have any customizable libraries that our software can call to obtain the necessary data. After many rounds of negotiation ACS agreed to provide some routines and keywords in their software for us to use. However, that still could not meet our needs for reliability and speed of computation. For example, the communication between our software and ACS was interrupted from time to time for some unknown reasons. It took a long time to call routines in ACS, especially considering our software needs to call the routines thousands of times during the iterations.

Second, the quality of AMI data needs to be verified for all the fields. In particular, this is important for the fields that are not used for billing purposes. We found that reactive power readings were incorrect after AMIs were installed. Following our request, this problem was corrected by the AMI installer. More aggressive review and validation of reactive data would support applying reactive rates tariffs and making accurate reactive data available to customers.

Thirdly, when processing AMI data, attention should be paid to the fields representing time and channel numbers. If time is not processed appropriately, the resulting load shape becomes abnormal.

Lastly, residential and commercial meters have channel settings. So when querying, one needs to differentiate between the two types of meters.

Recommendations/Best Practices

With regard to loss estimation we strongly recommend the spot load model based on the AMI data. The AMI data provide more accurate and timelier information about the load consumption at each distribution load transformer. This is superior to the connected KVA method or the historical consumption method.

We also recommend the scrutiny of AMI data before using them in other application. Inaccurate inputs would lead to useless outputs. Data screening procedures should be taken to ensure the quality of AMI data before they are carried into the next stage.

CAPACITOR CONTROL OPTIMIZATION

The objectives are to find an optimal capacitor control method and settings that would satisfy the reactive power needs, especially during peak dates and peak hours.

Design and Methodology (equipment)

Traditionally, the control of capacitor banks is very simple - they are controlled by a time-clock. When to switch them on/off is determined by analyzing the feeder load on the annual basis and all banks use the same setting. With availability of AMI data as well as historical time clock and pager log database, we can optimize the timing of all capacitor banks on the daily or even hourly basis. The optimization is based on the hourly simulation in CYME using the AMI load data.

Data and Analysis (graphs and charts)

Figure 23 below shows how capacitor banks can be set on/off. They can also be controlled in the software by using COM.

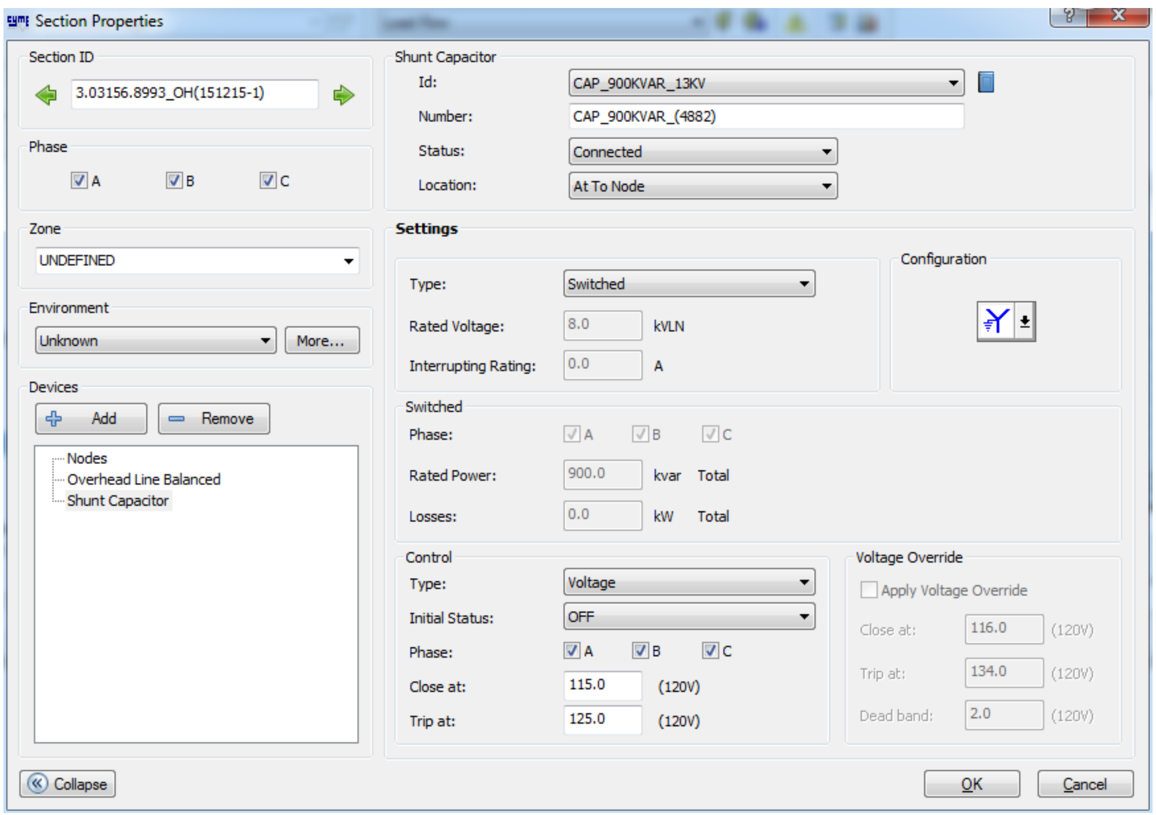


Figure 23 - Screenshot in CYME to Control Capacitor Banks

The following voltage profile is when the capactior banks are shut off.

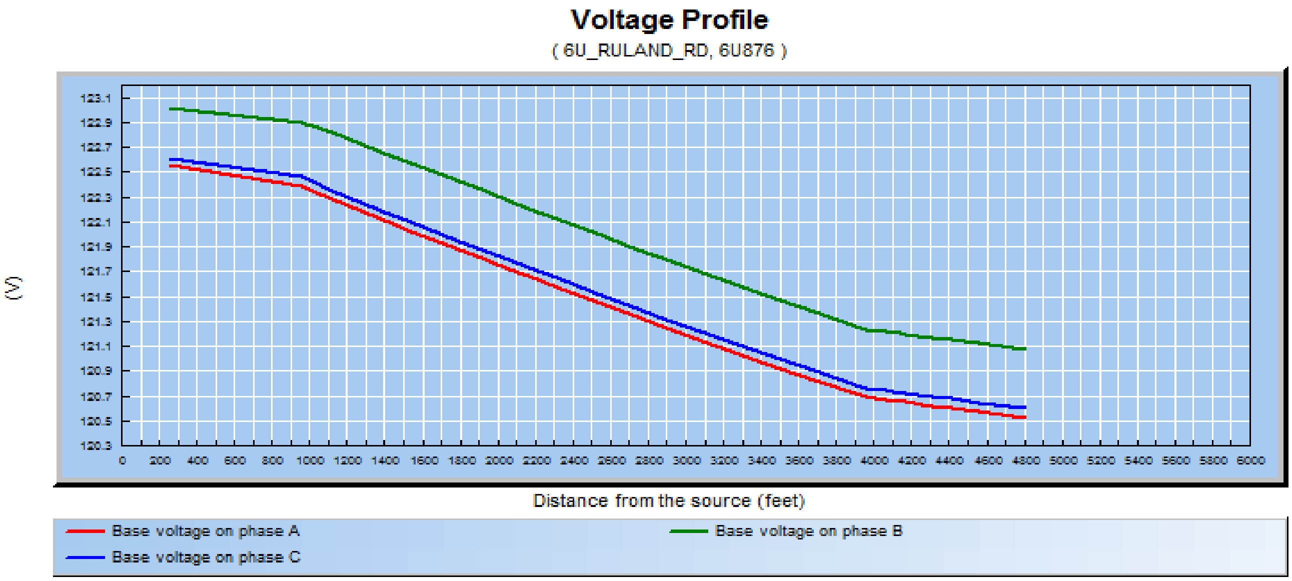


Figure 24 - Voltage Profile When Capacitor Banks Are Switched Off

When capacitor banks are switched on, the ending voltages are slightly higher. Note that due to the short distance in nature, the voltage rise is not significant. In this case the rise is about 0.2 volt.

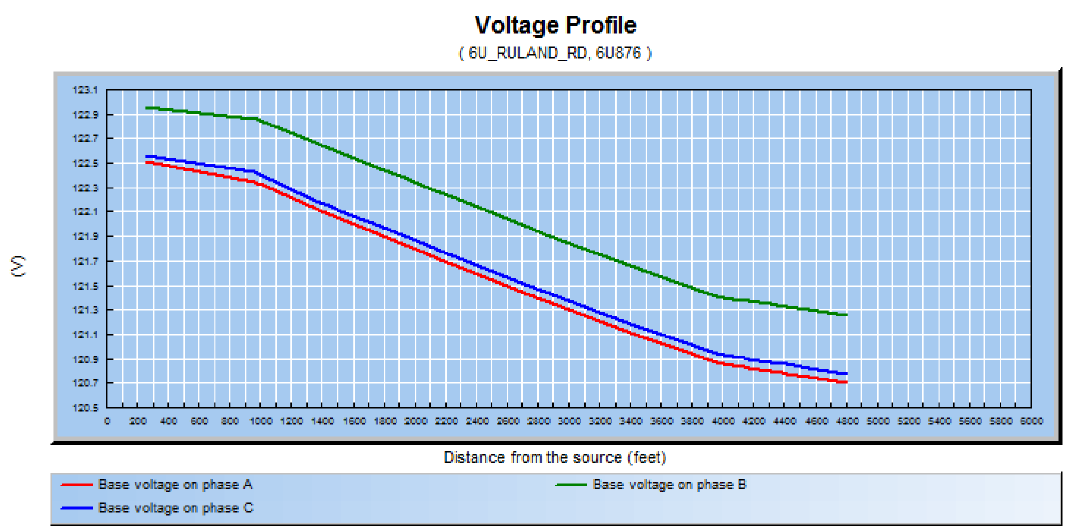


Figure 25 - Voltage Profile When Capacitor Banks Are Switched On

<u>Findings, Observations, and Lessons Learned (benefits/risks)</u>

With 24-hour simulation, we found that such optimization may reduce the power losses significantly, especially during peak dates and peak hours. With CYME and the accompanied Component Object Model (COM) programming capability, we were able to fully control and optimize the capacitor banks. We implemented advanced optimization algorithms to optimize the capacitor on/off status to achieve the minimum power losses and still meet the voltage requirements. More significantly, our integrated software was able to run the simulation continuously for any desired duration, from one hour to one year.

Recommendations/Best Practices

We recommend that capacitor control should be accompanied with tap changers to achieve the overall optimization. The optimization and its solution algorithms are discussed in the feeder optimization section. The control of tap changer would change the voltage level of the entire feeder. However, voltages at some local areas may still not be met. In that case capacitor banks can be effective to achieve local effect.

TRANSFORMER LOAD MANAGEMENT (TLM) ENHANCEMENT

The objective is to use AMI residential customer data to study customer load diversity (as a function of customer count, kW, kVar, etc.) at the distribution transformer level. This will allow better sizing of the transformer.

Design and Methodology (equipment)

AMI data are useful for building customer models and to study the customer load diversity. After proper database operations we were able to summarize customer loads (kW, KVar) by transformer ratings, by rate class, and by time. We built an Excel template to make the reporting easier.

Data and Analysis (graphs and charts)

Take the example of two feeders in the corridor network: 6K-447 and 6U-876. We first summarized the profiles of the two feeders:

	OH Feet	UG Feet	Total Feet	Cap Bank
6K-447	3303	2644	5947	3x900 kVar
6U-876	3309	2856	6165	1x900 kVar

	Peak Amps on 6/21/2012	Total Cust	Residential	Commercial
6K-447	268	319	55.80%	44.20%
6U-876	377	398	60.50%	39.50%

Table 7 -Feeder Profiles

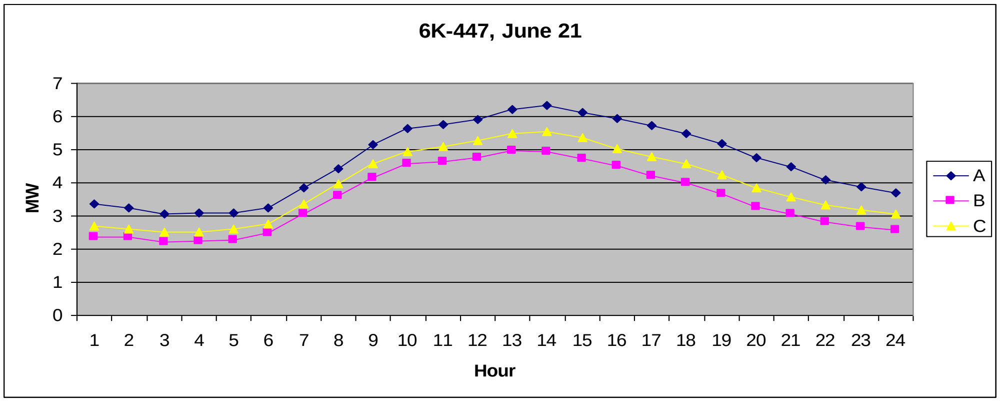


Figure 26 - Load Shape of 6K-447 on June 21, 2012

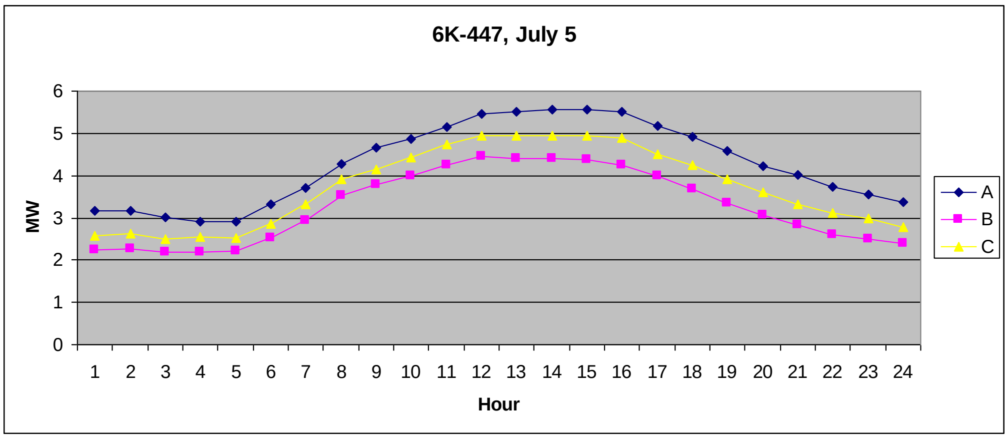


Figure 27 - Load Shape of 6K-447 on July 5, 2012

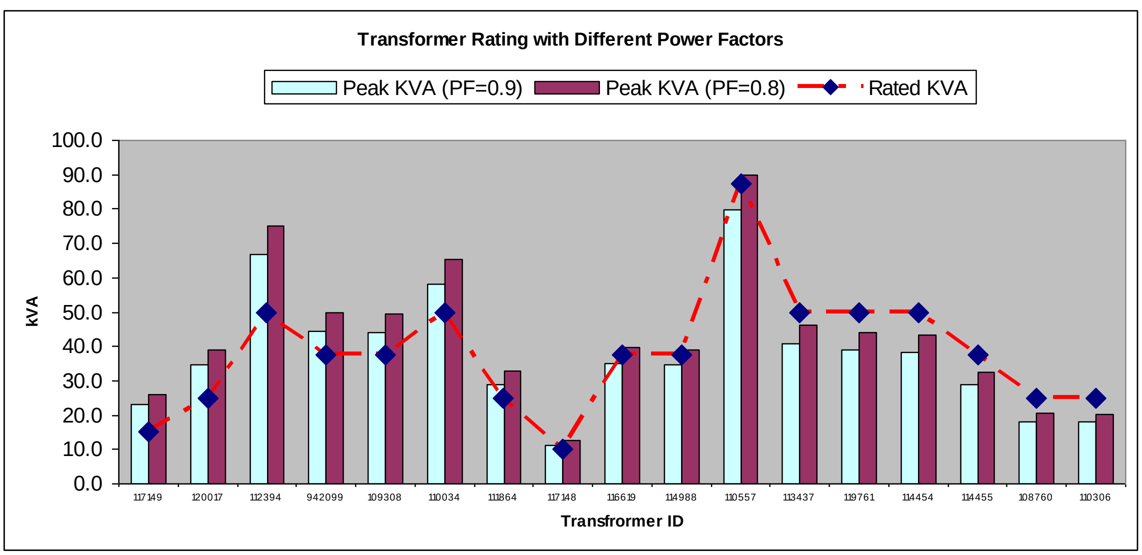


Figure 28 - Transformer Rating with Different Power Factors

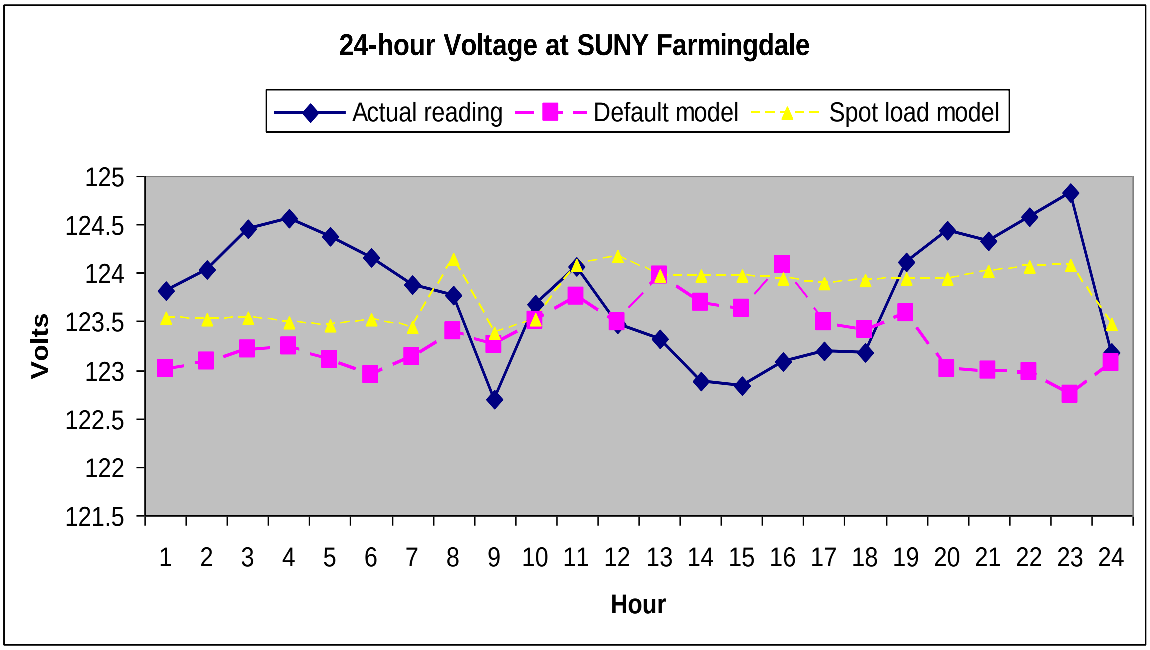


Figure 29 - 24-Hour Voltage at SUNY Farmingdale

Findings, Observations, and Lessons Learned (benefits/risks)

The enhanced TLM have many benefits:

1) We found that some transformers have very low utilization and others are overloaded or close to be overloaded. By summarizing transformers by their rating based on the AMI data, we can better predict which transformers are likely to be overloaded.
2) The enhanced TLM improves the load modeling which improves the accuracy of the power flow calculation and power loss estimation. See the Feeder Loss Estimation part for more details.
3) Voltage estimation is improved from the enhanced TLM.

Recommendations/Best Practices

Due to the extremely large number of records in the AMI database, Excel usually cannot fit the entire data, even for just one day. In order to still take advantage of Excel, we recommend the following:

1) When there are thousands of meters and each meter is recorded on numerous measurements (kW, kVar, current and voltage) for 96 intervals a day, it is often more convenient to work only with a subset of the data: either a subset of meters, a subset of time intervals or a subset of measurements. We can possibly work with the system manufacturers to develop software programs to fully utilize the AMI data for more accurate results.
2) It is often very helpful to build Excel templates and automatically update the data in Excel sheets on the periodic basis. The outputs (tables or charts) will be updated automatically.

3) It is useful to automate the procedures by writing some VBA scripts in Excel or Microsoft Access.

CUSTOMER VOLTAGE ASSESSMENT

The objectives are to use AMI residential customer meter data to assess feeder voltage regulation, to develop report showing minimum/average/maximum volts by transformer/customer/meter report, and to enhance report later to include commercial customer AMI data, when available.

Design and Methodology (equipment)

Since AMI data provide 15-minute voltage readings of all customers with AMI data, we are able to monitor the voltage of all customers (both residential and commercial). By charting the residential voltages in the corridor network, we found that the system is operating at the upper end of the voltage level. This has the potential disadvantage of increasing power consumption. By summarizing voltages in one chart, one is able to detect unusual voltage readings. Such unusual readings might be due to measurement error or actual voltage abnormality.

Data and Analysis (graphs and charts)

The two pictures below show the voltage profiles for 684 residential AMI customers from the entire corridor circuits recorded on September 6, 2013.

