GE Power

GE AERODERIVATIVES FOR GRID FIRMING

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CONTENTS

ABSTRACT

Over the past decades, the concept of the "electric grid" has evolved to meet the overall growth in energy demand amid a trilemma of economic, environmental, and regulatory constraints. The global footprint of GE's 5,000+ aeroderivative gas turbines have continuously helped our customers and grid operators to meet this evolving demand with world-class flexibility and reliability. Grid stability is the most critical need for grid operators, who must aggregate and dispatch the available energy resources in their network while minimizing overall cost and environmental impact. Additionally, customers must understand new ways to generate revenue by operating their equipment for grid support. In today's grid, the penetration of renewables is introducing new challenges as the grid must adapt to a greater decentralization of energy generation. The term "nameplate capacity firming," or grid firming, is widely used to address the gap due to intermittent wind, solar, and hydro resources (which have low capacity factors) to meet certain criteria of grid code. GE aeroderivative gas turbines have a track record operating side by side with renewables, lowering operational costs and air emissions with the highest reliability. In this new era, GE's well-proven technology is the missing piece of the puzzle to complement the renewable resources along with the energy storage technology.

INTRODUCTION

The global energy system is transforming. Integrating intermittent renewables and distributed energy into an aging grid requires flexible and resilient technologies, able to ramp rapidly and dynamically adjust to real-time grid signals. A picture is worth a thousand words, as shown in the chart below (Figure 1); the grid demand curve has transformed into a duck shaped curve due to the addition of renewable resources. Further evolvement of that curve led to what is graphed in Figure 2. The lower the belly of the duck becomes, the steeper the ramp to the peak will be, hence leaving grid operators and regulators with significant operational challenges (Tinne). Ideally, the steep load ramps required of the non-wind and solar sources would be fully satisfied by:

1. Demand management
2. Energy storage
3. The most efficient fossil fuel sources, which are combined cycle natural gas power plants

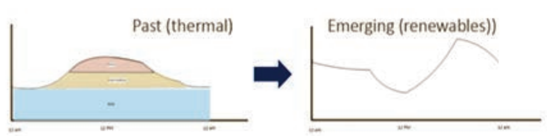

Figure 1 – The demand curve's change with renewables.

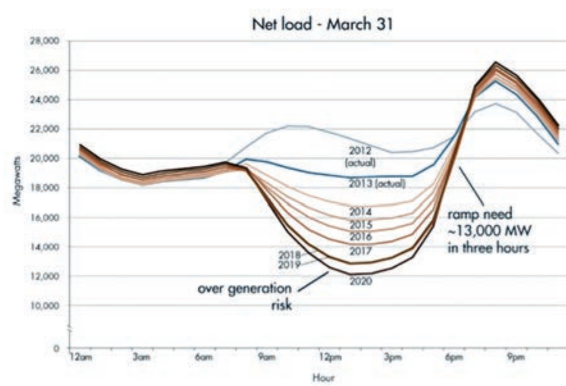

Figure 2 – The "Duck Curve" (Loutan, 2015).

Unfortunately, to fully equip a system in this way to achieve the required level of reliability, particularly sizing the adequate storage demand, would be cost prohibitive. Thus, the problem of satisfying the most extreme demand fluctuations in the system can be solved by having simple-cycle gas turbines available with the ability to start and stop quickly and adjust output at a very fast rate. With high-efficiency, excellent hot-day power output, fast starts, and the ability to provide very fast load ramps, the GE aeroderivative gas turbine technology is the ideal solution to many of the power grid reliability issues. Building on GE's vast prior commercial and technical expertise in this area, this white paper will address:

- Pain points faced by the various industry stakeholders when selecting the right technology for a stable grid.
- Considerations when investing in a hybrid technology of aeroderivative gas turbines and a battery energy storage system, so-called EGT™ (Electric Gas Turbine).

THE IMPACT OF RENEWABLES AND THE RISE OF ANCILLARY SERVICES

Global efforts to support decarbonization and cost-reductions in renewable energy technology have accelerated the development and addition of renewable resources globally.

California was one of the early adopters of the renewable portfolio standard (RPS), requiring electric utilities to have 50% of their retail sales derived from eligible renewable energy resources in 2030 and all subsequent years. California's three large IOUs (PG&E, SCE, SDG&E) collectively served 34.76% of their 2016 retail electricity sales with renewable power (California Public Utilities Commission, n.d.).

