Greening the Future Data Center Infrastructure via the GE Aeroderivative Technology and Microgrid Controls

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INTRODUCTION

How do you green an operation that requires reliable-resilient power 24/7/365, in a dynamically changing environment, while maintaining global environmental responsibility, sustainability, and profitability?

Some data centers consume more energy than a large town or small city. But those towns and cities have time to relax and shut down. While data centers are critical infrastructure, they also run our worlds critical infrastructure – so keeping them online can be a matter of life and death. Combine this with the continued need for more sustainable operations, renewable energy goals and objectives, and a dramatic increase for data storage services – and you have an interesting challenge.

The Data Centers Industry went through a massive growth pattern in the past decade due to cloud computing transformation, hyperscale, 5G networks and other technological and socioeconomic changes. This technological evolution introduced challenges to the Data Centers owners in terms of sustainability, cost effectiveness and reliable operation. Per Seagate.com , the expected growth for data centers will go from 33 ZB in 2018 to 175 Zetabytes (1 Zetabyte = Billion Terabytes) by 2025. Despite the fact that the energy consumed per transmitted data (KWH/GB) is getting more efficient, it's fair to assume that Data Centers at the start of 2020, consumed as little as 0.015 kWh/GB in the transmission of data through the internet to a user (datacenterknowledge.com). As much as this efficiency is supporting the growth, nevertheless, the expansion of the digital infrastructures will still be challenged by the energy (GWH) needed to support this growing segment. Hence, utilities are facing challenges to meet the Data Centers demands as the growth of data continues to expand.

Data Centers are thriving to reduce their carbon footprint by increasing operational efficiencies, and relying on Renewable Energy. These Renewable Energy's create other hurdles for Data Center operators in terms of intermittency and variability of power generation to support the operation 24/7. Given the current conventional model for data centers that ranks to the highest tiers (Fig.1) per the Uptime Institute or the Telecommunication Industry Association (TIA) certification where, as one aspect, the reliance on backup power from high-speed diesel generator sets doesn't make the "status quo" sustainable with the anticipated growth, increasing costs of fossil fuels, and corporate sustainability targets combined with legislation.

This white paper shows some models relying on the GE aeroderivative gas turbine technology, derived from the well proven GE aviation platform to support the mission critical segment in its continuation of transitioning to a greener more sustainable and efficient infrastructure. While many Data Centers have innovatively adopted several techniques to meet their energy demand needs, and to maintain the sustainability imperatives via corporate PPA's and acquiring RECs (Renewable Energy Certificates), this paper demonstrates the expansion of those efforts by challenging the standard design practices with more efficient, reliable and sustainable alternatives.

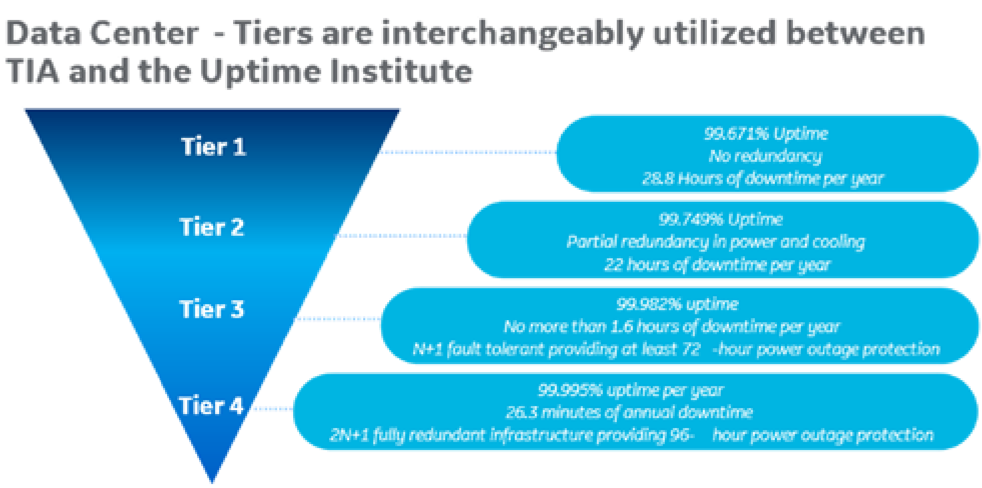


Figure 1.

AERODERIVATIVE TECHNOLOGY OVERVIEW

GE's LM2500* aeroderivative gas turbine is derived from the CF6 family of aviation engines that equipped such aircrafts as the Boeing 747 and 767, the Airbus A330, and the DC-10 and MD-11.

The LM2500 was launched in 1969 for the propulsion of the US Navy ship GTS Admiral W.M. Callaghan. Since this first application it has continued to develop and evolve "off the wing," more than doubling its power output and increasing its efficiency by incorporating new materials and technologies from the generations of aviation engines that followed.

