IoT Sensor Integration from Smart Buildings to the Smart Grid

Invited Lecture
Professor Saifur Rahman
Director, Virginia Tech Advanced Research Inst., USA
President-elect, IEEE Power & Energy Society

Northeast Electric Power Univ., Jilin City, China, 29 November 2017

Virginia Tech Research Center
Arlington, Virginia, USA

PPT slides will be available at www.saifurrahman.org
From Smart Buildings to Smart Grid

Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy...

Smart city: Complex system of interconnected infrastructures and services...

Smart Campus: A collection of buildings managed by the same facility manager...

Smart buildings: Intelligent building automation systems, smart devices, productive users, grid integration...

Supported by ICT and distributed networks of intelligent sensors, data centers/clouds

What makes a Building Smart

A single platform for monitoring and control of HVAC, lighting, water supply, sensor networks, security camera & fire emergency

IoT-enabled smart buildings offer in-building device mobility, occupant comfort, and indoor activities automation.

How do you make a large number of IoT devices work together?

Need a software platform.
Virginia Tech Platform for IoT Device Integration

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)
An Open Architecture Platform for Building Energy Efficiency

BEMOSS is a Building Energy Management Open Source Software (BEMOSS) solution that is engineered to improve sensing and control of all IoT-enabled equipment in commercial buildings.

BEMOSS monitoring and control:
- Three major loads in buildings:
  - Heating, Ventilation, AC
  - Lighting loads
  - Plug loads

BEMOSS value:
- Improves energy efficiency and facilitates peak load savings in buildings.

Multi-sensor Applications

BEMOSS monitoring and control:
- Three major loads in buildings:
  - Heating, Ventilation, AC
  - Lighting loads
  - Plug loads

BEMOSS value:
- Improves energy efficiency and facilitates peak load savings in buildings.

Multi-sensor Applications

BEMOSS monitoring and control:
- Three major loads in buildings:
  - Heating, Ventilation, AC
  - Lighting loads
  - Plug loads

BEMOSS value:
- Improves energy efficiency and facilitates peak load savings in buildings.
11/29/17

Raising the set point from 6am-6pm demonstrates 10.5% energy savings in HVAC load per degree temperature increase.

25,000 sqft building in Alexandria, VA

5 Wireless thermostats

Outdoor temperature profiles:

Indoor temperature set-points:

Classroom under Real-time Monitoring

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

Smart Light Intensity Control
Energy Savings by Controlling Light Intensity

Based on occupant requirements, light intensity level was reduced during October – December 2016. Results indicate the average kWh savings of about 34%.

<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>

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 on an Unified Platform
Solar PV and Smart Inverter Integration

Monitoring & Control of Renewables
Battery Storage Project at Virginia Tech in Alexandria

Battery Cells

5 kW 12 kWh

Battery Storage Data Access from BEMOSS
Battery Storage Monitoring & Control

Smart Campus

Utility/DR Aggregator

Internet

HVAC
Lighting loads
Plug loads
Power meters
Water meters
PV & storage
Security camera

Customers/Operators

Buildings
All Sensors Visible from one Dashboard

- Power meter
- Water meter
- HVAC
- Lighting load
- Plug load
- PV & storage
- Security camera

Building Energy Management Open Source Software (BEMOSS)

Provides building automation services to small to medium-sized buildings

Provides sensing and control services for roof-top solar, battery storage, security camera, etc.
Available from:

Open Source Version at: www.bemoss.org

Advanced Version (BEMOSS®-plus) at: www.bemcontrols.com
A **smart city** is an urban development vision to integrate **information and communication technology** (ICT) and **Internet of things** (IoT) technology in a **secure** fashion to manage a city's assets.


**ICT Applications in a Connected Smart City**

Schools, libraries, transportation systems, hospitals, power plants, water supply networks, law enforcement, **street lighting**, etc.
Smart City Connected Community

Evolution of the Grid

**Before** Smart Grid:
One-way power flow, simple interactions

**After** Smart Grid:
Two-way power flow, multi-stakeholder interactions

Source: Altalink, Alberta, Canada
Smart Grid

The Entire Electrical Power System From Generation to End Use

- Engaging Consumers
- Enhancing Efficiency
- Ensuring Reliability
- Enabling Renewables

Interconnected by a Communication Fabric that Reaches Every Device

Highly Instrumented with Advanced Sensors and Computing

Thank You

Professor Saifur Rahman

www.bemcontrols.com
www.saifurrahman.org