Demand Response Actualization in the Energy Market

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Demand Response

Motivation
• Wholesale Electricity Price changes over time.
Definition – Change consumption patterns (reduce demand)
• when the wholesale price is high
• when the reliability of the system is in jeopardy

Demand Response Programs Proposal

• One-hour Peak Load Events
• Multiple-hour Peak Load Events

Table 1. Summary of Top 100 peak load hours (05/01-10/31)

Rates

<table>
<thead>
<tr>
<th>Rates</th>
<th>Flat Rate</th>
<th>TOU (time of use) Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid peak</td>
<td>1.34</td>
<td>1.34</td>
</tr>
<tr>
<td>Non-peak</td>
<td>19.01</td>
<td>7.04</td>
</tr>
</tbody>
</table>

Load Forecast

Artificial Neural Network (ANN) Model

Performance Analysis

Table 2. Monthly Average & Max Mean Average Percentage Error (MAPE)

Efficient Load Shifting Strategy

Multi-Agent Load Shifting Modeling

Load Shifting Results

• The optimal shifting strategy is that customers can shift their reduced load to any hour after demand response (DR) as long as keeping the total load under the threshold triggered for DR.
• This strategy minimizes the average daily electricity price, helps to avoid new peak load, and provides some flexibility for customers to shift load at their convenience

Acknowledgement
Deepest Gratitude to my thesis advisor, Professor Judith Cardell
Smart Grid State Indicator
The future to save on electricity bills and improve energy efficiency
Jinjin Lu, Dr. Judith Cardell
Picker Engineering Program, Smith College

I. Do you care...?
✧ Electricity price changes every five minutes
✧ There is a smart way for you to budget your electricity consumption and to save energy!

II. Where to start?
The smart grid technology will enable the electricity users to make grid-friendly decisions based on grid states (120Volt & 60Hz). To manage electronic devices response, consumers will need the information on electricity prices and power system conditions, received from grid indicators.

1. Downloaded real-time market price LMP, ancillary service price, and load from New York Independent System Operator website.
2. Created a Matlab program to convert the composite price to signal index.

Signal components:
- LMP (locational marginal price), location, reliability index, and advisory indicator.
- CMP (composite market price) driven by wind power.

Figure 1. Potential prototype of grid indicator
Table 1. Signal Index value

- Pass in the latest five minute signal index and zonal load
- Initialize load agent for learning and define learning policy
- Set possible actions and reward given different signal index levels
- Choose best/random action and move to new state
- Calculate Q-value and update Q matrix
- Compare new Q-value with the old Q-value (diff=new-old)
- Find responsive load = real load + adopted action in learning cycle

Figure 3. Q-learning Flow Chart

III. First Glimpse...
Goal: Create an electricity signal consistent with grid states in New York State, and to assess the electricity demand response associated with the signal by adopting Q-learning algorithm (AI).

Signal components: LMP (locational marginal price), location, reliability index, and advisory indicator.
Signal representation: CMP (composite market price) driven by wind power.

New York State has 11 zonal areas as listed in Figure 2, and each area will need its own CMP.

IV. Creating Electricity Price Signals
- Downloaded real-time market price LMP, ancillary service price, and load from New York Independent System Operator website.
- Created a Matlab program to convert the composite price to signal index

Table 1. Signal Index value

<table>
<thead>
<tr>
<th>Meaning</th>
<th>Signal Index</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use More</td>
<td>0</td>
<td>-30</td>
<td>-30</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>-30</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>30</td>
<td>off peak avg</td>
</tr>
<tr>
<td>Use Freely</td>
<td>3</td>
<td>off peak avg</td>
<td>on peak avg</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>on peak avg</td>
<td>on peak avg</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1.1*on peak avg</td>
<td>1.33*on peak avg</td>
</tr>
<tr>
<td>Use Cautiously</td>
<td>6</td>
<td>1.33*on peak avg</td>
<td>1.67*on peak avg</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1.67*on peak avg</td>
<td>2*on peak avg</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2*on peak avg</td>
<td>3*on peak avg</td>
</tr>
<tr>
<td>Use Sparingly</td>
<td>9</td>
<td>3*on peak avg</td>
<td>6*on peak avg</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6*on peak avg</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. New York State load zones

