Smart Grid and IoT for the Integration of Renewables in Saudi Arabia

Keynote Speech

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www.ieee.org/elections
"Smart grid" is a concept with many elements where monitoring and control of each element in the chain of generation, transmission, distribution and end-use allow the electricity delivery and use to be more efficient.
Electric Power Grid

Source: www.sxc.hu
Desire to make the grid smarter, safer, reliable and more cost-effective using advanced sensors, communication technologies and distributed computing.
Difference Between a Normal Grid And a Smart Grid

Normal Phone

Smart Phone

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Starting and End Points of a Smart Grid

From Generator to Refrigerator

Power Plant
Transmission
Distribution
Home Business
End-use Appliances
Smart Grid Building Blocks

- Technology
- Standards
- Rates & Regulations
- Consumer Awareness & Education
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
Intelligent Load
Demand or price-driven control of appliances

Sensors
Detect outages, fluctuations, and disturbances

Distributed Arch.
Distribution Network
Interconnected micro grids

Intelligent Interconnected Microgrids

Local Monitoring and Control

Bulk Power Plant

Control Room Functions
Balance electricity Supply/demand across the grid

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Merging Power Flow with Information Flow:

Integrated Communications
Electric Power & Communication Infrastructures

1. Power Infrastructure
- Central Generating Station
- Step-Up Transformer
- Distribution Substation
- Receiving Station
- Distribution Substation
- Commercial
- Industrial
- Recip Engine
- Flywheel
- Fuel cell
- Cogeneration
- Residential Data Concentrator
- Photovoltaics
- Batteries
- Microturbine

2. Information Infrastructure
- Control Center
- Data network Users
- Recip Engine

Source: EPRI
Changing Landscape for the Electric Utility
In-depth look at Solar PV in KSA

2-MW Roof-top Solar PV plant at KAUST
Clean Panel Solar PV Output (100kWp)
Riyadh Area

PV AC Power Output During One Sunny Week

Sept: Day 1     Day 2     Day 3     Day 4     Day 5     Day 6     Day 7
Dust-covered Solar PV Output (54kWp) Riyadh Area

July: Day 1          Day 2          Day 3          Day 4          Day 5          Day 6          Day 7
Solar PV Panels in Saudi Arabia

Reality Check
Solar PV Panel Cleaning (when?)
IoT-based Building Automation Systems

• In KSA the roof-top solar is gaining popularity
• Roof-top solar helps with mitigating peak loads
• Building Automation Systems (BAS) help to maintain comfortable/healthy indoor environment
• Low-cost customizable BAS systems exist
Solar PV System at Virginia Tech
IoT Device Integration for Building Automation

HVAC Load Controllers
- CT30 (WiFi)
- CT50 (WiFi)
- CT80 (ZigBee SE)
- ICM (WiFi)

Sensors/PowerMeters
- Power meter (Modbus/MODBUS)
- Power meter (BACnet/MODBUS)
- Light sensor (BACnet)
- Occupancy sensor (BACnet)
- Plug load controller (BACnet)
- Smart plug (ZigBee)

Lighting Load Controllers
- RTU (Modbus)
- VAV controller (Modbus)
- Philips Hue (WiFi)
- Light switch (WiFi)
- Lighting load controller (BACnet)
- Step-dimmed ballast (ZigBee)
- Smart plug (WiFi)

Plug Load Controllers
- Step-dimmed ballast
- Smart plug
- Plug load controller
- Light sensor
- Occupancy sensor
BAS User Interface

Smart inverter control

Node 1: Der1

- **Power**
  - INCIDENT: 3536.12 W
  - DC: 5140.15 W
  - AC: 4958.0 W

- **Efficiency**
  - PANEL: 14.54%
  - INVERTER: 96.46%
  - TOTAL: 14.03%

- **Voltage**
  - DC: 35.7 V
  - AC: 212.3 V

- **Current**
  - DC: 14.37 A
  - AC: 23.51 A

- **Energy**
  - TOTAL: 6.52 MWh
  - TODAY: 14.41 kWh

- **Irradiance**
  - ARRAY: 865.0 W/m²
  - HORIZONTAL: W/m²

- **Temperature**
  - AMBIENT: 84.0°F
  - MODULE: 93.0°F

- **Wind Velocity**
  - 0.0 m/s

- **CO2 Saved**
  - 10105.01 lbs

REAL POWER CONTROL

POWER FACTOR

- Power factor limit: 100%
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>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>
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<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>
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<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>
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<tr>
<td>Total (October-December)</td>
<td>823.26</td>
<td>1250.08</td>
<td>34.14%</td>
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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.
Managing Battery Storage from a BAS Platform

5 kW 12 kWh

Battery Cells

LG Chem

www.bemcontrols.com
Battery Storage Data Access from BAS Network

www.bemcontrols.com
Battery Storage Monitoring & Control
Campus-wide Energy Management

Utility/DR Aggregator
- DR Event
- Pricing
- Billing

Encrypted Data Link
Router

Internet

Customers/Operators

Buildings

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

HVAC
Lighting loads
Plug loads
Sensors/power meters
Battery storage
PV Panels
Security camera

www.bemcontrols.com
New Paradigm for the Power System

- Historically: Demand driven supply (supply responds to demand)
- New Reality: Supply driven demand (demand needs to adjust to meet fluctuating supply with help from storage)

THE SMART GRID ECOSYSTEM
THE SMART GRID ECOSYSTEM

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

PES accomplishments:
- PES University
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