Proceedings of the Seventh IASTED International Conference
POWER AND ENERGY SYSTEMS
November 28 - December 1, 2004, Clearwater Beach, FL, USA

Demand Response Opportunity Pilot: Assessment of Feasibility of Load Reduction at a University Facility

S. B. Shetye, A. Domijan, Jr., S. Garg
Florida Power Affiliates and PQ Laboratory, Department of
Electrical and Computer Engineering, University of Florida,
314 Benton Hall, P.O. Box 116200, Gainesville, FL 32611 USA;
e-mail: alexd@ece.ufl.edu

Abstract

Progress Energy, Florida (PEF) in collaboration with University of Florida and Universidad Politécnica de Valencia are running a pilot program in an effort to research a new load management tool whereby the customers would be able to decide when and if they want to participate in the Demand Response (DR) programs and at what price, thus making it a completely voluntary program. In order to see the viability of this program in PEF's territory some commercial and industrial customers were signed up for this program. This paper presents the process followed in advancing the DR research pilot program at Anderson Hall facility, University of Florida. It throws light over the difficulties faced in performing the load reductions and the measures taken to overcome them. This paper also presents the analysis to be done on the DR customers so as to determine the ability and the contribution of the customer to towards these kinds of program.

Key Words

Demand Response, Demand Bidding, Load Management, Load Modeling

1. Introduction

Over several decades there has been an increasing interest in Demand Side Management by electric utilities [1]. A number of programs were developed around the country to use demand as a source of reducing the need for capacity in peak hours. There came out two kinds of strategies. One, price signals were used for the customer to change their pattern of consumption [3]. Thus, customers were charged depending on the time they were consuming. Higher charges for peak hours encouraged customers to switch loads to cheap periods. However, the potential reductions of these methods are limited, and so complementing methods are considered desirable. Another option, namely Direct Load Control program, also became popular. Within these programs the utility directly controlled the load and curtailed it when needed. Once the customer entered the program, they accepted the conditions, they would be curtailed a maximum number of times whenever the utility considered it necessary. Payment methods were usually for availability, offering lower tariffs for all periods. But some customers were not satisfied when they were curtailed despite the incentives. Another point is that the incentives provided were high compared to the market prices. Because of lack of a single good method, the demand-side participation concept kept on changing. Currently, regulators are showing a preference to customer choice and price awareness as opposed to direct load control and fixed incentives.

2. Demand Response Opportunity Pilot

University of Florida (UF), Gainesville and Universidad Politécnica de Valencia (UPV), Spain along with Progress Energy Florida continue to explore new avenues for greater customer choice in ensuring reliable energy across its system. We're researching a new load management tool that allows customers to choose when and if to participate and at what price. Commercial, industrial and governmental are the target customers who are not currently participating in traditional interruptible or curtailable load control programs.

This program (Demand Response Opportunity Pilot, DROP) offers to "buy-back" customers power at the listed or bid price per kWh during the selected peak hours of the day called "events". Any participation by the customer is entirely voluntary. The customer pledges the kW reduction they will provide for each hour of the event over the bidding interface. The pledges are then reviewed and if accepted, the customer is then expected to deliver the pledged amount of kW for each hour of the "event". The kW provided by the customer is determined by comparing their normal usage (baseline) to the usage during the buy back period. The customer is paid based on their reductions and the price accepted for their pledge for each hour. The program run is aimed at identifying the behavior of each consumer, customers most suitable for the program and categorizing the "customer type" to determine what "load-groups" should be considered for approximating their behavior.

The main objective of this pilot is to set up a comprehensive methodology for the analysis of the customer response when participating in Responsive Demand programs. It is difficult, according to DROP horizon and allocated resources, to perform this detailed analysis for all DROP participants, as it would involve extensive measurement, modeling and simulation. This paper provides the detailed analysis done on Anderson Hall, of University of Florida, as a customer participating in DROP.

2.1 Preliminary Customer Analysis:

The participation of the customer in such kind of programs depends on various factors such as their ability to switch on/off the loads either manually or remotely and at the same time not loosing the comfort index. [2]. The control actions to achieve the load reduction could either be accomplished by completely switching off the load device thereby discontinuing the service provided by the load or by cycling the load or even by using any voltage modulation techniques.

In order to take any kind of control actions the knowledge of the load pattern for the customer is very necessary. For the same, a site survey was conducted at the University Facility so that all the required data such as the lighting loads, A/C units and process loads and all other affecting parameters such as area, temp, light intensity, humidity and CO2 levels could be obtained.

