StoragePLUS Natural Gas
March 27, 2019
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ESA Membership

ESA works to ACCELERATE markets, CONNECT members and EDUCATE all stakeholders.

Contact Richie O’Neill, Membership Director
r.oneill@energystorage.org
Today’s Speaker

Kurt Waldner
Director, Strategic Marketing and Project Management
GE Energy Storage
unlocking the transition to a reliable low-carbon electrical system with flexible, modular Energy Storage Solutions
KURT WALDNER
Director – Strategic Marketing & Product Management
GE Energy Storage

Director – Strategic Marketing and Product Management for GE Energy Storage

Responsible for overall lifecycle management of GE’s Energy Storage and hybrid subsystem offerings

Multiple roles over a 22 year GE career including turbine design, Product Management, LTSA Productivity Leader and GM of the Aeroderivative LTSA business
AGENDA

- GE Energy Storage
- Today’s Environment
- The Renewables Conundrum
- Thermal Hybrids: Macroeconomic Benefits
- What is a Thermal Hybrid?
- Thermal Hybrids: Case Studies
- Conclusions, Next Steps
Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System
SERVING GLOBAL CUSTOMERS WITH LOCAL EXPERTISE

GE is globally recognized for designing and delivering customized energy storage solutions for diverse applications. With regionally located technical experts, our teams work directly with customers during the lifetime of the project. To date GE has more than 330 MWh of energy storage in operation or in construction globally.

248 MWh in North America
54 MWh in Europe
21 MWh in Asia
7 MWh in Africa

Services
52+ service and repair centers
17 technical institutes

INDUSTRY EXCELLENCE

10 years of storage experience
20 year performance guarantee

PIONEERING

1st Hybrid EGT storage + gas turbine peaker in operation
Black Start first proven emergency start of CCGT

LOCAL EXPERTISE

40+ Countries providing comprehensive consulting & services

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GE SOLUTION

GE’s Reservoir is a flexible, compact energy storage solution for AC or DC coupled systems. The Reservoir solution combines GE’s advanced technologies and expertise in plant controls, power electronics, battery management systems and electrical balance of plant – all backed by GE’s performance guarantees.
GE’s broad portfolio of Reservoir Solutions can be tailored to the operational needs enabling, efficient and cost-effective storage distribution and utilization of energy where and when it’s needed most.

1. **Consulting Services**
   - Customized solutions based on needs analysis

2. **Business Case**
   - Cost-Benefit Analysis

3. **Project Planning & Financing**
   - Value Engineering, Plan & Budgets, Financing

4. **Turnkey Service Project**
   - Implementation & Production Roll Out

5. **Service Agreement**
   - Training, Operations, Long Term Services

Our approach results in an investment grade business case that provides the basis of project planning and financing.
TODAY’S ENVIRONMENT

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System
Difficult to predict the pace of change
A LOT CAN HAPPEN IN 10 YEARS

Source: GE
**DECARBONIZATION**

**IMPACT**
- Generation is becoming difficult to forecast & variable
- Grid stability, Congestion Volatility on electricity markets

By 2040, **RENEWABLES will represent 30%** of global net electricity ... or more?

**DIGITIZATION**

**IMPACT**
- Allowing decision making based on dynamic and nodal prices

GROWING THE NUMBER of connected devices & smart sensors

**DECENTRALIZATION**

**IMPACT**
- End user becomes an active actor of the power system ('pro-sumer')
- Growing complexity of distribution grids

GROWING PENETRATION of distributed resources (renewable, storage, efficient devices)

**ELECTRIFICATION** in energy ecosystem

**IMPACT**
- Growth of Electricity demand, and an acceleration of decentralization of the power sector

ELECTRIFICATION OF ENERGY USES, transport (EVs) and heating

**DIGITIZATION**

GROWING THE NUMBER of connected devices & smart sensors

**IMPACT**
- Allowing decision making based on dynamic and nodal prices

Growing the number of connected devices & smart sensors

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INCREASING RENEWABLES CREATE NEW PRESSURES ON THE GRID

1. Overgeneration from PV
2. Quick changes
3. Volatility
4. Variation in Time of Day prices

5. Seasonal loss in renewable sources
6. Extended negative weather events

“Levelized” mindset inadequate for the future – time of day, seasonality, and extremes matter more than ever.
CHALLENGE: RELIABILITY IMPACTS OF AN EVOLVING FLEET

Load Following and Operating Reserves required to firm VERs is approximately 28% of wind and 20% of solar PV

Gas fleet CF shrinks, reliability needs grow as RPS increases, placing an even higher burden on remaining gas fleet
Adding renewables can require more operating reserves and 
ramping from existing gas plants, increasing local 
pollutants & causing diminishing returns on GHG reduction.

