Sample Research Projects at Virginia Tech Advanced Research Inst.

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PPT slides will be available at
www.saifurrahman.org
### Sponsored Projects at ARI

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<td>Partnerships for Innovation (PFI): Role of the Smart Grid in Alleviating Electrical Power System Stress Conditions Through Demand response</td>
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<td>A Test-Bed for Analyzing the Security and Resiliency of the DG-integrated Electric Power Distribution Network</td>
<td>US National Science Foundation</td>
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<td>4</td>
<td>US-Egypt Cooperative Research: Managing Grid Integration of Large-Scale Wind Power Parks using Energy Storage Technology and Demand Response</td>
<td>US National Science Foundation</td>
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### Organization

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<td>US National Science Foundation</td>
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<td>Building Energy Management Open Source Software (BEMOSS)</td>
<td>US Department of Energy</td>
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Role of the Smart Grid in Alleviating Electrical Power System Stress Conditions Through Demand Response

Objective: To design and develop a smart grid sensing and control hardware and software platform that enables efficient and flexible demand response programs with customer choice.

Sponsored by US National Science Foundation

www.ceage.vt.edu/ceage_projects

Electric Utility Efficiency Improvement

Dominion Virginia Power Load Curve (2010)

Peak load of 19,140 MW

Probability that peak loads exceed 16,000 MW is only 5% of the time

3,140 MW or 16.5% of peak load
Peak Load and its Duration

• In the US 20% of the load happens only 5% of the time
• In Australia 15% of the load happens less than 1% of the time
• In Egypt 15% of the load happens only 1% of the time

How is the peak load managed in the US today
Electric Utility – Smart Cooling Rewards ($40/year)

Utility installs an A/C cycling switch on home outdoor cooling system

AC Cycling Switch

Testing the AC Cycling Switch

Installing the AC Cycling Switch

AC Cycling Switch Installed

Electric Utility – Smart Cooling Rewards Events

- During periods of high demand between June 1 and September 30, Dominion may call an “event” and cycle ON/OFF the cooling system.
- Cycling times are limited to weekdays for 2-4 hours between 2pm and 6pm.

Events for 2013

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>August 12</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>August 9</td>
<td>2:30-4:30 pm</td>
</tr>
<tr>
<td>July 23</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>July 19</td>
<td>2:00-6:00 pm</td>
</tr>
<tr>
<td>July 18</td>
<td>2:00-6:00 pm</td>
</tr>
<tr>
<td>July 17</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>July 16</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>July 15</td>
<td>4:00-6:00 pm</td>
</tr>
<tr>
<td>June 26</td>
<td>3:00-5:00 pm</td>
</tr>
<tr>
<td>June 25</td>
<td>3:00-5:00 pm</td>
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</table>

Events for 2014

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 8</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>July 7</td>
<td>3:30-5:30 pm</td>
</tr>
<tr>
<td>July 2</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>July 1</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>June 19</td>
<td>1:00-3:10 pm</td>
</tr>
<tr>
<td>June 18</td>
<td>3:00-6:00 pm</td>
</tr>
<tr>
<td>June 17</td>
<td>3:00-6:00 pm</td>
</tr>
</tbody>
</table>
Drawback of the Current Approach

- Air conditioning is turned off when needed the most
- Homeowner has no control after the initial consent

Proposed Solution

- Electric utility sends a signal through the smart meter or home internet gateway
- Home Energy Management (HEM) system optimizes appliance/equipment operation to provide the peak load reduction requested, but maintains customer comfort
- The homeowner gives the utility the peak load saving it wants, but on his/her own terms

Virginia Tech Solution

Control multiple non-critical loads
### Example of Load Priority and Preference Settings

<table>
<thead>
<tr>
<th>Load</th>
<th>Water Heater (WH)</th>
<th>Space cooling (AC)</th>
<th>Clothes Dryer (CD)</th>
<th>Electric Vehicle (EV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>#1. Priority setting</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>#2. Preference setting</strong></td>
<td>110-120°F</td>
<td>76°F (±2°F)</td>
<td>Not to exceed 85°F</td>
<td>Finish the job by midnight</td>
</tr>
</tbody>
</table>

### Home Energy Management Unit Setup

- **Load Controller**
- **Data communication & control signal**
- **External control signal from a utility**
- **Demand limit (kW)**
- **Gateway**
- **Distribution board & meter**
- **AC unit (2-3kW)**
- **Clothes dryer (4-6kW)**
- **Electric vehicle (3.3-16.8kW)**
Web Services for Demand Response Applications

Utility Control Center

Smart meter

Firewall

Internet

Web services

DR signal from utility

HEM = Home energy management system

Appliances

HEM User Interface

Seen on an iPad

Virginia Tech Home Energy Management System

- HVAC
- Water Heater
- Clothes Dryer
- Electric Vehicle
- Total Household Consumption

Monitor:
- HVAC temperature set point
- Water heater temperature set point
- Clothes dryer temperature set point
- Electric vehicle charging

Graphs:
- HVAC temperature
- Water heater temperature
- Clothes dryer temperature
- Electric vehicle temperature

Buttons:
- Power
- Set
- Save
- Cancel

Text:
- Cool 75 F
- Heat 78 F
- Water heater temperature 140 F
- Clothes dryer running time
- Electric vehicle charging
- Electric vehicle charging time
- Electric vehicle charging duration
- Electric vehicle charging status
- Electric vehicle charging temperature
- Electric vehicle charging temperature set point

10.2 kW

(Street Address and City, State, Zip)
From the Residential to the Commercial Sector

Building Energy Efficiency

Buildings consume over 40% of the total energy in the US

90% of commercial buildings are small (<5,000 sq ft) or medium-sized (<50,000 sq ft) and have no energy saving measures available
Commercial Building Sizes in the US

Opportunities and Benefits of Energy Efficiency

These buildings typically do not use building automation systems to make them energy efficient.