While renewable resources have the lowest operational costs and fewest greenhouse gas emissions, they can initially have adverse system impacts when integrated into the grid. When the wind blows and the sun shines to produce greater power than demand requires, overcapacity generation must be evacuated at a loss to avoid overloading existing transmission and distribution assets.

Going green without "going down" requires a balance between developing renewable energy and system reliability to avoid power outages and disruptions. Luise Röpke in her reference paper The Development of Renewable Energies and Supply Security: A Trade-Off Analysis (Röpke, 2012) discusses a meaningful cost-benefit analysis of the impact of electrical-service disruptions by assessing three technical factors:

1. The system average interruption duration index (The SAIDI)
2. Value of lost load (The VoLL)
3. Value of supply security (The VoSS)

Using Germany as an example, this study concludes that "the transformation process towards a green and decentralized production structure will be costly for society, even though the costs can be reduced by different measures." Thus, grid operators and regulators need to quantify all economic considerations when integrating renewables.

The "challenges of renewables" can be more concretely visualized in Figure 3 below, a plot of renewable generation and power demand over 30 days from the Bonneville Power Administration in Portland, Oregon, USA (Cui, 2018).

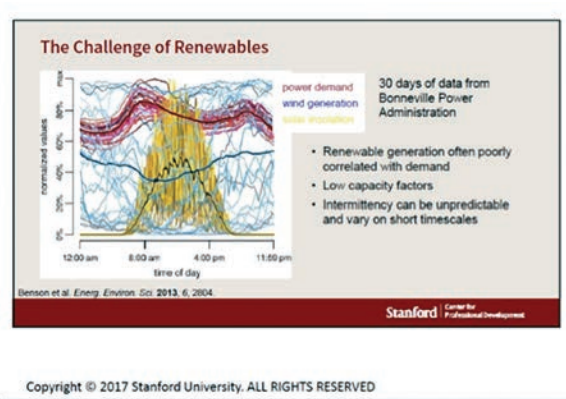

Figure 3 – Bonneville Power Example (Cui, 2018).

The overall power demand requirement shifts based not only on traditional time of day peaks and valleys, but also on the wind and solar generation. The changing mix and intermittency of these resources decreases the amount of thermal generation demand in traditional "intermediate load," which erodes some of the basic features of traditional grid stability, such as:

- Grid balance—the ability to match supply and demand
- Grid Inertia—the "residual load" which limits frequency variations during sudden changes
- Voltage control

Regulated and deregulated power producers generate revenue by selling the power they generate—whether via rate base or auction. Power producers use the grid as a "road" to deliver their product. However, the services required to maintain this road are not yet properly compensated in the traditional regulated or deregulated model.

This is where the so-called "ancillary services" segment steps in. The rise of the need for ancillary services to address the intermittent renewable resources shortfalls includes, but is not limited to, the services listed in Table 1.

Table 1 – Ancillary Services

Service	Description
Frequency Responsive Reserve/Primary Frequency Response	Automatic response triggered by frequency swings; typically deployed during contingency events. Arrests and helps to recover the frequency fall-off.
Regulation	Used continuously during normal operations to correct short-term imbalances between supply and demand, deployed via AGC signals.
Load Following	Slower than “regulation” and used primarily during normal operations; typically deployed via economic dispatch to correct an imbalance that will occur in the future.
Spinning Reserve	Type of contingency reserve that consists of resources which are connected to the power system and poised, ready to respond immediately.
Non-spinning Reserve	Type of contingency reserve that consists of resources which are capable of providing full response within a specified time; however, response does not need to be immediate.
Replacement Reserve	Deployed following a contingency event, intended to replenish contingency reserves; response does not need to begin immediately.
Reactive Power/Voltage Support	Provided by resources capable of injecting/consuming reactive power which is required to maintain voltages within acceptable limits throughout the power system.
Black Start	Provided by resources capable of starting themselves quickly without the support of an external electricity source; used to restore a power system following a major blackout.

TODAY’S GRIDS—CONCERNS AND SOLUTIONS

Grid operators around the world must manage this growing landscape of increasing renewable energy penetration, while determining the correct structure and compensation schemes for the developing ancillary services segment. Demand management is a low-cost option to best align supply and demand requirements. Increased grid interconnectivity aggregates generating resources over a greater area to help balance the increasing fluctuations in overall mix.