A preliminary customer analysis was done which was oriented towards investigating the physical processes present in University Facility. It focused on Air Conditioning and Space Heating loads and Lighting loads (External and Internal), these being the major loads. The distribution of the loads is shown in the pie chart in Fig. 1.

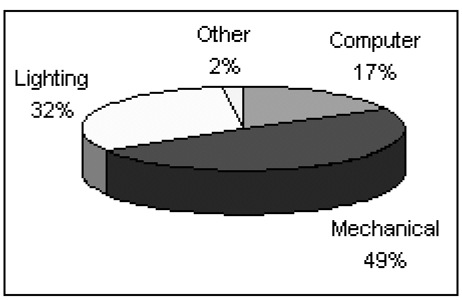

Fig 1: University Facility building Demand

The annual demand of University Facility building is about 432MWH.

To identify the load reduction potential based upon the equipments and specific operating patterns and to determine the normal usage a 15-minute interval meter with cell phone link was installed at the University Facility building premises and also the software system for online data presentation and analysis was installed. This way daily load shape information was made available through the Demand Exchange (Demx) Interface for the customers and the utility. Thus the customer believes that the payments made are fair and reasonable. Also, it eliminates the chances of gaming to a larger extent.

The baseline method used for University Facility building is the No Selection-No Adjustment method that calculates the baseline as a simple average of the ten previous business days. By analyzing the daily interval data on the Demx, it was found that this method worked fine during normal days of operation. However, after school breaks (Spring or Fall break) due to low consumption the method would underestimate the load and due to high consumption before the break it would overestimate the load during the break period. Hence to overcome this problem other methods for baseline calculation were proposed. Various methods such as No Adjustment (calculates the baseline through a simple average of data of some selected previous days (excluding holidays and days with average smaller than a minimum). These selected days are the 5 days with higher consumption average among the 10 previous business days beginning two days before the day for which the baseline is going to be calculated), Scalar Adjustment (similar to the previous one but after calculating an initial baseline with the simple average it adjusts it in a scalar manner. Adjustment factor is a relation between the baseline calculated for four hours previous to the event and the metered data of the same hours), Additive Adjustment Method (calculates an initial baseline through a simple average of data from the 10 previous business days. The final baseline is calculated with an additive adjustment of the initial one. The difference between the initial baseline calculated for two hours previous and the metered data for these hours is used as additive factor) were tested. The last method namely Additive Adjustment Method, proved to be the best. Fig. 2 shows the comparison of the baselines with simple average method and Additive Adjustment method and the metered load during and after the break period.

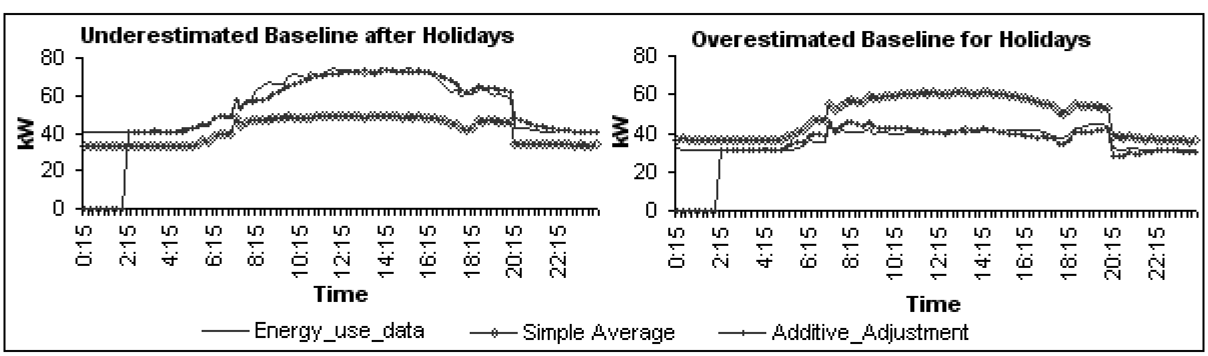

Fig. 2: Underestimated & Overestimated Baseline

2.2 Lighting loads

The major load in University Facility building comes from classrooms and the computer labs, due to the high A/C and lighting consumption. The following table shows the amount of the lighting consumption in the facility.

