The Simulation of Smart Grid Technology and Program Benefits

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Abstract

The Smart Grid will be a domestic electrical infrastructure that will span the US and will be capable of conveying large amounts of data. It will provide a renewable energy break through, provide a more reliable and efficient power supply, and allow for the usage of Smart Grid programs and technologies. Before the construction of the Smart Grid is implemented, evidence is needed to validate the feasibility of the Smart Grid, and businesses and individuals need to be convinced that their investment in the Smart Grid is beneficial. To resolve this, Smart Grid pilot studies have been implemented. Numerous Smart Grid pilot studies have been conducted in the past decade and businesses along with utilities have seen the potential benefits of implementing the Smart Grid. The next step would be to convince energy consumers to buy into the Smart Grid, and to do that, a simulation program was built to calculate the benefits of various combinations of Smart Grid Technologies and Programs in order to suit the preferences of the consumers. The simulation program provides quantifiable data and helps consumers see how investing in the Smart Grid is both beneficial to themselves and to their local utility companies.

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Abstract

The Smart Grid will be a domestic electrical infrastructure that will span the US and will be capable of conveying large amounts of data. It will provide a renewable energy break through, provide a more reliable and efficient power supply, and allow for the usage of Smart Grid programs and technologies. Before the construction of the Smart Grid is implemented, evidence is needed to validate the feasibility of the Smart Grid, and businesses and individuals need to be convinced that their investment in the Smart Grid is beneficial. To resolve this, Smart Grid pilot studies have been implemented. Numerous Smart Grid pilot studies have been conducted in the past decade and businesses along with utilities have seen the potential benefits of implementing the Smart Grid. The next step would be to convince energy consumers to buy into the Smart Grid, and to do that, a simulation program was built to calculate the benefits of various combinations of Smart Grid Technologies and Programs in order to suit the preferences of the consumers. The simulation program provides quantifiable data and helps consumers see how investing in the Smart Grid is both beneficial to themselves and to their local utility companies.

Review of Literature

The Smart Grid is a promising technology that seeks to transform the nation's electric grid. The current electric grid is neither reliable enough nor efficient enough. Blackouts and similar grid problems currently cost the US on average $150 billion dollars every year (Department 2009). The Northeast blackout of 2003 resulted in a $6 billion economic loss to the region. Currently, half of the money US citizens pay for electricity is just to maintain the grid to keep it from falling apart, and that price is rising. The current electric grid is also responsible for one third of the US's CO2 production (Department 2009). Other than the fact that there are many faults in the current grid, and that a new national grid would also bring reprieve to those faults, a new grid, the Smart Grid, would bring many new benefits. Central to the success to the Smart Grid are the technologies that enable it, such as the smart meter and the programs it implements. Since the Smart Grid is a large ambitious project, there are uncertainties as to its success. To test out the Smart Meter – its smart meter and different smart grid programs – Smart Grid pilots were created.

One of the primary reasons why a pilot should be implemented is that when there is large uncertainty about the cost versus benefits for a full-scale deployment of a program – by conducting a reliable pilot, this uncertainty can be greatly reduced. A pilot study is a study that takes a small sample of the population and gives the treatment to the sample to gather data about the whole. Pilot studies would reliably predict the results for full scale deployment of Smart Grid programs and technologies without actually having to risk full deployment failure. For a full scale deployment of a Smart Grid dynamic pricing program, the following three steps should be taken. 1. Estimating the net benefits of implementing dynamic pricing for each of the treatments that look promising based on a prior information about price elasticity and other aspects of customer behavior. 2. Estimating the costs of implementing each treatment during the sampling phase of the study. 3. Drawing the sample to maximize the probability of making the right decision, taking into account the tradeoff between value of information and cost of sampling. Benefits = (existing usage per customer x percent change in price x price elasticity) x number of participants while the Costs = unit cost per participant x number of participants (Hledik 2009). The next step in conducting a pilot would be ensuring the validity of the study, both internally and externally. Ensuring internal validity would be making sure that all variables can be strictly controlled, and that there are control groups so that real results can be differentiated from those caused by external factors. External validity would me making sure that results from the pilot can be extrapolated to the entire population. The goal of a pilot study is to have a group of people represent the population, and without external validity, the pilot would render useless.