However, recent news stories demonstrate that the levels of intermittency of renewables have reached a tipping point in a few cases. For example, a report by the Australian Energy Market Commission states that the power grid dropped outside “secure limits” 11 times during 2016–17 … up from seven times in 2015–16 and four times in 2014–15, due to the rapid addition of renewables into the energy mix (Kirkwood, 2018). In Germany, imbalances in the system due to renewable power and an “underdeveloped grid” are estimated to be costing the country close to one billion euro each year (Appunn, 2018).

Grid Operators

Critical considerations for grid operators include:

- Asset investment deferral on transmission & distribution and transformer upgrades vs. distributed generation
- Peak shifting management
- Black start capability
- Frequency regulation
- Voltage regulation
- Renewable power quality—how to ensure renewable generation capacity factors are in line with grid codes on frequency and voltage
- Compensation for spinning reserves vs. non-spinning reserves
- Asset utilization/optimization of existing assets
- High grid connection charges in bringing new assets online or managing existing assets
- Day-ahead prediction requirements
- Output curtailment—how to communicate to generators when over-supply
- Time-of-day pricing mechanisms
- Increased location restrictions for new generators

Regulators

For regulators, some of the main concerns include:

- Reliability
- Increasing ramp rate requirements for grid codes
- Stability

A few early adopters, such as the UK and the US, have led the way in setting up both regulatory and market-based ancillary services, but many regions still need to establish compensation schemes to ensure grid stability is valued.

Independent Power Producers
Considering the changing demand profile required of traditional thermal generation, existing asset utilization for power generators has changed. Understanding a few critical factors can help a specific power generator understand how it can meet evolving grid requirements and generate more revenue:

- Efficiency/heat rate—what is the generator's priority in dispatch stack?
- Price of fuel—what are the generator's baseline operational costs?
- Start costs—what is the economic threshold required for the unit to ramp up?
- Start time—what ancillary services can the generator qualify for?
- Turn down—what is the economic tradeoff between running at low load vs. shutting down and starting up?
- Reliability/availability—what is the generator's current state, and can more money be made if greater availability?
- Declining subsidiaries

WHY SELECT A GE AERODERIVATIVE GAS TURBINE FOR GRID FIRMING APPLICATION?

The following attributes and impacts of GE aeroderivative technology offer a wide range of features to address the grid pain points and support our global customers with proven capabilities to counter the renewable resources' intermittency and shortfalls:

Table 2 – Aero capabilities for grid firming

Attributes Required for Grid Firming	Aero Capabilities	Value to the Grid
Fast ramp rate	~50 MW/min	Balance ("regulation"), load following
Fast-start	~5 min starts to full power	Contingency/replacement reserve
Cycling capability with multi daily starts and stops	Multiple starts/day – with no maintenance penalty	Spinning/non-spinning reserves
High part load efficiency	~40% efficient at 50% of full load	Load following
Deeper turndown	Low minimum load ideal for load following	Load following
Added frequency support	Pro-boost (power boost short duration) and synch condensing capabilities where in some cases, the synch condensing is offered in a clutchless configuration	Frequency response Primary, secondary, tertiary
Operational considerations	Fuel flexibility (gas, LNG, LPG, diesel, naphtha, propane ,and ethane capability)	Viable thermal solution in many environments
Operational considerations	Fast installation (3-6 months for simple cycle)	Quick solutions for emergency situations
Operational considerations	Power density and transportability	Viable thermal solution in many environments
Operational considerations	Dry Low Emissions combustor for regions with water scarcity	Viable thermal solution in many environments
Operational considerations	Modular maintenance philosophy reducing downtime and allowing engine exchanges in 2 days	Higher reliability and availability

GE aeroderivatives in operation currently are complementing renewable resources and creating benefits to the grid operators.

- Four LM6000 gas turbines supply 180 MW for peak power or in case of lack of wind across the Kansas plains (RMEL, 2009).
- Three LM6000s, Indigo Generation Facility (energy.ca.gov), balance generation from 2,600 wind turbines in Palm Springs, Riverside County, CA.
- The 800MW CPV Sentinel (CPVS) energy project is a natural gas power plant built in Riverside County, California, US, with 8 LMS100 units. Spread over 37 acres, the project is designed to serve as a steady source of renewable energy. The project has an operational life of 30 years. Southern California Edison (SCE) purchases the power generated by the plant, under a long-term power purchase agreement with CPV. (energy.ca.gov/sitingcases/sentinel/)
- One LMS100 provides synchronous condensing support in Groton, SD.
- Nine TM2500s, a trailer mounted power generator, provide critical backup generation in South Australia.

