INCENTIVIZING FLEXIBILITY IN SYSTEM OPERATIONS AND RECOVERING THE COST OF FLEXIBILITY

Large-Scale Grid Integration of Renewable Energy in India

Nikhil Kumar (Nikhil.Kumar@Intertek.com)
OUR GLOBAL NETWORK AND CAPABILITIES

Global ATIC Business with over 42,000 Employees

- Global Market Leader in Assurance
- 3,000 auditors
- 100,000 audits
- 1,000+ laboratories and offices
- 100+ countries

Global Market Leader in TIC
Virginius Daniel Moody establishes Moody Engineering for construction and engineering projects in the US, later moving into oil and gas testing and certification.

Caleb Brett founds a marine surveying and cargo certification business in the UK.

Thomas Edison sets up the Lamp Testing Bureau in the US (this later becomes the Electrical Testing Laboratories or ETL – a mark that Intertek still applies today).

Intertek acquires APTECH Engineering to expand its Industrial Services offering, with focus on Engineering and Failure Analysis.

ATI (AWARE) joins Intertek Industry Service. Intertek adds Asset Integrity Management Software to its portfolio.
OUR GOAL

Grid Flexibility + Generator Flexibility = Increased RE

Incentive + Cost Recovery = Goal
IMPACT OF FLEXIBLE GENERATION ON THE CONVENTIONAL FLEET

- Maintenance/Overhaul Costs
- Forced Outage Rates
- Emissions Per MWh Generated
- Long Term Production Cost
- Long-Term Capacity Costs

- Revenue
- Plant Performance (efficiency)
- Capacity Factors
- Short Term – Production Cost
- Unit Life Expectancies
MECHANISM FOR INCREASED FLEXIBILITY
## GRID FLEXIBILITY

<table>
<thead>
<tr>
<th>Frequency Response</th>
<th>Frequency Regulation</th>
<th>Spinning Reserves</th>
<th>Non-Spinning Reserves</th>
<th>Ramping</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] Immediate Response</td>
<td>[ ] 0-10 Seconds</td>
<td>[ ] 10 Minutes</td>
<td>[ ] 10-30 Minutes</td>
<td>[ ] 5 Min</td>
</tr>
<tr>
<td>[ ] Frequency</td>
<td>[ ] Power imbalance</td>
<td>[ ] Sub-optimal dispatch</td>
<td>[ ] Sub-optimal dispatch</td>
<td>[ ] RE</td>
</tr>
<tr>
<td>[ ] Auto Control</td>
<td>[ ] AGC</td>
<td>[ ] Market Signal</td>
<td>[ ] Market Signal</td>
<td>[ ] AGC or Market Signal</td>
</tr>
<tr>
<td>[ ] No market</td>
<td>[ ] Auction</td>
<td>[ ] Auction</td>
<td>[ ] Auction</td>
<td>[ ] *CAISO</td>
</tr>
</tbody>
</table>
POWER PLANT FLEXIBILITY

MW

Range

Ramp Rate

Duration

MW/Min

MWh
WHOLESALE PRICES HAVE DECLINES IN THE U.S.

What is the average O&M of a Steam Unit?

Largest impact from Natural Gas price (not RE)

POWER PLANT FLEXIBILITY THEMES

What’s Important?
• Startup time
• Minimum Load (Turndown)
• Emissions Compliance
• Ramp Rates

Impact
• Safety
• Equipment Life
• Reliability
• Costs
• Revenue

Mitigation
• Operational adjustment
• Capital Improvements
• Assess which flexibility attributes are the most valuable
PROBLEM STATEMENT

• Why do we need to incentivize power plant flexibility?
  • A major root cause of increase in Capital and Operations & Maintenance (O&M) cost for many fossil units is unit cycling.
  • Utilities have been forced to cycle aging fossil units that were originally designed for base load operation.
  • Market signals are resulting in lower revenue.

• What can and should we do once we understand the impacts and costs?

Generation Units Originally Designed for Baseload Operations Running in Cycling Modes
OUR VIEWPOINT

- Almost any unit can be cycled.
  - This can be done with minimal capital investment.
- However, we have to account for:
  - Long term penalty of increased wear & tear damage and reduced reliability.
  - Short term penalty of higher heat rate, increased O&M, training requirements, and equipment efficiency.
- Component Damage can be determined
  - Understand amount of damage present
  - Rate of accumulation
  - Total damage before failure
- Cycling a power plant is more difficult operating mode than baseload operation.
### FACTORS AFFECTING POWER PLANT FLEXIBILITY COSTS

<table>
<thead>
<tr>
<th>Maintenance-related activities</th>
<th>Equipment design and manufacturer</th>
<th>Vintage of technology</th>
<th>Turbine design and pressure and MW capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel type, quality and deviation from design fuel specifications</td>
<td>Environmental equipment (including retrofits)</td>
<td>Time between planned outages (boiler overhauls)</td>
<td>Timing of turbine/generator overhauls,</td>
</tr>
<tr>
<td>Plant configuration, size, economies of scale and scope</td>
<td>Controls and instrumentation</td>
<td>Retrofit of equipment, especially, for greater flexibility in moving among duty cycles, and</td>
<td>Modes of cycling operation over time</td>
</tr>
</tbody>
</table>

