Energy Efficiency in Smart Buildings Through IoT Sensor Integration

Invited Lecture

Professor Saifur Rahman

Director, Virginia Tech Advanced Research Inst., USA
President, IEEE Power & Energy Society 2018 & 2019

IEEE Macedonia Section, 16 July 2020
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).
WiseBldg is a Building Energy Management Open Architecture Software solution that is engineered to improve sensing and control of all IoT-enabled equipment in commercial buildings.

Three major loads in buildings:
- Heating, Ventilation, AC
- Lighting loads
- Plug loads

Monitoring and control:

Value:
Improves energy efficiency and facilitates peak load savings in buildings.

www.bemoss.org
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 Built by BEM Controls

- Occupant comfort
- Demand response
- Energy Savings (kWh)
- Building Energy Management
- Peak demand (kW) reduction
- Alarm & Notifications
- Security Surveillance

Utility/DR Aggregator
- DR Event
- Pricing
- Billing

Encrypted Data Link
Router

Customers/Operators

Buildings

Internet

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

Virginia Tech
Invent the Future
WiseBldg can make an old building smart
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 Deployments in Four Buildings

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

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

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

4. **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
Classroom under Real-time Monitoring

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

Bemoss Core: Weather_Sensor21

Indoor Environment Status
- Temperature: 71.4°F
- Humidity: 22.0%
- Pressure: 30.65 Pa
- CO2: 484.0 ppm
- Noise: 47.0 dB

Outdoor Environment Status
- Temperature: 74.3°F
- Humidity: 49.0%
- Maximum Recorded Temperature: 74.3°F
- Minimum Recorded Temperature: 74.3°F

Graph: Weather_Sensor21: CO2
Using WiseBldg, the building operator reduced HVAC consumption by 27%.

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

Using WiseBldg, Building Operator saved 27% on HVAC consumption alone

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

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

**Temperature profile BEFORE WiseBldg Demand Reduction**

**Temperature profile AFTER WiseBldg Demand Reduction**

**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
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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></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>
</tr>
</tbody>
</table>
### Energy Savings by controlling light intensity

**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.

<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>
</tr>
<tr>
<td>November 2016</td>
<td>278.13</td>
<td>423.78</td>
<td>34.37%</td>
</tr>
<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>
</tbody>
</table>
Solar PV System Monitoring and Control
WiseBldg User Interface

Smart inverter control
Managing Battery Storage from WiseBldg Platform

Battery Cells

LG Chem

EGUANA AC BATTERY™

- BATTERY READY
- COMMAND READY
- SYSTEM CERTIFIED

5 kW 12 kWh

145 lbs 188 lbs 188 lbs

5 kW

12 kWh

-06L

-12L

48" above floor

PCS

battery

battery expansion

Virginia Tech
Invent the Future
Battery Storage Data Access from WiseBldg
Battery Storage Monitoring & Control

BATTERY STORAGE

CURRENT STATUS

CURRENT READINGS

STATE OF CHARGE

98.9 %

OUTPUT POWER

-0.013 kW

CHARGING
All Buildings should be Smart Buildings

Building Automation Systems (BAS) can slash power consumption and energy bills significantly, but they are too expensive for most buildings.

*BEM Controls breaks through this barrier.*

Our Wise Building (WiseBldg) platform is affordable and works with any existing loads to make any building smart, no matter the size or age.

[www.bemcontrols.com](http://www.bemcontrols.com)
I would like to see a broader IEEE

We need to ensure that we are “READY FOR RECOVERY”, when we get back to the “NEW NORMAL” after COVID-19. Let us enhance cooperation, collaboration and community spirit.

For this we need to make IEEE broader so that IEEE is more relevant to the work our members do regardless where they work.

We need more participation from volunteers globally in IEEE governance. A broader based IEEE will make the Institute more relevant to technologists and academics from all parts of the world.

I would like to see more IEEE Senior Members and IEEE Fellows from Regions 8, 9 & 10
IEEE President-elect Candidate 2020

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

Past-President of IEEE Power & Energy Society
Past-Chair, IEEE Publication Services & Products Board

PES accomplishments:
  PES University
  PES Corporate Engagement Program
  PES Chapters’ Councils in China, India, Africa and Latin America

website: https://www.srahman.org