GE has been at the forefront of developing complementary thermal solutions for renewables since the early 2000s, with many thought leadership white papers published discussing the work of the last decade, including:

- Advantages of Flexible Thermal Generation in High Wind Penetration Grids, Nicholas W. Miller*, Sebastian Achilles, Gene Hinkle, Devon Manz, General Electric, Schenectady, NY USA, VGB Konferenz Kraftwerke im Wettbewerb; Prague, April 2009
- Gas turbine station backup for wind farm and peaking power, Bill Owen, Gas Turbine World, September–October 2010.

OTHER TECHNOLOGIES FOR GRID FIRMING

Reciprocating Internal Combustion Engines (RICE)
The RICE technology is another alternative for grid firming applications, enabling operators to meet grid code requirements. Nevertheless, a complete study (including overall NPV and IRR) has to be conducted to make the right selection of technology for the relevant application. The GE aeroderivative technology has several advantages when compared to RICE, among those:

- **Efficiency:** When comparing heat rates or efficiencies, two important points must be verified: 1) Reciprocating engines have a ±5% fuel consumption tolerance, while gas turbines, by applicable standards, do not allow this tolerance. A 5% higher fuel consumption must hence be considered when evaluating reciprocating engines. 2) Besides fuel consumption, lube oil consumption in reciprocating engines must also be considered as a secondary source of chemical energy, further increasing the actual heat rate.
- **Operation and Maintenance Cost:** Aeroderivative gas turbines require significantly fewer operation and maintenance interventions. A large reciprocating engine requires over 70 maintenance events during three years of continuous operation, compared to an aeroderivative gas turbine that requires just four maintenance events in the same period. Aeroderivatives also save a considerable amount of manhours, requiring only 1,800 manhours of maintenance during a 3-year cycle, compared to over 15,000 manhours for reciprocating engines.
- **Availability:** Due to the maintenance philosophy of aeroderivatives, these gas turbines have the highest availability of any thermal power technology, since an aeroderivative gas turbine can be replaced in a few days for a major inspection, thereby providing a plant availability of over 98%. This directly follows the maintenance practices in the aviation industry, where an aircraft never stops for engine maintenance. The engine is swapped out overnight, and the aircraft can resume a profitable operation. Another benefit of this maintenance philosophy is lower installation costs, since multiple spare engines are not needed to cover long maintenance periods.
- **Emissions:** Aeroderivatives use best-in-class combustion systems and can offer 15 or 25 ppm NOx (depending on the specific model, fuel and configuration), without the need of SCRs (selective catalytic reduction) or the use of ammonia, thereby meeting strict EPA, World Bank, and international environmental requirements. Reciprocating engines produce 3–6 times more NOx, 10–17 times more CO, 6 times more particulate matter, and 6 times more VOC. Furthermore, when operating on certain HFOs, reciprocating engines also emit a high volume of sulphur gases, while aeroderivatives operating on natural gas or LPG have no sulphur emissions. Besides air emissions, noise generated by reciprocating engines is approximately 10 dB higher than aeroderivatives. The difference in the regulatory allowance for air emissions between both technologies has to be considered in the evaluation.
- **Fuel Flexibility:** Aeroderivatives provide fuel flexibility on gas and liquid without power derate or pilot fuel requirements. Gas turbines can operate on natural gas, LPG or diesel, switching between these fuels without stopping and without a power reduction. They use the same combustion system for a wide fuel spectrum, starting with lean gas, high hydrogen content, coke oven gas, butane, LPG, light liquid distillates up to diesel fuel or aviation kerosene, giving customers options to switch between fuels when economically preferred, as well as providing reliable power generation capabilities with fuels coming from different sources.
- **Startup Time:** Reciprocating engines require pre-warming, lube oil, and cooling conditions to start, so start times should be assessed for both a “hot” and “cold” engine. GE’s aeroderivative gas turbines have a time of cold start to maximum power delivered to the grid in 5 minutes. Furthermore, during downtime, aeroderivative gas turbines consume no auxiliary loads, while reciprocating engines require a considerable parasitic load to maintain start readiness, keeping the engine and lube oil warm.
- **Power Augmentation:** Aeroderivative packages can benefit from power augmentation solutions, such as evaporative cooling, chiller coils, sprint (water spray intercooler), etc., improving power and efficiency at high ambient temperatures. Reciprocating engines are subject to derating due to elevation and temperature in addition to air humidity and gas composition, which is not the case for aeroderivative gas turbines.
- **Ramp-Rates:** Typical Otto/Miller cycle medium speed reciprocating engines have a ramp rate of about 5 MW/min, due to the engine dynamics and the nature of the combustion system. GE’s aeroderivative gas turbines, on the other hand, all have a nominal ramp rate of 50 MW/min, providing a much faster frequency control response in small grids. An aeroderivative main gas metering valve, for instance, has a rated opening time, from idle to full load of only 200 ms, providing an instant response when needed. Another important feature when considering ramp rates is that aeroderivatives have no under-frequency trips, assuring they will remain online even during the most intense frequency fluctuations.

