Energy Management Through Peak Shaving and Demand Response

Presented by:
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CTO, Advanced Charging Technologies

• PhD in Electrical Engineering
• Founder / Co-founder of several high tech firms
• Developed innovative & patented battery charging, monitoring & cloud management technologies
Objectives

• Identify new opportunities for energy savings at manufacturing and distribution facilities

• Understand the basics of peak shaving and demand response

• Understand how to implement peak shaving and demand response for charger and battery fleets

• Identify requirements to implement these energy savings programs
Motivation

• Unlike other commodities, electricity **cannot** be easily **stored**

• As a result, the market **cannot alleviate price fluctuations** by drawing down reserves

• Inconsistencies in electricity **supply and demand** can create more frequent / more **dramatic price changes**

• Challenge: How can end users **mitigate impact of supply and price fluctuations** on their energy **costs**?
Nature of Electricity Market Cycles

• The electricity market tends to follow a **seasonal cycle**
  • Demand for energy **rises during winter** (peak heating season) and summer (peak cooling season) and **drops during spring and autumn**
Nature of Electricity Prices

• Electricity price quotes from energy suppliers is a function of:
  • **Price of energy supply**: quoted in cents or dollars per unit
  • Amount to be supplied (i.e. "usage")
  • Duration of the service with start and end dates
Impact on End Users

• Changes in electricity supply and demand can create more frequent / more dramatic price changes

• For end users, electricity prices are a function of:
  
  • Electricity Consumption (kWhrs)
  
  • Electricity Demand – Instantaneous peak power usage (kW)
  
  • Time of use
Electricity Consumption

• The total amount of electricity used measured in kWh
  • Aggregation of energy used regardless of instantaneous power variations
Electricity Demand

• The rate at which energy is consumed
  • Determined by the instantaneous power variations
Consumption vs Demand

Power x Time = Energy Consumption

- 100 Watts × 10 Hours = 1,000 Watt-hours or 1 kWh

- 10 x 100 Watts × 1 Hour = 1,000 Watt-hours or 1 kWh

10 Times

Same

10x More Demand
Understanding the Electric Bill

For large end users, such as manufacturing and distribution facilities, the electricity bill consists of two components:

1. Energy consumption charges (kWhrs)
2. Demand charges (kW)
Understanding the Electric Bill

• Rates may vary between summer and winter months as well as between day and night hours

• Time of Use Pricing (TOU) – Utilities charge different rates depending on the time when electricity is used

• Three types of TOU pricing options
  • **On Peak**: hours are when electricity demand is the highest
  • **Mid Peak**: hours when the demand for electricity is relatively average
  • **Off Peak**: hours when energy consumption rates are the lowest
Typical TOU Schedules

Time-of-Use Schedule for Summer (May 1 to October 31)
On-Peak vs. Off-Peak Rates

**NON-SUMMER**

**OCTOBER-APRIL**

On-peak hours are weekdays only (no weekends or major holidays)

**SUMMER**

**MAY-SEPTEMBER**

On-peak hours are weekdays only (no weekends or major holidays)
**Typical Electricity Bill**

Billing period: Jun 3 ‘14 to Jul 2 ‘14 (29 days)

<table>
<thead>
<tr>
<th>Electricity (kWh)</th>
<th>Demand kW</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Season</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On Peak</td>
<td>373,222</td>
<td>3,341</td>
</tr>
<tr>
<td>Mid Peak</td>
<td>542,682</td>
<td>3,302</td>
</tr>
<tr>
<td>Off Peak</td>
<td>1,015,878</td>
<td>3,284</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,931,782</td>
<td></td>
</tr>
</tbody>
</table>
# Typical Electricity Bill

## Details of your New charges

Your rate: TOU-8-B BIP - Billing period: Jun 3 ‘14 to Jul 2 ‘14 (29 days)