CAISO’s assessment of early economic 
retirement of gas-fired resources show 
shortfalls in load following and operating 
reserves with only 1,000 – 2,800 MWs of 
retirement

CAISO’s recent analysis of the CPUC’s 
proposed preferred portfolio noted 
capacity insufficiencies with more than 
2,150 MWs of thermal retirement due to 
the 40 year plant-life assumption

Source: CAISO Reliability Assessment of the IRP Hybrid Conforming Plan, 2019
CHALLENGE: GHG, CRITERIA EMISSIONS IN DISADVANTAGED COMMUNITIES

Increased cycling, ramping of thermal power plants will increase emissions, often located in sensitive areas ...

CLIMATE SOLUTIONS MUST START WITH OUR MOST IMPACTED COMMUNITIES!

Source: DEHHA AB 52 Report
THERMAL HYBRIDS: MACROECONOMIC BENEFITS

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System
**THE PRAGMATIC SOLUTION: HYBRIDIZE A SUBSET OF GAS PLANTS**

**Example: California**

<table>
<thead>
<tr>
<th>TECHNOLOGY TYPE</th>
<th>2018 RETIREMENT</th>
<th>2018 HYBRIDIZATION (464 MWS, 30-MIN. STORAGE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCGT</td>
<td>2,974 MWs (11 units)</td>
<td>3,682 MWs (6 units)</td>
</tr>
<tr>
<td>Peaker</td>
<td>2,665 MWs (58 units)</td>
<td>821 MWs (16 units)</td>
</tr>
<tr>
<td>Steam Units</td>
<td>6,416 MWs (19 units)</td>
<td>-</td>
</tr>
</tbody>
</table>

Relative to retirement case w/o hybridization:
- Reduces **energy neutrality** concerns
- Reduces cycling of gas fleet by an average of **940 starts a year**
- Reduces GHG emissions from gas fleet by **350,000 metric tons a year**

*Modeling was validated using GridPath, another capacity expansion model, with directionally similar results*

**Other resource types omitted from chart for ease of discussion; shed DR increased by 384 MWs with hybridization**

**Source:** Gridwell Consulting, Wellhead Electric Company, Inc.

Early procurement of hybrid facilitates **immediate** retirement of gas-fired resources w/o sacrificing reliability
Hybridization of an existing gas plant also increases its speed, operating range and flexibility.

**Quantitative Impact of Hybridizing a Subset of Gas Plants**

- Hybridization of a subset of the existing Peakers in DACs can allow them to provide immediately responsive operating reserves without burning gas.
- Hybridization of a subset of the current CCGTs can provide the same ramping capability (load following) from fewer resources without increasing GHG.

**1 Hybrid Peaker**

(e.g. 10 MW/5 MWh battery added to 50 MW existing gas peaker)

- Gas free operating reserves...
  -15,000 to -30,000 metric tons GHG
  (annual reduction)

**22 Hybrids**

(e.g. 460 MW batteries installed on ~4,500 MW existing plants)

- Gas free operating reserves AND additional load following can help create enough head room for ~5500 MW gas plants to retire

Example: California


Hybridization of an existing gas plant also increases its speed, operating range and flexibility.
WHAT IS A THERMAL HYBRID?
THERMAL HYBRID: SIMPLE CYCLE

TYPICAL CONFIGURATION

USE CASES / APPLICATIONS

Spinning reserve
Regulation
Frequency response
Load following
Voltage support

CAPABILITIES (FULLY AUTOMATED POWER PLANT IN HYBRID MODE)

- $P_{min} = 0.00\ MW$
- $P_{max} = GT\ P_{max}\ (47.00\ to\ 49.90\ MW)$
- Commitment time = 0.00 minutes
- Commitment cost = $0.00
- GT start/stop managed by the Hybrid Control System (HCS)
- Battery SOC managed by the HCS
- Minimum Down Time = 0.00 minutes
- Minimum Up Time = 0.00 minutes
- Precise Net MW Control
- ISO AGC Control (25 to 30 MW of high quality regulation)
- Automated response to grid events
- Primary Frequency Response
- Will start GT only if required
- Voltage Regulation
- Adjustable Trickle Charge to maintain battery SOC when GT is not running