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*Intertek Engineering Consulting*

Engineering | Failure Analysis | Technology
SOME RECENT EXAMPLES

Q. Please describe the outage at Boardman.
A. Boardman went offline on July 1, 2013. During a restart, the cold reheat line (CRH line) sustained damage due to a water hammer event. The CRH line directs steam from the High Pressure (HP) turbine back to the boiler reheater for further heat addition in order to improve efficiency. The source of the water was the reheate steam line attenuator, the device that cools superheated steam, when required, with cooler main feedwater to protect from overheating. After the plant inadvertently shutdown, the attenuator either continued or began leaking feedwater. As part of the standard plant restart procedure, steam was admitted to the HP turbine and the cold reheat non-return check valve opened. As the check valve opened, superheated steam mixed with saturated steam (a steam water mix) created by the attenuator leak, causing the water hammer event. This mixing resulted in a traveling pressure wave that lifted the CRH line and caused the hangers and restraints to break loose resulting in the damage discussed above.
EFFECTS OF CYCLING – RELIABILITY

Actual Plant Data Reflects Creep Fatigue Interaction Design Curve

THERE IS A COST TO CYCLING POWER PLANTS

Low Bound C&M Start Costs per MW Capacity

Plots all unit types together, but uses individual unit type box plots to identify outliers.

Scatter in cost estimates.
These are lower bound costs.
Actual Costs are significantly different.

CHALLENGE & OPPORTUNITY

RE will increase demand for flexibility.

RE will replace conventional generation, i.e. lower capacity factors.

Flexible power plants are less exposed to revenue loss and reliability impacts.

- Change in peak load timing
- Lower Average Prices ($/MWh)
- More hours at prices below $5/MWh
- Increased Price Volatility
- Higher AS Price

If we don’t build flexible resources, the incentives are moot! The system operator cannot dispatch what it doesn’t have.

Source: Impacts of High Variable Renewable Energy Futures on Electric-Sector Decision Making, J. Seel, A. Mills, R. Wiser (LBNL)
REVENUE – EVOLVING OPPORTUNITIES

Revenue

Energy

Wholesale markets

PPA

Balancing

Services

Capacity
INCENTIVE – MAYBE?

Energy based (Past)
- Waning PPAs and Bilateral Transactions, particularly on aging units.
- Revenue from Energy is insufficient – no incentive to build flexible generation

What’s Needed?
- Pricing Signal – capacity
- Pricing Transparency & Signal – flexibility
- New Services

Where is the incentive? Dispatch @ 5 Minute, but Pay @ 60 Minute
INCENTIVES EVOLUTION

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<th>Shorter Pricing Intervals</th>
<th>FERC issued Order 825, requires prices and settlements on 5 minute intervals, rather than hourly.</th>
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<td>Pay for performance</td>
<td>FERC Order 755 required all system operators to incorporate a resource’s speed and accuracy into a performance-based payment</td>
</tr>
<tr>
<td>Flexible Ramping</td>
<td>Upward and downward ramping capability. Reduce energy to provide ramp in 5-minute.</td>
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**INCENTIVES EVOLUTION**

**Real-time Price Adder**
Incentivize units with high flexibility, but low capacity factor with higher real-time energy prices during periods of scarcity.

**Resource Adequacy**
Procurement of fast-ramping capacity – minimize ramping uncertainty, and incentivize generators.

**Capacity Markets**
ERCOT’s target reserve margin is lower than PJM’s. Prices in ERCOT surged past $9,000/MWh.

Source: Grid data compiled by Bloomberg
POSSIBLE BRIDGE IN THE INDIAN CASE?

- Province of Alberta: Power Purchase Arrangement Regulation

- Alberta’s electricity system transitioned from regulated to a competitive deregulated market. PPA Buyers would bear the risk of buying and selling electricity in Alberta, but with possible profits.

- The PPAs took into account the operating and maintenance costs along with projections for capital upgrades over the period of 2001 – 2020 (20 years)

- PPA implicitly included flexible operation limits and cost recovery mechanisms: “Equivalent Hot Starts” and Limits on EHSs.

- PPAs were terminated.
UNINTENDED CONSEQUENCES – ENERGY STORAGE CASE

- RegD is the frequency regulation signal for fast-response resources (storage) in PJM
- Originally designed for energy neutrality within 15 min
- PJM found that quick response resources would sometimes worsen the frequency regulation problem
  - Fast response resources are energy-limited
  - If a battery is depleted while responding to the RegD signal, then it would start charging
  - More RegA resources (slow-response, not time-limited) are needed to correct the signal
- PJM reengineered the RegD signal in Jan. 2017 such that RegD resources are conditionally neutral within 30 min
  - No longer guarantees energy neutrality for RegD resources
  - Energy neutrality supported when extra capacity from RegA resources are freely available
  - Batteries are operating longer and subject to higher energy exchanges
  - More frequent high energy/power exchanges
  - More cycling
  - Higher average temperature
  - Concern: changed operation; irreversible reaction; accelerated degradation