Distributed Energy Resources and the Grid
Past, Present, and Future Monitoring, Control, and Operation of the Grid

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DER Resources – What are They?

**PV** – Distributed and “Behind-the-meter” PhotoVoltaics

**CHP** – Combined Heat and Power

**DR** – Demand Response

**DES** – Distributed Energy Storage

**SOC** – Self Optimizing Customer (Microgrid, VPP)

**PEV** – Plug-in Electric Vehicle
Stages in North American Market Evolution

**Markets 1.0**
- Wholesale Day Ahead Energy on Hourly Schedules
- Ancillary Services
- Balancing and Regulation
- Transmission Rights

**Markets 2.0**
- Co-optimized Energy and Ancillary Services
- Congestion Pricing
- Nodal Real Time Dispatch
- Capacity Markets for DR

**Markets 3.0**
- Renewables as Market Resources
- Dynamic Retail Pricing
- Demand Response for Ancillaries
- Capacity Markets for Renewable Firming and DR
- Dynamic Intra Hour Scheduling for Renewables
- Storage as Resource
- Tighter Linkage of Gas and Electric Supply

**Recent History:**
FERC Orders 745, 755, 784, and 1000

1995 - 2003
2001 - 2010
2011-2020
Threat from DER technologies to utility business model

- DER technologies considered a disruptive technology by many in the industry
- Potential to fundamentally change the electricity market place
- Potential DER threat cycle:
  - DERs lead to lost kWh, revenue and stranded cost recovery unless rates increase
  - Rate increases incentivizes more DERs

Source: EEI, Jan. 13, Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business
System Reliability & Customer Expectations

- Improving grid reliability has been a major concern
  - Recent power outages
- Limited automation and inability to “see the whole grid”
- Improved Monitoring, Controls and Integrated Information Systems and Operations
  - Enterprise Level Operations and Information Integration

Source: Roger N. Anderson Colombia Univ.
Intermittent and Distributed Resources
Renewable Portfolio Standards (RPS)

- Significant increase in the penetration of intermittent (Wind, Solar) resources is expected
- Intermittent resources are creating a major challenge for systems operators
  - Forecasting, Scheduling, Trading, Balancing, Regulation, Settlement

![Graph showing MW Capacity by 2006 and 2020]

State RPS Policies: 25 States and D.C.

Additional renewable energy “goals” established in IA, VT, VA, MO, ND, and ME

2006 source: US EIA data – 2020 source: a forecast
## The Smart Grid Move

<table>
<thead>
<tr>
<th>20th Century Grid</th>
<th>21st Century Smart Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromechanical</td>
<td>Digital</td>
</tr>
<tr>
<td>Very limited or one-way communications</td>
<td>Two-way communications every where</td>
</tr>
<tr>
<td>Few, if any, sensors – “Blind” Operation</td>
<td>Monitors and sensors throughout – usage, system status, equipment condition</td>
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<tr>
<td>Limited control over power flows</td>
<td>Pervasive control systems - substation, distribution &amp; feeder automation</td>
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<tr>
<td>Reliability concerns – Manual restoration</td>
<td>Adaptive protection, Semi-automated restoration and, eventually, self-healing</td>
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<tr>
<td>Sub-optimal asset utilization</td>
<td>Asset life and system capacity extensions through condition monitoring and dynamic limits</td>
</tr>
<tr>
<td>Stand-alone information systems and applications</td>
<td>Enterprise Level Information Integration, inter-operability and coordinated automation</td>
</tr>
<tr>
<td>Very limited, if any, distributed resources</td>
<td>Large penetrations of distributed, Intermittent and demand-side resources</td>
</tr>
<tr>
<td>Carbon based generation</td>
<td>Carbon Limits and Green Power Credits</td>
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<tr>
<td>Emergency decisions by committee and phone</td>
<td>Decision support systems, predictive reliability</td>
</tr>
<tr>
<td>Limited price information, static tariff</td>
<td>Full price information, dynamic tariff, demand response</td>
</tr>
<tr>
<td>Few customer choices</td>
<td>Many customer choices, value adder services, integrated demand-side automation</td>
</tr>
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</table>
3. Drivers affecting the trend to Markets 3.0

RPS Goals ➔ Renewable Penetration ➔ Forecasting Ramping Variability

Conventional Backup Reserves and Ancillaries ➔ 1 GW Conventional Backup for Every 1 GW of Renewables
250MW Ancillaries for Every 1 GW

Electricity Storage ➔ Automatic Demand Response Dynamic Pricing

Why are we spending $$B on Smart Grid (aka AMI) if we are not going to use those meters to enable dynamic pricing and customer participation in markets and operations ??
Growing need for flexibility starting 2015

MN load

- Increased ramp
- Potential over-generation

Significant change starting in 2015

Megawatts

- 2013
- 2015
- 2020

California ISO
Shaping a Renewed Future
Time Scales and Managing Variability

![Time scales in electric grid operation](image)

- one a.c. cycle
- AGC signal
- hour-ahead scheduling and resolution of most renewables
- integration studies
- dynamic system response (stability)
- wind and solar output variation
- service restoration
- demand response
- day-ahead scheduling
- T&D planning
- carbon emission goals

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Economic DR in Competitive Markets