Source: Wellhead Electric Company, Inc.; GE
# GE LM6000 HYBRID EGT VS. STANDALONE ASSET

<table>
<thead>
<tr>
<th>DIRECT PROJECT VALUE</th>
<th>EXISTING LM6000</th>
<th>10MW 4-HR. BESS ONLY</th>
<th>LM6000 EGT UPGRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contingency reserve value no emissions</td>
<td>0</td>
<td>10 MWs</td>
<td>50 MWs</td>
</tr>
<tr>
<td>Instant on</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>RA value</td>
<td>50 MWs</td>
<td>10 MWs</td>
<td>50 MWs</td>
</tr>
<tr>
<td>Max power</td>
<td>50 MWs</td>
<td>10 MWs</td>
<td>50 MWs</td>
</tr>
<tr>
<td>Min power</td>
<td>&gt;0</td>
<td>-10 MWs</td>
<td>-10 MWs</td>
</tr>
<tr>
<td>Spinning reserve value no emissions</td>
<td>0</td>
<td>10 MWs</td>
<td>50 MWs</td>
</tr>
<tr>
<td>Energy capacity</td>
<td>Unlimited</td>
<td>Very limited</td>
<td>Unlimited</td>
</tr>
<tr>
<td>High-speed frequency regulation</td>
<td>0</td>
<td>10 MWs</td>
<td>10-25MWs</td>
</tr>
<tr>
<td>Grid energy neutrality</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Blackstart with no emissions</td>
<td>x</td>
<td>?</td>
<td>✓</td>
</tr>
<tr>
<td>Utilize existing interconnect</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Utilize existing substation &amp; GSU</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Utilize existing communications and backhaul</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Utilize existing land</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Speed to install</td>
<td>N/A</td>
<td>Slower</td>
<td>Fast</td>
</tr>
<tr>
<td>Cost</td>
<td>0</td>
<td>$$$</td>
<td>$</td>
</tr>
</tbody>
</table>
THERMAL HYBRID: COMBINED CYCLE

CAPABILITIES

1. Eliminate ST lag
2. Increase flexibility

BENEFITS

PERFORMANCE

- Increased ramp rate
- Increased accuracy
- Less wear on turbo machinery

GRID / MARKET

- Increase in intra-hour, flexi-ramp/load following capability
- Primary frequency response available at $P_{\text{max}}$
- Fast, accurate generation

Source: Wellhead Electric Company, Inc.; GE
OPTIMIZING GENERATION FLEETS

INDUSTRY CHALLENGES

Reserve dispatching favors low-cost providers and often requires assets to run at non-optimum, minimum loads.

SYSTEM CHALLENGES:

- EFFICIENT INTEGRATION of variable generation
- FLAT LOAD GROWTH but faster ramps & higher peaks
- CONTINGENCY RESERVE & Inertial Requirements
- REDUCE EMISSIONS & Increase renewable penetration

OPERATIONAL CHALLENGES:

- MULTIPLE Starts per day
- INCREASED need for spinning reserve
- DISPATCH to minimum loads

View GE's SOLUTION
Optimize Generation Fleets

GE's solution combines steam and gas turbines with energy storage plus digital controls to reduce fuel costs and gas emissions, by optimizing the use of existing generation sources and enabling applications such as frequency response, black start, shifting and capacity markets.
HYBRID THERMAL CONFIGURATIONS

IMPROVED OPERATIONS

- GE EGT™ Regulation
- Hybrid Regulation
- Gross GT Output
- DISCHARGE / CHARGE

ELECTRICAL GRID

HIGH VOLTAGE AC

HIGH POWER SYNTHETIC INERTIA

HIGH POWER FREQUENCY RESPONSE

MID POWER CONTINGENCY RESERVE

MID POWER IMPROVED OPERATIONS

MID POWER STORAGE UNITS

DC

MID POWER INVERTERS

MEDIUM VOLTAGE AC

THERMAL GENERATION

20 MINUTE DISCHARGE

6+ HOUR DISCHARGE

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THERMAL HYBRIDS: CASE STUDIES