OBJECTIVES & PROPOSED MODELS

The GE Power Aeroderivative Gas Turbines (Aeros) demonstrate a strong fit when attempting to meet an affordable and sustainable energy supply model, either through captive generation, complementing Renewable Sources, or utilizing a mixture of renewable fuels. While the Aeros provide resilience, backup power, and the highest reliability and availability in the industry (exceeding the conventional diesel generator backup capabilities), there is a misconception that these systems lack the support for a green infrastructure.

Nevertheless, the GE Aeros have been operating in several sites in Thermal Hybrid mode with Renewable Sources (Solar and Wind) and Energy Storage (BESS) thanks to the GE Digital controls that enable those assets to operate as a fully integrated single resource including forecasting and dispatch optimization capabilities. With the development and accessibility of cleaner, greener, and more sustainable fuel sources, Aeros provide Data Centers the flexibility, longevity and greater versatility for future growth, resiliency and sustainability.

THE MODELS

A. Simple or combined cycle captive generation:

In some geographies some Data Centers lack the reliability of utilities and grids and tend to rely on captive generation. The Aeros provide several advantages in terms of fast installation and scalable capability to match the growth of the data center load. The Aeros also provide a smaller footprint, lesser emissions and noise sound levels when compared to Reciprocating Engines. While the simple cycle configurations provide fast starts and ramping as well as a smoother load following capability, they exhibit lower efficiencies when compared to combined cycle and heat recovery options. Such high efficiency schemes provide options to the data center for chilling and removing its heat loads. GE has several heat recovery options and multi fuel capability that while supporting the efficient power generation and chilling they serve a desired Tier classification. Additionally, these configurations provide competitive levelized cost of electricity and high reliability in weak grids.

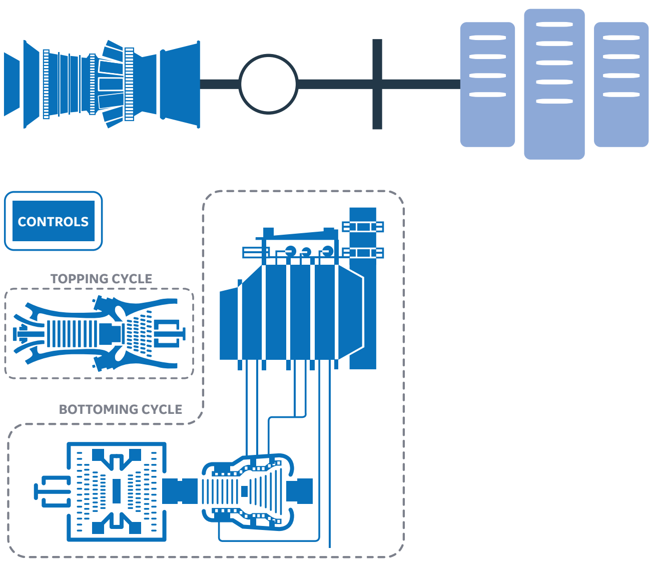
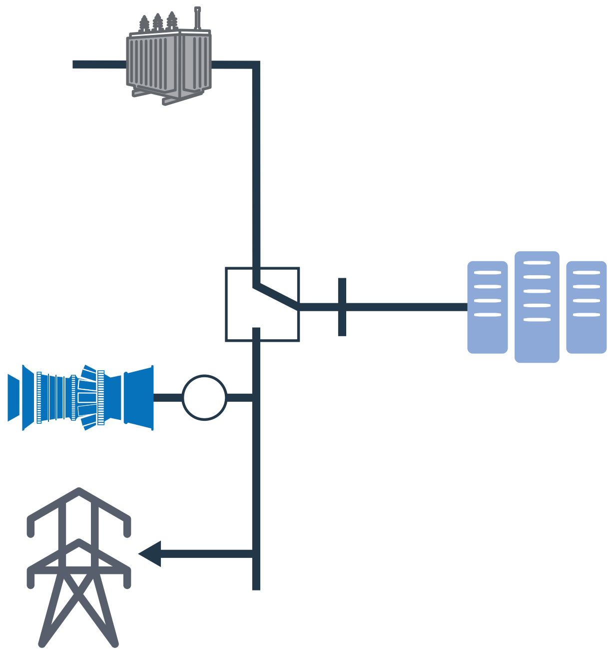


Figure 2. Captive Generation

- Simple or Combined Cycle and Heat Recovery Options
- Overcome High Electricity Pricing
- Higher Reliability Compared to Weak Grids

B. Grid connected with backup generation:

In this model, the data center could receive its prime power from the electric utility while relying on the Aeros as backup. Thanks to the fast starts of the Aeros, the units could start and take on the loads in 5 minutes (GE to be consulted on faster start needs). Moreover, given the role that Aeros have long played in the utility industry to serve grid peak loads and ancillary services, this configuration enables the data center to utilize the Aeros, when not needed for backup, to serve the utility and generate revenue which improves the balance sheet of the project and reduce the utilities burden. With the availability of renewable and blended fuel sources, Aeros provide a more sustainable and cost-effective alternative to traditional diesel operations.