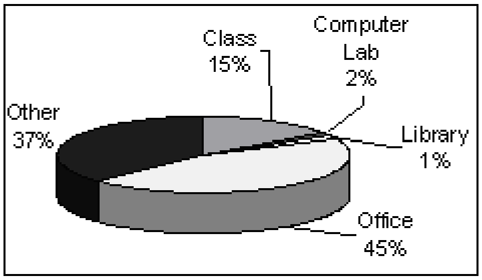

Fig 3: Distribution of Lighting Loads

The light controls in all the classrooms enable 50% reduction of lighting when daylight is available. The lights were on even when the classes were not there. Hence, suggestions were made for remote operation for the lights or motion sensors wherever preferred. It is estimated that on an average a saving of about 53kWh could be achieved daily. Also, a small, energy controller equipment was tested for one step voltage reduction for dimming of lights. This equipment enables 15% reduction in the lighting loads. Recommendations were made to install the unit in the Lighting panels.

2.3 A/C loads

University Facility building has a central air conditioning system in which the cooling is generated in a chiller and distributed to Air Handling Units (AHU) through a chilled water system. Each AHU serves different sectors of University Facility building.

To get the information regarding the internal temperature, evolution temperature sensors were installed in the building. Many of the classrooms and the offices already

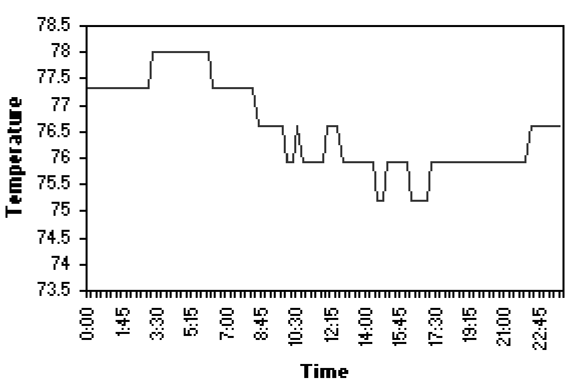

Fig. 4: Temperature Evolution for August

had the temperature sensors. These sensors were set to record the data at every 15 min interval. The following graph in Fig. 4 shows the evolution of the internal temperature in one of the classrooms. Similar data is being collected for all the rooms in the facility.

2.3.1 Events for University Facility building

To analyze the response of the customers to the prices as well as their willingness to participate in the program a number of events were carried out. The evaluation of these events would reveal the customer reaction potential in future programs. These events were carried out in three phases: training, evaluation and verification.

The primary goals for the training event were to ensure that the facility staff is comfortable with the bidding software interface and to gauge their understanding about the load reduction. The first training event for University Facility building was carried out on Nov 20, 2003 from 4pm to 6pm. Like other customers, UF was notified about the event through email as well as a phone call. The price offered was $25/MWh. The weather conditions were checked and found that they were similar to previous days so that no sudden changes were expected in the load consumption because of weather conditions. UF placed the bid for 10kW for the first hour and 15kW for the second hour with a total of 25kW.

To achieve the pledged reduction some of the major AHUs were scheduled to go offline. In the first hour 17kW reduction was achieved and in the second hour 16 kW of reduction was achieved. In both hours the reduction was more than the pledged. Fig.5 shows the baseline and the metered load for the event. Thus the response for the first event was good, but it was quite obvious that, the facility members needed to understand their load reduction capability and bid accordingly so as to benefit from the DR program.

For further training the second event was also scheduled very soon so that it was easier for the participant to relate to the earlier event and thus perform better. It was scheduled on Jan 15th, 2004 for three hours from 6am-9am at the rate of $80/MWh. UF placed the bid for 21kW for the first hour, 2kW for the 2nd hour and 1 kW for the 3rd hour. This time considering the class schedules instead of major AHUs, small AHUs were scheduled to go offline. Also some of the VAV (Variable Air Volume) boxes were shutdown. Fig 6 shows the baseline and the metered load for the second event. It seems very clear from this figure that the reduction was not achieved. According to the schedule for the EMS system this should have been the reasonable reduction but for some reason the same was not observed. Hence a third test event was scheduled for Jan 23rd, 2004 for a period of 4 hours from 6am to 10am at the rate of $75/MWh for the first 3 hours and $30/MWh for the last hour. Now this time the pledge

