Start-ups and Entrepreneurship Opportunities and Challenges for University Professors

Invited Talk
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Vellore Inst of Tech, Vellore, India, 13 February 2021
Areas of Focus

Smart Grid  
Smart Cities  
Energy Efficiency  
Renewable Energy  
Sensor Integration  
Internet of Things (IoT)

ARI Research Projects - 1

1. Partnerships for Innovation (PFI): Role of the Smart Grid in Alleviating Electrical Power System Stress Conditions Through Demand response  
Sponsor: US National Science Foundation

Sponsor: US National Science Foundation

Sponsor: US National Science Foundation

4. US-Egypt Cooperative Research: Managing Grid Integration of Large-Scale Wind Power Parks using Energy Storage Technology and Demand Response  
Sponsor: US National Science Foundation

5. Qatar Power System Transition to a Smart Grid  
Sponsor: Qatar National Research Foundation
ARI Research Projects - 2

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<td>7 Feasibility and Guidelines for the Development of Microgrids in Campus Type Facility</td>
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ARI Research Projects - 3

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<td>Commonwealth Edison Company (Exelon), Chicago</td>
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<td>15 A Probability-based Model for Cost-effective Integration of Renewables into the Electricity Grid</td>
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Purpose and Objectives

• Buildings consume over 40% of the total energy consumption in the U.S. Over 90% of the buildings in the U.S. are either small-sized (<5,000 square feet) or medium-sized (between 5,000 sf and 50,000 sf). These buildings typically do not use Building Automation Systems (BAS) to monitor and control their building systems from a central location.

• WiseBldg platform facilitates energy efficiency applications in commercial buildings using a very simple and scalable building automation system (BAS).

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.
How to Shift Load
Home Energy Management Unit

External control signal from a utility

AC unit (2-3 kW)

Demand limit (kW)

Gateway
Distribution board & meter

Load Controller
Data communication & control signal

Building Energy Management Open Source Software (BEMOSS) Platform

Objective: Develop a web-based Building Energy Management Open Source Software (BEMOSS) platform for optimizing electricity usage and building operations in small and medium-sized buildings.

Sponsored by US Department of Energy
Buildings consume over 40% of the total energy consumption in the U.S. Over 90% of the buildings in the U.S. are either small-sized (<5,000 square feet) or medium-sized (between 5,000 sqft and 50,000 sqft). These buildings typically do not use Building Automation Systems (BAS) to monitor and control their building systems from a central location.

Vision/Problem

Bringing custom energy control to small & medium commercial buildings

95%

U.S. Commercial Properties are less than 50,000 square feet

Current systems are too expensive, so energy is wasted
Classroom under Real-time Monitoring

- Power meter
- Thermostat
- Motion sensor
- Environmental sensor (CO2, noise, temperature, RH)
- BEMOSS core
- Plug load controller

Indoor Environmental Monitoring

- Bemoss Core: Weather Sensor 21
- Indoor Environmental Status:
  - Temperature: 71.4°F
  - Humidity: 22.0%
- Outdoor Environmental Status:
  - Temperature: 74.3°F
  - Humidity: 49.0%
- WeatherSensor: CO2
- Graph showing CO2 levels over time
Using WiseBldg, Building Operator saved 27% on HVAC consumption alone.

**Location:** Alexandria, VA  
**Area:** 25,000 square feet  
**Deployed Devices:**  
- 6 Thermostats  
- 6 Power meters  
- 1 Li-ion battery  
- 1 Environmental sensor

### Summer Months (June-July-August)

<table>
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<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Compressor consumption 2014 (Before WiseBldg)</td>
<td>8,340 kWh</td>
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<tr>
<td>Compressor consumption 2016 (After WiseBldg)</td>
<td>6,071 kWh</td>
</tr>
<tr>
<td>Average savings</td>
<td>26.8% savings</td>
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</table>

**Base case (w/o WiseBldg):**  
- **Setpoint:** 74 deg F  
- **Energy usage:** 2.72kWh  
- **Max demand:** 3.98kW

**Managed by WiseBldg:**  
- **Setpoint:** 77 deg F  
- **Energy usage:** 1.42kWh  
- **Max demand:** 0.5kW

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**Office Building, Arlington, Virginia**  

Office building size: 5,000 sqft
Using WiseBldg the building operator reduced HVAC consumption by 27%.

**Energy Savings from Lighting Control**

**Location:** Arlington, VA  
**Area:** 5,000 sq ft  
**Deployed Devices:**  
- 3 Lighting controllers  
- 1 Power meter

An average energy savings of 35% was achieved through dimming control:

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<tbody>
<tr>
<td>% Savings</td>
<td>33.7%</td>
<td>33.9%</td>
<td>34.4%</td>
<td>33.4%</td>
<td>35.9%</td>
<td>36.2%</td>
<td>35.0%</td>
<td>36.0%</td>
<td>36.3%</td>
<td>34.5%</td>
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**Energy Savings by controlling light intensity**

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Measured Energy Consumption (kWh)</th>
<th>Total Calculated Energy Consumption without Dimming (kWh)</th>
<th>Energy Savings by Dimming (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2016</td>
<td>264.37</td>
<td>399.90</td>
<td>33.89%</td>
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<tr>
<td>November 2016</td>
<td>278.13</td>
<td>423.78</td>
<td>34.37%</td>
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<tr>
<td>December 2016</td>
<td>280.76</td>
<td>426.40</td>
<td>34.16%</td>
</tr>
<tr>
<td>Total (October-December)</td>
<td>823.26</td>
<td>1250.08</td>
<td>34.14%</td>
</tr>
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**Note:** Scheduled dimming level from 6:30am to 9:00pm. Open office area A: 50%; Open office area B: 45%; Chief office’s desk area: 60%; Chief office’s meeting area: 50%; Conference room A: 50%; Conference room B: 45%. Lights are off after 9:00pm.
Solar PV System Monitoring and Control