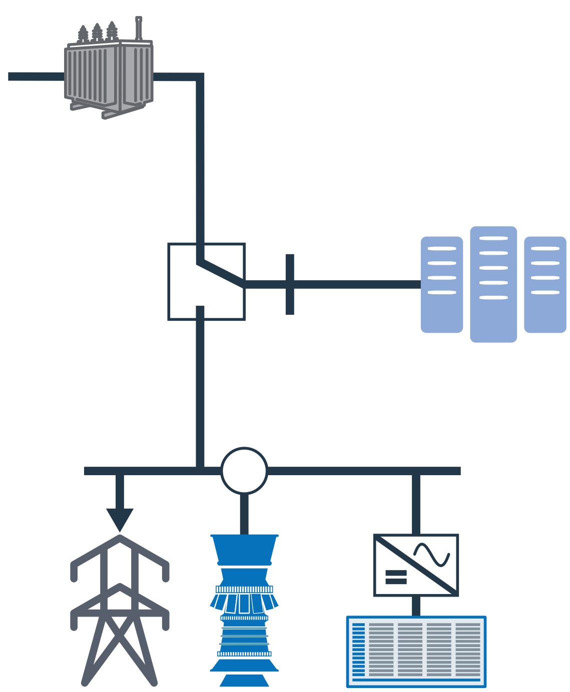


- 5-Minute Backup
- Revenue Generation When Not Feeding the DC Loads

Figure 3. Grid connected with backup generation

C. Grid connected with hybrid backup:

Similarly to the previous model, the Aeros could provide the backup via a hybrid solution with BESS (Battery Energy Storage System) and digital controls. This scheme serves data centers that need to initiate the backup in milliseconds instead of minutes while also being able to serve the grid and generate revenue when not in backup mode. The BESS , which is a constituent of the GE portfolio of products including LFP batteries and LV5+ inverters, operates in milliseconds to take on essential loads while the Aero ramps up to take over the total load.GE Aero has a proven track record in its EGT (Enhanced Gas Turbine) design where the Aero unit with the BESS and digital controls are transformed into a single resource when the 2 assets are interfaced via a Mark Vie hybrid controller to manage the operational profile.



- Immediate Backup
- Revenue Generation and Grid Support

Figure 4. Grid connected with hybrid backup

D. Grid connected with renewables and thermal hybrids:

In this model, the data center could acquire its green power needs via a thermal hybrid integrated solution either direct or via an off-take agreement. Thermal Hybrids allow the RE (Renewable Energy) asset to generate to its fullest capacity while turning down the thermal asset and hence reduce the curtailment, fuel burnt, provide a lower blended LCOE (Levelized Cost of Electricity) as well as lower CO2 emissions to enable complying with the decarbonization corporate imperatives for socially responsible data centers. Since one of the challenges in deploying Renewables in long term Offtake agreements is the intermittency and variability of the energy production, and where the battery energy storage technology lacks on its own the capability to firm the needed capacity within a 24 hours duration, the Aero Gas Turbines, with minimal penetration, could firm that capacity with a higher capacity factor especially in the case of hyperscale data centers when the hybrid asset is serving as the main generation unit of the IPP/Utility feeding the offtake. As known in the industry, there is a variety of PPA's that are normally structured to fit the needs of the off-taker with the proper risk mitigation, and it would be worth the effort to compare the thermal hybrids economics and financial performance indicators via modeling software tools such as the GE hybrid Architect, against RECs and carbon offsets that may not be the optimum sustainable solution. Moreover, the venue to utilize the asset to generate revenue while not in need is another alternative to improve the NPV and IRR and the bankability of the investment. In this model , GE leverages its wide portfolio of products to enable the implementation of such solution. As an example, the microgrid option comes in play where a group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries act as a single, controllable entity with respect to the grid/data center. A microgrid can connect and disconnect from the grid to enable its operation in both grid-connected or islanded mode. The GE GridNode microgrid solution enables such scheme via secondary and tertiary controls. The control functions include but are not limited to, synchronization , load sharing, firming capacity and frequency and voltage control to provide an optimized output to the load side via the adequate architecture. The GridNode Optimization Engines further manage Distributed Energy Resource (DER) assets for economics, sustainability, and reliability while continually maintaining system survivability as a primary objective.