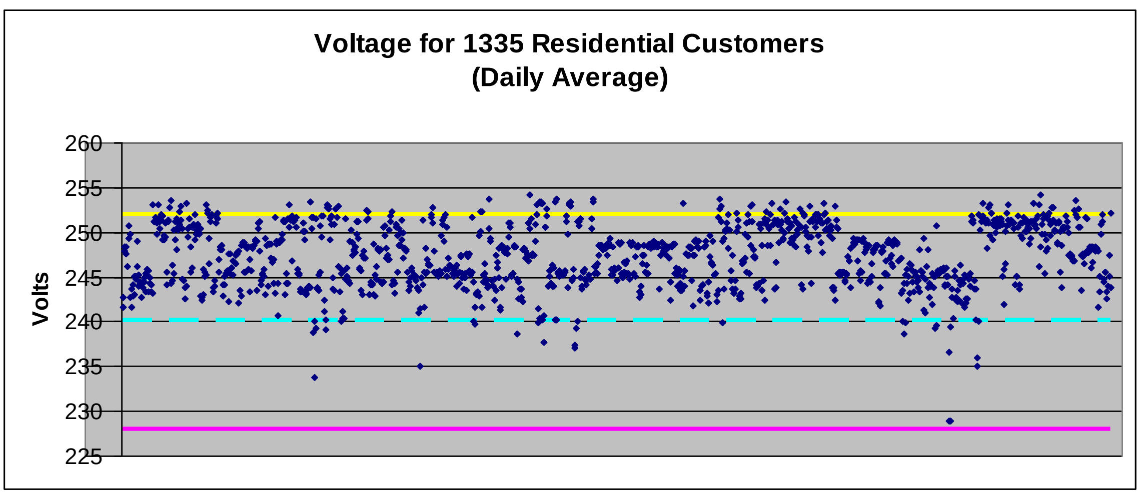


Figure 30 - Voltage for 1335 Residential Customer (Daily Average)

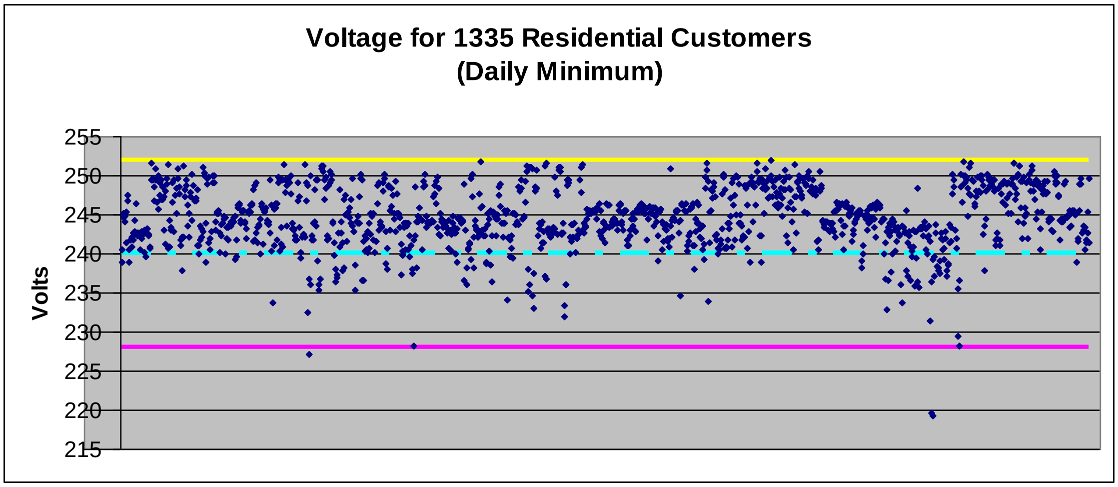


Figure 31 - Voltage for 1335 Residential Customer (Daily Minimum)

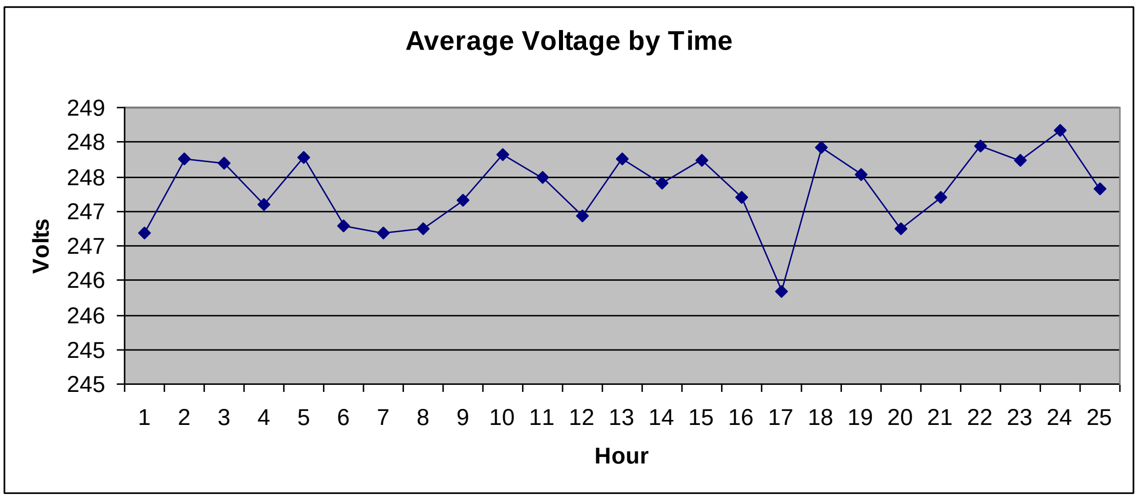


Figure 32 - Average Residential Voltage by Time

We can see that National Grid was operating the system at the upper end of the voltage level.

CYMEDIST reports overloading, low and high voltage conditions. Table 8 shows such a report.

Abnormal Conditions	Phase	Count	Worst Condition	Value
Overload	A	0	3.03156.8993_OH(151215-1)	91.98 %
	B	0	3.03156.8993_OH(151215-1)	92.80 %
	C	0	3.03156.8993_OH(151215-1)	92.09 %
Low Voltage	A	0	3.03257.2334_BB(64039)	99.80 %
	B	0	6U_RULAND_RD-1276	100.00 %
	C	0	3.03257.2334_BB(64039)	99.88 %
	A	0	6U_BANK_5	103.24 %

High Voltage	B	0	6U_BANK_5	103.24 %
	C	0	6U_BANK_5	103.24 %

Table 8 - Loading and Voltage Report from CYME

Findings, Observations, and Lessons Learned (benefits/risks)

AMI data provide some insights about the operational status of the distribution circuits. For example, analysis of the AMI customer voltage on 9/6/2013 revealed that National Grid, the predecessor to PSEG Long Island as the system manager for LIPA, was operating the system at the upper end of the voltage level. The ideal voltage that goes into the residence is 240 volts, but most customers have their daily average voltages above 244 volts. Even half of the AMI customers have their daily minimum voltage above 243 volts.

One implication of this finding is that PSEG Long Island, the current system manager, has a lot of room to optimize the current system. For example, the capacitor control optimization and transformer tap changer optimization can be implemented in order to achieve the goal of minimizing power consumption and power losses and maintaining satisfactory voltage level for all customers in the system.

The current AMI data are inconsistent in recording the voltages of residential and commercial customers, which makes the analysis of commercial customers' voltage profiles difficult. We recommend that when designing AMI database consistency should be considered. Inconsistencies within the data have been identified and corrective measures are underway to address this issue.

Recommendations/Best Practices

We recommend that utilities run such applications on the daily basis to constantly monitor the voltage profiles of the distribution network. The applications do not take much time to run. The outputs not only reveal any voltage issues but also reveal data abnormality. Voltage abnormalities may be used as a tool to further investigate and if necessary address other errors resulting from such conditions. The feedback could be used by the AMI data administration department to improve the quality of AMI data.

FEEDER OPTIMIZATION (FEEDER RECONFIGURATION, PHASE BALANCING, VOLTAGE CONTROL)

Feeder optimization is to alter the topological structures of distribution feeders by changing the open/closed states of the sectionalizing or tie switches or change the load assignment so that one or more of the following goals are attained:

- Minimizing the total system power consumption;
- Minimizing the total system power losses;
- Minimizing the operational costs;
- Satisfying the operational requirement such as line capacity and voltage limits.

We considered three feeder optimization procedures: feeder reconfiguration, phase balancing, and voltage control.

Feeder reconfiguration is to alter the topological structures of distribution feeders by changing the open/closed states of the sectionalizing or tie switches. The goal is to minimize the total system power loss while keeping the customer generation cost of distributed generators at minimum. Benefits of doing this include improvement of network load balancing, reduction of power losses, and prevention of service disruption in case of power outage.

Phase balancing aims to reduce the degree of unbalance of loads, by shifting them from overused to underutilized phases. Substantial research has been conducted on the problem of three phase feeder balancing for over fifteen years. The key challenge is to develop algorithms to identify the most critical loads to shift to economically keep the network in balance.

The purpose of voltage control in distribution networks is to change the tap position of transformer regulators in order to achieve the goal of reducing power losses while maintaining satisfactory voltage profiles. The change of voltage is through a number of on-load tap changers (OLTCs), each capable of regulating the voltage of the secondary side of a transformer at one point in the network.

Design and Methodology (Equipment)

Existing approaches of feeder reconfiguration focus mostly on minimizing network power losses by solving a static optimization problem subject to practical constraints such as power flow equation, bus voltage limits, feeder transfer capacity, and network configuration constraints. The emphasis is placed on optimizing system performance at a fixed time point rather than over a planning horizon. These approaches have drawbacks. For example, the optimization problem needs to be resolved every time whenever there is a change in the load level and switching costs are ignored. In our method, we effectively addressed the tradeoff between the need for frequent switching actions to reduce power losses and the desirability to keep the number of switching operations small in order to reduce the switching cost. Our proposed rolling horizon approach minimizes the total system losses over a planning horizon; say 24 hours, subject to voltage, transfer capacity and network constraints. The total system losses include two parts: the power losses and the switching costs.

The rolling-horizon approach solved the feeder reconfiguration problem in the following way:

- At each time t, assume the load forecast over the next H time units is available;
- use the forecast information to compute/estimate the current flow on all load section over the next H periods;
- Use dynamic programming to obtain the optimal switching policy with respect to the fixed H-horizon problem;
- Apply the initial switching action specified by the policy at time t; repeat the above procedure for t=t+1.

For phase balancing we formulated the problem as one to achieve the satisfactory phase unbalance index (PUI) with the minimum number of tap changes. Traditionally, we assume that three phases are largely balanced. However, this is not true. In order to measure the degree of unbalance we defined the phase unbalanced index (PUI) as follows:

PUI=|Max phase load - Min phase load| / Average phase load x 100%

For example, we found that for 6K-447 circuit the PUI during peak dates in 2012 was as high as 25%. Even if the loads at the feeder level are relatively balanced, they may not be balanced locally at the sub-branches. In the extreme case, we investigated the balancing situation of some large customers at the user-end and found that some large customers even have PUI greater than 100%.

We proposed and compared three solution algorithms: dynamic programming and two heuristic approaches (greedy algorithm and simulated annealing). The dynamic programming algorithm is pseudo-polynomial, meaning that its complexity depends upon size of the numerical input, not just the number of loads. Provided the range of values of loads is small relative to the number of loads or an absolute constant, this yields an efficient optimal algorithm. This proves to be the case in the simulations we have done relevant to the LIPA system. With some degree of simplification, dynamic programming algorithms very efficiently do an exhaustive but efficient search on the solution space by storing partial results, and so can suggest the optimal (e.g. minimal) number of expensive tap changes needed to bring phases into some desired degree of balance. We have extensive experience implementing dynamic programming on phase loading data.

Traditional voltage control approaches try to maintain the voltage levels of distribution systems at an acceptable range, for example, 120V ± 5% by changing the tap positions of Transformer Load Tap Changers (LTCs) and on/off status of Shunt Capacitors (SCs). With these traditional approaches voltage levels may not be optimal, power losses in distribution systems are not minimized and they often involve frequent operations of LTCs and SCs. In our proposed approach all three are integrated into one constrained optimization problem - minimizing power losses while maintaining the satisfactory voltage levels and limited numbers of operations.

All three optimization models mentioned above utilized the advanced CYME Corridor network model using the database incorporating feeder breaker, ASU, and capacitor bank metering points. CYME and the COM capability enable us to run the simulation continuously without user interference. We were able to run the 24-hour simulation and determine the optimal feeder configuration, optimal phase assignment, and optimal capacitor switching and tap changer position.

Data and Analysis (graphs and charts)

The figure below shows the degree of unbalance averaged over all feeders in the study for dynamic programming and two heuristic approaches (greedy algorithm and simulated annealing). A lower value on the log scale is better, demonstrating the superiority of the dynamic programming approach:

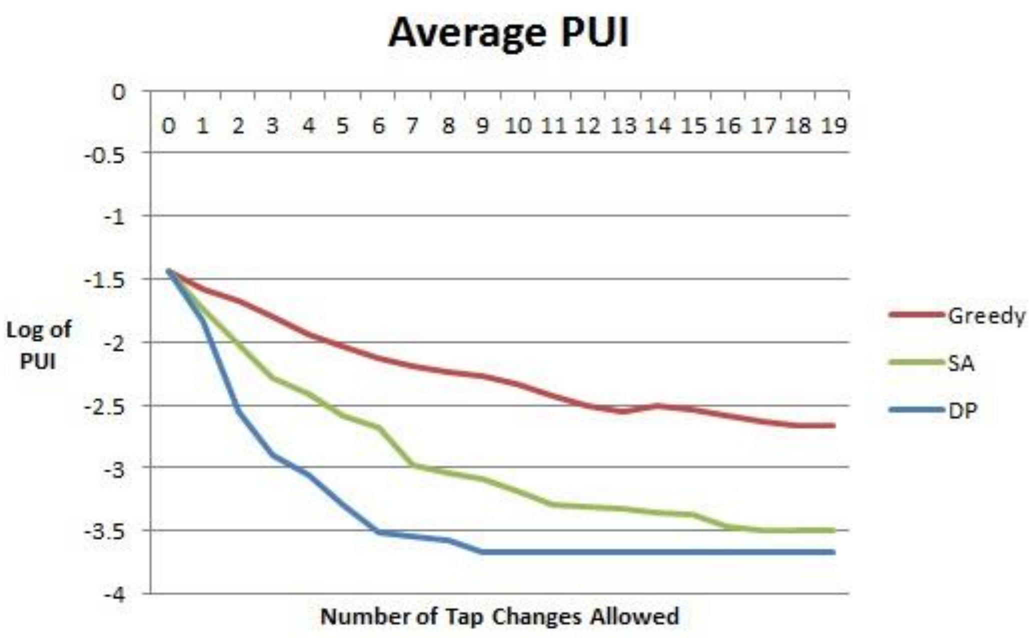


Figure 33 - Average PUI as the Number of Tap Changes Allowed is Varied

The two figures below show the difference of voltage profiles between the two models: one using the traditional allocation method and the other using the spot load from AMI data.

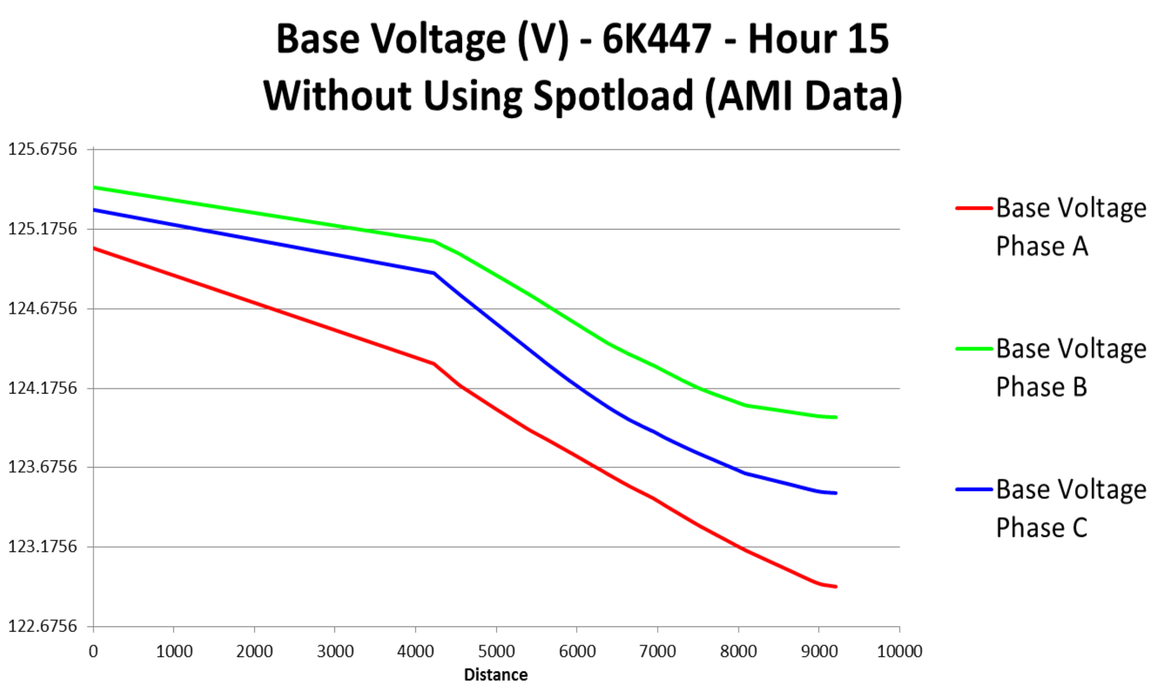


Figure 34 - Voltage Profile with the Traditional Method

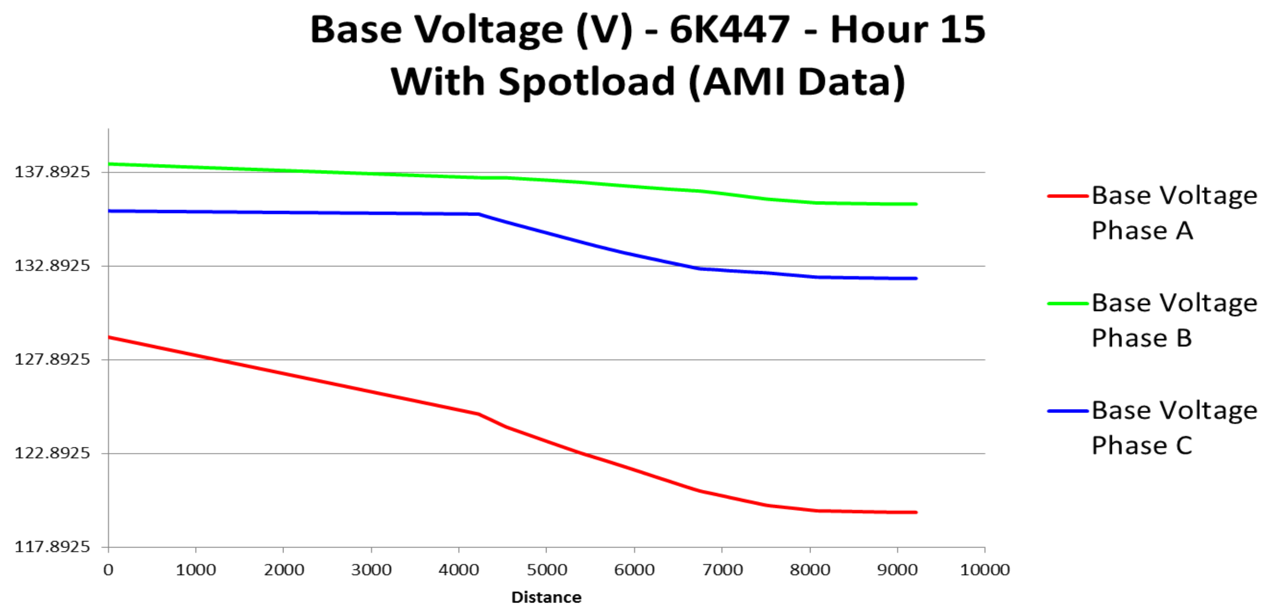


Figure 35 - Voltage Profile with the Spot Load Model

<u>Findings, Observations, and Lessons Learned (benefits/risks)</u>

Our major findings regarding phase balancing are:

1. The dynamic programming algorithm developed under this project is superior to existing algorithms in its ability to reach a certain degree of balance with a minimal number of tap changes.
2. There appears to be some resilience once phase balancing is performed on a feeder both in terms of changing daily electrical loads and even over almost a year's time span. This bodes well for the longevity of balancing once it is performed.
3. Positive reductions in power losses and associated monetary cost savings are possible.

Our major findings regarding voltage control are:

- Overall optimization of voltage control is feasible in practice. The optimization considers the system power losses, operational limits of tap changers and shunt capacitors, and voltage requirements.
- With CYME and COM model the voltage control problem is computationally tractable, meaning that an optimal solution may be obtained within a reasonable amount of time.
- With regard to solution algorithms, the Approximate Stochastic Annealing algorithm is an effective method for solving the voltage control problem. The Lagrangian Relaxation-Dynamic Programming (LR-DP) algorithm may be effective for solving some small-scale voltage control problems.

<u>Recommendations/Best Practices</u>

One lesson we learned is that the data from various sources should be time-consistent. In particular, AMI and SCADA should cover the same time intervals.

With regard to feeder reconfiguration:

1. We recommend the rolling-horizon approach to consider the planning horizon for at least 24 hours.
2. We recommend including the switching costs in the modeling.
3. To conserve computational resources the optimization problem can be applied to peak time only.

With regard to phase balancing:

1. We recommend the appropriate phase balancing, which is the best practice.
2. Utilities would benefit from the use of the dynamic programming algorithm to make phase balancing recommendations. A U.S. patent has been applied for and reported to the DOE.
3. The cost/benefit aspect of phase balancing would be a good candidate for further study. Current results are promising but preliminary.

With regard to voltage control:

1. It is recommended to place the numbers of tap changes and switching of shunt capacitors as the constraints instead of part of the objective function because of the difficulty in estimating the monetary costs of the operations. For a while we tried to estimate the monetary costs of one tap change and one switching operation but we did not succeed. For example, we tried to find the useful life in terms of number of switching operations. If that is known, we can divide the total cost of the tap changer by the useful life to get the monetary cost per switching. However, the useful life is usually in terms of calendar years. The adverse impact of the switching on electric users is another qualitative cost. That is even harder to estimate on the monetary basis.
2. CYME and COM model are recommended analytical tools for studying voltage control problems. The COM model provides great flexibility in controlling the network elements in the simulation.

CYBER-SECURITY

Smart Meter Security Evaluation

A major component of this demonstration project was the deployment of AMI technology along the Route 110 corridor. AMI technology effectively extends a utility's IT infrastructure into physically un-secure sites (i.e. every customer's home or business), so the AMI hardware must be resistant to both cyber and physical attacks. Otherwise, an attacker could potentially use a vulnerable AMI system as a stepping stone to infiltrate the utility's backend network. The goal of this task was to develop tools to evaluate the security of the specific AMI solution deployed in this demonstration project. LIPA selected the L+G Gridstream AMI solution for this

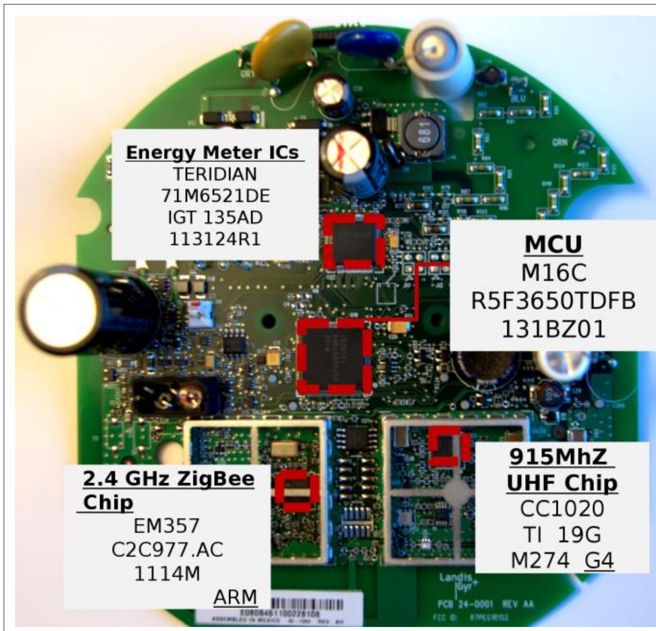


Figure 36 - L+G Gridstream Smart Meter

demonstration project. These meters use the unlicensed 902-928 MHz Industrial, Scientific, and Medical (ISM) radio band for transmitting data, form a mesh network to forward data from meters that cannot talk directly to a data collection device, use frequency hopping to make intercepting and interfering with their communications more difficult, and use encryption to protect data privacy and integrity.

