The Evolution of Energy Landscape

Future of Smart Grid
Global Perspective

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Problem Statement
Why Everyday People Need Us To Move Forward

- **We need more power**
  - By 2030, more than 60% of the global population will live in cities

- **Power must remain affordable**
  - Double-digit price increases are already commonplace

- **Sustainability must be achieved**
  - More than 40% of our current emissions are from electric generation

- **Industrialized nations are living on borrowed time**
  - Over the next 10 years, over 50% of T&D infrastructure needs to be replaced

- **Decreasing workforce**
  - Over 50% of skilled workforce are expected to reach retirement age in 5-10 years

- **Increasing customer expectation**
  - EPRI estimates that power outages and power quality disturbances cost businesses in the U.S. more than $120 billion a year
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Smart Grid
Technology Transformational Journey
Smart Grid...many definitions...
Solution, emerging functionalities, complexity, added value

**Generation**
- Wide-area monitoring, protection & control (WAMPAC)
- Large-scale renewable generation
- Adaptive Protection / SPS

**Transmission**
- Active voltage & reactive power management
- Advanced automation

**Distribution**
- Distribution Lines

**Industrial**
- Building / home automation
- Distributed Energy Resources Management / Microgrids
- EV charging infrastructure
- Energy management systems
- Advanced Metering Infrastructure (AMI)
- Demand response

**Commercial**

**Residential**
- Smart appliances

- Communication Infrastructure, Cyber Security
- EMS/DMS/OMS, Geospatial Asset Management, Optimization & Diagnostics, Work Force Management, Integration Platform
Smart Grid...technology transformational journey
Solution, emerging functionalities, complexity

Distribution Grid ~ Transmission Grid

Category

Prevention & Healing
(Anticipation and restoration)

Performance
(Dispatch and Efficiency)

Negotiation
(With all energy stakeholders)

Enablers

- Cross-boundary observability and controllability
- Situational awareness
- Fast simulation and modeling
- Dynamic remedial actions
- Real-time stability and performance analytics
- Big data management
- Advanced computing
- Intelligent alarming

Solution Trends

- Hyper-intelligent decision making optimizing reliability and performance
  - At a glance, visualization...human factors
  - High-fidelity control & operations migrates down to distribution system

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# Hyper intelligence components

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federated Data...</strong></td>
<td>Real-time caching, references to (distributed) data Industry Standards &amp; Security Adapters to legacy applications.</td>
</tr>
<tr>
<td><strong>Large Amount of Data...</strong></td>
<td>The ability to collect, store and process very large data sets... quickly</td>
</tr>
<tr>
<td><strong>Advanced Analytics...</strong></td>
<td>Advanced algorithms for prognostics Intelligent alarming Predictive analytics &amp; Decision Support</td>
</tr>
<tr>
<td><strong>Optimization...</strong></td>
<td>Advanced Optimization techniques for performance management</td>
</tr>
<tr>
<td><strong>Knowledge Mgmt...</strong></td>
<td>Configurable Domain Expertise &amp; BI KPIs Contextual Data: Right info, right time</td>
</tr>
<tr>
<td><strong>Distributed Intelligence...</strong></td>
<td>Put intelligence at the optimal layer/location of the grid</td>
</tr>
<tr>
<td><strong>Visualization...</strong></td>
<td>“At a Glance” visualization tied to analytics</td>
</tr>
</tbody>
</table>
Smart Grid hyper intelligence vision

\[ Y = f(x_1..x_n) \]

- Decisions made at optimal location
- Distributed Logic / architecture
  - Generation – Meter
- Only propagate usable data
- Self learning & autonomous

Integrated, End-to-End Solution Approach
Smart Grid...technology transformational journey
Fast simulation & modeling: Entire grid perspective

The Controllable Grid
Real-Time State Estimation

Synchrophasor Measurements

Distribution
Transmission

Supervising Center (Manual settings)

Control & Adaptive Settings

Fast Simulation & Modeling

Real-Time Contingency Analysis

Dynamic State

Data Reduction & Visualization

Pacific Time

09/13/00  Event at 14:44 Pacific Time  (09/13/00 at 21:44 GMT )
GE Consumer & Industrial