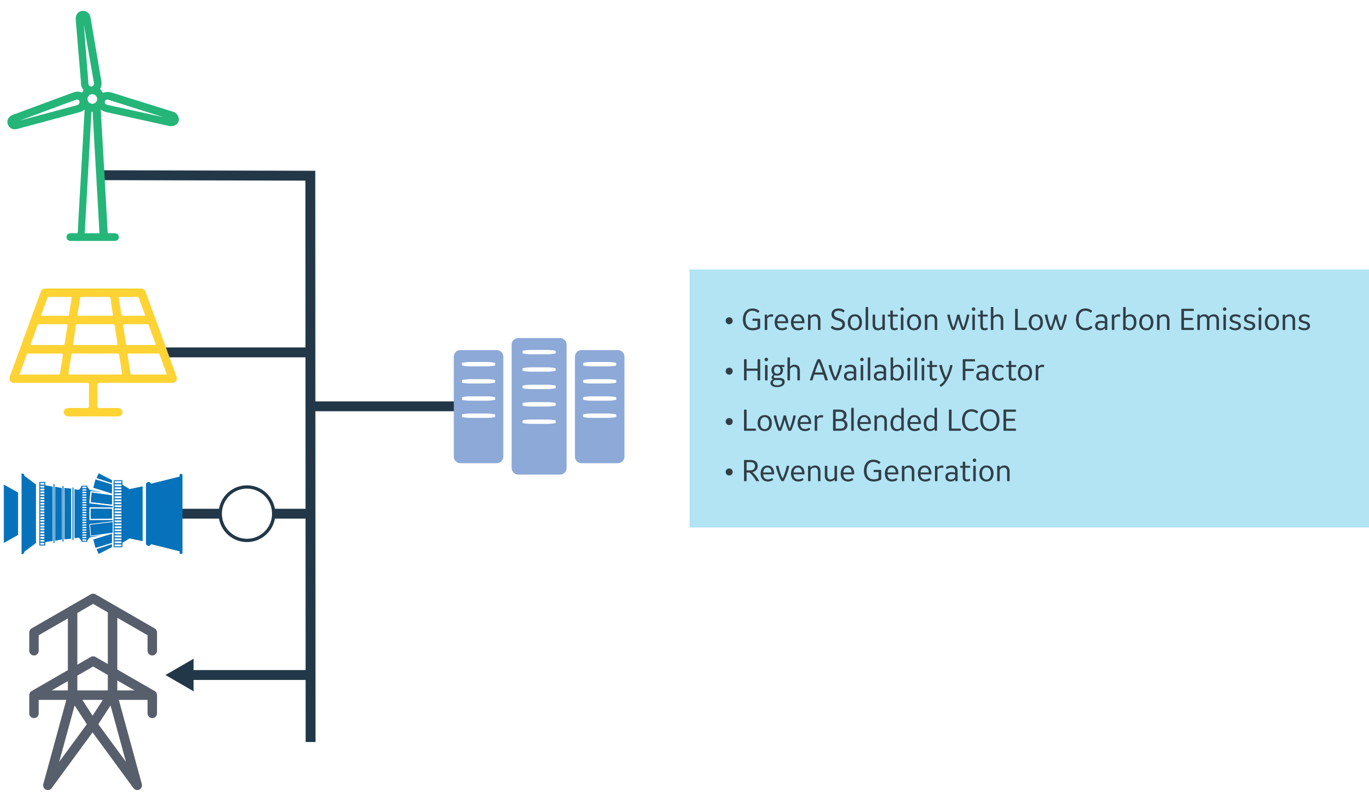


Figure 5. Grid connected with renewables thermal hybrids

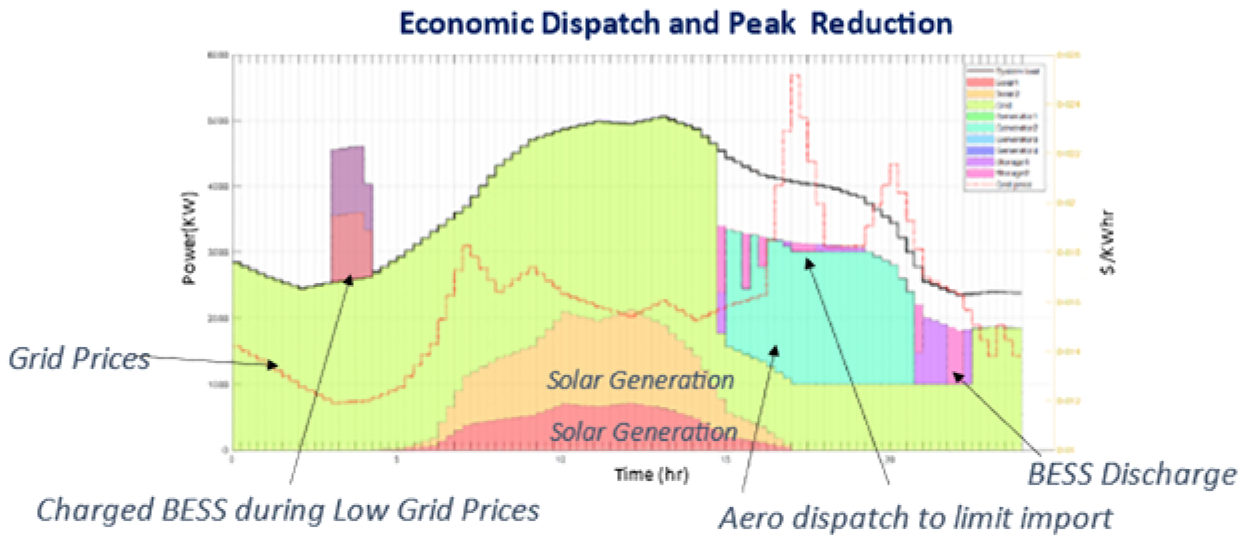


Figure 6. GridNode Optimization engine manages DER assets (BESS, Renewables, Aero) for economic and sustainability goals

What is a Thermal Hybrid?