- **Lube Oil Consumption:** Lube oil consumption for reciprocating engines is estimated to be over 330,000 liters of oil per year for a 100-MW plant. Aeroderivative LM2500s producing equivalent power will require less than 15,000 liters per year, saving approximately 300,000 liters per year of lube oil alone.
- **Footprint:** Aeroderivatives offer advantages in total amount of space required, power density, maintenance area, and storage facilities. A GE aeroderivative power plant has a footprint that is three to four times smaller than a typical reciprocating engine plant option for equivalent power. In an island grid, real estate can represent a significant part of power generation costs.
- **Speed of Implementation:** Due to their small size and modular nature, aeroderivatives can be transported, installed, and commissioned very quickly. As an example, two TM2500 units, rated at 34 MW each, were transported, installed, and started producing power in Puerto Rico, following Hurricane Maria, in only four weeks!
- **Transportation Cost and Time:** Compared to the aeroderivative LM2500, reciprocating engine transport costs are at least 3 times higher due to a factor of 42X weight, adding in cost and special transport considerations for a 100-MW plant. Air freight is not possible for major reciprocating engine components, requiring longer transport times, while some aeroderivative gas turbines can be delivered rapidly by air anywhere in the world.

Energy Storage Technologies

Energy storage has been contemplated as one of the means for grid firming since the rise of renewable generation that has not accurately correlated with demand.

Several technologies are considered for energy storage, such as gas storage, pumped hydro, flywheels, and batteries. The Ragone plot below provides the various types of energy storage technologies and compares their energy and power density attributes (Kanan, 2018).

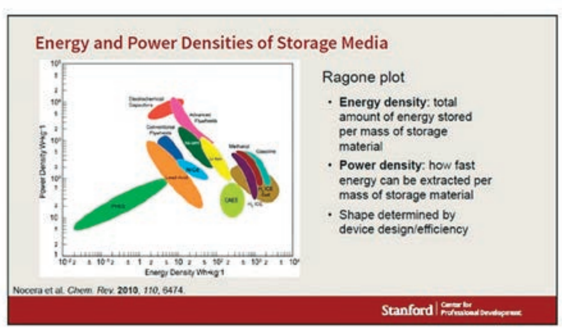

Figure 4 – Energy Density Plot (Kanan, 2018).

Battery energy storage systems (BESS) are used for energy time shift, transmission lines upgrade deferral, capacity firming, and ancillary services traded in the day-ahead or spot segments. BESS are becoming more popular in the grid firming industry since their cost is constantly declining and, in some cases, could be perceived as an alternative to peaker gas turbine units due to their low-carbon emissions and their fast response time. Nonetheless, the limitations of batteries in terms of time, duration, and total discharge to fully meet the gap when renewable power is not producing, give aeroderivatives the advantage. The reliability benefits of large-scale battery storage systems in operation have not been fully demonstrated and understood.

Bloomberg New Energy Finance's most recent power forecasts have greatly increased demand for peakers over the next 15 years. Their analysis has concluded that renewables and batteries are unable to meet extreme peaks in demand, and peakers present the most economical option (Henbest, et al., 2018).