### Delivery charges

<table>
<thead>
<tr>
<th>Facility rel demand</th>
<th>3,341 kW x $14.99000</th>
<th>$50,081.59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy-Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On Peak</td>
<td>373,222 kWh x $0.02010</td>
<td>$7,501.76</td>
</tr>
<tr>
<td>Mid Peak</td>
<td>542,682 kWh x $0.02010</td>
<td>$10,907.91</td>
</tr>
<tr>
<td>Off-Peak</td>
<td>1,015,878 kWh x $0.02010</td>
<td>$20,419.15</td>
</tr>
<tr>
<td>DWR bond charge</td>
<td>1,931,782 kWh x $0.02010</td>
<td>$9,910.04</td>
</tr>
</tbody>
</table>

### Demand-Summer

| Demand-Summer       | 3,341 kW x $25.33000 | $84,627.53 |
| On Peak             | 3,302 kW x $7,160000 | $23,642.32  |
| Off-Peak            |                      |            |

### Energy-Summer

| On Peak             | 373,222 kWh x $0.12752 | $47,593.27  |
| Mid Peak            | 542,682 kWh x $0.06733 | $36,538.78  |
| Off-Peak            | 1,015,878 kWh x $0.04017 | $40,807.82  |

### Total New Charges

$332,030.17

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**Consumption kWh Charges**

$173,678.73

**Demand kW Charges**

$158,351.44

~48%
Demand Charges

• Monthly charges based on the highest 15-minute monthly peak within a 12-month period, which is measured in kW.

• Typically account for 30–70% of an electricity bill and differ by season and time of the day.

• They are quite higher in the summer months as compared to winter months as well as day hours versus night hours.
Nature of Electric Demand

- Demand kW usage is dictated by the type and number of loads operated at a given point in time.

- Demand kW usage varies throughout the day and throughout the year.

Peak demand is typically determined based on the maximum amount of electricity drawn from the grid or over a short period of time, typically 15 minutes.

- Base Demand = 300 kW @ $8/kW
- Average Demand = 380 kW @ $8/kW
- Peak Demand = 520 kW @ $16/kW
Peak Demand

- Determined based on the maximum amount of electricity drawn from the grid over a short period of time, typically 15 minutes.
Reducing Energy Costs

• End users can reduce their energy costs by actively managing their peak demands throughout the year

• Peak demand can be reduced through
  
  1. Peak Shaving
  
  2. Demand Response Programs
Peak Shaving

• Reducing electrical usage during periods of maximum demand for the power utility

<table>
<thead>
<tr>
<th>Current Demand (kW)</th>
<th>Energy Saved</th>
<th>New Demand with Peak Shaving (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midnight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6am</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9am</td>
<td></td>
<td></td>
</tr>
<tr>
<td>noon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midnight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Peak Shaving

- Peak shaving can be realized using:
  - **Load Shedding**: Switching off loads during periods of peak demands
    - HVAC systems, some lighting, non-essential industrial machines, ...
  - **Adding Capacity via On-Site Generation**: Adding on-site generation can be added to offset peak demand
    - Renewable energy sources – such as solar PV, and battery energy storage – can be used for peak shaving programs
    - **Challenge**: Matching solar generation peaks with utility demand peaks!!
What is Demand Response (DR)?

Grid operators must meet peak demand reliably with all available resources.

If load increases:

1. Build generation
   - Build transmission
   - Build distribution

2. Consume less
   - Curtail during critical periods
   - Shift consumption to low peak periods

Supply

- Plant 1 Capacity
- Plant 2 Capacity
- Plant 3 Capacity

Demand

- Building 1 Demand
- Building 2 Demand
- Building 3 Demand
Demand Response (DR) Programs

• Demand Response (DR) is reducing electricity usage temporarily based on change in the price of power

• Designed to induce lower electricity use at
  • Times of high wholesale market prices
  • When system reliability is jeopardized
  • Without DR, grid operators would rely on expensive and polluting auxiliary power plants or stop supplying certain areas

• End-users that participate in DR events are financially compensated to reduce non-essential electricity
A customer reduces their peak demand by ~300kW from a baseline of 1,285kW to 965kW from 2:00 pm to 4:00 pm.
## DR Reduction Options