A residential pilot program, the Smart Energy Pricing (SEP) Pilot was tested between June 1, 2008 and September 30, 2008, by the Brattle Group for the Baltimore Gas & Electric Company. Three dynamic pricing structures were used in the SEP: a dynamic peak pricing (DPP) program, a low rebate level (PTRL) program and a high rebate level (PTRH) program. Included in this study were also the effects of two different technologies, the Energy Orb and a switch for central air conditioning. Under the DPP program, there were three dynamic pricing rates: Peak pricing rate(PPR), Critical Peak Pricing rate (CPPR), and Off-peak pricing rate for a rate of $0.14, $1.30, and $0.09 per kWh, respectively. Within these pricing rates, technology combinations were also tested in this pilot. Different groups were given either the Energy Orb or Energy Orb and an A/C Switch. Groups without any enabling technology were also tested. The population was distributed evenly to test out the different combinations of technologies and programs. From this pilot, the effects of different pricing rates along with the effects of different technologies were found.

A second study is the California Statewide Pricing Pilot. It was conducted between July 2003 and December 2004, with some 2,500 customers. It ran a few pricing concepts, including Time-Of-Use(TOU), Critical Peak Pricing – Fixed (CPP-F), and Critical Peak Pricing – Variable (CPP-V). An Information Only treatment was also examined. In addition to the different pricing plans, California was divided into many regions based on climate; Costal, Inland, Inland Hot, and Desert Hottest (See Image 1). The study produced quantifiable results that provided information regarding the effects of different dynamic pricing programs along with different climate regions (See Image 2).

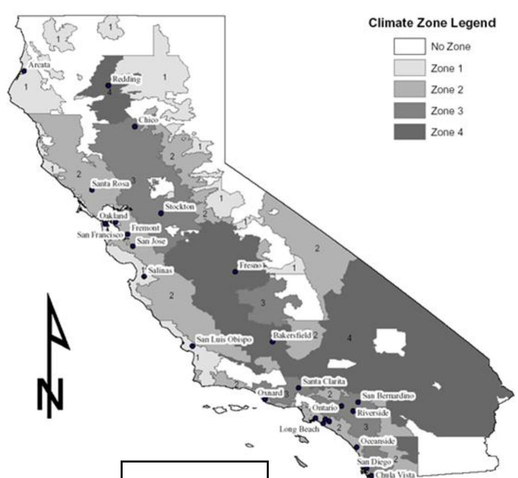
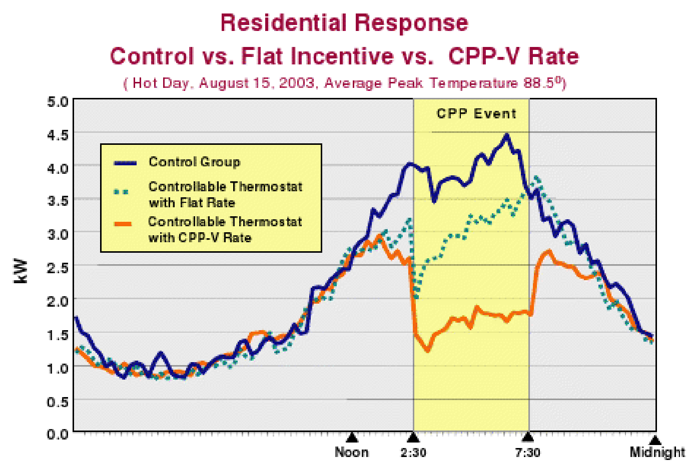


Image 1



Source: Response of Residential Customers to Critical Peak Pricing and Time-of-Use Rates during the Summer of 2003, September 13, 2004. CEC Report.

Image 2

The data provided from the above two studies are few of many studies that will be essential in the creation of the project. Different pilot studies provide different points of view on how different dynamic pricing programs effect the consumer and how energy usage is effected by the pricing programs and other variables. By using pilot studies and have both internal and exteral validity, the core of the simulation project is reliable and accurate.

Research Objective

Formally, the objective of the project is:

1. Simulate the effects of various combinations of Smart Grid technologies and Smart Grid programs
2. Provide quantifiable data that facilitates the user of the simulation program to assess the advantages and disadvantages of investing in various Smart Grid technologies and Smart Grid programs.
3. Generate the potential effects of the usage of Smart Grid technologies and Smart Grid programs on utility companies per region.