Multiline

Technology Challenges

• 12 Million DER attachments expected in the next 20 years
• Advanced asset controls and protection required

• Energy Management:
  o Optimization of generation, storage and load operation
  o Intermittency management
  o Aggregate dispatch

• Advanced controls for transition between grid-parallel and island operation

• Cost-effective electrical and thermal energy storage
Smart Grid...technology transformational journey
Grid operation support beyond demand response

Peak Shifting

Contingency Response
Spinning Reserves
Frequency Regulation

Today

Tomorrow
Business Need

Optimal balance (supply and demand) of distributed resources to enable reliable and economic operation.

Provide solutions and services to plan, forecast, schedule, and dispatch

What

- **Load resources** – dispatchable consumption
- **Distributed generation** – <10 MW renewable or non-renewable generation
- **Integrated resources** – load and generation systems

Where

- **Local** – residential, commercial, and industrial
- **Substation/Feeder** – distribution system
- **Market Operator** – electricity and balancing market
**Load Leveling**

Shift loads away from peak to flatten the load profile

**Load Reduction**

Reduce loads at the distribution substation to relieve congestion

**Awareness & Control**

Allow load to increase by operating with reduced margins, leveraging reduced uncertainty and faster controls

### Technologies

**Accurate Awareness**
- Synchrophasors
- Visualization
- Wide-area Analytics:
  - Real-time stability assessment
  - Real-time contingency analysis
  - Fault location ID

**Advanced Control, Protection**
- Wide area protection
- Wide area controls
- FACTS

**Energy Efficiency**
- Line-loss minimization
- Distribution Voltage Regulation

**DG Integration**
- Solar PV
- CHP

**Demand Response**
- Advanced Meters
- Utility DSM signals (DLC, TOU, CPP, RTP)
- End-user energy management
- Smart appliances

**Distributed Energy Resources**
- Coordination controls for peak shaving with DER

### Value & Performance

**Value & Performance**

- **Line-loss Min**
  - $20\% < \text{losses} \Rightarrow \approx 1\% > \text{energy}

- **ChP**
  - $657/MW-yr_{(bs)}

- **DSM**
  - $60K/MW-yr_{(EIA, \sim 11 \text{ GW/yr}_2)}

- **BESS**
  - $250K/MW-yr

- **Diesel**
  - $270K/MW-yr_{(bs)}

- **Transmission & Distribution Upgrade**
  - **BESS**
    - $250K/MW-yr
  - **Diesel**
    - $270K/MW-yr_{(bs)}

- **Generation Upgrade**
  - **ChP**
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- **Demand Response**
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### Reliability Penalties
Up to $1 million per violation, per day

### Generation Upgrade
- **BESS**
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- **Diesel**
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- **Demand Response**
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**Cost**

- **Transmission & Distribution Upgrade**
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- **Demand Response**
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- **Distributed Energy Resources**
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**Solution & Performance Scalability**
... today many technology pilot projects
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Smart Grid

Business/Customer Transformational Journey
A. Operating Model: progressive and accelerated migration vs. defensive and incremental migration (innovative leader vs. fast followers)

B. Utility vs. Customer Centric: clear balance of customer/societal vs. utility/grid operation benefits (well-defined outcomes)

C. Partnerships: ensures a close ‘marriage’ of public and private partnerships and allows the utility and local city/communities to work in tandem for a ‘better’ outcome

D. Business Case: well-defined and justified business value

E. Smart policies and regulations
A. Utilities operation model must evolve

- Utilities must embrace new role as portfolio managers and service provider rather than “infrastructure owner”
- Utilities must identify and close talent gaps in core skill sets e.g: technical, marketing, IT/Comms, consumer outreach, etc.
- Utilities straying too far away from core competencies may meet with taxpayer or regulator push back
- Utilities must push to get incentives aligned through regulatory reform
- Consumers will need to see value in a better choices and smarter consumption of a commodity like electricity
- Consumer education is key to industry/utility transformation
- Other
B. Smart Grid drivers...value