Figure 36 shows the major components of such a meter. The energy meter Integrated Circuits (ICs) measure power usage information and send it to the central processing unit. The Microcontroller Unit (MCU) is an 8-bit Central Processing Unit (CPU) with burned-in code. The ZigBee chip was disabled in our meters. The 902-928 MHz chip handles communications between meters and data collection devices and meter-to-meter communication in the mesh network.

Design and Methodology

We built a protocol “fuzzer” for these meters. A protocol fuzzer sends invalid messages to a target device. If the target device does not reject the messages, or at least do something reasonable with them, then there is a likely security bug in the target device. Fuzzing has been shown to be an extremely effective method for discovering bugs of all kinds, including security bugs.

A fuzzer must be able to communicate with the target device. We built a transceiver that can listen to meter transmissions and transmit messages of our choosing to meters. A fuzzer is typically most effective if it sends messages that are “almost valid”. There are generally two approaches to generating almost valid messages: through deep protocol knowledge and through mimicry with errors. A fuzzer with deep protocol knowledge essentially re-implements the entire protocol used by the target device. It can generate valid messages and participate in the communications exactly like a real device. However, it has the additional ability to generate messages that deviate slightly from the next message it would normally send. Deep knowledge fuzzers are useful for stateful protocols since the fuzzer can drive the target device into a particular state by sending a sequence of valid messages before sending an invalid one. Mimicry fuzzers use a corpus of previously-seen valid packets. They choose from among the packets in the corpus, apply some error, and then transmit the modified packet. Mimicry-based fuzzers are much easier to develop, since they do not require full knowledge of the protocol.

We developed an online mimicry-based fuzzer. Our fuzzer interposes on the communications between two devices. Whenever one of the devices attempts to transmit a message to the other, our fuzzer intercepts that message before it can reach the intended recipient. Our fuzzer then makes a small set of random changes to the message before forwarding it to the originally intended recipient.

Our fuzzer is implemented as a generic framework that can be used to perform several different types of tests. The fuzzer provides a small programming language in which users can describe the test they want to perform. The language allows the user to specify constraints on the incoming packet and actions to perform when those constraints are met. For example, one could specify that whenever the fuzzer receives a packet that is destined for meter at network address 0x12345678, the fuzzer should “jam” the message so that the intended recipient cannot receive it. The fuzzer supports essentially arbitrary constraints and several actions:

- Forward the packet un-modified

- Forward the packet with random modifications
- Jam the packet

The fuzzer can also manage several radios attached to a single host computer, enabling complex testing set ups, such as that shown in Figure 37. For example, Figure 37 shows two meters that have each been placed in "isolation chambers". The isolation chambers prevent any radio signals from entering or leaving the chamber. Thus only the fuzzer antennas placed inside the chambers can communicate with these meters. The fuzzer can be configured with arbitrary rules for forwarding messages between the different devices. For example, the fuzzer could be configured to forward messages from meter A that are addressed to meter B, but not vice versa. This enables us to simulate a wide variety of real-world scenarios by setting up isolation chambers and configuring the fuzzing software.

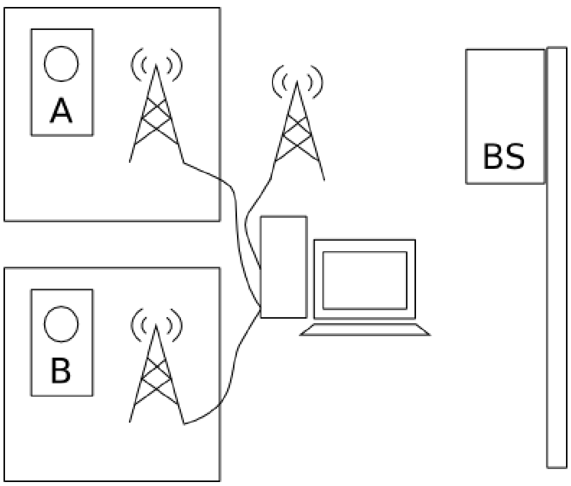


Figure 37 – isolation Chambers

Data and Analysis

As mentioned above, the meters use frequency hopping in the 902-928 MHz ISM band. We have observed the meters transmitting data using both On-Off Keying (OOK) and Frequency Shift Keying (FSK). Packets have a 52-bit preamble consisting of the pattern "101010...10". Each payload byte in the packet is encoded as 10 bits: a 1 start bit followed by the byte followed by a 0 stop bit. All packets that we observed were 42 bytes in length. We were able to interpret the meanings of many of the bytes in the packet through observations. When a meter first receives power, it broadcasts a message to locate a base station. If the base station responds, they engage in a short handshake protocol. After that, the meter appears to transmit small packets every 15-20 minutes. When the meter does not hear from the base station, it will continue to send beacon packets at regular and short intervals (e.g. every minute or so) indefinitely.

Findings, Observations, and Lessons Learned

We have found that the frequency hopping used by the meters to make it difficult to eavesdrop on their transmissions is not an effective defense alone. By using a powerful desktop computer and two software-programmable radios, we have implemented a wide-spectrum receiver that can monitor the entire 30MHz band the meters use for transmissions. The total cost of the equipment is less than $10,000, and in fact, would be much less if it were purchased today (perhaps less than $5,000) rather than 5 years ago at the beginning of this project.

The frequency hopping used by the meters is not harmful to security, has other benefits, and is constrained by the size of the unlicensed band used by the meters. One way to make frequency hopping more effective is to hop around among a wider swath of the spectrum – the meters cannot do this because they are already using the entire unlicensed ISM band. Frequency hopping enables the meters to cope with interference from other devices. Frequency hopping does not cause any security problems we are aware of.

Fortunately, the meters have other security defenses in addition to frequency hopping. If frequency hopping were their only defense against eavesdropping, we would strongly encourage the vendor to add encryption and authentication to their protocol. Since frequency hopping is only one layer of their defense, we do not believe the manufacturer needs to take any action based on this finding. Our fuzzing experiments have not revealed any anomalous meter behavior. This is a success for the meter manufacturer.

Recommendations and Best Practices

Now that we have completed a black-box security evaluation of these meters, we believe the DoE should focus future efforts on white-box security audits. A white-box evaluation would involve having computer security experts evaluate security based on the source code and design documents for the meters. If at all possible, the experts would also apply automated security-auditing tools to the meters' source code. These automated tools can find many bugs that experts would miss and that are very unlikely to be discovered through testing alone. White-box security evaluations are necessary to really understand the security of the smart grid infrastructure, but they require close collaboration with the device vendors.
Therefore, we recommend that the DoE:

1. Encourage device manufacturers to collaborate with national Labs, private security auditing firms, and universities to perform white-box security testing of their products.
2. Encourage future proposal writers to include device vendors in the grant-writing process or to obtain letters of support from any relevant device vendors. These letters of support should specify the resources the device vendors will provide to enable the project's security auditing team to perform a white-box security evaluation.

Collaborative Worm Defense

In a long-term IT deployment, such as with AMI technology, operators must be prepared to deal with security bugs that are discovered after equipment is installed in the field. Furthermore, they must be prepared to respond to “0-day” vulnerabilities, i.e. vulnerabilities that are discovered and exploited by hackers first, so that operators and vendors become aware of the vulnerability only because they observe attacks on their networks.

Today, the primary method for dealing with vulnerabilities in deployed systems is patches. Patches, written by an expert software developer familiar with the system, can provide a definitive fix to a vulnerability, but may take days or even weeks to develop and test. In the case of 0-day vulnerabilities, customer networks remain vulnerable to attack during the patch development process.

When vulnerable devices are networked, attackers can effectively attack all vulnerable devices in a very short time frame – often on the order of seconds or minutes – by creating a self-replicating worm. It is not practical to have humans in the loop of the system for responding to attacks based on worms using 0-day vulnerabilities.

The goal of this task was to research methods for deployed systems to rapidly and automatically respond to worms exploiting 0-day vulnerabilities. The goal of the automated response is to detect attacks, identify the vulnerability being exploited, alert all vulnerable devices of the vulnerability, deploy a stop-gap fix for the vulnerability, and alert operators and the vendors of the vulnerability so that the vendor can develop a long-term solution to the vulnerability (i.e. a patch). Therefore the system must be able to respond rapidly, but does not need to provide a fully-functional fix to the underlying vulnerability.

Methodology and Design

Our system consists of two main components: a specialized compiler that adds self-monitoring code to executables, and a network protocol for disseminating alerts about newly discovered vulnerabilities to all vulnerable devices. The compiler analyzes the code to compute every point in the code where there might be vulnerability. It then inserts extra code at each vulnerable point to check whether the current execution will trigger the vulnerability and, if it will, abort the program.

In theory, this produces executables that are free of vulnerabilities, but the additional code inserted by the compiler can slow down the program's execution, sometimes by up to a factor of 10x. This makes it impractical to perform these safety checks all the time.

Our approach solves this problem by making the safety checks probabilistic. Each node runs each safety check with only some small probability, say 5%. This reduces the overhead of the safety checks to an acceptable level, but leaves each individual node relatively vulnerable to attack. A node by itself has only a 5% chance of detecting an attack.

To provide a high degree of protection for all devices in the network, we add a system for sharing information about detected attacks. Once a single node detects an attack, it immediately begins flooding the network with alerts about the vulnerability. The alert specifies the exact safety check that nodes can use to detect the new attack. When a node receives such an alert, it permanently activates that safety check, rendering itself invulnerable to the attack.

There are two primary evaluation criteria that must be measured to determine whether such a system is feasible:

- Is it possible to build a probabilistic safety check system that has low overhead and that supports dynamically activating individual safety checks in response to incoming alerts?

- Is it possible to disseminate alerts quickly enough to protect most nodes in the network, even when the attacker is using a fast-spreading worm that can infect the entire network in seconds?

We implemented a prototype compiler for a specific class of security bugs – spatial memory errors. This class includes the classic "buffer overflow" and is the most common type of vulnerability exploited by attacks on the Internet.

Data and Analysis

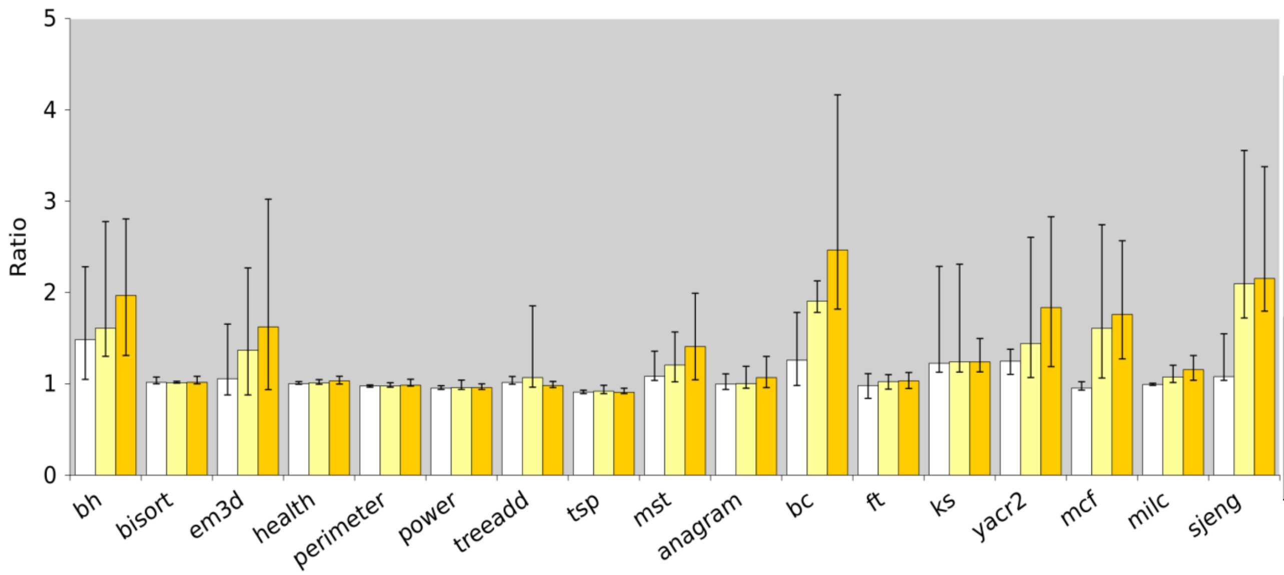


Figure 38 - Overhead of Our Defense with 1 Check, 5% of Checks, and 10% of Checks Activated

We measured the overhead of programs from the Olden, Ptrdist, and SPEC2006 benchmarks compiled using our system. Figure 38 shows the average overhead and the distribution of overheads. Many programs, such as health, perimeter, power, and treeadd, have almost no overhead. The average overhead for all the programs in this benchmark is below 100%. These results suggest that our approach can allow programs to probabilistically monitor their own execution with acceptable overhead.

We evaluated the ability of the system to contain a worm spreading through a network by performing network simulations. In our simulations, each node had a 5% chance of detecting the attack. If it detected the attack, it would begin notifying other nodes of the vulnerability. Otherwise, it would become infected and begin spreading the worm to other nodes in the network. The worm used advanced techniques to spread as quickly as possible.

Figure 39 shows that, even though each individual node only has a 5% chance of detecting the attack, our system is able to protect over 80% of the nodes in the network. Without our defense, the worm was able to infect all nodes in the network in about 30 seconds. Other experiments show that, as the network gets larger, the fraction of protected nodes increases. For example, in a network of one million nodes, we expect the defense would protect over 95% of the nodes.

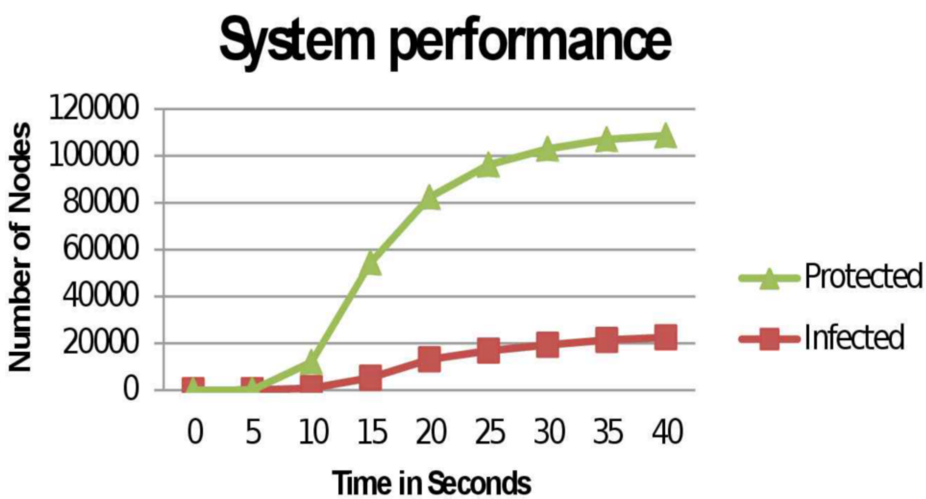


Figure 39 - Number of Nodes Protected and Infected in Simulations of Our Network Defense

Findings, Observations and Lessons Learned

The above results strongly suggest that a defense system in which probabilistic safety checks are inserted at compile time and nodes share alerts about attacks they detect can protect almost all nodes while imposing modest run-time overhead.

Additional experiments (not shown here) showed that the effectiveness of this approach improves as the network gets larger, and that it is relatively robust to the network structure, the detection rate, and many other parameters of the network and defense.

Another important feature of this defense is that customers can test the defense in advance. They can turn on all the run-time checks in a test environment and verify that none of the run-time checks will interfere with the normal, correct operation of the devices in their installation. This can all be done in advance and the deployed system can then be set up to activate checks automatically based on incoming alert messages. This completely removes a human from the loop. In contrast, patches not only take a long time to develop, but installation sites are often reluctant to install them without testing them locally. But patches cannot be tested until they are developed, so this testing process further widens the window of vulnerability between when an attacker begins exploiting a bug and the time when a patch is installed on vulnerable deployed systems.

The primary challenge in this project was the development of the compiler and run-time infrastructure to insert dynamically-activatable run-time checks. We had to implement many optimizations to get good performance. Extending this system to other classes of bugs will likely be a substantial additional development effort. If we were to do the project again, we would consider using dynamic binary translation, i.e. just-in-time (JIT) compilers. JIT compilers generate executable code only when it is needed. They cache the results of their past code generation, so most programs can run at nearly full speed. It should be possible to implement a system that supports dynamic run-time checks by extending the JIT compiler to be able to generate code with or without checks. When the program first starts, the JIT compiler will generate all code without checks. When an alert arrives requiring a check to be activated, then the JIT compiler can invalidate any cached instance of that code and regenerate it, with checks enabled, the next time it is executed.

Recommendations and Best Practices

The goal of this project is to give guidance to DoE about the viability of this research direction.
The conclusion based on our experiments is that this is a viable research direction. The DoE should consider funding follow-up research based on the JIT approach described above. The DoE should also compare this approach to concurrent developments in secure software development. For example, over the course of this five-year project, other researchers have worked hard to make run-time checks as inexpensive as possible. If their research pays off, then eventually run-time checks may become so inexpensive that they can all be turned on all the time. That would obviate the need for dynamically-activatable checks and a network for disseminating alerts. We're not there yet, but DoE should watch both lines of research and allocate funds accordingly.

VISUALIZATION (VIS)

The visualization team at Stony Brook University has been working on Energy Scout – a consumer oriented dashboard for smart meter data analytics. A commercial trademark for the name 'Energy Scout' was recently awarded and efforts to commercialize the software by partnering with companies in the space of smart energy metering are on the way. This visualization tool was developed with four objectives in mind.

Objective 1: Construct a visual platform for energy consumers allowing them to efficiently browse and analyze data captured by smart meters

Smart meters and other energy monitoring devices come in many different setups and platforms, but all of them serve a common purpose. They record total energy consumption of a device or a set of devices in the household at small periodic intervals on the order of minutes. Existing commercial interfaces in the consumer space, such as eMeter, OPower, and others, typically only provide a quick glance onto real-time consumption monitoring. Past usage is almost always represented through a long line chart with little to no emphasis on focused visual data analysis. Simple bar charts representing the energy consumption over a fixed interval of time are also often found. We have aimed to design a visual interface that is more dynamic than these, providing users with convenient mechanisms to slice and dice the data in many ways.

Objective 2: Put high emphasis on a visual platform that can educate energy consumers about their use of energy and drive behavior change

Systems like OPower focus on social aspects such as competition among neighbors. The consumer is given only light information feedback. For that reason, gaining awareness of the sources of high energy consumption is often a guessing game. However, without tools that allow deeper data analysis the competitiveness of a household in this energy saving game is rather low. And since competition is the main driver of the energy savings, a sub-optimal system follows. While sophisticated tools could be employed to visually analyze the data to the fullest, these generally require steep learning curve and most likely will fail to attract most consumers, defeating their purpose. We aimed to provide tools that are easy to use but yet sufficiently powerful to provide effective insight to consumers, educate them about the sometimes complex relationships governing energy consumption, and eventually drive behavior change.

Objective 3: Build in facilities that allow utilities to communicate incentives to reduce energy at certain times of the day

Dynamic pricing is an instrument utilities use to encourage consumers to shift their energy consumption to off-peak hours of the day. We have aimed to provide special visual elements and analytical tools that can alert users when they have used energy in these times of the day. We also provide interface elements that allow them to play what-if analyses, watching their energy bill shrink (or grow) when shifting certain device utilizations in time.

Objective 4: Make the interface appealing to use

As the success of the Apple iPhone vividly demonstrates, aesthetic appeal and elegant solutions to achieve certain functionalities are very important for user acceptance of a product. We have taken these aspects into account to distinguish our implementation from the rather basic ones already available. We have especially aimed to achieve fluidity in the transitions from one visualization image to another, providing more immersion to the user and keep him or her looking.

Design Methodology

From the very moment we set out to design our system, we had to ensure we understood user expectations and their acceptability level well enough. Generally, in design of a visual analytics system, the overall flow follows a sequential waterfall approach with the design phase kept separate from user feedback or evaluation. For our work, we decided to involve such feedbacks as an integral part of the design process. We were lucky enough to have a panel of domain experts in our collaborators at LIPA, National Grid, and now PSEG Long Island, who were already heavily involved with the expansion of the smart grid, understood the need of the consumers, and had good first-hand experience of using different existing commercial interfaces.

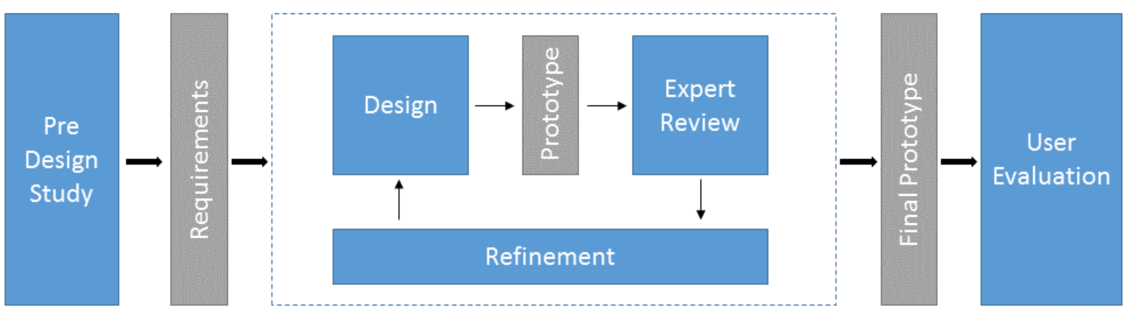


Figure 40 - Overview of the Design Process Steps of Energy Scout

To maximize utilization of our collaborators, we laid out our design process around them into three phases, illustrated in Figure 40. We proceeded as follows:

- In the first stage, we tried to understand what functionalities the system should include and how they should behave. We did so by analyzing the features offered by different existing interfaces and understanding our supporting panel's experience, preference, and desires.

- In the second stage, we took an incremental approach to design our prototype. In each iterative step, we designed a new feature or modified an existing one and had it tried out by our domain experts. Depending on their feedback and experience, we then modified our design goal and moved into the next iteration.

- The third stage was entered when we reached an agreement that the interface could be considered functioning and useful. Here, we performed a user study with human subjects from varying background to evaluate the success of our design.

Predesign Study

During the predesign study, our goal was to get a clear picture of the data to be represented, understand the mindset of our audience, what they wanted from such interfaces, and identify a set of features that would ensure continued usage.

Insights from interviews with consumers

We interviewed a set of randomly sampled people in public places around New York. The purpose of the interviews was to have informal discussions about their energy bill, their interest in such analytics interfaces and any experience in using analytic interface if they had any. We interviewed 6 persons, 3 male and 3 female. All of them were aged in the range between 30 and 50 years and were involved in some way in handling energy bills at their house. We found the following:

- The respondents generally did feel confused about their spiked up energy cost at the end of the month, but none of them were active users of the analytics tool available to them to try to understand the bill.

- The respondents did not think time spent behind such analysis provided enough benefit to them compared to the time spent.