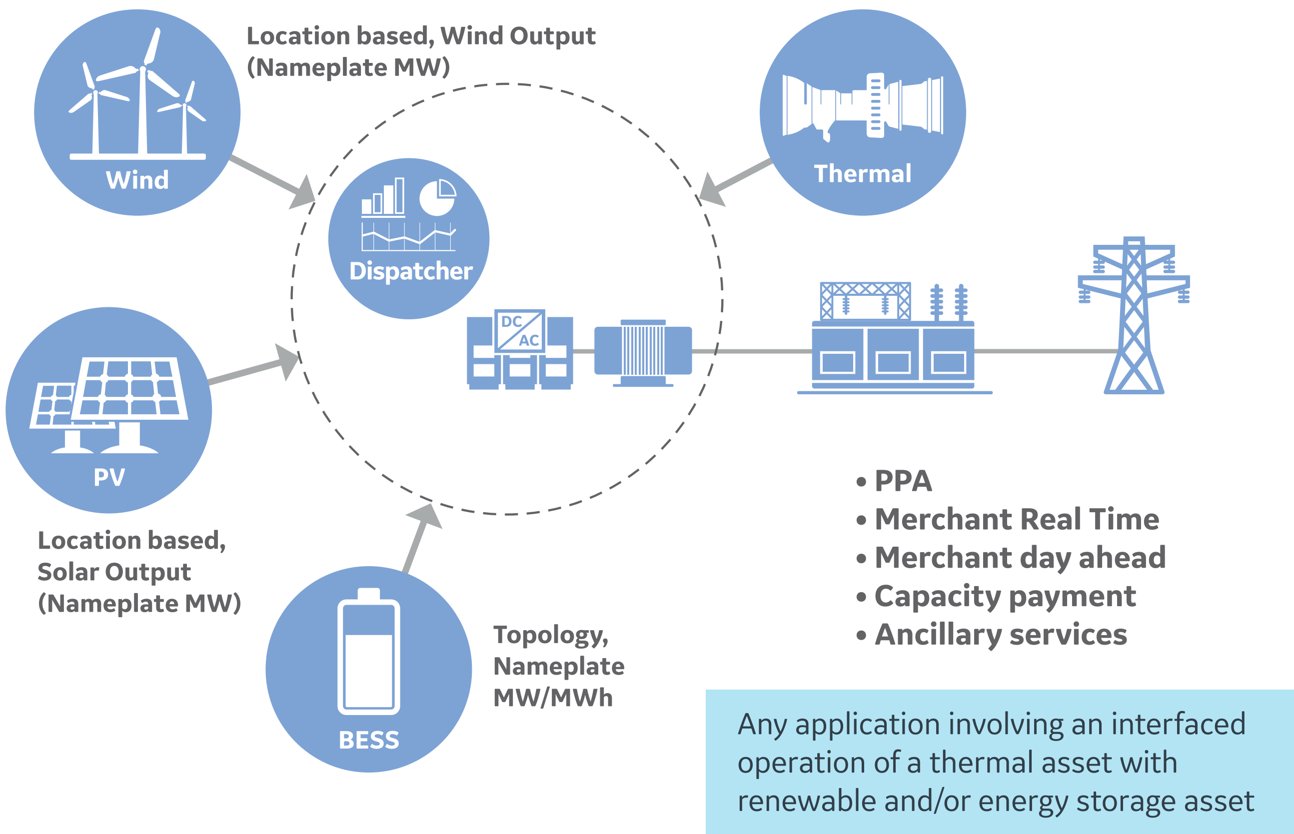


Figure 7. Thermal Hybrids

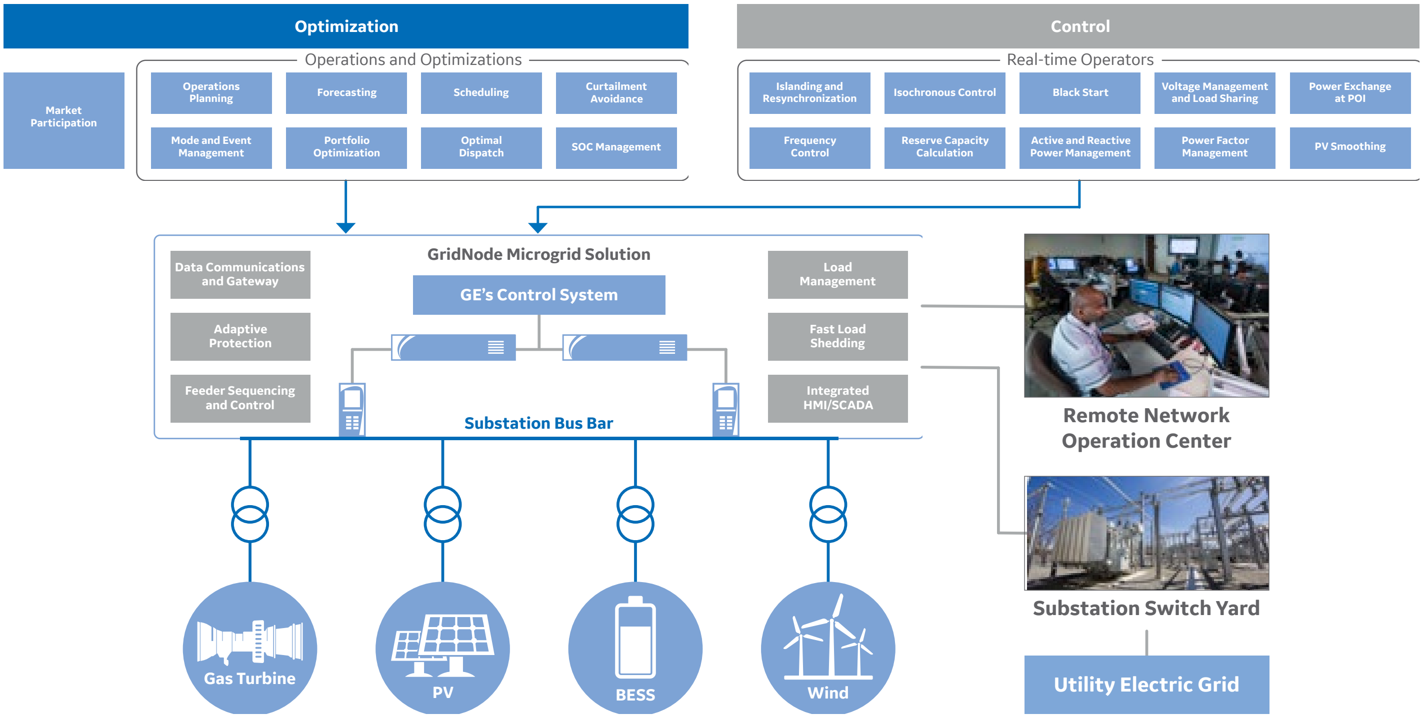


Figure 8. GE GridNode Typical microgrid functions

E. Additional models: Temporary solutions and multi utility feed:

Additionally, the GE Aero could fit other models for the data centers industry , such as providing a temporary solution via the TM 2500 (Trailer mounted) where those units could serve during the data center commissioning and testing phase or bridge any gaps from the utility committed energy feed. Another model that is worth mentioning is the utilization of reliable grids with a double feed that may be considered as the 2N while the Aeros would act as the +1 given its well known reliability and availability from its aviation platform heritage.