Additionally, there is ongoing research on the recycling implications and cost for cobalt and lithium, which are currently the main ingredients of the Li-Ion Battery storage technology that has become more common in the industry due to its high electropositivity and high specific energy. The Li-Ion technology is still developing, in terms of cost and safety, and is not yet a viable alternative to

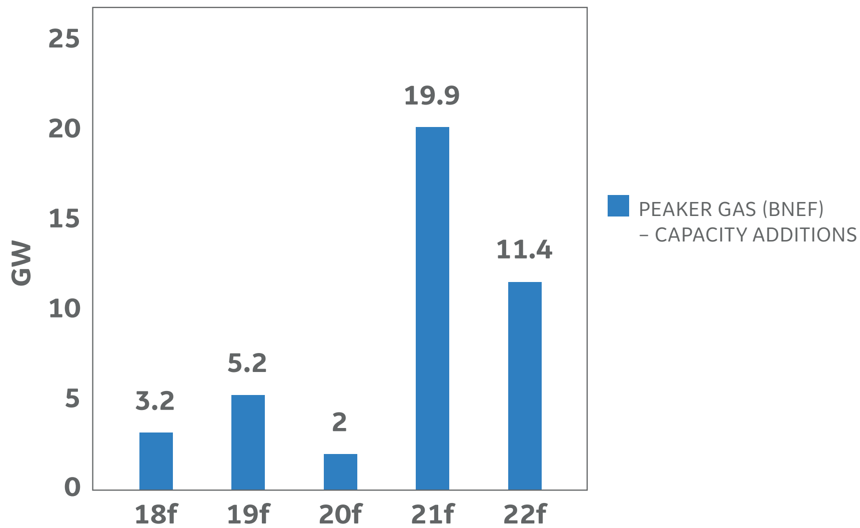

Figure 5 – Peaker Gas, Capacity Additions – Bloomberg New Energy Outlook, June 2018. (Henbest, et al., 2018).

gas turbine technology.

The Best of Both Worlds—Hybrid Aeroderivative Gas Turbine with BESS – EGTTM

One solution recently developed by GE and its partners utilizes a hybrid electric gas turbine (Hybrid EGTTM) to address these challenges. With the increasing proportion of intermittent resources supplying the grid, battery storage holds significant promise in coming years. Like renewable technologies before it, manufacturing scale and technical advances will drive costs lower. Bulk storage will provide backup power, peak shaving and ancillary services. Transmission and distribution investments may be deferred as batteries provide congestion relief during times of peak demand.

The GE Hybrid EGTTM is the world's first gas turbine and battery storage hybrid, coupling a 10-megawatt battery with a 50-megawatt (MW) GE LM6000 Gas Turbine, operated by an integrated digital turbine control system. Key benefits include:

- "Spinning reserve" without firing the gas turbine, utilizing near instantaneous battery power through inverters.
- Enhanced primary frequency response and voltage support.
- Reduced greenhouse gas emissions.
- Smooth transient response with less turbine thermal stress, thereby lowering maintenance costs.
- The EGTTM Hybrid Application is the combination that offers the best of both worlds (GT and BESS) as it provides the environmental and cost benefits of battery storage, along with flexibility and other ancillary services of aeroderivatives needed to balance renewables, with an unlimited capacity.

As an example, the Stanton Energy Reliability Center (SERC) will consist of two General Electric (GE) LM6000-based EGTs. EGT refers to the LM6000 PC Hybrid EGT jointly developed by General Electric International, Inc. (GE) and Wellhead Power Solutions. The EGT combines a combustion gas turbine with an integrated battery storage component operated by a proprietary software system. SERC will provide needed generation for local reliability in the Southern California Edison (SCE) West Los Angeles Basin Subarea and was selected by SEC as part of SCE's 2013 Local Capacity Requirements (Stanton Energy Reliability Center, 2018).

There is growing customer interest in hybrid solutions and further technical discussion and thought leadership on the EGTTM Hybrid Application:

- State of the Art Hybrid Solutions for Energy Storage and Grid Firming, James DiCampli, P.E. Donald Laing CEng FIMechE, POWER-GEN & Renewable Energy World Europe, 28 June 2017.
- Hybridizing Gas Turbine with Battery Energy Storage: Performance and Economics, N. W. MILLER, V. KAUSHIK, J. HEINZMANN, J. FRASIER. General Electric Company, Southern California Edison Company, 2018.