Supply Curve

Reduced Demand Lowers Market Clearing Price
Creating Large Consumer Benefit

Consumer Benefit

Avoided Costs

P_0

P_1

Q_0

Q_1

Demand Reduction
Actual Bid Stacks Can Be Very Steep at the High End
Calculating Reduction for Dispatchable DR Settlement

Requires a Customer Baseline (CBL) Calculation for each participating customer

But…

There is no savings meter
- Only actual usage is metered
- Savings or reduction is the difference from the load that would have been used (CBL)
- Methods for calculating the CBL have been negotiated in each jurisdiction, often contentiously
Microgrids – Global Markets

- Exponential Growth Predicted, 2011 - 2017
  - 330% capacity growth → 1,400 MW to 4.7GW
  - 467% revenue growth → $3B to $17B
  - North America strongest in planned capacity growth
  - Developing world, particularly remote applications, strongest long-term market

- Growth Drivers
  - Denmark: only country examining the policy issues of non-utility owned DER
    - Driven by grid operators attempting to manage distributed wind power of 25%+ penetration, anticipated CHP growth, and goal of 50% RPS by 2050
  - North America, e.g. US, strongest overall market due to:
    - Pockets of poor power quality
    - Structure of markets for DER → creative aggregation potential behind the meter
    - Offers a quality and diversity of services utilities have not been able to tap → potential for new distribution utility paradigm
Self Optimized Load Example

**Load reduction**

- Time (hr): 0 5 10 15 20 25 30
- MW: -4000 -2000 0 2000 4000
- Lines: TS = 600, TS = 1000, TS = 2000, TS = 3000

**AC load**

- Time (hr): 0 5 10 15 20 25 30
- MW: 0 500 1000 1500 2000
- Line: Total AC

**Inside Temp**

- Time (hr): 0 5 10 15 20 25 30
- °F: 67 68 69 70 71 72 73
- Line: Inside Temp

**Total Grid purchase**

- Time (hr): 0 5 10 15 20 25 30
- MW: 0 500 1000 1500 2000
- Lines: TS = 600, TS = 1000, TS = 2000, TS = 3000

**Thermal Storage level**

- Time (hr): 0 5 10 15 20 25 30
- MW: 0 500 1000 1500 2000
- Lines: TS = 600, TS = 1000, TS = 2000, TS = 3000

**Amount sent to Grid**

- Time (hr): 0 5 10 15 20 25 30
- MW: 0 500 1000 1500 2000
- Lines: TS = 600, TS = 1000, TS = 2000, TS = 3000

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Note: The graphs show the load reduction, AC load, Inside Temp, Total Grid purchase, Thermal Storage level, and Amount sent to Grid over time. Each graph includes multiple lines representing different thermal storage levels (TS).
PEVs (automated & manual charging)

PEV Load Profiles for Counties in California in 2030

Variability modeled by traffic count
Charging Scheme Descriptions

**Opportunity**
PEVs charge immediately upon parking

**Night Only**
Charges after the last trip home. Assumed slow charging (L1), 1.6kW
Few vehicles charge in the daytime

**Time Of Use**
Lower nighttime costs encourage drives to charge at night. A ±4-hour random delay is added to each vehicle’s TOU start time to prevent artificial peaks, also representing drivers who may not car about cost.

**Day-Night**
Assuming daytime public charging at L2 rate (3.3/6.6kW). Upon the last arrival home, L1 charging begins (slow residential-overnight charging)
Weekend/weekday comparison
- Similar to utility load, weekends PEV loads are slightly more spread out and smaller in magnitude

Parameters defining load shape:
1. Morning peak magnitude
2. Evening peak magnitude
3. Evening peak duration
4. Congestion delays
5. Early morning magnitude
6. Utility Effects (not shown)
Communications Capabilities Today

- **Other/3rd-Party**
  - Private Network
  - Coverage / Availability Density: 1 min

- **Utility DA**
  - Private Network
  - System Polling Time: 5 min

- **Customer Internet**
  - 1 hour

- **Public Carrier**
  - Wireless

- **Utility AMI**
  - Private Network
  - Broadcast
    - Semi-Control Only
Device density and rate of change are the drivers for Communications technology and costs.
Integrating Distributed Energy Resources

- Early euphoria being replaced by challenge realization!
  - Visibility – no telemetry (Automatic Metering is NOT the solution!)
  - Control (Definitely NOT AMI; multiple technologies for each end use / resource
  - Grid Security - Backfeed, fault ride through, frequency response
  - Market Integration “estimated response” for settlements; estimating elasticity in market clearing

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Research / Policy Needs

- How to Exploit the Internet and Mobile Computing for End Use Integration
  - Everything else is too expensive
  - Cyber Security and Business Model Solutions Needed

- Short Term Forecasting of Renewables Production
  - Reduce Ancillaries Costs, improve operations

- Incorporating Stochastics / Probabilistic Analysis into Planning and Operations

- Markets 3.0 Design – Achieving market reliability with distributed / decentralized markets – how to achieve:
  - Market efficiency
  - Desirable allocation of market surplus to demand side and supply side participants
  - “stability” - avoid volatility as an artifact of market design
  - Affordability – no more $x00M market system implementations!
  - Integration with system operations - reliability