- They had mixed opinions about automated appliance scheduling, possibly even done by the utility.

Insights from interviews with domain experts

During our predesign study phase, we called for an open discussion session with a few utility professionals – a customer technology manager, a smart-grid program lead analyst, and a customer support manager. We presented our experiences so far in understanding the present solutions and customer mindset and asked to share their own insights and suggestions. The discussion that followed gave us some valuable insights, in particular the perspective of utility companies. Coping with the increasing consumer demand and handling the peak demand is a major concern for utility companies. Some of the crucial comments they gave were:

- "We introduce peak/off-peak rates and other schemes to encourage our consumers change their heavy usages so that we don't have to worry about that sudden surge during peak hours of the day. We introduced smart-meters and also bought solutions for people to look at the data through our portal, but hardly anyone is using them."

- "My experience with customers tells me that people try out these systems once or twice, then eventually stop using them. For average consumers, they are not really interesting to use or may not be so intuitive. For enthusiasts, they may be too basic. The system that we are using, doesn't give much other information than showing you meter records from the past month. It is still better than not having any access, but I can't really tell much by just looking at those lines".

- "People are getting used to those smooth and nicer apps in their phones and tablets that they find these old-school design outdated, clunky, boring, and hard to use".

We were given access to one such system to test it ourselves. We found that even though it was kept simple to cater to a mass audience, the most common operation of exploring historical data required significant clicking through dropdown date boxes.

Study of Existing Commercial Products

To understand where market gaps are, we conducted a study of the existing landscape of products. A summary is presented in Figure 41. We found that depending on scale and target users, the overall market can be analyzed based on following four segments:

- **Utility scale analytics**: There are analysis tools based on massively large scale data collected over a region or grid. They are targeted towards professional energy analysts working in corporations. These solutions by their very nature are complex and provide deep analysis with advanced visualization techniques. Techniques utilized in such interfaces are rarely designed to keep usability as an important factor, and thus are generally not suitable for the masses. Known vendors in this sector are IBM, Siemens, SAS, SAP, GE etc.

- **Building level analytics:** These are **s**olutions for building managers or analysts of an industry who need to understand energy consumption over a collection of establishments. Popular solutions in this sector are BuildingIQ, C3 Energy, Wegowise, Ecova, Retroficiency, EnergySavvy, etc. Apart from providing summaries and on demand details, common techniques involve correlation of environmental factors such as weather information with historical data, identification of surge patterns, and methods for communicating with the consumers. These interfaces also require some training and apart from an often appealing visual design, they do not attempt any other usability improvement or user engagement techniques.

	Scale	Analytics	Ease of Use	User Cost	Engagement	Recommendation
Big Data Analytics for Utilities IBM, SIEMENS, SAS, SAP, EMC, GE	Grid	Advanced/ Complex	Requires Trained Analyst	Very High	N/A	N/A
Industrial & Building Energy Analytics BuildingIQ, C3 Energy, wegowise, AGILIS / ENERGY, ecova, Retroficiency, EnergySavvy.com	Building Complex	Moderate	Requires Trained Analyst	High	Visual Design	Minimal / None
Smart-Plugs and Monitors efergy, TED, energy circle, EnviR, nest, BizEE, ONZO, wattvision	Single Home	Minimal/No Analytics	Easy	Device Price	None	None
Household Energy Analytics						
OPOWER	Single Home	Summary/ Basic	Easy	None	Social Motivation	Social
eMeter	Single Home	Summary / History	Moderate	None	None	None
bidgely	Single Home	Summary / History	Moderate	Device Price	Visual Design	None
HEA	Single Home	Summary / History	Easy	Device Price	None	None
ENERGYSCOUT	Single Home	Contextual Exploration / What-If	Easy	None	Social, Fun Interactivity, Gamification	Social / Data Driven/ Feature Driven

Figure 41 - Study of Products in the Energy Analytics Space, Comparing Them to Our Energy Scout Framework (last row, not commercial)

- **Consumer end smart-plugs and monitors**: These are small pluggable devices sold directly to end users to monitor single appliances or the entire household. Companies who provide such solution (e.g. efergy, TED, Onzo, EnvIR, wattvision, etc.) also have associated web or mobile applications that provide visual access to the data. Such interfaces, in most cases, are limited to the direct plotting of data streams with some level of data summarization. To ensure fast adaptation, systems in this segment are made to be used out of the box without training and hence almost always lack any deep analysis option.

- **Home energy analytics**: These are purely software centric analytics systems provided directly to consumers for managing the smart-meter data collected by their utility company. They are based on total consumption of a single household and are designed to help consumers reduce their energy bill. Notable companies in this segment are OPower, eMeter, Bidgely, Google meter, Microsoft Hohm, etc. OPower thrives off social motivation through simple comparative charts on the printed bill, with support for social recommendation and basic data exploration on their web/mobile interface. eMeter, Google meter, and Bidgeley provide direct plots of data through line/bar charts with provision for summary analysis. Microsoft Hohm provides user data driven model based prediction and recommendations to help energy savings.

From the study of these products, we identified their various features and classified them into the following categories for easier analysis.

- **Real-time energy monitoring:** These visualizations directly represent the energy consumption in kWh or dollars, as generally displayed on the meters themselves. Some interfaces prefer to use line plots; others create abstractions using more appealing graphics, iconification, or ambient visualizations to gain better acceptability from average consumers. Traditional solutions utilized dedicated display units along with other control mechanisms. Modern solutions, on the other hand, are inclined towards mobile apps and web based solutions for the convenience of remote monitoring. Real-time monitoring in some cases also comes with provisions for alerting the user to sudden spikes or other unusual activity to prevent any significant accumulated month long damages.

- **Historical data exploration:** Most web centric solutions provide a way of exploring historical energy consumption over the household using interactive line or bar plots. For multiple data streams from different devices, stacked charts are often utilized even though they tend to clutter the display quickly. Summarized charts for displaying the average use over some predefined interval are also commonly used and are preferred by users for quick glance of their household performance.

- **Energy consumption prediction:** Based on consumption data, the energy model of the household and other contributing factors such as weather and events, some systems provide an approximate estimate of the upcoming bill to spare the consumer from sudden surprises. However, to make such a model reasonably accurate, considerable knowledge about the house and its appliances are required. Some systems provide extensive profile building (e.g. the now discontinued Microsoft Hohm), while others skip the cumbersome user input phase to rely more on empirical data.

- **Recommendations:** Some of the systems provide energy saving tips and recommendations to the users based on their energy consumption profile as well as data from similar households. Such recommendations can be direct tips from the utility companies or they might be auto-generated based on community data generated through social interaction. Recommendation systems have the potential for a strong impact on consumers if implemented and promoted correctly. But, considered to be more of an extended or optional feature in energy analytics.

- **Device control:** For convenience, some systems are integrated with smart devices and smart-plugs resident in a thermostat, the AC, lights and other household appliances. They are typically controllable either remotely or in a pre-programmed manner. Features like these are in most cases part of some integrated solution and do not directly cater to the kind of energy analytics we prefer to improve upon. Particularly, it doesn’t directly apply to smart-meters, unless they have provision for collecting data from other smart appliances in the house.

- **What-if Analysis:** Some systems have methods that allow for future planning, estimating approximate changes in cost/consumption based on modifications of the virtual house or behavior model. The scale and extent of the what-if analysis may vary greatly depending on how much freedom the system allows its users

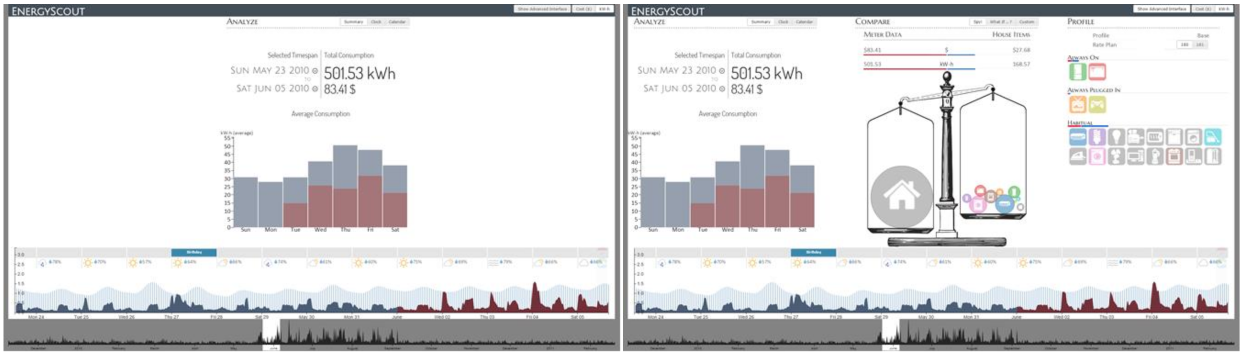


Figure 42 - The Energy Scout Interface Showing Two Different Perspectives – Basic Mode for New Users (left) and Advanced Analysis for Enthusiast (right)

in asking questions. A what-if analysis system is a great feature that can be improved upon based on visual analytics theories and techniques. A good implementation should provide a versatile and expressive analysis system, yet retain acceptable convenience and usability for its users.

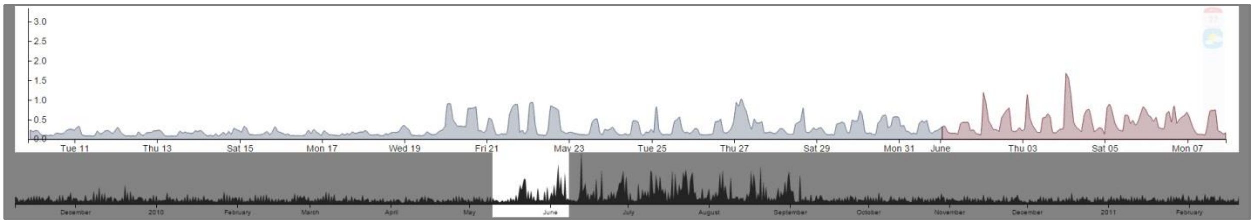
Lessons Learned from the Market Analysis

Based on this initial analysis, we decided that a good prototype should have the following aspects:

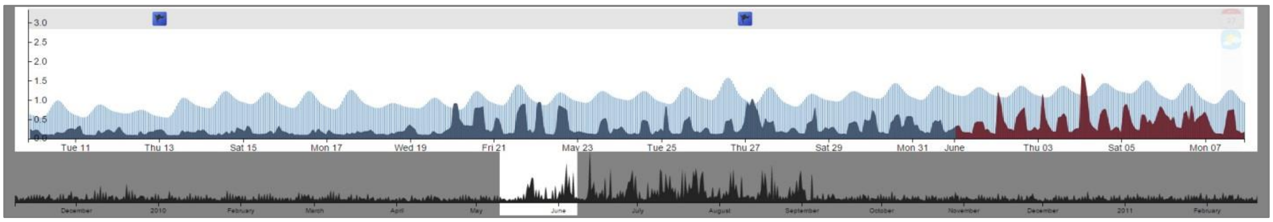
1. Allow analysis based on the entire house smart-meter data, rather than device specific monitor data. We chose so, because smart-meters are going to be readily available in home of masses and also, the need of research behind better analytics tool is more prominent when we lack the opportunity of data driven automations.
2. Real-time monitoring interfaces and control units are mostly well designed and widely implemented. On the other hand, analytics of historical data is rarely adapted by consumers and needs improvement.
3. It should include provision to keep an average consumer involved and interested in continued usage of the system.
4. It should provide an expressive what-if analysis tool that meets the needs of an enthusiast.
5. It should also double as an educational tool to make people think about energy usage and improve awareness.
6. As a development platform, we chose to make the prototype a web application rather than mobile. This limits interaction to mouse only, but provides convenience for testing comparatively complex visualizations and interactions without having to worry about resource limitations

The Energy Scout System

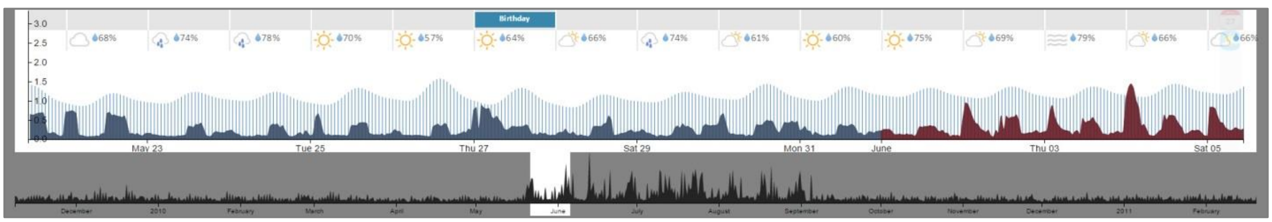
Two full screenshots of the Energy Scout interface are shown in Figure 42. Energy Scout runs over the web in any modern browser and is therefore easy to access. It is designed as a single view dashboard with multiple connected interactive visual analytics components. Each of these components provides a high level of interactions and always reflects its results in the other parts of the interface, providing a unified analysis environment. In the following paragraphs, we briefly discuss how each of these components works.



(a) Zoomed-Out View without Contextual Information



(b) Zoomed-Out View with Contextual Information



(c) Zoomed-in View with Contextual Information

Figure 43 - Historical Data Exploration with Different Levels of Zoom and Contextual Data

Data Exploration

At the very bottom of the interface (see Figure 43), the entire history of household energy consumption is shown in form of a traditional line chart. A smaller time span can be selected by dragging the mouse over it. The other interface elements will then only reflect analyses results obtained within the selected time-window. This time window can be adjusted interactively and the remainder of the interface gets updated dynamically. Just above the overview chart is the details view of the energy history. To produce a smooth experience, this detailed chart always automatically adapts to a correct resolution of data depending on the time-span selected. To allow users to perform root-cause analyses on the fly, the interface also provides two types of contextual data channels along with the detailed view – daily weather information and an active editable calendar. In addition, the calendar panel can also be used to annotate any part of the energy time-line to record interesting findings.

A Lesson Learned – Keep it Simple!

As we were working with the smart-meter data collected from several households, we felt that the simple exploration of meter data as a line chart wasn't telling the full story. Due to user behavior patterns and day/season cycle, energy data has an inherent periodic pattern. To bring out such periodic information we created a radial heat-map. It immediately started exposing some interesting information not evident from regular line plots. This map is shown in Figure 44. For some household it showed clear day to day cycles, for some it showed how they stay up late in weekend and holidays, for some it showed the clear seasonal transition when there is no electric heating but used air-conditioning in summer. As visualization enthusiasts, we felt having such radial plot in form of 24 hour clock would be useful to users. We added it as new component and connected to the exploration interface.

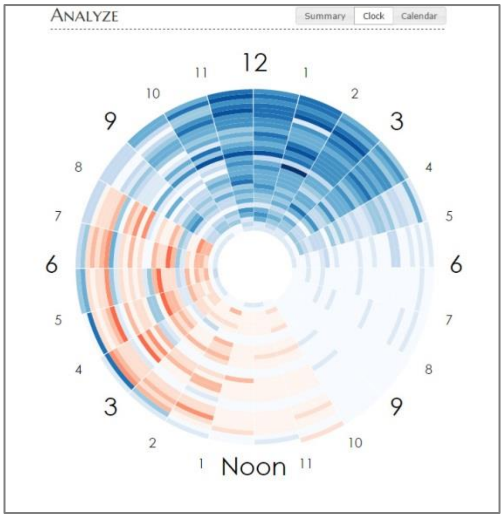


Figure 44 - Radial Heat-Map of Smart Meter Data to Identify Periodical Patterns. Here, Darker Shades Represent Greater Energy Consumption. This House in Particular Shows Significantly More Night Time Consumption Than Days – A Pattern Not Evident from Traditional Line Plots

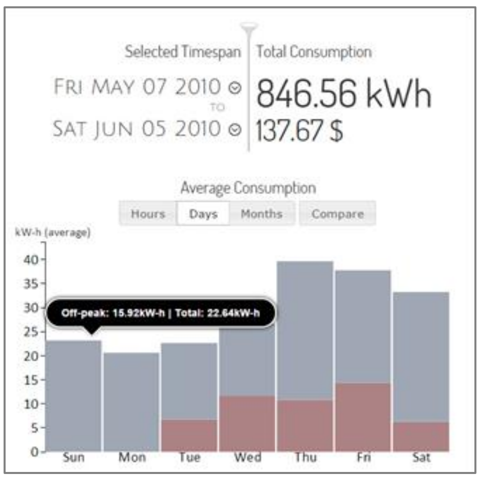
When we showed the prototype to our panel, the response was mixed. Radial plot, particularly use of heat-map, was not common in everyday use. That meant, at the first look, they felt clueless about what it should represent. When we explained how it functions, several of them liked the flexibility of having periodic pattern discovery but an important objection was raised.

"People are really repulsive of something they can't quickly learn or comprehend. Having such a chart in an important part of the interface may lead to rejection by the users. There may be a few who may really like it and use it, but for most it can be overwhelming".

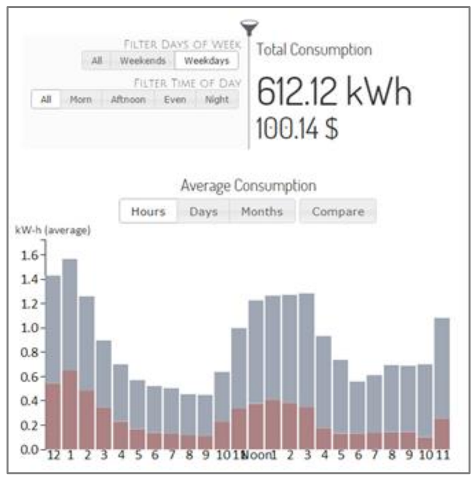
We agreed with their view and decided to allot that part of the interface to more consumer preferred visual modalities, keeping it as an optional view only.

<u>A More Acceptable Solution for General Users</u>

While the radial display was not accepted, we still aimed to help user appreciated their average consumption over different time intervals (days of week, month of year or hour of day). Encouraged by our consumer experts, we now chose a bar chart (see Figure 45), but we added some life to it. In our case, we used a stacked bar chart to differentiate between peak and off-peak consumption. Hovering over the chart brings out a toolbar that allow the user to switch between different perspectives. Also, a toggle button called "compare" can be used to bring out a comparative chart between most recent consumption and the selected time range. Such summary charts of averages can answer some questions, but to us it felt too restrictive. Hence, we introduced a simple and easy to use data filter mechanism. The selected time-interval can be further filtered by days (All, weekends only, weekdays only) or time of day (All, Mornings, Afternoons, Evenings, Nights). Having such filter meant users can ask question like: "How bad does my summer weekend nights look compared to regular average use? Or, "I have been doing my laundry in weekdays. Is it really having any significant impact?" With such a filtered data analysis system, we brought our system somewhat towards the direction of expressiveness of radial plot for identifying periodic patterns – all without deviating too much from commonly preferred visualization techniques.



(a) Average consumption over days of week.



(b) Average consumption over hours of day, with data filtered to show only weekdays.

Figure 45 - Summary Analysis Panel

Devices and Comparative Analysis

In the center of our interface is an animated weight scale (see Figure 46). This gives a real life analogy of how much energy the overall house and the individual appliances and devices are consuming. All consumptions are shown as circles or 'weights' on this scale with the area being proportionate to the weights. The users can pick a device from their house profile, modify its periodic usage by adding events through an intuitive clock interface (not shown) and immediately see the scales move according to the weight in a physically accurate fashion. We created this playful interface to engage users in understanding how their habits affect energy usage. Also, looking at the sizes of these balls immediately eliminates any misunderstanding of energy cost of the respective devices. We grouped the devices into three intuitive criteria and gave them visual comparisons through thin bar lines.

Lessons Learned with the Weight Scale Comparative Interface

We presented our version of weight scale based comparative analysis to the expert panel and asked them to test it themselves. Their initial response was more of astonishment because they were not familiar with any

Figure 46 - The Weight-Scale Based Comparison Panel. This Screenshot Shows the Operation in Spy Mode. Device Icons Shown on the Right Are Taken from the Profile of the House. Color and Icons are Used for Easy Association. Gray Colored Ones Do Not Have Any Associated Events

such approaches for a fun interactive comparative tool. After spending several iterations of weight scale balancing, they pointed out an important factor: “Using this weight-scale is fun for a while, but I can hardly think of a situation where I will actually seriously sit down and spend time behind perfecting my virtual house. Although, we do like how those circles makes you think. Most people have no clue how much those appliances actually consumes. This weight scale can be educational.” We also agreed on the fact that it indeed is much better suited as a sandbox. Interacting directly with those weight balls and watching them grow and shrink as you update your profile can be strong media for creating awareness and increase understanding. Also, in case we do have access to device specific data, the weights and device details would be automatically filled out giving the user all the benefit without the hassle of time consuming input phase.

<u>What-If Analysis</u>

Our physics driven weight scale provided us with a nice platform for visually comparing two sets of devices. This allowed us to implement the what-if analysis or future planning section of the dashboard in a different way than what is generally practiced. At any stage, the system can be switched to what-if analysis mode from spy mode. In what-if mode, the system allowed comparison between two virtual household. One of them is built by the user in the spy mode. We called it base profile where weights are kept in the right scale. Another profile called what-if profile is created cloning the base profile. Its weights were presented on the left scale replacing the weight representing the whole house (Figure 36). Now, we still have all the tools presented before at our disposal. We can add/remove devices, change usage behavior by modifying events, try out different rate plan schemes promoted by the utility companies, etc. Also, adding provision for changing models of the devices can be easily incorporated by connecting the interface to a database of appliances.

With such flexibility, users can easily ask questions like “Would it help if I used water pumps over weekend than weekdays?” or “If I changed my old AC with that new model, how much money would I save over electricity monthly?” or “People always talk about energy saving CFLs over my older bulbs, I want to see how much it really saves me if I replaced 10 of those”. Any changes to the energy profile were immediately reflected to the weight scale, updating the weights in the physics model giving a very engaging experience when dealing with such questions. Also, our core exploration interface stayed integrated with the interface, meaning we can have completely separate usage profiles and what-if analysis performed for different time of year or seasons. Figure

36 shows how a user might compare two different laundry scenarios to see which one is more energy efficient and by how much.