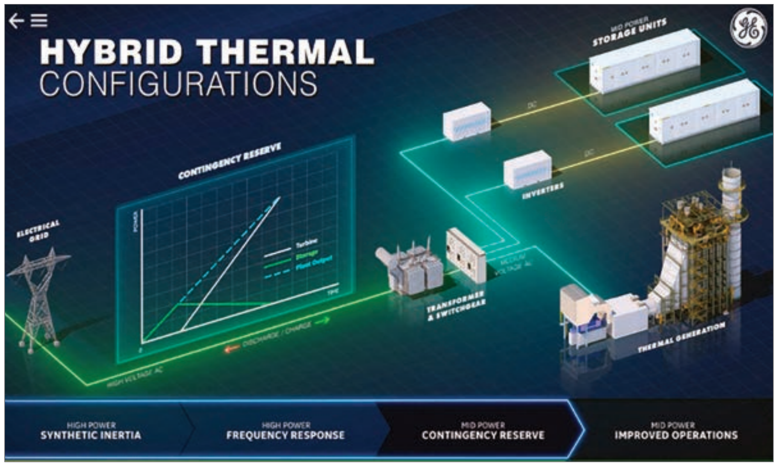

Figure 6 – Hybrid EGT.

The following charts illustrate the benefits and value proposition that the EGTTM brings to the table:

- Lower energy prices
- Reduced emissions
- Higher asset utilization
- Qualifies as a spin reserve without spinning
- Instant response from standby
- Flexible response without start time

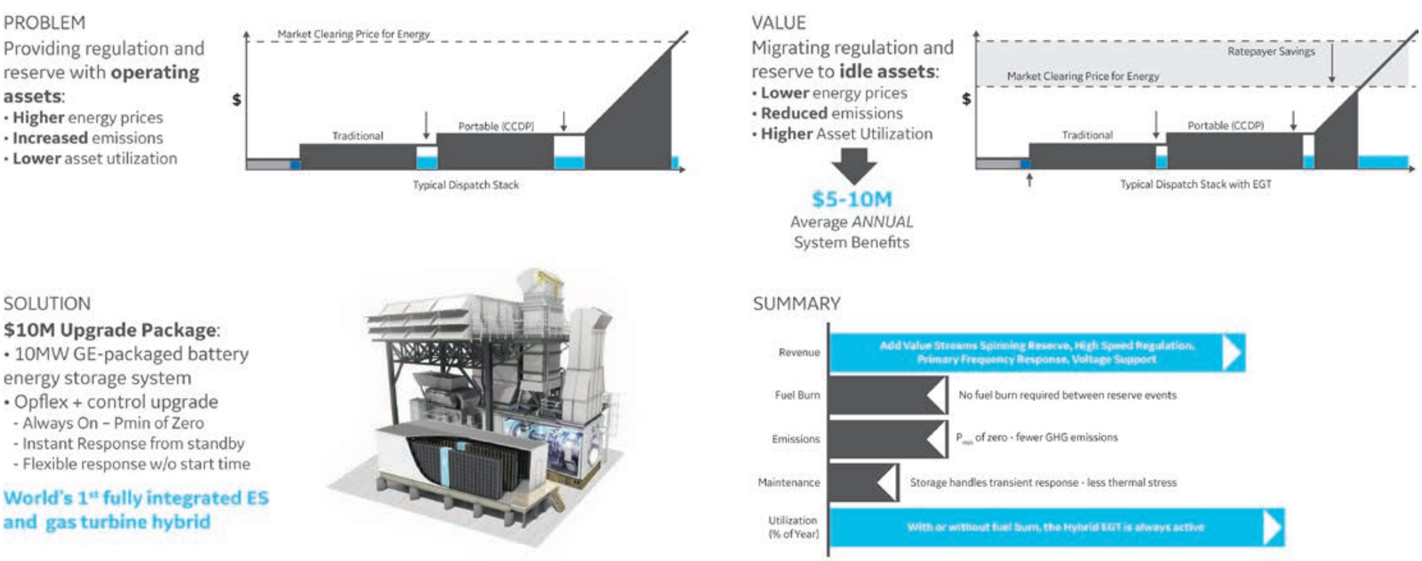

Figure 7 – Hybrid EGT Benefits.

Table 3 – LM6000 vs. Battery vs. EGT.