<table>
<thead>
<tr>
<th>Activity</th>
<th>Office Buildings</th>
<th>Retail</th>
<th>Data Center</th>
<th>Healthcare</th>
<th>Industrials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn off non-essential lighting</td>
<td>⬤</td>
<td>⬤</td>
<td></td>
<td>⬤</td>
<td></td>
</tr>
<tr>
<td>Raise air conditioning set points</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
</tr>
<tr>
<td>Reduce use of elevators and escalators</td>
<td></td>
<td>⬤</td>
<td></td>
<td>⬤</td>
<td></td>
</tr>
<tr>
<td>Delay dishwashing, laundry and ice machines</td>
<td>⬤</td>
<td></td>
<td>⬤</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay battery chargers, scrap compactors &amp; bailing machines</td>
<td>⬤</td>
<td></td>
<td>⬤</td>
<td>⬤</td>
<td></td>
</tr>
<tr>
<td>Delay batch processes &amp; non-essential pumping machines</td>
<td></td>
<td></td>
<td>⬤</td>
<td></td>
<td>⬤</td>
</tr>
<tr>
<td>Turn on allowable on-site generation</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
<td>⬤</td>
</tr>
<tr>
<td>Shift load to alternative locations</td>
<td></td>
<td>⬤</td>
<td></td>
<td></td>
<td>⬤</td>
</tr>
</tbody>
</table>
Why Would a Company Participate in DR?

• Commercial or institutional customers can save money and help the grid stay stable

• Reducing power at peak times can be more or less transparent to the end user
  • For example, changing thermostat settings on a supermarket freezer or dimming the lights in a hotel lobby for 15 minutes can be done in a way that doesn't affect people
DR Programs: Example PJM

• Emergency Load Response Program (ELRP)
  • A mandatory commitment to reduce load or only consume electricity up to a certain level → Penalties will be applied for non-compliance

• Economic DR
  • A voluntary commitment to reduce load in the energy market when the wholesale price is higher than the monthly net benefits price

• Synchronized Reserve Market (SRM)
  • The ability to reduce electricity consumption within 10 minutes of PJM dispatch
# DR Programs: Example PJM

<table>
<thead>
<tr>
<th>Effort Required</th>
<th>ELRP</th>
<th>Economic DR</th>
<th>SRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonality</td>
<td>June 1 to September 30</td>
<td>Year around</td>
<td>Year around</td>
</tr>
<tr>
<td>Effort Required</td>
<td>LOW</td>
<td>HIGH</td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td>▪ 0-2 dispatches, varies by zone</td>
<td>▪ You choose when and how long to participate. More participation yields higher earnings</td>
<td>▪ 5-15 dispatches. Need deep expertise to develop a bidding strategy to see a return from participation</td>
</tr>
<tr>
<td></td>
<td>▪ (Last mandatory dispatch was in 2013)</td>
<td>▪ You choose when to be notified - by 1:30 pm day prior or 2 hours ahead</td>
<td>▪ Dispatches are 12 minutes, on average, 30 minutes max.</td>
</tr>
<tr>
<td></td>
<td>▪ Dispatches range from 4-6 hours</td>
<td>▪ Get notified 10 minutes in advance</td>
<td>▪ Get notified 10 minutes in advance</td>
</tr>
<tr>
<td></td>
<td>▪ Get notified 30 minutes - 2 hours in advance.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reward Potential</td>
<td>MEDIUM</td>
<td>LOW</td>
<td>LOW</td>
</tr>
<tr>
<td></td>
<td>Earn $30-$70K per year per 1 MW. Earn even if there are no dispatches.</td>
<td>Earn $20K or more per year per 10 MW of demand for up to 20 hours a year.</td>
<td>Earn $15-$30K per year per 1 MW, 24x7. Earn even if there are no dispatches.</td>
</tr>
</tbody>
</table>
How Do DR Programs Work?

1. Notification
   - Notification is sent by demand response provider.

2. Curtailment Decision
   - Viewing energy and demand profiling to determine when and if you can curtail your energy usage.