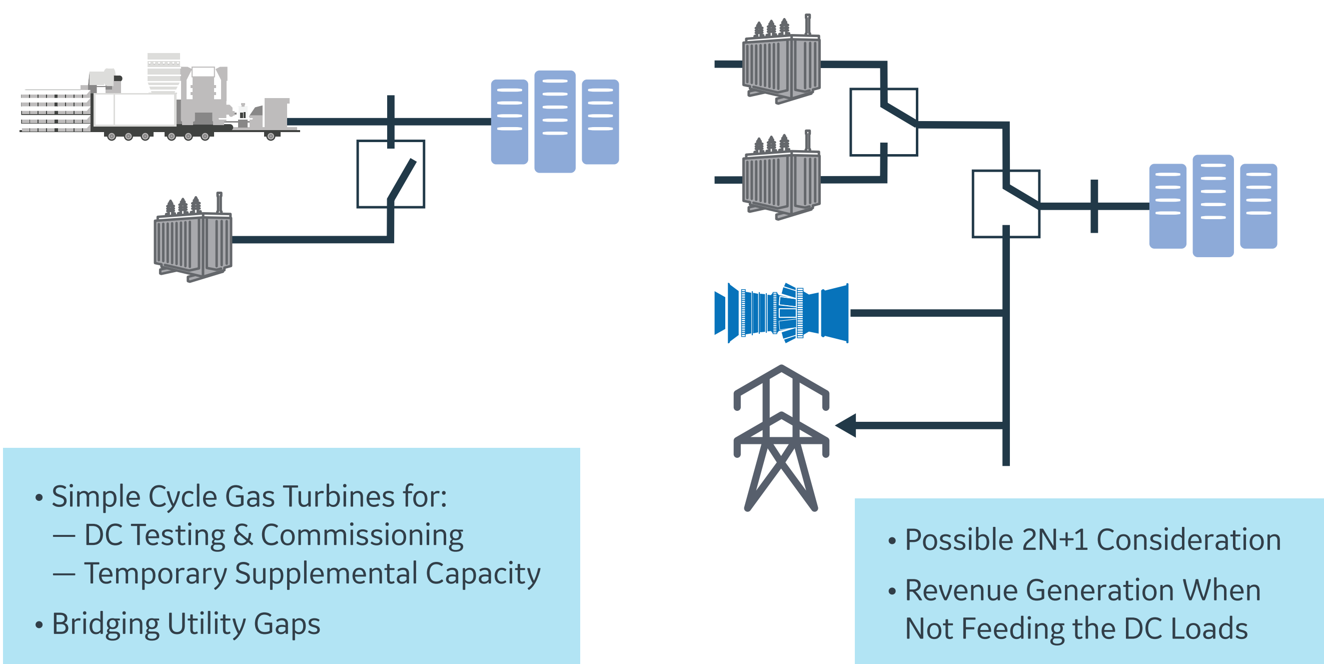


Figure 9. Other Models Where the GE Aero is a Fit

F. Green Hydrogen sustainable models:

Additionally, Fuel Diversity is among the Aero Gas Turbines attributes and advantages where different GT models have the capability to burn a wide range of liquid and gaseous fuels. These gases present a broad spectrum of properties due to both active and inert components. Among those gases, with the proper conversion and additional mixing skids, the Aero product SAC (Single Annular Combustor) gas turbine has the capability to burn currently a mix of Hydrogen and Natural gas with a H2 content by volume of up to 85%. There are over 2,600 gas turbines configured with this combustion system; these units have accumulated more than 100 million fired hours on a variety of fuels. The SAC models require a water injection system for NOX abatement. On the other hand, the DLE (Dry Low Emissions) model doesn't require any water injection for NOX reduction, nevertheless, the Hydrogen content in the fuel mixture is limited to currently 35% at this point with a phased target to reach eventually 100% of H2 content by volume.

Under the above context, the Aero Gas turbines offer multiple options to achieve lower carbon emissions, either through pre combustion by using a renewable fuel such as hydrogen or post combustion where carbon capture technologies are utilized. While Hydrogen could be obtained from Fossil Fuels (Brown Hydrogen), nevertheless, as the industry is incentivizing Renewable Hydrogen, where it is generated from Renewable Sources (Green Hydrogen), the focus of this article is on such type. While Green Hydrogen when mixed with Natural Gas provides a substantial CO2 reduction when compared to pure Natural Gas, the levelized cost of hydrogen (and $/KG) is still facing many hurdles such as high cost (2.5 – 7 $/KG in 2019 down to 1.4 to 2.9 $/KG by 2030) ,lack of economies of scale and infrastructure. However, with the ongoing funding ventures globally and regulatory reforms those hurdles are continuously being mitigated to improve the hydrogen penetration and scale. An intermediate proposed model such as the one shown in Fig. 9, allows the Hydrogen production and storage when Renewable Energy is available in order to use it when it's not. The model relies on onsite Hydrogen generation via PEM or Alkaline Electrolyzers and storage.