WiseBldg User Interface
Managing Battery Storage from WiseBldg Platform

Battery Storage Data Access from WiseBldg
Battery Storage Monitoring & Control

EERE News Archives & Events

March 11, 2015
Virginia Tech Selected to Continue Development of Innovative Building Automation System

The Energy Department announced on March 4 that it has awarded the Virginia Polytechnic and State University Advanced Research Institute nearly $2 million to continue research and development of its Building Energy Management Open Source Software for small and medium-sized commercial buildings. Currently, small and medium buildings make up more than 50% of the floor space and consume about 50% of the energy used by commercial buildings in the United States each year.

Most commercial buildings in the U.S. are small (less than 5,000 square feet) or medium-sized (between 5,000–50,000 square feet), and fall outside of the scope of most commercial buildings automation systems. The goal of this project is to develop an open source software as a backbone for improving building automation systems that enable major building components to interconnect with each other. This includes heating, ventilation, and air conditioning systems, lighting, water heater, and significant ancillary loads. More interconnection among the systems will lead to improved occupant comfort, while reducing energy use and the cost of building ownership and operation. See the Energy.Department news release.
Buildings automation systems are key to reducing energy use in America since commercial buildings consume 30% of all the fossil energy used in the United States. A major problem we’re working to solve is that 30% of all commercial buildings are 50,000 square feet or less in size and most of these smaller buildings can’t use energy-saving automation systems designed and proven for larger buildings. Learn how we’re supporting researchers at Virginia Tech who are building an open source solution that can make buildings more energy efficient and enhance occupants’ comfort: http://go.usa.gov/xb37x.

Virginia Tech Selected to Continue Development of Innovative Building Automation System

March 4, 2015 – 11:05am

The Energy Department has awarded the Virginia Polytechnic and State University Advanced Research Institute nearly $2 million to continue research and development of its Building Energy Management Open Source Software (BEMOSS) for small and medium-sized commercial buildings. Currently, small and medium sized buildings make up about 95% of commercial buildings, and represent about 50% of the floor space in this sector.

Most commercial buildings in the U.S. are small (less than 5,000 square feet) or medium-sized (between 5,000-50,000 square feet), and fall outside the scope of most commercial buildings automation systems (BAS).
Transitioning from a Research Project to a Commercial Enterprise

www.bemcontrols.com
Building Energy Open Source Management Software (BEMOSS)

Open Source Version at: www.bemoss.org

Commercial Version (BEMOSS®-plus)
at: www.bemcontrols.com
Smart Lighting and AC Control

Cherry Dale
Library in Arlington, Virginia

LED Lighting Control

Equipment Bureau Building in Arlington, Virginia
Smart Appliance Control

- Remotely accessible WiFi Plug Load Controller

Building Automation System (BAS)

- Scheduled operation
  - Heating, Ventilation and central AC systems
  - Lighting systems
  - Escalator operation
Efficacy of Light Bulbs

- **Incandescent**
  - 15 lumens/watt
  - 1000 hour life

- **CFL**
  - 50 lumens/watt
  - 8,000 hour life

- **LED**
  - 100 lumens/watt
  - 30,000 hour life

WiseBldg supports multiple IoT devices through industry standard protocols and communications technologies.
Multiple-protocol Interoperability

Communication Technologies
- Ethernet (IEEE 802.3)
- Serial Interface (RS-485)
- ZigBee (IEEE 802.15.4)
- WiFi (IEEE 802.11)

Data Exchange Protocols
- BACnet (IP and MS/TP)
- Modbus (RTU and TCP)
- Web (e.g., XML, JSON, RSS/Atom)
- ZigBee API
- Smart Energy (SE)
- OpenADR (Open Automated Demand Response)

WiseBldg Platform for Campus-wide Application

Utility/DR Aggregator
- Energy management
- Security

Customers/Operators
- Occupant comfort
- Demand response
- Energy Savings
- Billing

Internet
- HVAC
- Lighting loads
- Plug loads
- Sensors/power meters
- Water meters
- PV & storage
- Security camera

www.bemcontrols.com
Customers controlling buildings optimized for savings

Measured energy savings across deployments
- 20% HVAC Energy Savings
- 25% Lighting Energy Savings

**Improved operations and maintenance:** WiseBldg analytical platform enables operators to detect faults when devices operate outside standard thresholds enabling building operators to investigate prior to device failure.

**Occupant satisfaction:** spaces controlled by WiseBldg have been more comfortable due to more consistent temperature profiles and healthier air quality through consistent monitoring of environmental factors (CO2 levels, PM 2.5).
WiseBldg can make an old building smart
WiseBldg Deployments in Four Buildings

Building 1 – VT Classroom Building
- Location: Alexandria, VA
- Demonstration: HVAC, plug load control

Building 2 – Equipment Bureau Building
- Location: Arlington, VA
- Demonstration: Lighting control

Building 3 – VT Lab Building
- Location: Blacksburg, VA
- Demonstration: HVAC control

Building 4 – PG County Community Building
- Location: Camp Springs, MD
- Demonstration: HVAC control

Building 1 – VT Building in Alexandria, VA
- Alexandria, Virginia, USA
- Area: 25,000 SF
- Energy: 14-25 MWh/mo.
- Peak load: 61 kW
Thank You

IEEE President-elect Election

www.ieee.org/elections

Prof. Saifur Rahman (s rahman@ieee.org)