3. Control Action
   - Load control scheduling is performed with predefined curtailment scripts.

4. Participation Response
   - Accept/reject curtailment response creating the cost saving for your business.
How Much Companies Can Expect to Earn?

• DR payments vary widely based on region, load profile, etc.
• PJM, considered very progressive in implementing DR, pays significant sums to companies that do voluntary reductions
  • In one month in 2012, PJM paid out $5 million to DR providers
  • DR programs can earn back 5% to 25% of the annual electricity costs
  • Users can expect payments in the range of $20-$45K per MW curtailed each year
DR Event Notification

• End users are notified via email, phone, pager, etc.
• End users then execute your predetermined curtailment plan
  • This process can be manual or automated
• Telemetry requirements
  • Hourly interval data
  • Revenue-grade one-minute interval data (+/-1% tolerance)
Application to Battery & Charger Fleets

• Battery chargers constitute a significant percentage of the electric demand at manufacturing & distribution facilities

• Managing battery and charger fleets’ energy use through peak shaving and DR allows facilities to reduce energy costs & meet sustainability goals
Implementation of DR for Charger Fleets

• There are two ways of implementing DR programs for charger fleets
  
  • **Static Energy Management (Manual)**
    - Upon receiving DR event notification, manually set the DR curtailment
    - Upon termination of DR event, revert to normal operation
  
  • **Dynamic Energy Management (Automated)**
    - Automatically receive and parse DR event notifications (e.g. email)
    - Build automated algorithms to set DR curtailment and termination
Enabling Technologies for Dynamic DR Programs

• Highly intelligent battery chargers & monitors

• Wireless / Remote monitoring & control

• Cloud-based monitoring and asset management

• Advanced / Automated Dynamic Energy Management Algorithms
Highly Intelligent Battery Chargers & Monitors

• Industrial Battery Chargers/ Smart Appliances → Industrial IoT (IIoT) Appliances
  • Integrated 2-way wireless communication
  • Machine-to-machine (M2M) communication
  • Remote command & control
  • Continuous data capture & upload
  • Real-time firmware updates
Wireless / Remote Monitoring & Control

• Employ a standard, well established, wireless technology (e.g. 802.11 b/n/g Wi-Fi)
  • Allows connectivity to a large number of devices
  • Utilizes a dedicated private Wi-Fi network
  • Isolated from client’s Wi-Fi networks

• Utilize a dedicated and isolated wireless backhaul (e.g. 4G/LTE)
  • Fully isolated from client’s IT infrastructure
  • Leverages existing network infrastructure
Cloud-Based Monitoring & Asset Management

- Web-browser based cloud application
- Centralized command & control
- Centralized data warehousing
- Centralized dashboard view & management
- Centralized reporting & analytics
Sample Cloud Application

- Load Balancer
- Web / Application Servers
- Database Servers
- Caching Servers
- Mail Server
Advanced Dynamic Energy Management Algorithms

• Fixed Curtailment:
  • Set a fixed x% curtailment for each charger (up to 100%)
    • Ex: For a 10kW charger fleet, for a 90% curtailment, set max power command for each charger to 10% or 1kW

• Dynamic Curtailment
  • Set a charger fleet wide % curtailment
    • Ex: For a fleet of 100, 10kW chargers (1 MW max load), for a 90% curtailment, set the max power of all chargers to 100kW
    • Implement an algorithm for optimizing battery fleet charging during reduced peak power periods
DR Algorithms: Fixed Curtailment

Static Peak Shaving Programming
DR Algorithms: Fixed Curtailment

Aggregate charger demand curtailed based on DR command while optimizing battery charging
DR Algorithms: Dynamic Curtailment

Aggregate charger demand curtailed based on DR command while optimizing battery charging.