Methods

To create the simulation programs, a data base is first needed. This data base is obtained via the results from existing pilot studies conducted over the past decade. The results that are to be used must come from pilot studies that have both external and internal validity. These are the steps on how to ensure both external and internal validity. First, to be able to measure the impact of a program, the design should account for the uncontrollable variables, such as weather and economy, and should be able to predict what the customers would have done if they weren't on the treatment. This can be done by including a control group, and by comparing the results of the control group with that of the experimental group or groups. There should be a large enough sample size, to account for differences between each sample, and each customer should be randomly selected to put into the treatment group or the sample group. Customer's socio-demographic characteristics and attitudes toward energy use should also be taken into account. There should be multiple treatments to construct a customer price response model. Lastly, customers should be encouraged to stay in the program as long as possible, and if any gratitudes are given, that they not be of any effect to the study (Hledik 2009).

After the external and internal validity is ensured, the data needs to be extracted so that it is usable in the simulation program. The quantified effects of each individual Smart Grid program and of each individual Smart Grid technology along with other variables will be taken from the different studies and compiled into the simulation program. The program will compile the data and produce user results based on user input of parameters.

Prior to the use of the simulation program, the user will be briefed on the different types of Smart Grid Dynamic Pricing programs and the different types of Smart Grid technologies. User understanding of what each program and technology entails, and the user requirements that come along with each program and technology is vital to sustained commitment to the Smart Grid project. A user who does not understand what is necessary of them to successfully utilize the Smart Grid technologies and programs will not benefit, and ultimately drop out of the program, hurting both general user belief in the Smart Grid program and the Smart Grid project overall. Thus, before the simulation program even requests information from the user, and definitely before a user implements actual Smart Grid program and technologies, it is necessary that the customer understands the Smart Grid Pricing programs and technologies.

The simulation program will request from the user their state, current electricity usage, type of customer, along with the programs and technologies they plan to use. Their selection of state will help determine; their current electricity prices, their region (for climate variables), and the state's electricity capacity data. Their current electricity usage will be what provides the quantified results of the simulation program; how much energy is saved and how much money that turns into. Additionally, it quantifies how much of load capacity reduction utility companies experiences and how much it alleviates the difficulties of the utilities. Their selection of the programs and technology is the primary factor in determining the reduction of energy usage overall and reduction of energy usage during peak hours. The type of user – as in their profession; because students and full time normal hour workers user electricity at different times than part time, night shift, or unemployed workers – will also help determine when they use their energy, and thus how much, if any, they would contribute to peak energy reduction, and how much they would be charged with and without a dynamic pricing plan. These variables are the ones that are to be included in the simulation program; there are other minor variables that may affect the results but they will be beyond the scope of this simulation program.

Results and Discussion

The Simulation Program created takes input from the user, including the User's residential region, current energy usage, the type of user that he or she is, and the planned implementations of the Smart Grid technologies and programs. It takes the inputs from the user and calculates the expected results from data from existing pilot studies that have been completed.

In a typical run of the simulation program, when implemented, the user will first be requested to state his or her state of residency. In the example shown below (Image 3), the user has input New York as his state. The user will then be requested to provide his or her current monthly electricity usage in kilowatts. In Image 3, the user has input 700 kilowatts, which is typical for a family of four. Following, the user will be requested to choose a Smart Grid program to follow, and then a Smart Grid technology. In Image 3, the user has input Critical Peak Pricing Rebate Pricing Plan and has input Energy Orb as the chosen technology. Lastly, the user will be requested to state the type of user that he or she is. In Image 3, the user has chosen an Unemployed or Self Employed Worker. All user input areas are denoted by the arrows (not actually in simulation program).