<u>A Lesson Learned -- Gradual Learning for New Users</u>

With each prototype cycle, we kept on refining or adding newer components to our multi-view dashboard. We found that this worked really well. Reviewers of our system were quite familiar with the incremental steps of our system and adapting the changes was easy. For new users for our system, the same doesn't hold true. Individually, the components may be intuitive to use but having so many buttons and elements presented together for the first time can easily confuse a potential user. This situation was correctly identified towards the end of our design phase. To solve this problem, we introduced a gradual self-learning process within the interface. When someone first opens our dashboard, he is presented with only basic part of the interface

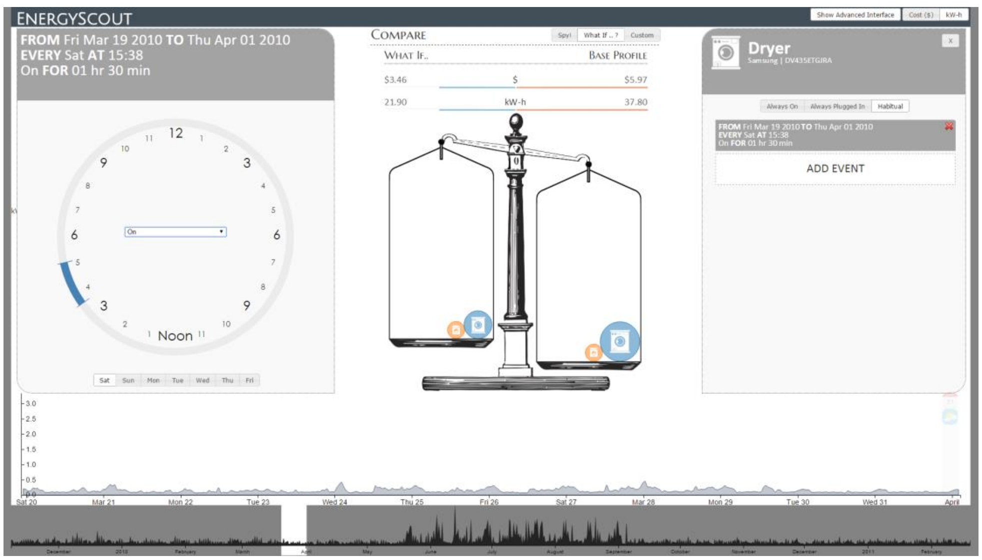


Figure 47 - Future Planning in Energy Scout Using What-If Analysis Mode. Here We Are Comparing Two Different Laundry Scenario to See Which One is More Energy Efficient and By How Much

(Figure 47), which consists of the exploration interface (with weather and events toggled off) and summary bar charts without showing any buttons. Becoming familiar with its data representation and interaction with the summary view becomes apparent after only a few swipes. When the user decides to check out details of summary panel, hovering the mouse over the chart reveals the toolbar that lead to further views and data filter options. Such gradual discovery of features has two fold advantages – it makes self-learning without any external tutorial feasible, and keeps the natural curiosity of the human mind satisfied. For many users, the analysis provided by the basic perspective of the interface is good enough. Others, including the enthusiasts, may choose to switch to advanced analysis mode that reshuffles layout to expose our weight scale based comparative and what-if analyses. With mastery over features of the basic interface, learning about the physically inspired weight scale also doesn't introduce a strong challenge. Such gradual learning scheme is analogous to control of flow in game design where increasing difficulty is always introduced to ensure the balance between challenge and boredom. A well designed consumer facing interface should never require separate tutorials or training.

Findings from User Studies

We were able to host two separate study sessions. The first session was hosted in Long Island, New York. Among the participants were 7 female and 1 male, aged between 30 and 50 years. All of them reside in suburban houses, with varying background. The second session was hosted in Raleigh, NC on 9 participants – with 3 female and 6 male. Participants were younger, living in their rented apartments or newly bought houses. We divided the study into two separate phases – basic exploration (Task 1) and advanced analysis (Task 2). In each phase, we followed the following steps:

- A quick demonstration of the interface and its purpose.
- Let the participants discover the interface by themselves, record any comments/questions.
- Ask them to perform a specific task involving the current set of tools. Observe their interactions and record their comments/suggestions.
- Ask them to fill out a very short questionnaire.
- Open discussion among all participants for any more topics not addressed earlier.

	Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
easy to use	0.00%	0.00%	33.33%	45.83%	20.83%
easy to learn	4.17%	4.17%	20.83%	66.67%	4.17%
practical	0.00%	8.33%	29.17%	54.17%	8.33%

Table 9 - Summary of Responses from User Evaluation

The first three questions of the questionnaire asked about ease of use, ease of learning and practicality of features in Likert scale. Table 9 summarizes the overall responses from the participants, expressing their general acceptance of the interface concepts.

When we asked which feature seemed useful/interesting in task 1, the crowd favorite was the smooth exploration scheme with mouse drag. For task 2, it was the what-if analysis. “Zooming in out of data was fun to use. Also loved that I can get those per day information so easily.” People identified the contextual weather and event data to be “very interesting and practical”. During the study when users figured out there is a way to incorporate Google calendar information, some of them started inquiring if it also supported other popular calendars (e.g. Microsoft Outlook, Apple Calendar), clearly showing their interest in actually associating these features. Task 2 generated keen attention from several of the participants when we showed how the weight scale can bring out comparison between different devices. We found many participants, particularly females, trying to simulate many different usage behavior and device combination to see how they impact cost. “After using this software, I think it is very useful. I thought I knew about how my devices were behaving, but you can’t be sure about everything without hard facts. The software cleared up some of my confusions and was fun to learn new stuff about things that you think you have known all along.”

For some people though, the controls to add/modify device profiles were a turnoff. “It was fun to juggle around with those weight, but I wouldn’t have guessed how it would function if you hadn’t explained”. We could also see diminishing interest as they struggled to fill out every little detail about energy behavior to balance the scale. This was an expected result from out hypothesis of design phase. Trying to gather such detailed input will always be a pitfall for such interfaces. But, promoting it as a playfully informative awareness building tool may bring more success.

We asked the participants if they can think of a feature that would be more useful than what we have offered. Most suggestions revolved around refinement of font choices and colors to make them stand out even more. One participant in particular was trying to be very precise in query of the time interval, and found time-window to be a bit frustrating to use in very fine adjustment cases. “As much as I loved using the sliders, I would still prefer a simple date picker when I know the exact date/time I’m looking for”. We agreed on his suggestion and added this as an additional feature. In case of device profile display and modification, suggestions were made to have alternate list views if numeric comparisons were sometimes desired. Such requests reflect onto one important fact - every individual has their own taste when it comes to the details of analytics interface interactions. Having several options of doing the same interaction may broaden the demography of acceptance.

We asked about the visual design and overall look and feel of the interface. Responses were mostly neutral to positive - “Pleasing, easy to interpret”, “It is pretty user friendly. One can get enough information from this interface”. But some of them expressed their concern about having too much content on the screen. “The concept is good but I think it may be too complicated for some customers to understand without a full clear explanation”.

As our final question, we asked them if they would use this tool for their own house if made available. The opinion was divided. One participant said “Absolutely”. Seven of them said “Yes”. But there were also some strong “No” from 3 participants while the rest said “May be/Sometimes”.

Observations and Lessons Learned

In the project we learned valuable lessons on the simplicity of interface elements, on the need to provide engaging initial overviews without requiring interaction, and the importance of fluidness and playfulness for deeper exploration. We also learned to our surprise that it is the utility that benefits most from users engaging and learning from the experience. Utilities are under constant pressure from public service commissions in reducing their load growth and, in fact, do not have the capacity to satisfy increased user demands. Since it requires immense investment to increase capacity, utilities have a keen interest in customers preserving energy. However, in interviews with customers we found that most do not care about their energy bill. They simply accept and blame the utility as being greedy when the bill is too high. An important lesson therefore, is to construct a system that entices users to actually go and inspect their data. This is then the first step in forming awareness of possible overuse. The next challenge is to make users concerned about overuse which can be accomplished with appropriate visual designs and also metaphors, such as glaciers melted or severity of a storm in their neighborhood due to global warming. Finally, consumers need to be given solutions that can apply to act upon these deficiencies. We have developed our system towards these directions but more work is needed.

Recommendations and Best Practices

The following is essentially a summary of our findings presented in the previous sections. An effective consumer-based visual analytics system for smart meter energy data must:

1. Provide a fluid interface with various interconnected components to visualize different aspects of the data
2. Make the interactive components very responsive as even small delays can lead to loss of interest
3. Provide a set of initial views with interesting events in the data which do not require any interaction
4. Create compelling visualizations with interesting metaphors that make consumers care about the data
5. Provide tools that allow playful what-if analyses so users can quickly test in an experiential way what preventive actions might work and what effect they might have
6. Add contextual secondary data, such as weather and social events, to the energy data that can be used to explain abnormal use

FARMINGDALE STATE COLLEGE

DEMONSTRATIONS

The Farmingdale State College (FSC) focused on residential and commercial models showing how intelligent devices can enable customers to understand and control their usage and respond to price signals, as well as integrating distributed renewable energy. FSC also developed a curriculum and implemented training relating to AMI infrastructure, integration of distributed renewable generation, and PHEV systems to provide for a trained workforce. Over 1,250 people from private, public, and educational sectors attended the various training sessions and seminars.

FSC has accomplished all of its demonstration and training goals with the exception of hydrogen generator and associated battery storage. FSC has erected an Energy Smart House incorporating Solar PV, Solar Thermal, Smart Louvers, and a Smart Meter. Unfortunately, smart appliances have not materialized in the market place, and could not be included in the project. Additionally, FSC implemented a Small Scale Wind Farm with three Skystream 3.7 wind turbines for a total of 7.2kW, and a Solar Carport and EV Charging Station that produces 94.08kW of solar energy and supports 20 plug-in hybrid electric vehicles. A PHEV lab fitted with tools and a commercial/industrial demonstration space were constructed in Lupton Hall. This demonstration space showcases smart technologies including Smart Louvers and a building management system

Smart Energy House

Figure 48 - Long Island's First Smart Energy House

Solar Photovoltaic System

The Solar Photovoltaic system on the Smart Energy Home is an array of 20 solar panels totaling 5.17 kW. The house system utilizes a SMA Sunny Boy inverter that has a web-based monitoring system that can be accessed either on a PC or mobile phone. In case of a power outage the inverter has a backup system that provides 1500 watts to essential loads from the outlet seen in Figure 49a (to the right of the inverter). The web-based monitoring system shown in Figure 49b is displaying the bell curve for the kWh production on a typical cloudless day in June. Figure 49c shows the layout of the solar panels on the roof.

(a) SMA Sunny Boy Inverter (b) Web-based Monitoring (c) Solar Panel Layout

Figure 49 - Solar Photovoltaic System

Solar Thermal System

Based on the performance ratings from Solar Rating and Certification Corporation (SRCC), the max output in terms of energy is approximately 12.9 kWh per day, or 44.2 BTU per day. Unfortunately, solar thermal collectors do not have a comparable STC (Standard Test Conditions) rating similar to photovoltaic modules. This is due to its power rating is highly dependent on climate and irradiance.

The collector will gather an approximate maximum of 720 W per square meter (assuming an efficiency of approximately 72% (in cold, high irradiance conditions) and applying that to the commonly used irradiance of

(a) Evacuated Tube Solar Collectors (b) Data Acquisition System (c) Web-based Monitoring

Figure 50 - Solar Thermal System

1,000W per square meter). When multiplied by the collector's total aperture area of 2.833 square meters, the outcome is a power rating of 2,040 Watts, or approximately 2.04 kW. This is close to the "rules of thumb" that approximate the collector to have a power rating of 1.8 -1.9 kW. In summary, the max power rating is 2.04 kW. Figure 50a is a picture of 30 evacuated tube solar collectors on the roof of the Smart Energy Home. Figure 50b shows the data acquisition system connected to the solar thermal system. The temperature from the panels and tank are collected, as well as the flow rate. Figure 50c is the SunReports web-based monitoring that allows the collected data to be viewed.

Smart Louvers

The Smart Energy Home's external venetian blinds (aka "Smart Louvers") are controlled autonomously by the WAREMA Climatronic® System. By using data collected from a weather station installed on the roof, the blinds can be positioned in the orientation that will increase the efficiency of the house HVAC system. Data gathered by the system includes solar irradiance, wind speed and direction, precipitation and internal and external temperature.

The blinds have been pre-configured to operate based on the location of the house. This allows the blinds to not only measure the surrounding environment, but also know where it is in relation to the sun at all times.

The control panel seen in Figure 51b allows the homeowner to manually override individual blinds and adjust the position and pitch of the blinds.

The blinds help maintain a steady and comfortable temperature by acting as a heat shield in the summer, and an additional insulator in the winter. Figures 51a shows the blinds in the fully closed configuration, blocking light from entering the house, but also creating a thermal barrier in front of the windows. Figure 51c shows the blind closed, but with the slats open to let light into the house. The slat angle can be adjusted to control the amount of light entering the window.

(a) Smart Louver: Slats Fully Closed

(b) WAREMA Climatronic® System Control Panel

(c) Smart Louver: Slats Open

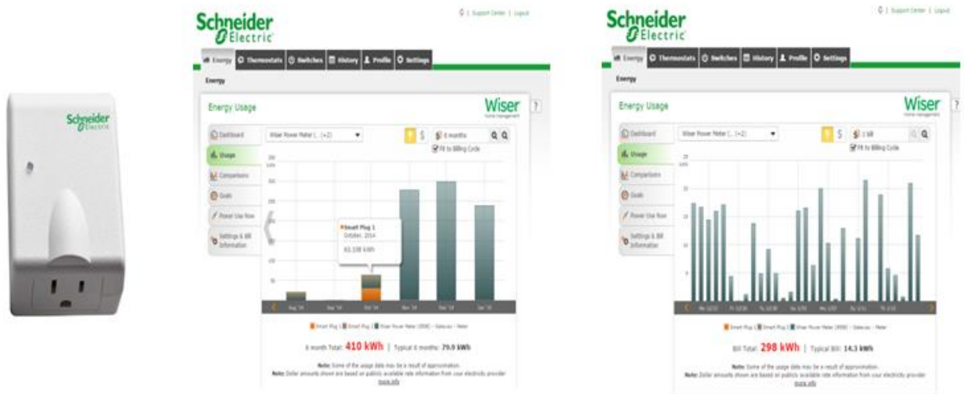
Figure 51 - Smart Louver System

Smart Meter

The AMI meter seen in Figure 52 has been installed on the Smart Energy Home by LIPA. This meter provides access to the energy data through the residential portal on the PSEG Long Island website. This allows us to view 15 minute interval energy data from the net energy consumption of the house. The house has also been equipped with a Schneider Smart Energy Home Area Network.

Figure 52 - AMI Meter

The smart plug in Figure 53a is both an energy monitoring device and control switch. This smart plug can be connected with any appliance in the house to monitor its energy consumption. Figure 53b is a screenshot of the Schneider Wiser Energy Dashboard which allows the energy consumption of any appliance plugged into the smart plug to be viewed over the internet. The Schneider Home Area Network can display the energy consumption over the course of a billing cycle, allowing for comparisons of energy usage to the PSEG Long Island meter reading, thus providing the ability to study energy consumption and the development of load profiles for the house during different seasons.



(a) Smart Plug

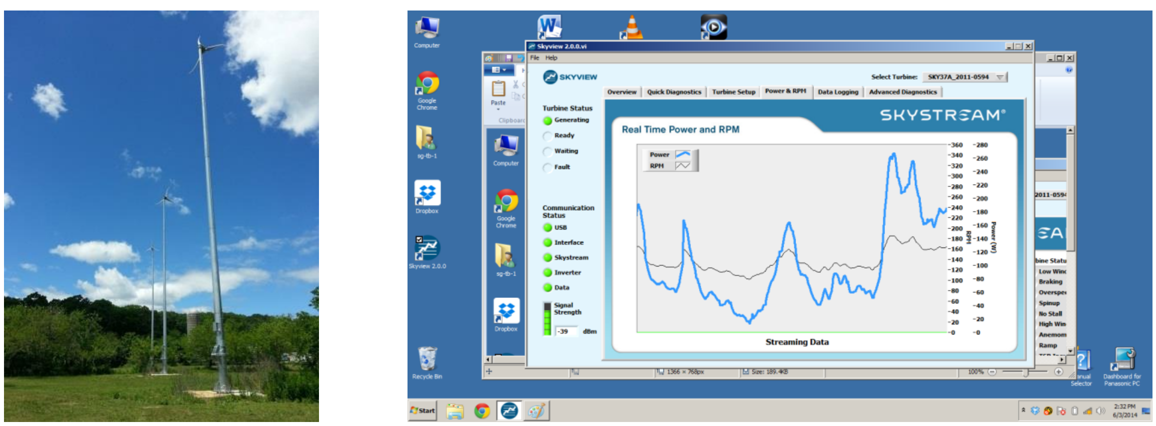
(b) Smart Plug Energy Usage vs. Total Energy Consumption

(c) Monthly Energy Usage

Figure 53 - Home Area Network

Small Scale Wind Farm

The three Xzeres Skystream 3.7 wind turbines have been installed in back of the campus, in an open field, where there is a greater wind resource. Each of the turbines produces a maximum power of 2.4kW which is a total of 7.2kW that is fed back into the campus energy grid. The wind turbines have a wireless communication data acquisition system that enables FSC to monitor and diagnose the turbines. The real time data is also gathered and stored on a local computer.



(a) Wind Turbines

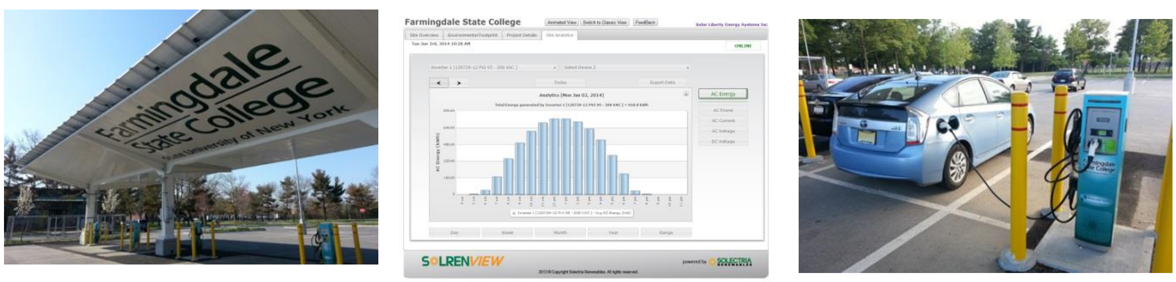
(b) Live Energy Monitoring

Figure 54 - Small Scale Wind Farm

Solar Carport and Electric Vehicle Charging Stations

The solar carport produces 94.08kW of solar energy from the 384 panels mounted on the canopy. Beneath the carport structure are 20 plug-in hybrid electric vehicle charging stations that are accessible to the campus community (faculty, staff and students). The charging stations are independent from the solar panels, and do not require sunlight to charge vehicles.

The solar energy fed into the campus grid can be monitored and displayed on the internet using the SolrenView website. On this website, the lifetime energy delivered, as well as other environmental footprint facts about the carport system can be viewed. Figure 55a and 55c are photos of the carport and charging stations. Figure 55b is an example a screenshot of the SolrenView website. This website is accessible through FSC's website, and can be viewed by the public. The data is also accessible to anyone who wishes to download it.



(a) Solar Carport

(b) Web-based Monitoring

(c) Plug-in Hybrid/Electric Vehicle Charging Station

Figure 55 - Solar Carport and Plug-in Hybrid/Electric Vehicle Charging Stations

PHEV Maintenance and Repair Lab

The PHEV lab has been constructed in Lupton Hall, and is equipped with the necessary tools and training equipment for working on electric vehicles. Figure 56 is a photo of the PHEV lab with our hybrid/electric vehicles.

Figure 56 - Left to Right: Toyota Prius, Nissan Leaf, Chevy Volt

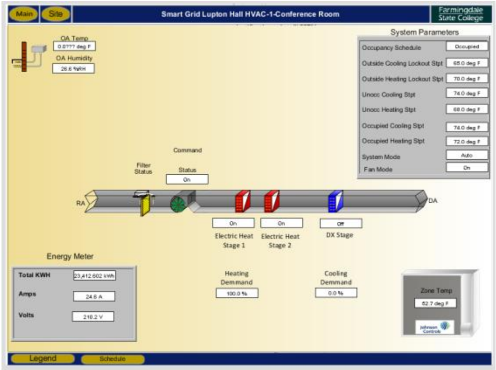
Commercial/Industrial Demonstration

The commercial/industrial demonstration space serves as the new main entrance to Lupton Hall. This demonstration space showcases the Johnson Controls Energy Management System, and is used to demonstrate how businesses can implement renewable energy, smart meters and building management systems into their facility. The demonstration space contains a smart meter provided by PSEG Long Island, an energy management system from Johnson Controls, Inc. (JCI) and a two floor "building inside of a building".

The commercial demonstration space has been separately metered so that FSC can view the energy consumption of the office space independent of the rest of the campus. The smart meter is on display within the building for demonstration purposes. We have also installed energy monitor equipment for the HVAC units on the roof and display the lifetime kWh. These energy monitors have been integrated into the JCI Metasys system, and can be monitored by Facilities Management. Figure 57a is a screenshot of the commercial/industrial HVAC system from the JCI Metasys system. Energy consumption and other parameters are easily viewable from a central point on campus.

The JCI Metasys system not only allows full control over the commercial/industrial demonstration space, but it also monitors and controls the entire campus. This campus wide system allows the administrator to view the status of the entire campus from a single workstation anywhere on campus.

The lobby has been used as a starting point for campus tours, and allowed FSC to display our renewable energy training equipment and related student projects.



(a) Johnson Controls Screenshot: HVAC Status and Energy Monitoring Screen

(b) Main Entrance

Figure 57 - Commercial/Industrial Demonstration

Renewable Energy Generation

RENEWABLE ENERGY RESOURCE	ENERGY DELIVERED	SYSTEM CAPACITY	COMMISSIONING DATE	DATE OF ENERGY READING
Solar Carport	195 MWh	94.08 kW	05/30/2013	03/30/2015
Small Scale Wind Turbine Farm	3.50 MWh	7.20 kW	09/06/2013	03/30/2015
Smart Energy House Solar Thermal	3.30 MWh	2.04 kW	02/04/2014	03/30/2015
Smart Energy House Solar PV	7.20 MWh	5.17 kW	05/18/2014	03/30/2015

Table 10 –Nenewable Energy Generation

OUTREACH

The College engaged in a strenuous outreach effort with a plethora of workshops, seminars, tours, and conferences for students, businesses, community, and energy professionals. Workshops covered Solar Photovoltaics, Solar Thermal, Plug-In Hybrid Electric Vehicles (PHEV), and Small Scale Wind. Seminars included the subject titles: “Introduction to Renewable Energy”, “Introduction to Smart Grid”, “Introduction to Green Data Centers”, ”Introduction to Smart Meters”, “Automotive Energy Technology”, “Energy Smart Campus Implementation”, “Production of Useful Cost Effective Energy for Waste Biomass Material”, and “PCB – Design for Manufacturability”. FSC hosted various tours for student and civic groups. The highlight each year was the annual International Energy and Sustainability Conference held in 2012, 2013, and 2014.

On November 10, 2014, Farmingdale State College provided a tour of its Smart Grid Demonstration Project to the Cologne University of Applied Sciences. The schools exchanged ideas and discussed ways to improve the smart grid and renewable energy demonstrations and curriculum on both of their campuses. FSC staff toured of the Institute of Power Engineering in Germany in January of 2015 at the invitation of Cologne University. A student exchange program is being established to give students from both schools the opportunity to study smart grid and renewable energy abroad. In addition, efforts are being made to conduct distance learning where faculty from the University of Applied Sciences will bring their knowledge to FSC students. A full report from FSC staff on their trip can be found in the Appendices section at the end of this report.