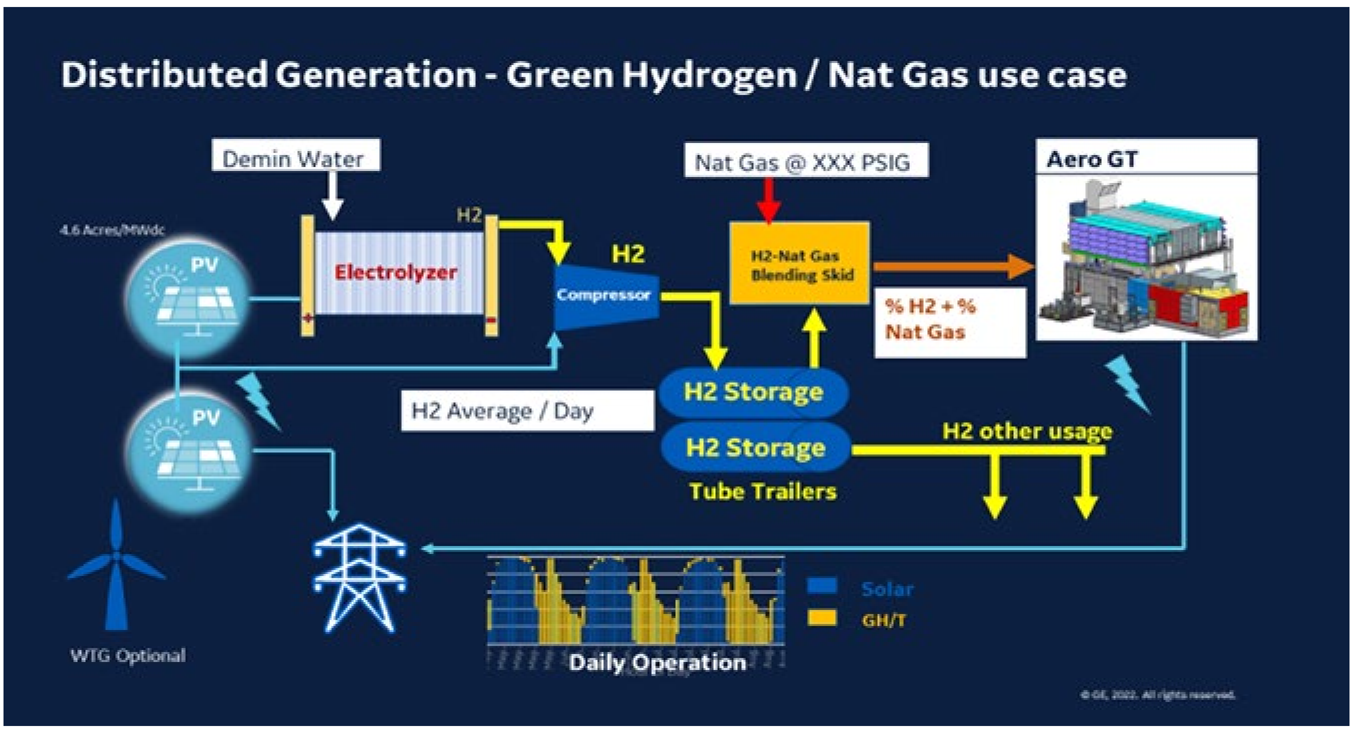


Figure 10. Green Hydrogen Power Generation Diagram

CONCLUSION

- This white paper showed the various models that could serve the data center industry in achieving a more sustainable and green operation while supporting its growth pattern.
- The models also showed the advantages of the GE Aeroderivative technology when operating solo or when hybridized with Renewable Sources and Batteries to achieve lower GHG emissions and operate at a relatively low blended LCOE while providing the required reliability.
- The white paper also shed some light on the Green Hydrogen operation where the Aeros represent a strong fit by joining thermal hybrid operation along with Electrolyzers.
- GE has a wide portfolio of Products, including Renewable Energy assets, Energy Storage , GTG's (gas Turbine Generators) as well as Digital and Microgrid controls that ease the implementation of a complete system when combined with Electrolyzers and storage.
- GE has an in house built software tool called the Hybrid Architect that can provide an in depth analysis and estimates of the annual energy production of the RE asset to feed the Electrolyzer and hence provide an estimated hydrogen production and an estimated average LCOH/LCOE for specific projects.
- The GE Aero solution is a strong fit demonstrating the value prop that can serve the Data Centers segment current and future needs.

ABOUT THE AUTHORS

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Ihab Chaaban is a global technical and commercial development leader with over 30 years of experience in the Power Generation and Systems industry, 14 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 renewables assets and 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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Steve Halford is the Microgrid Leader for GE Grid Solutions, bringing together multiple GE business' to deliver reliable, efficient, and sustainable Microgrid systems to customers within North America. Steve has over 25 years of electrical power experience focusing on power quality, energy efficiency, power system design, and microgrid planning, design and development. Steve was the previously the Director of North America for Dranetz Technologies, and Traction Power, Mission Critical, and OEM Business Development Manager for SEL prior to joining GE in 2018. Steve serves as a co-chair to the IEEE Traction Power Committee for substation protection and control, and participates in an advisory role on different NFPA standards groups, and is also a volunteer firefighter and serves as his county lead safety trainer on energy storage systems for first responders.

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