- Economic competitiveness
- Energy reliability & security
- Empowerment-Consumer
- Environmental sustainability
**B. Value driven approach**

*Enabler: Technology*

<table>
<thead>
<tr>
<th>What</th>
<th>Why</th>
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<tbody>
<tr>
<td><strong>Demand optimization</strong></td>
<td>Peak management via control of power consumption</td>
</tr>
<tr>
<td><strong>Distribution optimization</strong></td>
<td>Reduce delivery losses in distribution systems</td>
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<tr>
<td><strong>Asset optimization</strong></td>
<td>Prognostics for proactive equipment maintenance</td>
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<tr>
<td><strong>Transmission optimization</strong></td>
<td>Wide area protection &amp; control for improved visibility</td>
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<tr>
<td><strong>Workforce Eng. &amp; Design optimization</strong></td>
<td>Productivity, planning, and design tools</td>
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B. Who are your customers?
Market assessment & segmentation

Select target markets
Focus groups
Conjoint analysis
Analyze & create plan
C. Partnerships
Stakeholder alignment is at the heart of building a smart grid

Energy Smart Miami Partners
- The City of Miami
- GE
- Cisco
- FPL
- Silverspring Networks
- Miami Dade College

Maui Smart Grid
- Hawaiian Electric Company
- Maui Electric Company, Ltd.

Partner Types
- **Political alignment**
  - Grid operators / Utilities
  - Governmental organizations
  - Cities
  - Universities

- **Private sector engagement**
  - High-tech companies
  - Financial institutions
  - Transport / Waste
  - Automotive

- **Citizen engagement**
  - Citizens

- **Customers**

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D. Business Case

Well-defined and justified business value

<table>
<thead>
<tr>
<th>Smart Grid Business Case Summary</th>
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<tbody>
<tr>
<td><strong>20 Year NPV ($MM)</strong></td>
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<tr>
<td>Benefits</td>
</tr>
<tr>
<td>Annual operational impact</td>
</tr>
<tr>
<td>Revenue enhancement</td>
</tr>
<tr>
<td>Avoid cost of fuel (load shedding)</td>
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<tr>
<td>Avoid cost of fuel (line loss)</td>
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<tr>
<td>O&amp;M saving</td>
</tr>
<tr>
<td>Reduce annual capital spending/deferral</td>
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<tr>
<td>Annualized avoided new built capital</td>
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<tr>
<td>Generation</td>
</tr>
<tr>
<td>Transmission</td>
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<tr>
<td>Distribution</td>
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<tr>
<td>Total annual benefit</td>
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<table>
<thead>
<tr>
<th>Reliability Benefits</th>
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<tbody>
<tr>
<td>Index</td>
</tr>
<tr>
<td>SAIDI</td>
</tr>
<tr>
<td>DMDI</td>
</tr>
<tr>
<td>SAIFI</td>
</tr>
<tr>
<td>MHNI</td>
</tr>
<tr>
<td>VOS ($MM)</td>
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<table>
<thead>
<tr>
<th>Annual Environmental Benefit</th>
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<tbody>
<tr>
<td>CO2 reduced tons</td>
</tr>
<tr>
<td>CO2 reduced $MM</td>
</tr>
<tr>
<td>Annual Load Reduction (MWh)</td>
</tr>
<tr>
<td>Net load reduction</td>
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<tr>
<td>Line loss reduction</td>
</tr>
<tr>
<td>Revenue increase - no load charge</td>
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<table>
<thead>
<tr>
<th>Generation Reduction</th>
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<tbody>
<tr>
<td>Pecker</td>
</tr>
<tr>
<td>Mid motors</td>
</tr>
<tr>
<td>Base</td>
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<tr>
<td>Reliability Cost Reduction</td>
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E. Smart policies help us move forward

**Policymakers... establish the targets**

1. Energy Efficiency resource standard
2. Peak load reduction standard
3. Clean energy standard

**Regulators... provide the incentives**

1. Cost recovery guidelines
2. Innovative rate designs
3. Equal treatment of demand-side resources
Questions.....