Summary of People Trained

TYPE OF EVENT	PEOPLE TRAINED
Workforce Training	145
Educational Seminars	259
Conferences	676
Community Outreach Tours	182
TOTAL TRAINED	**1262**

Table 11 – Number of People Trained

LESSONS LEARNED

Fuel Cell

There are a limited number of companies that have the experience and knowledge of how fuel cell systems and renewable energy projects should be designed. This affects how the project architects, electricians and professional engineers design the specs, and can result in project delays such as re-bids. More effort should be made in the area of education for contractors.

Small Scale Wind Workforce Training

There are currently only five North American Board of Certified Energy Practitioners (NABCEP) certified small wind installers. The NABCEP website states that they have suspended their certification program[2]:

"The Small Wind Installer Certification Program has been suspended…NABCEP administered the Small Wind Installer Certification from 2010 until 2012. As of 2012 the program is no longer open to new applicants; however, existing certificants may continue to renew their certification every three years by documenting continued education and experience in the field. Those individuals who maintain active Small Wind Installer Certification are listed below."

The lack of certified master trainers has made it difficult for FSC to find an instructor for our Small Scale Wind Workshop.

Workforce Training

Funding should be allocated for workforce training instructors in the startup phase of the program. These new types of workshops don't attract a large audience, and have low student counts. If the workshop relies on student tuition to fund the *current* workshop, then a lack of student interest means the workshop will not run. FSC has had to cancel numerous workshops for this reason. If there was "startup" money to subsidize these

[2] http://www.nabcep.org/certification/small-wind

workshops, instructor salaries could be funded even if there were only a few students registered for the workshop. Our primary source of advertising is through word of mouth, and if these workshops fail to run due to the lack of student enrollment, then the College reputation will become tarnished. This leads to another lesson learned, there should be budget allocation for advertising.

Advertising

We need a wider range of advertising in order to increase an interest in wind training. If we reach a larger range of people our workshops would run more frequently.

Wind Turbines

The most important part of planning a wind turbine installation is ensuring the process is understood from the start by all parties involved. Also, deciding a project's budget before other steps are completed should be avoided since complications arise when a project is determined primarily by budget. First, a preliminary study should be performed to provide an idea of which wind turbines are available on the market, and there should be an understanding of the mounting, foundation, and electrical work required. This will assist in the pitch to Physical Plant, and allow them to take the lead in finding the best possible locations for installation. Options can later be narrowed down after reviewing these potential locations with a wind turbine installer. The initial study mentioned above was completed; however, FSC's Physical Plant was not involved until a later phase of the project. Having Physical Plant involved from the start would have reduced complications during purchasing and installation.

The next step should be to do an environmental impact study as required by the National Environmental Policy Act (NEPA). However, for this project, this step was done after the budget and manufacturer was determined which wasted important time. This study can also be more general than what was submitted. It doesn't need to include the power requirements and manufacturer information. The study provides some important restrictions that will aide later in the purchasing process. For instance, the FAA will specify a maximum height restriction of a turbine. This plays a large role in the budget and manufacturer decision.

The budget should be decided upon following an environmental impact study, determination of an approved location for the wind turbines, learning the restrictions in pole height, manufacturer selection, and determination of any additional contractor work that needs to be done such as running conduit to the nearest electrical interconnection point, etc. Unfortunately, the budget for this project was determined prior to the environmental impact study.

In collaboration with Physical Plant, a realistic budget including the necessary prevailing wages and additional Davis Bacon requirements, and increase equipment cost projections for the next few years should be determined, and should be the final budget submitted in the proposal for funding.

As mentioned above, specifying the budget early on in the decision making process puts unnecessary restrictions on a project. Generally, a project will go out for bid under state contract, but due to the limited budget for this project, FSC was required to "shop around" for the lowest prices in fear that our bidding process would come in over budget. However, this led to further complications requiring FSC to find Minority and Woman Owned Enterprises (MWBEs) that were available to do this type of work.

Although we eventually found a company, they knew that they had to work within FSC's limited and unrealistic budget. As a result of the limited Physical Plant involvement and cooperation from the start, there were additional unexpected costs to the installer. Between the budget restrictions and additional costs, the installer's profit margin was decreased. This ultimately hindered the ongoing relationship between FSC and the installer, and resulted in their reluctance to work with FSC to solve additional complications with the wind turbine (from a manufacturer that went out of business during installation).

NEPA Summary

As mentioned above, in order for a wind turbine to be installed on a campus the following agencies need to be contacted and approval should be granted. This process is important and should be finished early in the planning process.

Federal Aviation Administration (FAA)
PROCESS
Check if the turbine is within the flight path of the nearby airport
Keep the turbine lower than a 100:1 height ratio from the airport
Provide the structure, location, latitude, longitude and height
Submit to FAA
RESULT
Determination of No Hazard to Air Navigation

United States Fish and Wildlife Service – Section 7 (USFWS Section 7)
PROCESS
Provide an explanation of the project with studies to back up the impact on fish and wildlife
RESULT
Determination of "No Effect"

New York Department of Transportation (NYDOT)
PROCESS
Complete FAA study
Provide the project location and results from the FAA to NYDOT
RESULT

No Objection

State Historic Preservation Office (SHPO)
PROCESS
Provide location, distance and visibility from any nearby state parks
RESULT
Letter of No Concern/No Effect

Local Support
PROCESS
Reach out to local township/agencies for support
RESULT
Citizens Campaign for the Environment wrote a support letter discussing the benefits of wind energy and the environmental and economic benefits to the local community

State Environmental Quality Review (SEQR)
PROCESS
The campus Physical Plant does a self-review and maintains all required documentation
RESULT
Approved

Table 12 - NEPA Results

CONCLUSION

The Long Island Smart Energy Corridor Project achieved its seven objectives. LIPA demonstrated and validated how Smart Grid technologies can reduce customer costs for electricity and decrease peak loads and system demand. Through the use of direct load control equipment and software, some LIPA customers can obtain information from the AMI meters and the utility or its agent to affect load curtailments remotely via the internet or on site at the thermostat. The installation of ASUs and PMHs showed how Smart Grid technologies enhanced reliability by reducing the frequency and duration of outages. The mobile data capture via iPad delivered further improvements in damage reporting and assessment shortening the response time and duration of the outage.

Farmingdale State College demonstrated how distributed generation can be integrated with Smart Grid technologies to reduce system demand and can defer utility investments if brought to scale. Stony Brook University assessed vulnerability of the communications path by conducting attacks on the AMI equipment and provided insights how cybersecurity can be strengthened. The University developed and demonstrated how AMI data can be used in load modeling, load forecasting, phase balancing, transformer load management, customer voltage assessment, and feeder optimization. It developed ways to present AMI data to customers to arrive at a deeper understanding of the drivers of their electricity usage. The University through dialogue with a provider of meter data management software is investigating the opportunity for commercialization of the visualization software tool.

The Smart Energy Corridor Project went well beyond DOE's goals for demonstration of Smart Grid technologies with 500 AMI meters. In total, 2,550 AMI meters were successfully installed and integrated into our business processes. The technologies deployed in distribution automation, substation automation, and AMI networks worked as expected in production and delivered on the promise of improved reliability. The Project experience yielded dividends for LIPA even before its completion. The progress and results of the Project gave LIPA confidence to fund and install 4,500 additional AMI meters in Fire Island as part of its restoration and system improvement in the aftermath of Superstorm Sandy.

Recently, PSEG Long Island, as LIPA's system operation agent, incorporated AMI expansion in its strategic and operation planning and in its rate case filing. The current Smart Grid Demonstration Project AMI infrastructure is expected to be expanded to cover the entire LIPA territory in 2015. The rate case filing, if approved, will add another 55,000 AMI meters to the LIPA system each year for 3 years. The successful demonstration of ASUs and PMHs has led LIPA to budget for the installation of 800 to 1,350 of these devices to improve reliability in the next 4 years. LIPA is also planning to install an additional 4 to 6 JMUX cables at its substations to duplicate the improved data flow rate and reliability achieved in the Demonstration Project. Leveraging the experience of using iPads to perform damage reporting and assessment, LIPA will be expanding this innovative technology to iPhones and other devices with connectivity to its new CGI Outage Management System. While Superstorm Sandy devastated Long Island and caused significant delays many project tasks, it also provided a rare and valuable window to learn that operations, restoration, and training will need to be modified to accommodate AMI meters and related technologies. This will help LIPA and its customers in the long run.

The research at Stony Brook University gave LIPA a better understanding of how to make its delivery system more efficient from a planning and operations perspective. The cybersecurity research gave LIPA a good understanding of the technology's current defenses against attacks and of the need for continued vigilance. Stony Brook University applied for a patent on its forecasting methodology and obtained a trademark on the Energy Scout software as well as pursuing its commercialization through discussions with vendors in the meter data management space.

Through Farmingdale State College and Stony Brook University, the project's education and community outreach touched a widespread audience to further the utility and the public understanding and acceptance of Smart Grid technologies and their benefits. More importantly, the Long Island Smart Energy Corridor Project afforded these teaching institutions and LIPA the opportunity to invigorate interest from students, teachers, researchers, technicians, businesses, and residents in smart grid and renewable technologies to achieve energy efficiency and a greener planet.

Overall, this project is a success and has provided a lasting and beneficial impact on Long Island. LIPA, Farmingdale State College, and Stony Brook University thank the Department of Energy for its guidance, sponsorship, and support of this project.

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APPENDICES

APPENDIX A: MILESTONES

Milestone Number	Org	Task	Milestone Title	Milestone Status	Milestone Planned Finish	Milestone Actual Finish Date
1			Prelim. Design and NEPA Review Complete	Complete	10/29/2010	12/31/2010
2			Finalize and Submit Interop & Cyber Security Plan	Complete	11/29/2010	12/20/2010
3	LIPA	4.1	Finalize and Submit Metrics and Benefits Reporting Plan	Complete	03/15/2011	03/15/2011
4	LIPA	2.7	All Retrofit Materials Ordered (Phased)	Complete	10/04/2011	09/30/2011
5	LIPA	2.7	Place order for RTUs (long lead item)	Complete	04/21/2011	04/19/2011
6	LIPA	2.7	RTU Retrofits Complete	Complete	04/15/2012	05/11/2012
7	LIPA	2.8	Order of Capacitor Controllers \Complete	Complete	10/18/2011	03/31/2012
8	LIPA	2.8	Controllers Tested and Received at sites	Complete	03/02/2012	10/02/2012
9	LIPA	2.8	Installation of 51 Controllers Complete	Complete	05/31/2013	07/24/2013
10	LIPA	2.8	PMH/ASU Order Complete	Complete	01/21/2011	01/24/2011
11	LIPA	2.8	PMH/ASUs Received	Complete	07/25/2011	07/29/2011
12	LIPA	2.8	Installation of Supervisory Control Smart Switches Complete	Complete	10/18/2012	12/29/2011 02/04/2013
13	LIPA	2.9	Installation of residential HAN/IHD Devices Complete	Complete[1]	05/31/2013	02/01/2015
14	LIPA	2.1	Communications Interface Integration Complete	Complete	09/18/2012	01/23/2013
15	LIPA	2.15	OMS Hardware/Software Ordered	Complete	05/06/2011	08/26/2011
16	LIPA	2.15	OMS Hardware/Software Received	Complete	08/01/2011	10/28/2011
17	LIPA	2.15	Interfaces between AMI, MDMS and new LIPA OMS complete	Complete	05/01/2014	09/30/2014
18	LIPA	2.6	Field Inventory Control System in place	Removed	Removed	Removed
19	LIPA	2.6	Order AMI Meters for first 1836 installations	Complete	08/11/2011	12/07/2011
20	LIPA	2.6	Receipt of AMI Meters for 1836 installations	Complete	12/15/2011	12/19/2011
21	LIPA	2.6	1836 AMI Meters Installed	Complete	05/31/2012	08/31/2012
22	LIPA	2.6	Automated Billing for residential AMI customers	Complete	05/31/2013	05/31/2013
23	LIPA	2.6	Installation of web tools for AMI Customers	Complete	05/31/2013	05/31/2013
24	LIPA	2.6	Select AMI Customers	Complete	02/21/2012	12/01/2011
25	LIPA	2.4	AMI Marketing	Complete	12/03/2013	02/01/2015
26	SBU	3.1	Completion of Smart Grid Testing/Validation Node with associated testing protocols	Complete	08/02/2011	08/05/2011
27	SBU	3.1	Completion of Virtual Smart Grid Infrastructure facility with associated testing protocols	Complete	07/01/2011	08/05/2011
28	SBU	3.1	Delivery of report on technical controls to prevent/contain/foil cyber attacks	Complete	11/01/2013	02/01/2015
29	SBU	3.1	Report: Security Test Results	Complete	11/01/2013	02/01/2015
30	SBU	3.1	Report: NIST-Consistent Guidelines, Criteria and Test Suite	Complete	10/28/2014	02/01/2015
31	SBU	3.3	Software for Feeder Load and Reactive Modeling	Complete	07/30/2012	08/27/2012
32	SBU	3.3	Decision Support Software for Optimization Modeling	Complete	04/30/2013	02/01/2015
33	FSC	2.13	Complete Installation of Solar PV Parking Lot and PHEV Charging	Complete	03/14/2013	08/31/2013
34	FSC	2.13	Complete Installation of Residential Systems	Complete	07/15/2013	02/01/2015
35	FSC	2.13	Complete Installation of Wind Turbines	Complete	05/31/2013	09/30/2013
36	FSC	2.13	Campus-wide energy management system installed	Complete		02/01/2013
37	FSC	2.13	Smart louvers installation and integration complete (Commercial Demonstration)	Complete	05/31/2013	10/30/2013
38	FSC	2.13	Commercial demonstration model	Complete	05/31/2013	03/31/2014
39	FSC	2.13	Installation and integration of distributed energy (solar and fuel cell) to residential demonstration unit complete	Complete[2]	07/15/2013	02/01/2015
40	FSC	2.13	Installation of solar thermal hot water equipment	Complete	07/15/2013	03/31/2014
41	FSC	2.13	Residential demonstration model complete	Complete	07/15/2013	02/01/2015
42	LIPA	2.6	Installation of 400 of the additional 500 AMI meters complete (additional work approved in March 2012, with revision in July 2012 to focus on commercial meters)	Complete	05/01/2013	05/01/2013
43	LIPA	2.6	Installation of last 100 of the additional 500 AMI meters complete (additional work approved in March 2012, with revision in July 2012 to focus on commercial meters)	Complete	09/01/2013	08/13/2013
44	LIPA	2.6	Automated Billing for commercial AMI customers	Complete	11/30/2013	11/30/2013
45	LIPA	2.7	Installation of solar PV at Ruland Road, State School and Farmingdale substations	Removed	Removed	Removed
46	LIPA	2.6	Customer automation solutions in place for selected commercial/residential customers	Complete	04/01/2014	02/01/2015
47	LIPA	2.6	Upgrade, integration, and testing of AMI software and related system to enable latest functionalities including AMI over cellular	Complete[3]	12/31/2013	02/01/2015
48	LIPA	2.6	Mobile Application for AMI complete	Complete	12/31/2013	02/01/2015

49	LIPA	2.6	New Residential Time of Use Rate in place	Complete	05/31/2013	05/31/2013
50	FSC	2.13	Smart louvers installation and integration complete (Residential Demonstration)	Complete	07/15/2013	03/31/2014
51	FSC	2.12	Campus-wide energy management system integrated with Commercial Demonstration	Complete	05/31/2013	03/31/2014

1 - Due to privacy concerns from customer feedback and operational concerns relating to provisioning devices, LIPA did not deploy a configuration where the meter served as the communications path to the utility for data and control. Our implemented configuration included data collection and control through an installed "gateway" that interfaced with the home devices via ZigBee. The gateway utilized an internet connection to communicate with the

2 - The solar installation is completed and operational. Farmingdale State College did not receive contractor interest in the first bidding process for the installation of the hydrogen fuel cell and associated energy storage. After the second RFP, the lone bidder later withdrew. Farmingdale is in the process of a third RFP attempt and is pursuing installation outside this project.

3 - AMI software has been upgraded, integrated, and tested. The AMI technology provider, Landis + Gyr is still working on communications over common carrier for hard to reach segment.

APPENDIX B: FSC OUTREACH

Workshops

SOLAR PHOTOVOLTAICS

The workshop introduces the fundamental concepts in Photovoltaic technology. It provides training in the design, installation and maintenance of grid connected residential photovoltaic systems. The course is developed based on Task Analysis of NABCEP. Topics covered include:

- Overview of PV Systems
- Sunshine basics
- How PV works
- Components of a PV systems
- Setup, configuration and sizing
- Wiring and controls
- Relevant sections of NEC
- Zoning laws and building codes pertaining to PV systems
- Interconnection requirements in New York State
- Specific parameters of concern to utilities in grid connected systems
- Practical experiments and demonstrations of different aspects of PV
- Site visit with detailed explanation of maintenance and troubleshooting
- Actual hands on set-up of a small scale grid connected system

In addition, basic electrical concepts and safety issues related to PV installation and maintenance work will be covered. It is a 6-day, 48-hour training course that includes extensive hands-on experience and real world applications. The first day provides an introduction to basic electricity and PV concepts and it is optional for engineers and licensed electricians. Students are eligible to take the NABCEP Entry Level PV Exam after completing this course.

The Solar Energy Center at Farmingdale State College is accredited as a training institution and continuing education institution on solar energy by the Institute of Sustainable Power. This is the first such center to be accredited in the Northeast and the fourth in the entire USA. The center promotes education, applied research, training and public awareness in sustainable energy and in particular solar energy. Farmingdale State College is the site of the first utility scale photovoltaic demonstration project in the Northeast U.S. Three 20 kW units and one 20 kW unit were installed at various locations on campus in 1992 and 1993 respectively.

DATE	PEOPLE TRAINED
02/07/2011 – 02/11/2011	19
01/16/2012 – 01/20/2012	8
09/17/2012 – 09/22/2012	8
06/08/2013 – 06/21/2013	13
09/23/2013 – 09/28/2013	11
05/05/2014 – 05/10/2014	15
09/15/2014 – 09/20/2014	9

SOLAR THERMO

The workshop introduces the concept and the necessary background in solar thermal technology. It provides training in design, installation and maintenance of residential Solar Hot Water systems. The workshop is designed for installers new to solar thermal technology. It is a 5-day training course that includes extensive hands-on and real world applications. The selected topics are listed below.

- System components and their functions
- Drainback systems
- Active indirect pressurized glycol antifreeze systems
- Solar thermal collectors
- Solar hot water savings and performance estimates
- Active direct open-loop systems
- System controls, monitoring, testing and troubleshooting
- Site surveying and collector orientation
- Solar pool heating

DATE	PEOPLE TRAINED
10/01/2012 – 10/05/2012	11

PLUG-IN HYBRID VEHICLE

The intermediate plug-in hybrid electric vehicle (PHEV) course provides an introduction to hybrid engine technology. This course is a part of series of courses for PHEV training. The suggested targets for this course are professional auto workers.

The concept of hybrid technology along with its history will be discussed. A brief explanation on air standard thermodynamic cycles will be included. The definition of efficiency and advantages and disadvantages of using hybrid technology will be highlighted. Different designs of hybrid electric vehicles will be analyzed. This course also covers the safety and maintenance procedures of hybrid vehicles. The selected topics are listed below:

- Concept of hybrid
- Introduction to thermodynamic
- Power cycles
- Environmental impact
- Power sources
- Efficiency
- Electrical machines
- Energy storage
- Design of HEV
- Maintenance and service
- Equipment and tools
- Safety

DATE	PEOPLE TRAINED
10/09/2011 – 12/14/2011	4
02/28/2012 – 04/25/2012	19
07/06/2012 – 09/24/2012	13
12/10/2012 – 02/12/2013	13

SMALL SCALE WIND

This workshop introduces the fundamental concepts of small scale wind technology. It is a 3-day training course that covers the design and maintenance of small scale wind systems and the following topics are discussed:

- Turbines and their Components
- Wind & Geographic Conditions
- Assessing Wind Sites
- Town Codes
- Rebates & Financial Assessment
- Installation
- Monitoring & Maintenance
- Risks and Mitigation

DATE	PEOPLE TRAINED
01/28/2015 – 01/30/2015	2

Seminars

INTRODUCTION TO RENEWABLE ENERGY

This seminar is designed for individuals desiring to enhance their knowledge and understanding of energy resources. It offers insight into the latest in technological advancements in a way that is easy to understand. It will address sustainability, renewable energy and associated technologies. Prior knowledge in this area is not required.

Topics for this seminar include but are not limited to, the following:

- Solar Thermal
- Wind Turbine Technology
- Solar PV
- Fuel Cell Technology
- Plug-in Hybrid Electric Vehicle Technology

DATE	PEOPLE TRAINED
12/06/2013	60

INTRODUCTION TO SMART GRID

Topics for this seminar cover subjects in power & energy engineering, including but not limited to the following topics:

- Smart Grid Clarifications
- Smart Grid Defined
- Areas affected by Smart Grid
- Smart Grid and the Future of Electric supply and demand operation
- Key Drivers of Smart Grid

DATE	PEOPLE TRAINED
12/10/2013	60

INTRODUCTION TO GREEN DATA CENTERS

Topics for this seminar cover subjects in power & energy engineering, including but not limited to the following topics:

- Introduction to data centers and their energy consumption
- Trends and issues of data centers
- Approaches to green data centers

DATE	PEOPLE TRAINED
03/19/2014	22

INTRODUCTION TO SMART METERS

This seminar cover subjects in power & energy engineering and is designed for home owners as well as individuals working for power companies. It will highlight the fundamental concepts of smart meter technology along with their features. The talk will also touch upon the privacy and security issues related to smart meters.

DATE	PEOPLE TRAINED
04/23/2014	28

AUTOMOTIVE ENERGY TECHNOLOGY

Outline:

- Current vehicle fuels, breathing, power and efficiency and economics.
  - Gas
  - Gas turbo
  - Gas direct injection
  - Gas Direct injection Turbo
  - Diesel
  - Diesel Turbo
  - Hybrid – how it gains power and efficiency. Economics
- Current plug in all electric vehicles and power efficiency and economics.
- Hydrogen Fuel cell
- Effects of traffic congestion on performance
- Other
- How each of the major players is doing since the financial crash and major reorganization.
- Other costs of each type of vehicle
  - Politics of oil and costs involved...
  - Health costs
  - Future costs of non-renewable energy and materials and rare elements.
  - Traffic congestion
  - Global warming
  - You pays now or you pays later
- Highways and roads:
  - Lack of maintenance
  - Lack of reengineering – modernization
  - Safety planning
  - Need for intelligent planning
  - Traffic congestion

- Need for efficiency and safety
- Cost to improve and cost not to improve

DATE	PEOPLE TRAINED
06/20/2014	13

ENERGY SMART CAMPUS IMPLEMENTATION

Topics for this seminar cover subjects in power & energy engineering. The campus demonstration facilities that are discussed are listed below and a tour of these facilities will be provided following the presentation.