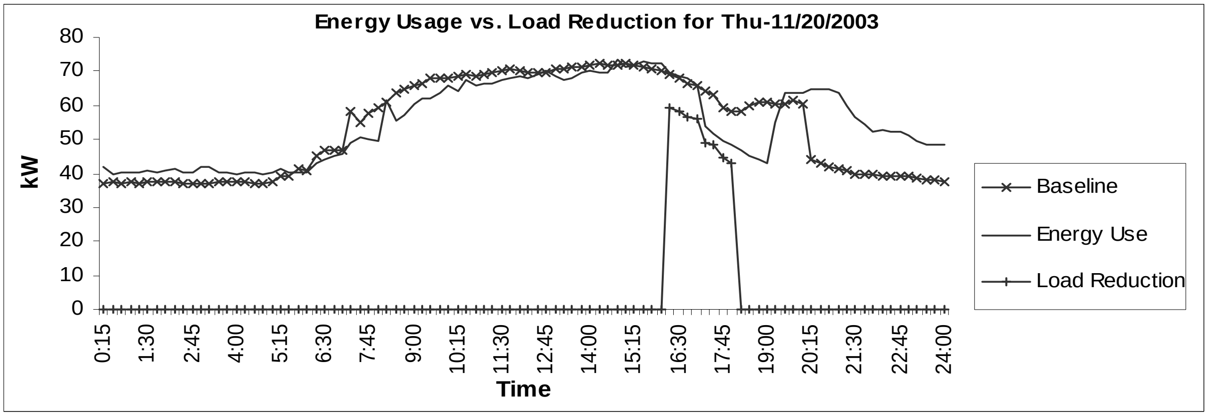

Fig 5: Load Profile for the First Event

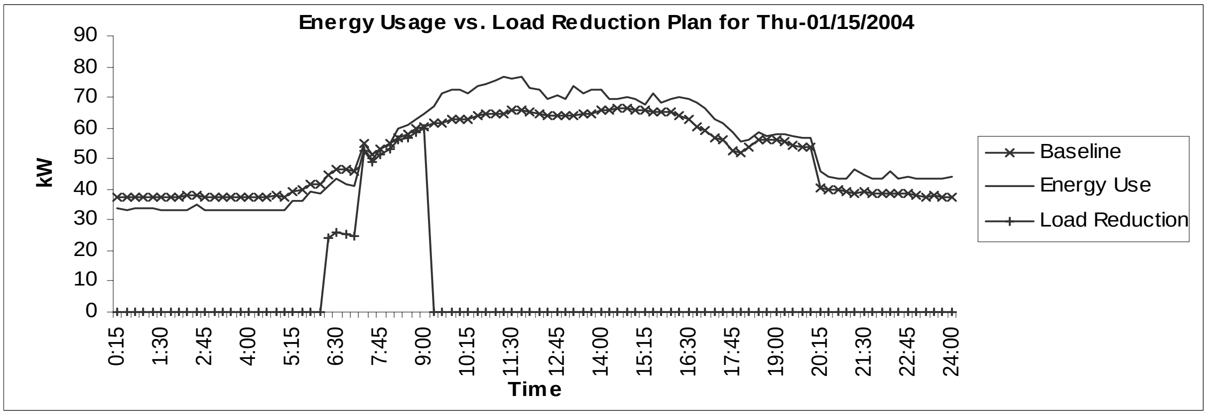

Fig 6: Load Profile for the Second Event

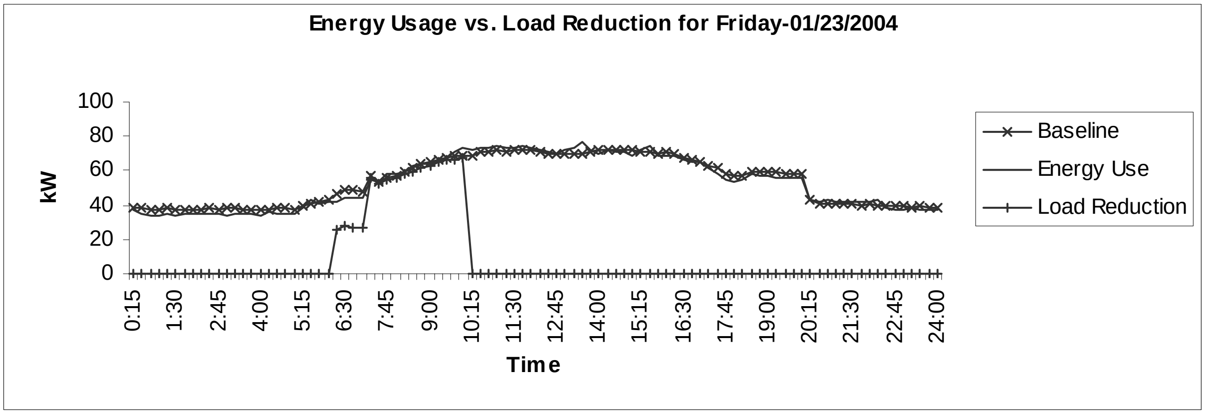

Fig 7: Load Profile for the Third Event

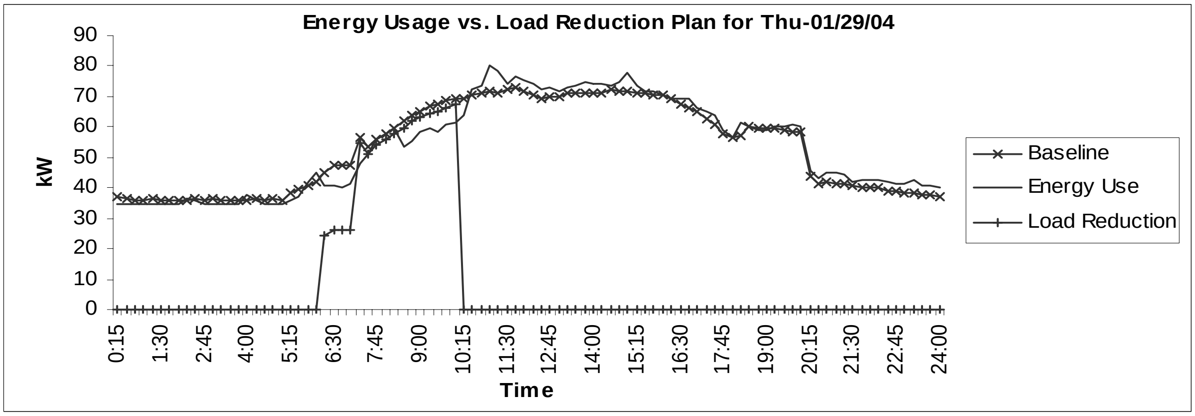

Fig 8: Load Profile for the Fourth Event

did not depend on the price offered, as the main aim this time was to pledge a reduction that could be considerably achieved. Considering the class schedule this time some of the small as well as major AHUs were turned off. UF pledged for 21kW for the first hour and 2kW in every hour after that till 10am.Fig. 7 shows the baseline and the metered load for the third event. From this figure also it is clear that the pledged reduction was not achieved. It shows that just during the first hour a reduction of about 5 kW was achieved.

To investigate this, kW meters were installed in the panels to check the actual contribution of the AHUs. The test results showed that the AHUs were running at varying duty cycle thus not contributing to the reduction as planned.

Based on this information during the fourth event pledges were made accordingly. The fourth event was scheduled for 29th Jan for a period of 4 hours form 6am to 10am at the rate of $100/MWh. For the first hour the pledge was for 21kW and 2kW