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System
Introducing thermal hybrids on their system allowed SCE to change how and when its other assets were dispatched
• Saves 2 million gallons of water per year
• Reduces starts by half, GHG and other emissions by as much as 60%

**CUSTOMER**  PUBLIC POWER UTILITY

**CHALLENGE**  Addressing local grid reliability concerns

**GE SOLUTION**  10MW / 4.3MWh BESS, integrated controls

**APPLICATION**  Hybrid - Thermal (EGT)
Spinning reserve

**LOCATION**  Southern California (US)

**STATUS**  In operation

This project consists of two 10 MW of battery energy storage systems, each paired with GE’s proven 50 MW LM6000 aeroderivative gas turbines, capable of providing instantaneous response during a spinning reserve event.
OPTIMIZING GENERATION FLEETS

GE's SOLUTION

Gas Turbine + Energy Storage + Digital Controls

INCREASED UTILIZATION:

50 MW
of greenhouse gas-free peaking energy for local contingency

25 MW
of high speed frequency regulation for improved response

-8/+5 MVAR Voltage support & primary frequency response when offline

INTEGRATED SYSTEM OPTIMIZATION
for both the turbine and the battery storage

REDUCED SYSTEM COSTS & EMISSIONS:

REDUCED THERMAL STRESS
on turbine for extended asset life

ZERO FUEL & EMISSIONS
between dispatch events while supporting ancillary services

Reduce costs by optimizing the use of existing generation sources and enabling contingency (spinning) reserve without fuel-burn.
“As we navigate the transition to a 100% renewable future we need the gas fleet to become faster and more flexible (lower minimum load level, short start-ups). Like what Edison did with their EGT’s by adding batteries to their Peakers. We need more solutions like that.”

- Mark Rothleder, Vice President of Market Quality & Renewable Integration, CAISO
**INTEGRATING MORE RENEWABLES**

Imperial Irrigation District manages high levels of solar and wind generation, in and across their network. The energy storage system provides multiple services to increase grid reliability by managing dynamics events at multiple time scales.

<table>
<thead>
<tr>
<th>CUSTOMER</th>
<th>PUBLIC POWER UTILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHALLENGE</strong></td>
<td>Providing grid stability &amp; smoothing renewable output</td>
</tr>
<tr>
<td><strong>APPLICATION</strong></td>
<td>Standalone - Transmission</td>
</tr>
<tr>
<td></td>
<td>Emergency power / black start capability, distribution management system integration, ramp rate control, frequency response, spinning reserve</td>
</tr>
<tr>
<td><strong>LOCATION</strong></td>
<td>Southern California (US)</td>
</tr>
<tr>
<td><strong>STATUS</strong></td>
<td>In operation</td>
</tr>
</tbody>
</table>

Located in California, which has some of the most aggressive renewable portfolio requirements in the US, this 33MW / 20MWh battery system complements the integration of renewable resources, such as solar and wind, by adding stability and improving power quality.
“Without the battery, before, losing the S Line like that would’ve affected a much wider size of our territory. And the fact that it ... in the dead of summer ... that it was isolated still, I think is due to the battery.”

“We had talked about the value of the battery from operational and in ... all inclusive, we had hit more than three-quarter million dollars a month in value. [...] So it’s a tremendous value.”
CONCLUSIONS, NEXT STEPS

Energy Storage Solutions: Unlocking the Transition to a Reliable Low-Carbon Electrical System
ECONOMICAL, SOCIAL, & ENVIRONMENTAL BENEFITS OF THERMAL HYBRIDS

Benefits to disadvantaged communities

- Reduction in GHG & criteria emissions
- Contribution to local RA
- Increased flexibility
- Feasible/cost competitive
- Other local benefits
A ZERO CARBON ROADMAP USING EXISTING THERMAL RESOURCES

1. Achieves immediate air quality benefits
2. Could facilitate faster gas plant retirement
3. Ensures reliability (including local constraints) in a cost-effective manner
4. Storage capacity increasingly used to shape renewable and/or high efficiency, baseload CCGT generation until gas is only for backup or burning renewable fuel

GHG Emissions

# Gas Plants
“HYBRIDGE” TO THE FUTURE OF ENERGY
Q & A

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