VI. What can be achieved?
- Load response expectation
  - Signal index 0-2: increase load by 20%
  - Signal index 3-5: increase load by 10%
  - Signal index 6-8: decrease load by 10%
  - Signal index 9-10: decrease load by 20%
- Predicted load after learning cycle
  - Load response in the same direction as expected
  - The amount would be less than expected

Many thanks to my research advisor, Dr. Judith Cardell.
Consumer Interface for Real-Time Electrical Demand
Changing the way we use electricity
Geneviève de Mijolla '13 and Professor Judith Cardell
Smith College

Smart Grids

- Integrate an extensive set of sensors, as well as various control and communication methods, in order to monitor, protect, and optimize the delivery of electricity, both at the transmission and distribution levels
- Enable two-way communication between generators and consumers
- Improved operational efficiency
- Economic, environmental, and reliability advantages
- Allow for demand response programs to not only be more effective, but also more widespread: smart grids have the potential to involve consumers in a way that the current grid does not.

Physical Interface

Main advantages of the physical interface:
- More attention-grabbing than other display forms
- More intuitive to use, and thus more engaging for the whole family
- Especially effective when convincing less motivated customers to change the way they view and use electricity

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Objectives of this study

- To draw interest to power issues.
- To provide information to users about the current grid status and their electricity consumption
- To empower consumers to be make informed decisions about their electricity use

Website Interface

Main advantages of the website interface:
- The information on it is available from anywhere
- Historical information is available through this display
- A comparison of a user’s energy consumption to that of other buildings is provided through this display

Testing these displays by:
- Recording consumers’ impressions and feedback on the design
- Comparing the electrical load of residences using these displays to their previous electrical load to get an idea of their capacity to reduce electricity consumption during peak demand hours

Acknowledgements

I would like to acknowledge Professor Judith Cardell, Professor Paul Voss, Aaron Cantrell, Dale Renfrow, Eric Jensen, and Gregory Young for their contributions to this project.
Glowing Light: Electricity Consumption Monitoring Device

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Project Statement

The purpose of the electricity consumption monitoring device is to use the real-time electricity usage measurements of campus buildings accessible and alert the consumers if the electricity consumption exceeds the usual needs. The device is designed to indicate the current electricity consumed in a building both in numerical values and in colors: green, yellow, red.

Monitoring Device Design

Hardware
The circuit for the electricity monitoring device is mainly built of:
1. Arduino Mega 2560 board
2. Ethernet shield connected to an Ethernet cable
3. Prototyping shield as shown in Figure 2.

On the prototyping shield, six super bright single color LEDs are wired with the corresponding resistors as shown in Figure 2. The light pipe is connected to the LEDs with heat shrinks. The circuit is powered by a 9Volt battery.

Software
The Arduino board is programmed to extract the real-time electricity usage data from a sample html page via Ethernet and displays the data on the LCD screen. The device glows lights in three different colors (green, yellow, red) depending on the current power used in the building and the specified threshold kilowatt values.

LED Design Iterations

Figure 1. Prototype with electronic components soldered onto prototyping shields

To indicate the electricity usage level, six lighting options were tested:
1. Single color LED x6
2. Super bright single color LED x6
3. Diffused LED-10mm x6
4. Multicolor RGB LED, x2
5. Triple output high power RGB LED x2
6. Electroluminescent wire x3

Result
Super bright single color LED provides the brightest lighting both under the daylight and in the dark and requires less complicated wiring.

Electricity Consumption Threshold Plots

Figure 3
Figure 3 shows Smith College Park Annex electricity consumption for 15 different days in October 2011. The pattern is almost similar. To calculate threshold values (green, yellow and red regions), a percentage margin was created around that average.

Conclusion and Future Work

Future work will be forecasting electricity data (our thesis), putting the device in Park Annex House and observe the demand response from residents.

Acknowledgements

This project is completed with the help of Professor Judith Cardell, Zhouchangwan (Smith College), Eric Jensen, Greg Young and Dale Renfrow (Clark Science Center) and the funding from National Grid and SURF.

Reference