- 95kW Solar Carport with Electric Vehicle Charging Stations
- 7.2kW Small Scale Wind Farm
- PHEV Maintenance and Repair Lab
- Commercial/Industrial Demonstration Facility
- Smart Energy Home (5kW Solar PV, 2kW Solar Thermal, Smart Louvers, EV Charging Station, Home Area Network)

DATE	PEOPLE TRAINED
08/27/2014	20

PRODUCTION OF USEFUL COST EFFECTIVE ENERGY FROM WASTE BIOMASS MATERIAL

Recent concerns over the security and reliability of the world's energy supply has caused a flux towards the research and development of renewable sources. A leading renewable source has been found in the biomass gasification of biological materials derived from organic matters such as wood chips, forest debris, and farm waste that are found in abundance in the USA. There is a very strong interest worldwide in the development of technologies that allow the coupling of biomass gasification and hydrogen fuel cell systems to produce high-energy efficiency, clean environmental performance and near-zero greenhouse gas emissions. Biomass gasification is a process which produces synthesis gas (syngas) that contains 19% hydrogen and 20% carbon monoxide from organic matter.

In order to efficiently produce hydrogen from biomass that is capable of energizing the Proton Exchange Membrane (PEM) fuel cell to generate combined heat and power, ultraclean hydrogen with carbon monoxide (CO) content less than 10 parts per million (ppm) must be fed to the PEM fuel cell to prevent the poisoning of its platinum catalyst.

Therefore, this paper/presentation is designed to shed some lights on various methods and current techniques used for the cleanup and purification of hydrogen produced by gasification.

DATE	PEOPLE TRAINED
09/24/2014	11

PCB DESIGN FOR MANUFACTURABILITY

The seminar will cover areas of interest to electrical engineers, mechanical designers and PCB board designers:

- General Fabrication requirements
- Stack-up generation for impedance(s)
- Fabrication notes and call outs
- Design Rule Checks for manufacturing
- Discussion on design for manufacturability

These topics are presented as ways to reduce delays, and to improve communications between design, manufacturing, and assembly.

DATE	PEOPLE TRAINED
11/13/2014	45

Tours

EVENT	PEOPLE TRAINED	DATE
Long Island High School Guidance Counselors	37	05/30/2014
IESC Advisory Board Meeting	12	06/12/2014
Suffolk County Community College Counselors	10	06/19/2014
Sustainability Workshop for High School Teachers - Molloy Sustainability Institute	29	07/07/2014
Hempstead 3rd to 8th Grade Students and Counselors	40	07/09/2014
Microcontroller Class	8	07/10/2014
SUNY ESF	11	07/21/2014
Proton OnSite	1	07/28/2014
President and Chief Operating Officer of PSEG Long Island - David Daly	2	09/24/2014
PSEG Long Island & NYS Department of Public Services	24	10/07/2014
Cologne University of Applied Sciences – Institute of Electric Power Engineering	5	11/10/2014
Suffolk County Legislature	3	12/16/2014
TOTAL TRAINED	**182**	**02/17/2015**

Conferences

IESC2012

The International Energy and Sustainability Conference 2012, "Shaping the Future Through Smart Grid Technologies" was a two day conference including keynote speakers, paper presenters and a poster session. Paper presenters were given the option of having their paper published in the IEEE Xplore® provided their paper met the IEEE manuscript requirements. The conference had 8 partners, 28 exhibitors and over 60 speakers.

DATE	PEOPLE TRAINED
03/22/2012 – 03/23/2012	145

IESC2013

The International Energy and Sustainability Conference 2013, "Renewables in Smart Grid Technology for a Sustainable Future" was a one day conference including keynote speakers, paper presenters and a poster session. The poster session was changed from the day of the conference to the day before and had over 20 posters including Graduate, Undergraduate and High School students.

Paper presenters were given the option of having their paper published in the IEEE Xplore® provided their paper met the IEEE manuscript requirements. The conference had 11 partners, 29 exhibitors and over 40 speakers. An exhibitor track with over 20 companies was added that allowed them to discuss their products in a more commercial setting. The other tracks were strictly educational.

DATE	PEOPLE TRAINED
03/22/2013	213

IESC2014

The International Energy and Sustainability Conference 2014, "Renewables in Smart Grid Technology for a Sustainable Future" was a one day conference including keynote speakers, paper presenters and a poster session. The poster session was changed from the day of the conference to the day before and had over 20 posters including Graduate, Undergraduate and High School students.

Paper presenters were given the option of having their paper published in the IEEE Xplore® provided their paper met the IEEE manuscript requirements. The conference had 11 partners, 29 exhibitors and over 40 speakers. An exhibitor track with over 20 companies was added that allowed them to discuss their products in a more commercial setting. The other tracks were strictly educational.

DATE	PEOPLE TRAINED
10/23/2014 – 10/24/2014	318

APPENDIX C: SBU CURRICULUM DEVELOPMENT

Stony Brook University Faculty team enhanced and developed new credit curriculum and delivered non-credit seminars on topics related to their research in smart grid as it related to the demonstration project**.**

Faculty members represented in this report include:

Eugene A. Feinberg
Distinguished Professor
Department of Applied Mathematics and Statistics
Eugene A. Feinberg received his Ph.D. in Mathematics, 1979 from Vilnius University, Lithuania.
The epitomic example is his work with the Long Island Power Authority in helping to develop smart electric grids - essentially, an electric power delivery network with sufficient embedded sensors plus an optimal control strategy that enables power managers to successfully handle electric load forecasting. Dr. Feinberg's groundbreaking work has appeared in over 130 articles in journals and conference proceedings; he has served as an NSF panelist for grant reviews, and was elected as a fellow to the Institute for Operations Research and Management Sciences (INFORMS).

Dr. Eugene A. Feinberg is Distinguished Professor at the State University of New York with the appointment in the Department of Applied Mathematics and Statistics of Stony Brook University. His research interests include stochastic models of operations research, Markov Decision Processes, and industrial applications of Operations Research and Statistics. Since 1999, he has been working on electric energy applications. He has published more than 150 papers and edited the Handbook on Markov Decision Processes. His research is partially supported by several federal and state agencies including the National Science Foundation, Department of Energy, Office of Naval Research, NYSERDA, and by industry including Long Island Power Authority, New York Power Authority, and NYISO. He is currently a leading scientist and Stony Brook Project Director on the Long Island Smart Energy Corridor project awarded by the US Department of Energy (DOE) to the Long Island Power Authority and two universities as a part of the US Smart Grid Demonstration Initiative. He is a member of several editorial boards including Mathematics of Operations Research, Operations Research Letters, and Applied Mathematics Letters.

He has been awarded Honorary Doctorate from the Institute of Applied System Analysis, National Technical University of Ukraine. Dr. Feinberg is a Fellow of INFORMS (The Institute for Operations Research and Management Sciences) and he is a recipient of 2012 IEEE Charles Hirsh Award "For developing and implementing on Long Island, electric load forecasting methods and smart grid technologies." He is also a recipient of 2012 IBM Faculty Award.

Samir R Das
Professor, Computer Science Department
Director, Network Technologies Division, CEWIT

Samir R. Das is currently a Professor in the Computer Science Department at Stony Brook University, State University of New York (SUNY). He also serves as the Director of the Networking Technologies Division in CEWIT, the New York State Center of Excellence on Wireless and Information Technology. Samir Das received his Ph.D. in Computer Science from Georgia Institute of Technology, Atlanta, in 1994. His research interests are in wireless networking and mobile computing, focusing on protocols, systems and performance evaluation. He received the U.S. National Science Foundation's CAREER award in 1998 and the best paper award in ACM MobiSys conference in 2007. He has been a speaker in the Distinguished Visitor program of the IEEE Computer Society during 2001-03. He co-chaired the technical program committees for the ACM MobiHoc Symposium in 2001 and ACM MobiCom Conference in 2004. He has served on the editorial boards of major journals including IEEE/ACM Transactions on Networking, IEEE Transactions on Mobile Computing, ACM/Springer Wireless Networks Journal and Ad Hoc Networks journal.

Arie E. Kaufman

Distinguished Professor & Chair
Computer Science Department
Chief Scientist, CEWIT
the Director of the Center of Visual Computing (CVC), the Chief Scientist of the Center of Excellence in Wireless and Information Technology (CEWIT), and a Distinguished Professor of Radiology at the State University of New York at Stony Brook University. He joined the faculty at SBU in 1985 and was appointed Chair in 1999.

Kaufman was internationally recognized for his contributions to information technology and specifically to visualization and graphics. Kaufman has conducted research for over 40 years in visualization, graphics, virtual reality, user interfaces, multimedia, and their applications, especially in biomedicine. He has published extensively totaling in excess of 300 refereed papers, books, and book chapters, more than 250 conference presentations and non-refereed manuscripts, and has been awarded/filed more than 40 patents, most of which have been licensed. He has been a principal/co-principal investigator on more than 100 research grants. His work has been featured in numerous media communications, including *Science, New York Times, U.S. News & World Report, Business Week, Wall Street Journal, Saturday Evening Post, PC Week, Good Morning America, Fox TV* and *Newsday*.

Rob Johnson

Assistant Professor, Computer Science Department

Rob conducts research in Software Security, System Security, Usable Security, Cryptography, and Big Data Algorithms. Rob is director of the Security, Privacy, And Theory (SPLAT) lab at Stony Brook, the Cryptography Lab at the New York Center for Excellence in Wireless and Information Technology (CEWIT), and the Smart Grid Cyber-security Testing Lab of the New York Advanced Energy Research and Technology Center (AERTC). Rob Johnson received his Ph.D. in Computer Science from University of California, Berkeley.

Erez Zadok
Associate Professor, Computer Science Department, Stony Brook University
Email: ezk@cs.stonybrook.edu
Eb: http://www.cs.stonybrook.edu/~ezk
Research focuses on storage systems and file systems. Zadok investigates those systems from various dimensions: security, performance, convenience, scalability, ease-of-use, energy efficiency, and more. Zadok's projects and research often led to software releases used worldwide: Unionfs, am-utils, and fistgen, among others. Zadok is the author of "Linux NFS and Automounter Administration" (Sybex, 2001). Dr. Zadok earned his PhD from Columbia University and serves on the faculty of Stony Brook University.

Jun Fei Jun.Fei@StonyBrook.Edu
Research Scientist, Depart of Applied Mathematics & Statistics
Jun Fei conducts research at Stony Brook University in stochastic modeling and its application, electric power system and smart grid, and integration of smart grid technologies. Jun is the managing director of the Smart Grid Lab at the Advanced Energy Research and Technology Center (AERTC).

Klaus Mueller, PhD
Professor of Computer Science
Stony Brook University (State University of New York)
Vice President, Academic Affairs and Finance
Chair, Computer Science Department
State University of New York, Korea Campus (SUNY Korea)
mueller@cs.stonybrook.edu | http://www.cs.stonybrook.edu/~mueller

Klaus has a B.S. in Electrical Engineering from the Polytechnic University of Ulm, Germany, and an M.S. in Biomedical Engineering and a Ph.D. in Computer Science, both from The Ohio State University. Apart from his appointment at the Computer Science Department at Stony Brook University, he also holds adjunct faculty positions at the Biomedical Engineering Department and the Radiology Department, and he is an adjunct scientist at the Computational Science Center at Brookhaven National Laboratory. His research is sponsored by NSF (including the Career award in 2001), NIH, DOE, DHS, and private industry and research labs.

Klaus Mueller's research and publications group into these general areas: Medical imaging, Volume visualization, Filters and grids, Computer graphics: color, texture, details, points, Simulation of natural phenomena and urban security applications, General purpose computing on programmable graphics hardware (GPGPU), Visual analytics, visual data mining and information visualization, Face recognition

Credit courses developed and enhanced

AMS 691 Topics in Applied Mathematics: Smart Grid Modeling

Instructor: Eugene Feinberg

Course overview

Smart Grid is an emerging technological concept in energy whose importance some experts compare to the Internet. There has not been a uniform definition of Smart Grid, but what is commonly agreed is that a Smart Grid is a future generation of electric power grids that will use digital technology and two-way communication to deliver electricity to consumers. Using digital technology helps the grid to operate more efficiently and also helps consumers to save energy and costs while reliability of the grid is increased. Smart grids are considered to be "green technology" and are more environmentally friendly although often more prone to cyber-attacks. According to the US department of Energy (*The Smart Grid: An Introduction*), Smart Grids apply technologies, tools and techniques available now to bring knowledge to power – knowledge capable of making the grid work far more efficiently. One of the reasons for the efficiency and reliability improvements is that significant amounts of information on various conditions of the grid will be automatically monitored, transmitted, timely processed by using mathematical methods, and utilized in control decisions.

A Smart Grid is expected to have the following advantages over the traditional power grid:

(1). Ensuring its reliability to degrees never before possible.

(2). Maintaining its affordability.

(3). Reinforcing our global competitiveness.

(4). Fully accommodating renewable and traditional energy sources.

(5). Potentially reducing greenhouse gas emissions.

(6). Introducing advancements and efficiencies yet to be envisioned.

Partnering with LIPA (the Long Island Power Authority) and SUNY Farmingdale, Stony Brook University participates in the Smart Energy Corridor development and demonstration project along the Route 110 corridor on Long Island. The project, funded by the Department of Energy, demonstrates the integration of a suite of Smart Grid technologies on distribution and consumer systems, such as smart meters, distribution automation, distributed energy resources, and renewable generation. The project also includes testing cyber-security systems, identifying optimal combinations of features to encourage consumer participation, and educating the public about the tools and techniques available with the Smart Grid.

As part of the Smart Grid initiative at the university, we offer this introductory research-oriented course on Smart Grid modeling, analysis and optimization. The course will include, but not limited to, the following topics:

Overview of generic electric power system: structure, operation, and models

- Overview of Smart Grid: elements, functions, and distinction from the traditional grid
- Electric power system models: concepts, generation, transmission system, distribution system, load models, and power flow
- Optimal generation models: unit commitment problem, via mixed integer programming, Lagrangian relaxation, dynamic programming and genetic algorithm
- Self-healing from power disturbances: load reduction, load transfer, fault detection and location, via pattern recognition, statistical learning, artificial neural networks, and wave form analysis
- Power markets, demand-side management via electric load/price forecasting: regression, time series, artificial neural network and other artificial intelligence based methods
- Reliability, efficiency and power quality in the Smart Grid: quantification and control
- Integration of renewal energy generation and environmental impacts

Ari Kaufman

Course: CSE654: Visualization (Grad course, enhanced, 10 students per semester)
- Existing seminar. Taught every year
- About three weeks of the semester
- Topics: User interface for smart grid customers. Energy consumption visualization. Ambient visualization of energy use.

Course: CSE648: Graphic (Grad course, enhanced, 10 students per semester)
- Existing seminar. Taught every year
- About two weeks of the semester
- Topics: User interface for smart grid customers. Ambient display of energy use. Energy consumption display.

EREZ Zadok
Areas addressed: remote/local file/data security.

Course: CSE506: Operating Systems (Grad course, enhanced)
- Existing course; taught several times in past five years
- About two weeks of the semester
- Topic: Local storage file/data kernel encryption techniques; network storage security (servers/clouds).

Course: CSE376: Advanced Systems Programming in Unix/C (Undergrad and Grad course, enhanced)

- Existing course; taught several times in past five years
- About two weeks of the semester
- Topic: Local storage file/data user-level encryption tools and techniques; remote/secure authentication systems.

Course: CSE595: Special Topics: Storage Systems (Grad course, enhanced)

- Special topics course, taught irregularly; twice in past 5 years
- Three weeks out of the semester
- Topic: Local/remote secure storage, data encryption and integrity.

Both CSE 570 and CSE 370 are existing courses that have been enhanced.

Course: CSE570: Wireless and Mobile Networking (Grad course, enhanced)

- Offered every fall, existing course
- 4 weeks out of the semester
- Typical enrollment: 40-60 students
- Topics relevant to SGDP: multiple access protocols, wireless ad hoc/mesh networks, ad hoc/mesh network routing, unlicensed vs licensed spectra, white space and lightly licensed spectra, sensor networks

Course: CSE370 Wireless and Mobile Networking (Undergrad course, enhanced)

- Offered occasionally in spring, existing course
- 4 weeks out of the semester
- typical enrollment: 15-30 students
- Topics relevant to SGDP: multiple access protocols, wireless ad hoc/mesh networks, ad hoc/mesh network routing, unlicensed vs licensed spectra, white space and lightly licensed spectra, sensor networks

Rob Johnson

Course: CSE 509-System Security (Grad course, enhanced)

Fall 2010

Methods and tools for writing secure software (e.g. Avoiding buffer overflows, format string bugs, SQL injection bugs, etc.)

Course: CSE409- System Security (Undergrad course, enhanced)

Fall 2011

Methods and tools for writing secure software (e.g. Avoiding buffer overflows, format string bugs, SQL injection bugs, etc.)

SMART GRID ENERGY SEMINARS: NON /CREDIT

2014 OUTCOMES

Sept 23 - Smart Grid Optimization, 7 attended - 5 industry, 2 Stony Brook emails

Oct 21 - Wireless Networking, 4 attended - 3 industry, 1 stony brook email

June 4 - Smart Grid Modeling - 4 attended out of 9 registered, all 4 from industry

All the other workshops had three or less register, so were rescheduled, re-marketed, and not held.

SECURITY ISSUES IN THE SMART GRID
May 29, 2014 9:30 a.m.—11:30 a.m.
Facilitator: Rob Johnson, Ph.D.
This workshop focuses on high-level security issues that smart grid software and devices must manage, including cryptography, key management, secure software development, and security updates. The focus is on software developers and project managers facing these issues for the first time. *For Project Managers, Software Developers for Smart Grid Devices, and those dealing with Security Software.*
http://www.stonybrook.edu/commcms/cet/courses/energy_management/SmartEnergySeminars.html

EDUCATE AND INCENTIVIZE CONSUMERS TO SAVE ENERGY
May 7, 2014 9:00 a.m.—12:00 p.m.
Facilitator: Klaus Mueller, Ph.D.
This three-hour extended seminar will educate attendees about the important role that data presentation plays in educating users on their energy usage, helping to change habits for a greener and leaner future. Topics include fundamentals of human-computer interaction and data visualization, iterative user interface design and visual design principles; and the use of game-like incentives to change behavior. *For consumers, energy conscience individuals, those interested in saving energy.*
http://www.stonybrook.edu/commcms/cet/courses/energy_management/SmartEnergySeminars.html

SMART GRID AND SMART GRID MODELING
June 4, 2014 12:30 p.m.—2:30 p.m.
Facilitator: Jun Fei, Ph.D.
This workshop highlights the traditional power grid and its limitations, and outlines features of the smart grid, including key technologies, Advanced Metering Infrastructure (AMI), and load modeling and forecasting. *For the general public, students who are interested to enter the utility power career path, and utility power professionals.*
http://www.stonybrook.edu/commcms/cet/courses/energy_management/SmartEnergySeminars.html

WIRELESS NETWORKING FOR SMART GRID
June 5, 2014 8:30 a.m.—10:30 p.m.
Facilitator: Samir Das, Ph.D.
This workshop focuses on enlightening the augmentation and extending the mobile and wireless network offerings to support smart energy grid innovative thinking. *For students interested in Smart Grid Wireless Networking procedure and information, and business owners and any manager/executive/individual seeking better understanding of this topic.*

http://www.stonybrook.edu/commcms/cet/courses/energy_management/SmartEnergySeminars.html

FALL 2014

SMART GRID OPTIMIZATION (2 PDHs*)

September 23, 2014 12:30 p.m.—2:30 p.m.
Presenter: Jun Fei, Ph.D.
This workshop focuses on AMI based load modeling, optimal generation, optimal transmission, optimal distribution and delivery, optimal planning and operation, and computational challenges and research opportunities.

VISUALIZATION OF SMART METER DATA (3 PDHs*)
September 30, 2014 9:00 a.m.—12:00 p.m.
Presenter: Klaus Mueller, Ph.D.
Attendees will learn how interactive visualization can reinforce and amplify human cognition of abstract data and information. The course will first give some background on human visual perception and then demonstrate the power *of* visualization via some examples of practical systems. As a specific example on the visual analytics of smart meter data we will present our Energy Scout system.

BUSINESS OPPORTUNITIES IN SMART GRID SECURITY (2 PDHs*)
October 7, 2014 9:00—11:00 am
Presenter: Rob Johnson, Ph.D.
Smart grid security concerns will create several new business opportunities. Power companies will need devices to detect intrusions in their networks, and will need software/hardware solutions for managing cryptographic keys on a large scale. End-users will need tools to manage the security of their Zigbee-based in-home appliance networks, and easy-to-use authentication for controlling access to their in-home networks.

WIRELESS NETWORKING FOR SMART GRID (2 PDHs*)
October 21, 2014 8:30 a.m.—10:30 a.m.
Presenter: Samir Das, Ph.D.
This workshop focuses on enlightening the augmentation and extending the mobile and wireless network offerings to support smart energy grid innovative thinking. For students interested in Smart Grid Wireless Networking procedure and information, and business owners and any manager/executive/individual.

Lessons learned

Curriculum development and outreach program was developed in two directions. One is to develop new courses or enhance existing courses by adding smart grid related materials. The other is to give seminars and workshops to students and the general public.

Smart grid is an emerging concept and technology based on traditional power grid. In order to understand it basic knowledge about the traditional grid is necessary. From the curriculum development point of view, it is important to include this basic knowledge in the course syllabus. In the AMS 691 class, we covered models in the traditional power grid. We also introduced some mathematical models that can be used to optimize the traditional grid to make it "smarter". We found that students were interested to learn about the traditional grid because it was new to them - most of them were not from engineering background. While mathematics was not an issue to them, understanding the structure and model in the traditional power grid usually was. In order not to daunt students, it is important not to jump to advanced stuff in electric power field.

People respond to incentives. While students were in general interested in this new concept of smart grid they more wanted to expand their opportunities of future career. They wanted to know how taking the classes may help them locate job and they also wanted to know how the job market in this field will be in the future. So when developing courses, this information should be incorporated too.

Understanding of wireless networks is an important component of successful adoption of smart grid. This is the only realistic means how smart grid devices such as meters communicate. However, characteristics of smart grid devices and deployment scenarios need specific rehashing of network protocols and development of new standards around it. The course students appreciated this new, practical application domain of wireless networking. They explored and evaluated the need for new spectrum for grid networks and policy issues around it. They developed simulation projects to gain insights in smart meter network performance and gained knowledge in new standards. Though not directly related to these classes, they also got curious in general about energy management, specifically related to IT equipment. This developed a general awareness in addition to developing specific technical strengths. The course instructor learnt the need for development of new course materials given that the knowledge in the field is quite scattered at this time.