Policies encouraging building energy efficiency can reduce energy consumption and encourage product development and job opportunities in the service sector.
Breakdown of Electricity Usage

Electricity use in buildings

Source: EIA - Commercial Building Energy Consumption Survey (CBecs)
http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption#e1a

Three major loads in buildings:
- HVAC
- Lighting loads
- Plug loads

HVAC
30%

Lighting load
38%

Plug load
6%

Others
26%

Building Energy Management Open-Source Software

VT OS

HVAC Controllers

Lighting Controllers

Plug load Controllers

VT OS

Linux

Objects

Building 1

Building 2

Building 3
Study Diverse Building Types

Long Branch Nature Center
Arlington, VA

VT Architecture building
Alexandria, VA

VT building
Blacksburg, VA

Virginia Tech Architecture Building

3 floors
25,000 sq ft

Exterior lighting

Entrance to Parking Garage
Hardware/Software Deployment for Small Buildings

Software on Various Embedded Devices

<table>
<thead>
<tr>
<th>Device</th>
<th>CPU</th>
<th>RAM</th>
<th>Ethernet</th>
<th>USB 2.0</th>
<th>Price</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raspberry Pi</td>
<td>700 MHz ARM processor</td>
<td>512MB SD</td>
<td>10/100 RJ45</td>
<td>Available</td>
<td>$35</td>
<td>3.4”x2.2”</td>
</tr>
<tr>
<td>beagleboard</td>
<td>1GHz ARM Cortex-A8</td>
<td>512MB SD</td>
<td>10/100 RJ45</td>
<td>Available</td>
<td>$55</td>
<td>3.4”x2.1”</td>
</tr>
<tr>
<td>panda board</td>
<td>Dual core 1.2GHz ARM Cortex-A9</td>
<td>1GB SD</td>
<td>10/100 RJ45</td>
<td>Available</td>
<td>$220</td>
<td>4.5”x4.0”</td>
</tr>
</tbody>
</table>
Bi-Level Demand-Sensitive LED Street Lighting Systems

*Pis: Dr. Saifur Rahman and Dr. Manisa Pipattanasonporn*

Objective: To design, develop and demonstrate an energy efficient bi-level demand-sensitive LED street lighting system and returned to full intensity when traffic is detected.

The streetlight will be dimmed at night.

Sponsored by US Army Corps of Engineers
Department of Defense

LED Lighting Project @ Carderock
People/cars are clearly visible under the white LED light.

June 11, 2012 @ 9:14PM
Light Intensity = 80%
HPS vs LED
Monthly Electricity Consumption

Average electricity savings of 75% was experienced after the installation.

LED Street Lights in Arlington
Solar Photovoltaics

Roof-top Solar at Virginia Tech Arlington Research Center

Dominion Virginia Power’s MW-scale Solar PV Facility at a Canon Facility in Virginia

Growing Renewable Energy in the Commonwealth

Source: www.dom.com
Mid-Atlantic Off-shore Wind Resource

http://www.midatlanticocean.org/map.html
Virginia Wind Area of Potential

20 blocks = 2,400 MW @ 6 MW & 3,000 MW @ 5 MW
Name plate capacity at full build-out of WEA

VT Advanced Research Institute is a Founding Member (www.vcerc.org)
National Capital Region Highlights

Department of Energy awards Dominion $47 million for wind project; Advanced Research Institute has key role

The federal Department of Energy (DOE) has awarded Richmond-based Dominion Virginia Power an additional $47 million over the next four years to help fund the construction of a 12-megawatt offshore wind turbine demonstration project off the coast of Virginia Beach. Dominion was one of three companies — out of seven finalists — to advance to the second phase of demonstration.

The Dominion-led Virginia Offshore Wind Technology Advancement Project (VOWTAP) consists of two 6-megawatt direct-drive offshore wind turbines that will produce enough electricity to power up to 3,000 homes. It will be located in federal waters about 24 miles off the coast of Virginia Beach, directly adjacent to the commercial area Dominion is leasing from the Bureau of Ocean Energy Management.

Dominion said it intends to apply the research and lessons learned from VOWTAP to the development of the commercial lease.

Virginia Tech Advanced Research Institute (ARI), representing the Virginia Coastal Energy Research Consortium, is part of the VOWTAP team.

Other On-Going Work at ARI – Electric Vehicles

Study distribution transformer overload due to EV charging
Thank You

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