Cloud Application
Implement dynamic curtailment

Power command sent to chargers on site

DR Command
Case Study: Cold Storage Facility

• A Cold Storage Facility in the US with 48, 12kW chargers
  • Peak charger demand = 615kW
  • Represents a significant % of facility demand (785-928 kW)

• Facility demand rate schedules for large commercial customers

<table>
<thead>
<tr>
<th>Summer: June – September</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Peak kW Rate</td>
<td>$19.81 per kW</td>
</tr>
<tr>
<td>Off-Peak kW Rate</td>
<td>$8.11 per kW</td>
</tr>
<tr>
<td>Winter: October – May</td>
<td></td>
</tr>
<tr>
<td>Max. kW Rate</td>
<td>$8.11 per kW</td>
</tr>
</tbody>
</table>
Case Study: Cold Storage Facility

• Peak demand and demand charges for 9 months
  • Min demand: 785 kW
  • Max demand: 928 kW
  • Max demand charge: $18,384

<table>
<thead>
<tr>
<th>Month</th>
<th>Peak Demand (kW)</th>
<th>Min. Demand Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>785</td>
<td>$6,366</td>
</tr>
<tr>
<td>February</td>
<td>787</td>
<td>$6,383</td>
</tr>
<tr>
<td>March</td>
<td>833</td>
<td>$6,756</td>
</tr>
<tr>
<td>April</td>
<td>836</td>
<td>$6,780</td>
</tr>
<tr>
<td>May</td>
<td>826</td>
<td>$6,699</td>
</tr>
<tr>
<td>June</td>
<td>871</td>
<td>$17,255</td>
</tr>
<tr>
<td>July</td>
<td>908</td>
<td>$17,987</td>
</tr>
<tr>
<td><strong>August</strong></td>
<td><strong>928</strong></td>
<td><strong>$18,384</strong></td>
</tr>
<tr>
<td>September</td>
<td>900</td>
<td>$17,829</td>
</tr>
</tbody>
</table>
Case Study: Fixed DR

- A fixed DR schedule was implemented
  - 17% curtailment of peak charger load demand
  - Peak power command set to 83% (max out current set to 250A vs 300A)
  - Power limit schedules were enabled between 10am and 3:30am
Case Study: Fixed DR

• Potential monthly peak demand savings vary from 133kW to 158kW

• This can yield $1,082 to $3,125 of monthly savings

• Over a 12-month period, the annual savings may exceed $23,000

<table>
<thead>
<tr>
<th>Month</th>
<th>Peak Demand (kW)</th>
<th>Demand kW Savings</th>
<th>Min. Demand Charges</th>
<th>Min. Demand Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>652</td>
<td>133</td>
<td>$5,284</td>
<td>$1,082</td>
</tr>
<tr>
<td>February</td>
<td>653</td>
<td>134</td>
<td>$5,298</td>
<td>$1,085</td>
</tr>
<tr>
<td>March</td>
<td>691</td>
<td>142</td>
<td>$5,607</td>
<td>$1,148</td>
</tr>
<tr>
<td>April</td>
<td>694</td>
<td>142</td>
<td>$5,627</td>
<td>$1,153</td>
</tr>
<tr>
<td>May</td>
<td>686</td>
<td>140</td>
<td>$5,560</td>
<td>$1,139</td>
</tr>
<tr>
<td>June</td>
<td>723</td>
<td>148</td>
<td>$14,321</td>
<td>$2,933</td>
</tr>
<tr>
<td>July</td>
<td>754</td>
<td>154</td>
<td>$14,930</td>
<td>$3,058</td>
</tr>
<tr>
<td>August</td>
<td>770</td>
<td>158</td>
<td>$15,258</td>
<td>$3,125</td>
</tr>
<tr>
<td>September</td>
<td>747</td>
<td>153</td>
<td>$14,798</td>
<td>$3,031</td>
</tr>
</tbody>
</table>
Key Takeaways

• Manufacturing and distribution facilities can realize significant energy savings by participating in DR events.

• Since charger fleets constitute a significant percentage of their load, enlisting these assets in DR events is essential.

• Smart charger and battery appliances are essential to implementing advanced DR algorithms and maximizing energy savings.
For more information

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