There were not many attendees to the workshops or seminars. This might be because of several reasons:

First, lack of interest in smart grid among students. This can be related to the curriculum development. Without taking any class related to the power grid, students did not know about this concept and technology.

Second, insufficient advertisement on campus. At present we placed the workshop and seminar fliers online at Stony Brook University's Center for Corporate Education. According to our talk with the attendees, most of them signed up for the workshops and seminars because they knew about this website. For those who do not know about the website, they do not know about the workshops/seminars.

Third, selection of topics. The general public is more interested in some technologies that can be "seen" or "felt". Unlike academic circles, they are not keen on advanced models. Instead they want to see how these advanced models can achieve. By saying that, software demonstration or test use may be more interesting to them.

APPENDIX D: FSC GERMANY TRIP REPORT

Farmingdale State College
Germany Trip - 2015
Dr. Kamal Shahrabi
Mr. Neil P. Ramos
March 30, 2015

Overview:

I. Summary
II. Cologne University of Applied Sciences
III. Lucas-Nülle, Inc.
IV. Heliocentris, Inc.
V. Wind Farm

VI. Lessons Learned

I. Summary

Farmingdale State College provided a tour of our Smart Grid Demonstration Project to the Cologne University of Applied Sciences on November 10, 2014. As a follow up to this meeting, and to create an ongoing relationship with Cologne University, we attended a tour of their Institute of Power Engineering in Germany. Through this collaboration, we exchange ideas and discussed ways to improve the smart grid and renewable energy demonstrations and curriculum on both of our campuses. We are also setting up a student exchange program to give students the opportunity to study abroad. Students will gain knowledge in the field of renewable energy and smart grid technologies through coursework and assisting with faculty research. We have also discussed a faculty exchange program for teaching abroad and offering online virtual seminars.

We also attended a tour of two training equipment manufacturers, Lucas Nülle, Inc. and Heliocentris, Inc. Lucas Nülle is one of the leading equipment trainer manufacturers in Germany; they develop training equipment including renewable energy, automotive technology and smart grid technology. We've already purchased their small scale wind trainer and had the opportunity to see the rest of the renewable energy trainers and how they can be connected into a laboratory smart grid training system. We also witnessed a group of students doing a laboratory experiment in the Lucas Nülle Academy; their on-site training facility. As a result of this visit we have a firm understanding of their product line and how they're used in a classroom setting. We will continue to work with their United States representatives to incorporate these trainers into our curriculum.

Heliocentris is another training equipment manufacturer that we've purchased equipment from. Their "New Energy Lab" (NEL) training system is a small scale version of the Smart Grid Demonstration Project at Farmingdale State College. The renewable energy components of this system consist of solar energy, wind energy, fuel cell energy, hydrogen storage and batteries. During our visit we attended a training session on how to use the NEL and incorporate it into our curriculum. Going forward will continue to provide them feedback about their training equipment and work with them to develop new laboratory experiments for their system.

The United States and Germany are two of the leading countries utilizing renewable energy and smart grid technologies. Through our relationship with Cologne University of Applied Sciences we will continue to gain knowledge and experience on a variety of issues in these fields of study. This knowledge will be given back to our community and students through our campus tours, workforce training, and our new study abroad program. The tour of Lucas Nülle and Heliocentris has broadened our understanding of their training equipment and gave insight to new ways to present these technologies to our students and relate the laboratory equipment directly to our campus demonstration project.

The Renewable Energy and Sustainability Center and the Smart Grid Demonstration Project at Farmingdale State College are examples of what can be accomplished on a State University of New York (SUNY) campus. Farmingdale State College will continue to take the lead in promoting renewable energy and smart grid technologies.

II. Cologne University of Applied Sciences

Contact:
Prof. Dr-Ing. Habil. Ingo Stadler
Managing Director
Institute of Electrical Power Engineering
Benzdorfer Strabe 2, 50679 Cologne, Germany

Purpose:

- **Tour the Institute of Electrical Power Engineering laboratories:**
  - Basic AC/DC electronics lab
  - High power lab, electric generation and measurement equipment.
  - Renewable energy lab with solar photovoltaic rooftop arrays, microgrid energy storage, energy management, and photovoltaic module development.
  - High voltage lab, high energy circuit protection, energy surge protection.
  - Demonstration of Lucas-Nülle smart grid and renewable energy training lab at Cologne University.

- **Student foreign exchange program:**
  - Exchange of students for undergraduate thesis or capstone projects through research/coursework, under the guidance from energy engineering faculty advisors.
  - Research areas include but are not limited to solar photovoltaic, solar thermal, wind, smart grid and smart metering, fuel cell and energy storage.
  - Academic foreign exchange programs are being be reviewed further with our office of International Affairs.

- **Faculty foreign exchange program:**
  - Faculty exchanged during a semester.
  - Distance learning through online sessions.

  - Guest speakers from each institution during courses related to energy such as Farmingdale State Colleges ENV 101 Energy Sustainability and Environment.

III. Lucas-Nülle, Inc.

Contact:
Gerald W. Shex
Sales Director
Lucas-Nülle, GmbH
Siemensstrasse 2, 50170 Kerpen, Germany
www.lucas-nulle.com

Purpose:

- **Tour of the training equipment showroom**
  - Unitrain basic training and development kits were discussed. These can be used in our energy lab to introduce students to renewable energy technologies. Unitrain kits are a prerequisite to the renewable energy training systems.
  - The renewable energy training system provides an in-depth overview of the energy technology being studied. These all-in-one training systems provide the curriculum, energy emulation hardware and measurement equipment. Each can act as a stand-alone system, but can also be linked together to form a larger energy network.
  - Each of the renewable energy trainers can be linked with the transmission line, smart grid, and energy management trainers to form an intelligent energy network within the lab environment. These trainers allow the student to generate and transmit the renewable energy to different loads through the energy management module. The smart grid system can simulate power outages and other fault conditions where the power needs to be controlled and managed.
  - The renewable energy sources include photovoltaics, fuel cell technology, wind power plant and hydro power.

- **Lucas-Nülle Academy**
  - Observed a group of students using the wind power plant system to generating power back to the smart grid.

- **Demonstration of Hybrid Automotive Trainer**
  - Attended training session with the Lucas Nülle product engineer for the Hybrid Automotive training module.

- Different types of electric/hybrid drive systems were demonstrated; serial hybrid, parallel hybrid, serial-parallel hybrid, electric vehicle, fuel cell vehicle.
- The system allows students to run tests on different drive trains using one training system.

IV. Heliocentris, Inc.

Contact:
Martin Zippel
Product Line Manager
Education, Training & Research
Rudower Chausse 29, 12489 Berlin, Germany
www.heliocentris.com

Purpose:

- New Energy Lab Demonstration
  - Farmingdale State College purchased the Heliocentris "New Energy Lab" which was demonstrated during the visit.
  - The New Energy Lab is an all-in-one renewable energy and energy management training system.
  - Energy Sources: solar photovoltaic, wind and fuel cell energy.
  - Energy Storage: hydrogen and batteries.
  - The solar energy is generated by three sources, a roof-top array, mobile panels that can change orientation/pitch and a benchtop solar photovoltaic array emulator.
  - The wind energy is generated by a small scale roof-top wind turbine.
  - Hydrogen is generated, stored and used to power fuel cell all within the New Energy Lab system.
  - Each of these sources, including the batteries, is controlled by the main terminal. From this terminal the student has the ability to create energy management scenarios for different load profiles.
  - All of the system data can be collected and viewed in real time.

V. Wind Farm

Geographic Coordinates: 51°08'34.9"N 11°58'14.6"E

VI. Lessons Learned

By visiting Germany we have a better understanding how other countries teach renewable energy and smart grid technology. We have seen the methods used for training energy engineering and the types of equipment used. We have also seen how the University of Applied Sciences uses the Lucas Nulle equipment to teach smart grid. We only purchased the Small Scale Wind trainer, but will now consider purchasing their entire training equipment lab.

The University of Applied Sciences uses 100% electric vehicle projects to motivate students to learn more about renewable energy concepts. Farmingdale State College currently has a Baja racing program as part of the automotive engineering department, we can encourage our students to produce a fully electric version and compete in racing competitions. This is a fun way to teach renewable energy to our students.

We have also learned that the Faculty at the University of Applied Sciences is willing to bring their experiences and knowledge to our students via distance learning. We will continue to partner with their college and benefit both German and United States students. This will expose our students to the new technologies in Europe and allow them to compare with the United States.

Germany has such a high amount of wind power in their energy mix. We have had the opportunity to travel through a large portion of their countryside and noticed that they integrate wind turbines in many of their farm lands along the highway system. These wind turbines are also not as loud as we assumed, there are documentaries being produced that speak negatively about the decibel level. After visiting some of these farms during our travels we learned that they’re not as bad as people make them out to be. These types of documentaries are very bad publicity for turbines which are reasons why projects such as the Long Island offshore wind projects fail.

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APPENDIX F: AMI EQUIPMENT LIST

PROPERTY NAME/DESCRIPTION	Property ID	Model #	Serial #	Grid Location	Property Location (address)	Circuit	QUANTITY
Long Island Power Anuthority							
Distribution Automation							
1. Automated Switches							
Original scope of work:							
PMH Gear and Enclosure							6
Radio Controlled PMH-9	PMH - 91692 (9)	256352R4-A10F12H2J2Y4-S118	**112932**	031-34-9712	ROUND SWAMP RD N/O OLD COUNTRY RD, , MELVILLE	6K-9P4	*1*
Radio Controlled PMH-9	PMH - 93637 (9)	256352R4-A10F12H2J2Y4-S118	**112931**	040-09-0691	VERONA DR B/W MADEIRA BLVD AND ALTESSA BLVD, HALF HALLOW	6K-9P5	*1*
Radio controlled PMH-10	PMH - 92811 (10)	256242R4-A10F12J2Y4-S105	**112878**	031-43-2718	LONG ISLAND EXPY SERV. RD E/O OLD COUNTRY RD, , MELVILLE	5SK-194/6K-9P4	*1*
Radio controlled PMH-11	PMH - 93402 (11)	256362R4-A10F12H2J2Y4-S101	**113131**	040-01-4379	ALTESSA BLVD N/O RUBICON PLAZA, HALF HALLOW	6K-9P4/6K-9P5	*1*
Radio controlled PMH-11	PMH - 93403 (11)	256362R4-A10F12H2J2Y4-S101	**112995**	040-01-5384	ALTESSA BLVD N/O RUBICON PLAZA, HALF HALLOW	6K-9P5	*1*
Radio controlled PMH-11	PMH - 93239 (11)	256362R4-A10F12H2J2Y4-S101	**113018**	040-09-4900	ALTESSA BLVD E/O VERONA DR, HALF HALLOW	6K-9P5/6K-446	*1*
S&C Scadamate Switch							12
	ASU-3201	148112R2-A1E3G25-S104	**11-21007**	031-59-1705	PINELAWN RD N/O NORTH SERVICE RD, MELVILLE	6K-9P3	1
	ASU-3202	148112R2-A1E3G25-S104	**11-20278**	031-59-1366	RTE 110 N/O NORTH SERVICE RD, MELVILLE	6K-9P3/6Q-877	1
	ASU-3203	148112R2-A1E3G25-S104	**11-20279**	031-42-2732	OLD COUTNRY RD W/O BENSIN DR, MELVILLE	6K-9P4	1
	ASU-3204	148112R2-A1E3G25-S104	**11-20280**	030-48-0521	ROUND SWAMP RD N/O NORTHERN STATE PKWY, WEST HILLS	6K-9P4/6Q-671	1
	ASU-3205	148112R2-A1E3G25-S104	**11-20281**	040-10-5963	HALF HOLLOW RD W/O BLOSSOM ST, HALF HALLOW	6K-446	1
	ASU-3206	148112R2-A1E3G25-S104	**11-20496**	031-51-8409	WALT WHITMAN N/O NORTH SERVICE RD, MELLVILLE	6K-447/6U-692	1
	ASU-3207	148112R2-A1E3G25-S104	**11-20495**	031-57-3751	WALT WHITMAN N/O NORTHER STATE PKWY, MELVILLE	6K-448	1
	ASU-3208	148112R2-A1E3G25-S104	**11-20458**	031-52-7898	RTE 110 B/W SOUTH SERVICE RD & MELVILLE PARK RD, FARMINGDALE	6U-877	1
	ASU-3209	148112R2-A1E3G25-S104	**11-20480**	040-08-2367	SMITH ST W/O WELLWOOD AVE, FARMINGDALE	6U-875	1
	ASU-3210	148112R2-A1E3G25-S104	**11-21006**	032-57-9131	CENTRAL AVE W/O WELLWOOD AVE, FARMINGDALE	6U-875/6U-646	1
	ASU-3213	148112R2-A1E3G25-S104	**11-20481**	032-57-3577	NEW HWY N/O MILBAR BLVD, FARMINGDALE	6U-696	1
	ASU-3214	148112R2-A1E3G25-S104	**11-20457**	032-50-7123	N/O GAZZA BLVD S/O SCHMITT BLVD, FARMINGDALE	6U-695	1
S&C Control Cabinet unit							12
	ASU-3201	54411R1-S101	**11-0037**	031-59-1705	PINELAWN RD N/O NORTH SERVICE RD, MELVILLE	6K-9P3	1
	ASU-3202	54411R1-S101	**11-0097**	031-59-1366	RTE 110 N/O NORTH SERVICE RD, MELVILLE	6K-9P3/6Q-877	1
	ASU-3203	54411R1-S101	**11-0039**	031-42-2732	OLD COUTNRY RD W/O BENSIN DR, MELVILLE	6K-9P4	1
	ASU-3204	54411R1-S101	**11-0038**	030-48-0521	ROUND SWAMP RD N/O NORTHERN STATE PKWY, WEST HILLS	6K-9P4/6Q-671	1
	ASU-3205	54411R1-S101	**11-0095**	040-10-5963	HALF HOLLOW RD W/O BLOSSOM ST, HALF HALLOW	6K-446	1
	ASU-3206	54411R1-S101	**11-0099**	031-51-8409	WALT WHITMAN N/O NORTH SERVICE RD, MELLVILLE	6K-447/6U-692	1
	ASU-3207	54411R1-S101	**11-0036**	031-57-3751	WALT WHITMAN N/O NORTHER STATE PKWY, MELVILLE	6K-448	1
	ASU-3208	54411R1-S101	**11-0096**	031-52-7898	RTE 110 B/W SOUTH SERVICE RD & MELVILLE PARK RD, FARMINGDALE	6U-877	1
	ASU-3209	54411R1-S101	**11-0089**	040-08-2367	SMITH ST W/O WELLWOOD AVE, FARMINGDALE	6U-875	1
	ASU-3210	54411R1-S101	**11-0096**	032-57-9131	CENTRAL AVE W/O WELLWOOD AVE, FARMINGDALE	6U-875/6U-646	1
	ASU-3213	54411R1-S101	**11-0092**	032-57-3577	NEW HWY N/O MILBAR BLVD, FARMINGDALE	6U-696	1
	ASU-3214	54411R1-S101	**11-0098**	032-50-7123	N/O GAZZA BLVD S/O SCHMITT BLVD, FARMINGDALE	6U-695	1
GE DART RTU with S&C sensor board							18
	ASU-3201	579-0315	**000204**	031-59-1705	PINELAWN RD N/O NORTH SERVICE RD, MELVILLE	6K-9P3	1
	ASU-3202	579-0315	**000203**	031-59-1366	RTE 110 N/O NORTH SERVICE RD, MELVILLE	6K-9P3/6Q-877	1
	ASU-3203	579-0315	**000247**	031-42-2732	OLD COUTNRY RD W/O BENSIN DR, MELVILLE	6K-9P4	1
	ASU-3204	579-0315	**000241**	030-48-0521	ROUND SWAMP RD N/O NORTHERN STATE PKWY, WEST HILLS	6K-9P4/6Q-671	1
	ASU-3205	579-0315	**000205**	040-10-5963	HALF HOLLOW RD W/O BLOSSOM ST, HALF HALLOW	6K-446	1
	ASU-3206	579-0315	**000209**	031-51-8409	WALT WHITMAN N/O NORTH SERVICE RD, MELLVILLE	6K-447/6U-692	1
	ASU-3207	579-0315	**000210**	031-57-3751	WALT WHITMAN N/O NORTHER STATE PKWY, MELVILLE	6K-448	1
	ASU-3208	579-0315	**000255**	031-52-7898	RTE 110 B/W SOUTH SERVICE RD & MELVILLE PARK RD, FARMINGDALE	6U-877	1
	ASU-3209	579-0315	**000200**	040-08-2367	SMITH ST W/O WELLWOOD AVE, FARMINGDALE	6U-875	1
	ASU-3210	579-0315	**000243**	032-57-9131	CENTRAL AVE W/O WELLWOOD AVE, FARMINGDALE	6U-875/6U-646	1
	ASU-3213	579-0315	**000249**	032-57-3577	NEW HWY N/O MILBAR BLVD, FARMINGDALE	6U-696	1
	ASU-3214	579-0315	**000259**	032-50-7123	N/O GAZZA BLVD S/O SCHMITT BLVD, FARMINGDALE	6U-695	1
	PMH - 91692 (9)	579-0315	**11-0148**	031-34-9712	ROUND SWAMP RD N/O OLD COUNTRY RD, , MELVILLE	6K-9P4	*1*
	PMH - 93637 (9)	579-0315	**11-0149**	040-09-0691	VERONA DR B/W MADEIRA BLVD AND ALTESSA BLVD, HALF HALLOW	6K-9P5	*1*
	PMH - 92811 (10)	579-0315	**11-0150**	031-43-2718	LONG ISLAND EXPY SERV. RD E/O OLD COUNTRY RD, , MELVILLE	5SK-194/6K-9P4	*1*
	PMH - 93402 (11)	579-0315	**11-0153**	040-01-4379	ALTESSA BLVD N/O RUBICON PLAZA, HALF HALLOW	6K-9P4/6K-9P5	*1*
	PMH - 93403 (11)	579-0315	**11-0151**	040-01-5384	ALTESSA BLVD N/O RUBICON PLAZA, HALF HALLOW	6K-9P5	*1*
	PMH - 93239 (11)	579-0315	**11-0152**	040-09-4900	ALTESSA BLVD E/O VERONA DR, HALF HALLOW	6K-9P5/6K-446	*1*
Additional work approved by T.George 3/28/12:							
S&C Scadamate Switch							6
S&C Control Cabinet unit							6
GE DART RTU with S&C sensor board							6
2. Capacitor Bank Controllers							
Original scope of work:							
GE MDS repeaters							2
Additional work approved by T.George 3/28/12:							
GE MDS Repeaters							?
3. Substation Automation							
Remote Terminal Unit (RTU)							5
Telvent - 6U1	6U1	C3400-000-116-00W	110711-00309	031-55-95	Ruland Rd Substation, Ruland Road E/O Route 110 and W/O Republic Road, Melville	All 6U Circuits	*1*
Telvent - 6U	6U	C3400-000-116-00W	110711-00308	031-55-95	Ruland Rd Substation, Ruland Road E/O Route 110 and W/O Republic Road, Melville	All 6U Circuits	*1*
Telvent - 7UM	7UM	C3400-000-116-00W	110711-00311	032-46-92	S. Farmingdale Substation, Fulton Street (109) E/O Carmans Road and W/O Route 110, South Farmingdale	All 7UM Circuits	*1*
Telvent - 6K	6K	C3400-000-116-00W	110711-00312	040-01-54	State School Substation, Altessa Blvd E/O Rubicon Place and W/O Savoy Drive, Melville	All 6K Circuits	*1*
Telvent - 6U2	6U2	C3400-000-116-00W	110711-00310	031-55-95	Ruland Rd Substation, Ruland Road E/O Route 110 and W/O Republic Road, Melville	All 6U Circuits	*1*
4. AMI							
[No equipment; Collectors provided at $0 under agreement with AMI vendor							
5. OMS							
Computer hardware	Tagged			AERTC Building	SUNY STONYBROOK	N/A	1
DMS Load forecasting and modeling module	Tagged	Software	ACS License	AERTC Building	SUNY STONYBROOK	N/A	1
Xpert SIM--Simulator Mode, Protection Coord.	Tagged	Software	ACS License	AERTC Building	SUNY STONYBROOK	N/A	1
6. Distributed Generation							
Additional work approved by T.George 3/28/12:							
Solar panels for three substations							
7. Equipment and supplies to be tested by Stony Brook University [All items are likely "supplies" -- i.e unit cost <$5K]							

PROPERTY NAME/DESCRIPTION	Property ID	Model #	Serial #	Grid Location	Property Location (address)	Circuit	QUANTITY
Farmingdale State College							
1. Campus Wide Energy Management System							1
2. Parking lot Solar PV and Charging Stations							1
5 KW Fuel Cell							1
3. Residential and Commercial Demonstration Models							
Green Data Center Demo System - Computer lab with 25 computers which are networked as a local area network. Projection equipment for presentation, Printer, Server, UPS, Laptop with Projection attachment							1
5kW Hydrogen Generators							1
12x60 Amp Batteries							1
Data Acquisition System							1
Bus bar with inputs and outputs							1
Inverter							1
4. Solar Thermal System Design and installation Demo							
Drainback System with 2' x 3' Flat Plate Solar Panel							1
Pressurized Glycol System with 2' x 3' Flat Plate Solar Panel							1
Sundog Rover & Companion Wagon							1
Small Scale Wind Demo System Wind Turbine and components. Three wind energy systems package consisting of 45' non-segmented monopole galvanized, 42" Foundation kit, 3 KW wind turbine, tilt over pipe tower, communication interface							3
PHEV - 1 Plug-in Electric Vehicle							1
PHEV - 1 Plug-in Electric Vehicle							1
PHEV - measuring system							1
PHEV - Scan tool for vehicles purchased							1
PHEV - servo drive							1
PHEV - slipside console							1
Smart Heat Pump System							1
Residential Wind Turbine							1
Residential Solar Panels							1
Smart Louver Installation							1
Smart Photocopier							1
Smart LCD Television							1
Smart Soda Vending Machine							1
Smart Snack Vending Machine							1
Stony Brook University							
Walk-in Faraday Cage							1
Measurement equipment including: external frequency meter, resistance conductance meters, voltage meters							1
Software radios							1
Dedicated server							1
2 high end workstations: mgt of test processes, protocols, analysis							2
100-node computer cluster equipped with virtualization hardware/software							1
Wireless network connectivity hardware for 40-node subset supporting 3G cellular, Zigbee, WiFi and WiMAX							1
3G cellular network service subscription							1
Software licenses for smart grid communications protocol implementations and simulations							1
NetApp storage Filers							1
Four Dell Servers							4
Two racks, KVMs, HP Procurve switches, and four UPSs.							2
One 8-way GPU computing cluster							1
4 PC's for graduate students							4
8 Laptops for faculty and students for demonstrations, presentations, and data collection.							8
8 Workstation desktops to run and test software							8
4 Uninterrupted power supplies (UPS)							4
3 High quality printers							3
Energy Management Software licenses to run and test applications							1

Long Island Power Authority