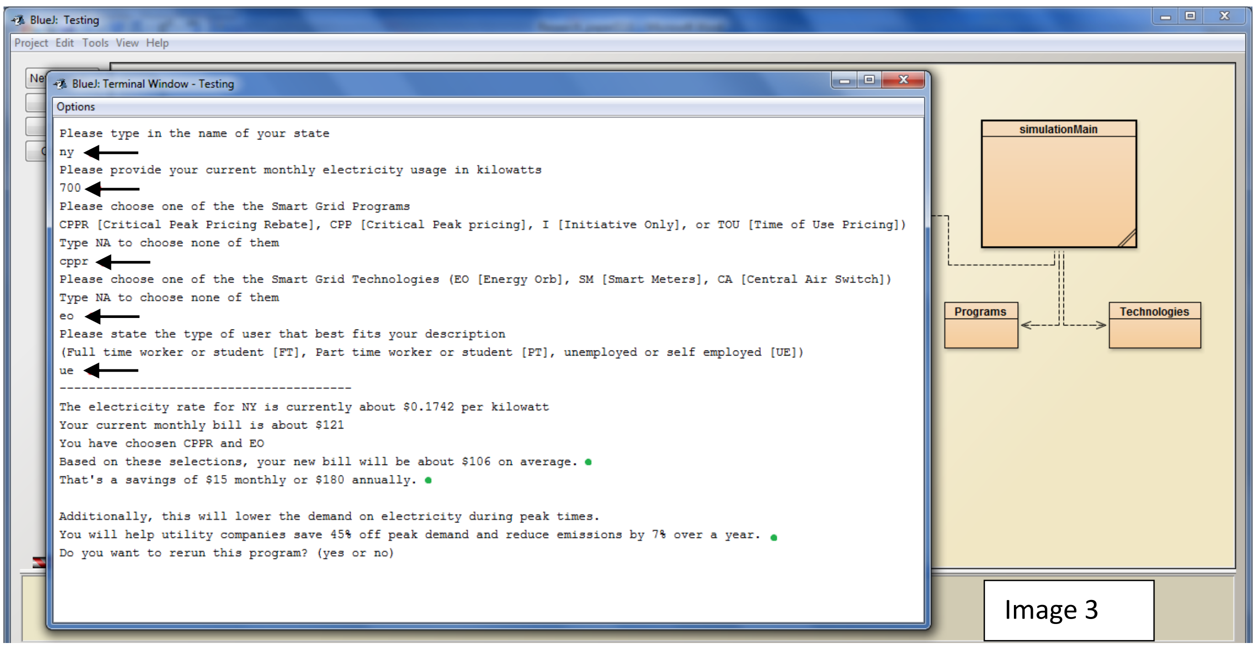


Image 3

In providing information, there are some limitations. Currently the program only has simulation data for the state of New York. Input of any other state will result in error. In the future, the program will be useful for both residents in the State of California and of Maryland, as they both are states that have already approved of Smart Meter rollouts for customers. After that, simulation data can be created or derived for the 48 contiguous states in the US. Hawaii and Alaska will not be participating in the Smart Grid Project. There are no limitations as to the input for monthly electricity usage in kilowatts, though it is important to note that extreme values, either high or low, will result in less reliable results. The inputs available for Smart Grid Programs are currently limited to Critical Peak Pricing Rebate, Critical Peak Pricing, Initiative Only, and Time of Use Pricing, or none of them. The inputs for Smart Grid technologies are currently limited to the Energy Orb, Smart meters, and the Central Air Switch. There are other dynamic pricing programs and technologies, but they are currently not available to choose from in the simulation program. The next step into making the simulation program universal would be to add a larger variety of Smart Grid programs and technologies. The reason that other programs and technologies are not currently available in the Simulation Program is because of a necessity for simplicity. Additional options will be added when the User Interface has been converted into a more graphical display, thus further making the simulation program end-consumer user friendly while increasing its accuracy. Users will have to choose between the available technologies and programs for the current duration of time. For the final user input, the type of customer they are is currently confined to Full time worker or student, Part time worker or student, and unemployed or self employed. The purpose for the type of user they are is to determine when they are at home – where they have full control over their energy usage – and thus how much pricing rates will affect them, including if they will experience peak time pricing rates. The next step in expanding this area would be allowing the user to input the hours he or she is at home, which provides ultimate flexibility in regards to the time period in which the user will be effected by the Smart Grid programs and technologies.

Following is an explanation as why each input is necessary. The user input of the state is necessary because it allows the simulation program to know 1) the electricity prices of the state 2) the energy situation; how much peak stress there is and the average energy output and energy production efficiency rate 3) the climate in which the user resides, which affects how a user might respond to different dynamic pricing programs and or technologies. The next input, of the user's monthly electricity usage is not directly vital to the simulation program, as the program could express all results in relation to a predefined base point, but if the user provides quantified energy consumption, the simulation can provide specific quantified results. The input of Smart Grid program and technology is the most important input, as it is the primary drive of the Smart Grid. The Smart Grid programs and technologies are the primary focus of the Smart Grid project. It is used to determine how much energy the user will conserve. The type of user is important for determining how active the user will be in using the different Smart Grid programs and technologies. A full time worker or student will most likely miss peak hours, which are during the early afternoon. Additionally, they are away from their home most of the active part of the day, which significantly reduces their usage of Smart Grid technologies and programs. The same concept applies to a part time worker or student, and unemployed or self employed customers; the more or less they are at home, the more or less active they are in participating in the Smart Grid projects and programs.