in the following hours. Fig. 8 shows the baseline and the metered load for the fourth event. It is very clear from the figure that the pledge was not met during the first hour. The reduction was just about 6kW, whereas for the rest of the 3 hours UF delivered more than pledged.

Further analysis showed that the contribution during the first hour from the AHUs was less due to the fact that they were running at varying duty cycles, but even that was less than the predicted.

To conclude, through various conducted events, the proper coordination between utility and the facility was obtained but due to lack of understanding of control system, UF facility was not able to perform as expected during the various events. Hence further analysis and testing was required.

2.3.2 Analysis of Events & Testing:

Analyzing all the events together, it was concluded that, when the AHUs were set to go OFFLINE, the AHUs actually did not turn off completely rather went into some another state. To verify this, an attempt was made to completely shut down the fans and then see the

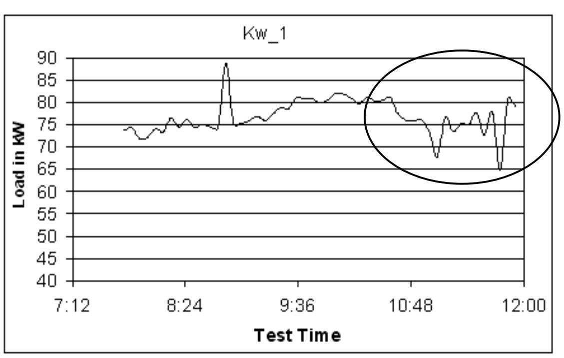

Fig 9: Load Profile for Test Period

contribution to the reduction for each AHU. Following is the testing done and the load curve in Fig. 9 shows the results. The circled portion in this figure shows the actual test period.