Direct Project Value	Existing LM6000	10 MW 4 Hr BESS Only	LM6000 EGT Upgrade
Contingency reserve value no emissions	0	10 MW	50 MW
Instant on	✗	✓	✓
RA value	50 MW	10 MW	50 MW
Max power	50 MW	10 MW	50 MW
Min power	>0	-10 MW	-10 MW
Spinning reserve value no emissions	0	10 MW	50 MW
Energy capacity	Unlimited	Very Limited	Unlimited
High speed frequency regulation	0	10 MW	10-25 MW
Grid energy neutrality	✓	✗	✓
Black start with no emissions	✗	?	✓
Utilize existing interconnect	N/A	✗	✓
Utilize existing substation and GSU	N/A	✗	✓
Utilize existing communications and backhaul	N/A	✗	✓
Utilize existing land	N/A	✗	✓
Speed to install	N/A	Slower	Fast
Cost	0	**$$**	**$**

CONCLUSION

The economic and operational consequences of renewable integration pose both near- and long-term system impacts. A complete overview and study must be considered when selecting the applicable technology for grid firming applications to ensure a reliable and sustainable solution is in place. Though many of the cases and examples in this paper draw from the experience of the United States, the topics and challenges discussed have global reach and implications. For regulators and generators, understanding their own country's version of the "duck curve" will show the ramping and frequency response challenges for renewable resources that could be easily addressed by GE aeroderivative gas turbines. Energy storage, specifically batteries, when operating solo, should not be considered as a straight alternative for aeroderivative gas turbines as they lack the synchronous inertia, and are still limited in capacity and duration when compared to GE aeroderivatives technology to support contingencies in grids when operating solo.

Other Future Elements Necessary to Keep in Consideration:

- Government renewables subsidies, where applicable, may no longer exist in the future with the cost decline of solar panels and other renewable resources, in addition to the uncertainty of global tariffs that comes in as a new factor and risk.
- Ancillary services for grid stability as well as ramp rates remain as hidden necessities, already implemented in developed grids, while emerging for some others, especially those regional grids undergoing a reform.
- Recycling cost and regulation (where applicable) of renewable resources have to be included in the economic model for a comprehensive review of all things considered (Pickerel, 2018) (Hopkins, 2018).

Grid operators must balance multiple objectives to reliably and economically deliver the most environmentally friendly power mix, and power plant operators can profitably support this effort with the right regulatory structures in place. GE aeroderivative technology in SC or EGTTM applications, when balanced correctly into the resources mix, make perfect sense only when demonstrated via economical models developed and driven by the region's and project's characteristics.

ABOUT THE AUTHORS

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Ihab Chaaban is a global technical and commercial development leader with over 27 years of experience in the Power Generation and Systems industry, 10 of which with GE, with deep domain expertise in the Energy, Utility and Electrical Power Businesses. Chaaban started his career as an Electrical Engineer and held several roles in Engineering, Sales and Services in the Caterpillar and Solar Turbines organizations via global assignments in the Middle East, Africa, Brazil, Canada and the USA.

Chaaban started his career with GE as an Application Engineering Lead for the Aeroderivative global division followed by other roles in commercial operations leadership and proposal management for Aeroderivative, Distributed Power and Industrial Frames Gas Turbines. Chaaban assumed the role of GE Aeroderivatives global commercial development director to support the grid firming segment including the Gas Turbines Hybrid Operations with Batteries. Chaaban is a Licensed Professional Engineer in Ontario Canada, holds a B.Sc. in Electrical Engineering from Alexandria University, an MBA from Lansbridge University and speaks five languages (English, French, Arabic, Portuguese proficiently with a good command of Spanish).

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Ann Elise DeBelina is an interdisciplinary commercial leader specializing in new business growth, value modeling and operational excellence. She has over two years of experience as part of GE's Accelerated Leadership Program, leading global customer engagement, new product introductions, commercialization and sales operations for product lines across the power and water sectors.

Before joining GE, DeBelina worked for four years at Environmental Resources Management in New York City, leading emissions reduction programs and environmental and social risk management for oil & gas, manufacturing and power industry clients in emerging and developed markets. She previously served as the co-chair of the Young Professionals in Energy of New York. DeBelina has an MBA from Notre Dame with a concentration in business analytics, and a BA in Environmental Engineering from Dartmouth College.

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