From these inputs; of state, monthly electricity usage, Smart Grid Program, Smart Grid Technology, and user, comes the following outputs: Price and energy reduction, monthly and annually, assistance towards peak reduction has successfully been able to simulate the effects of various combinations of Smart Grid technologies and Smart Grid programs. The outputs are all derived from existing pilot studies. The simulation program listed some facts based on user input, such as current electricity price, and the estimated current electricity bill of the user based on usage and cost of the usage. It reconfirms user inputs, and then proceeds to display the final results of the calculations, of how much money the user will save, both monthly and annually if the Smart Grid dynamic pricing plan and technologies were utilized as they should be.

Following, the effects on utility are also displayed, showing how user activity can benefit the utility (the statistical data assumes that a large portion of the utility's customer population is participating). In image 3, (duplicate displayed below) the electricity rate for NY is displayed at $0.1742 per kilowatt, followed by an estimation of the current monthly bill of about $121, which was calculated from the user input of energy usage. After reconfirming that CPPR and EO were chosen as the Smart Grid dynamic pricing plan and Smart Grid technology, the simulation displays the price of the new monthly bill, here shown to be $106, followed by the monthly and annual savings of $15 and $180 respectively.

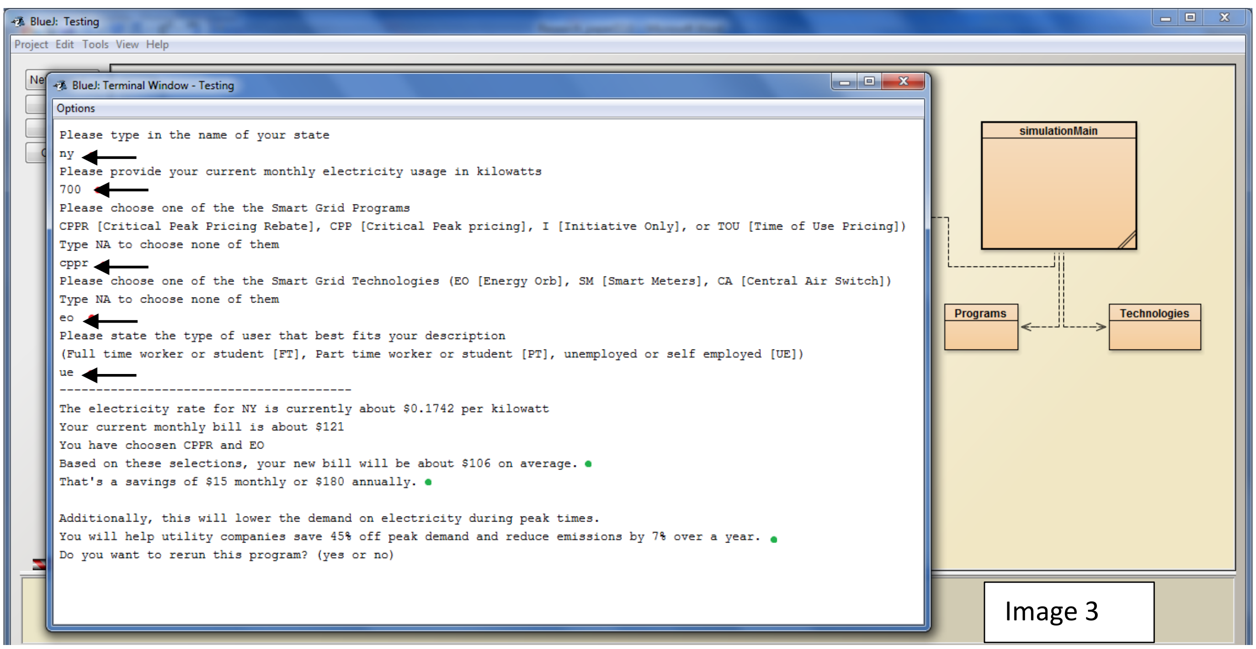


Image 3

Ultimately, the research objectives have been completed. The effects of various combinations of the Smart Grid technologies and Smart Grid programs have been successfully simulated. Quantifiable data that facilitates the user of the simulation program in accessing the advantages and disadvantages of investing in various Smart Grid technology and Smart Grid program have been provided. Lastly, the potential effects of the usage of the Smart Grid technologies and Smart Grid programs on utilities have also been calculated and provided via the simulation program.

Conclusions

By providing quantifiable data that shows consumers potential benefits from using Smart Grid technologies and programs, they will ultimately feel safe in investing in the Smart Grid project. Although a simulation program is now available to assist consumers in understanding the benefits, the simulation program remains to be able to be universally applied with maximum flexibility. However, once enough pilot studies have been conducted to allow for enough data to import into the simulation program, the program will be able to assist all consumers with maximum flexibility.

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