First of all, duty cycle for all the major AHUs was checked. All the control actions were taken with the help of the control provided by the VFD (Variable Frequency Drive) control. The duty cycle for all the major AHUs was reduced by 5% from their present settings. This was done for about 10 minutes. A drop in the load curve can be seen in Fig. 9 starting from 10.40am. A further decrease in the load curve is observed by an additional 5% decrease in the duty cycle of the AHUs. At 11:00am one of the AHU was completely shutdown by stalling its fan. As a result of this the load curve dropped from 74kW

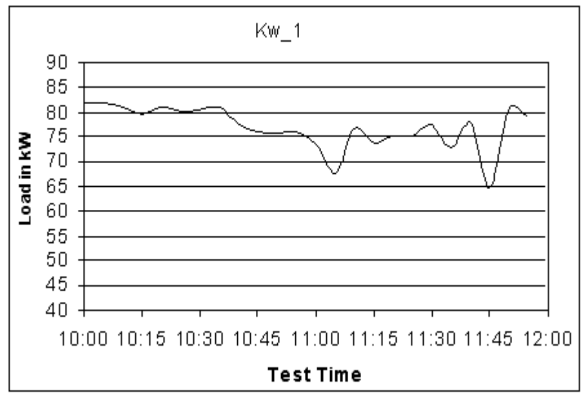

Fig 10: Expanded Test Period

to 69kW. The control was released in about 5 minutes resulting in the load to rise to about 76kW. At 11.10am another AHU was stalled in the same manner resulting in the load curve drop of about 3kW as expected. In another 5 minutes the control was released and the load was back to 76.6kW. At 11.20am the third AHU was similarly stalled. This resulted in a drop of about 4kW. Again in 5 minutes the control was released, and the load was back to 77.8kW. A fourth AHU was stalled at 11.30am resulting in a drop of about 5kW. After 5 minutes all the controls were released making the load curve shoot to 78.4kW. At 11.40am all the major AHUs were stalled. As expected a dip in the load curve of about 15kW can be seen in Fig. 10. These results clearly show that when the AHUs were scheduled to go offline they were not actually shutting down. The same reduction could be achieved by just shutting down the fans for the AHUs completely. Thus it is expected that now the desired performance could be achieved.

3. Conclusion

For a successful DR program, we understand that some of the most important points to consider on the utility side are, good coordination between the utility and the customers, a customer friendly interface for bidding. On the customer side, proper understanding of the program and the interface medium or the bidding platform, transparency of data, a good understanding of the controls and the equipments in the facility are essential.

The number of experimental events carried out at University Facility building enable to track a behavioral pattern for the building, which could be used for the conduct of load control and reduction events in the future. By utilizing the discovered behavioral pattern for the testing of other customers, proper control methods could be developed for each category of customers. These form a foundation for the development of a reliable control strategy or tool for the load reduction for each and every kind of customer under varied circumstances.

3.1 Future Work:

Development of various load models that can be customized for any customer participating in the program is planned. It is anticipated that these models could predict the behavior of the customer to a large extent under most of the circumstances. These models would provide a very customer friendly interface, enabling the customer to decide the amount of load reduction, control actions to achieve that reduction and also enable him to calculate the monetary benefits from the particular control actions. This way the voluntary reduction program can be suited to meet the expectations at the utility end along with a maintained liberty and freedom at the customer end.

Acknowledgements

Many Thanks to Mr. Jeff Johnson, Energy Management Coordinator, Operations Engineering, Physical Plant Division, University of Florida, Gainesville, FL and Mr. Charles L. Thomas, P.E., C.E.M Lead Engineer Program Development & Administration, Progress Energy Florida for their extended cooperation in furthering this research.

References

[1] IEEE Tut. Course. “Fundamentals of Load Management”, IEEE Course Text 89EHO089-9-PWR.

[2] C. Alvarez, Member, IEEE, A. Gabald´on,Member, IEEE, and A. Molina Student Member, IEEE. “Assessment and Simulation of the Responsive Demand Potential in End User Facilities: Application to an University Customer”.

[3] Marija Ilic, *Fellow*, IEEE, Jason W. Black, *Student Member*, IEEE, Jill L. Watz, *Student Member*, “Potential Benefits of Implementing Load Control”, *IEEE Proceedings of the IEEE PES Winter Power Meeting*, New York City, NY January 27-31 2002