Evolution of Data Center Onsite Power Use

WHITE PAPER

by Rich Scroggins

SYNOPSIS

There are two major forces at play redefining how onsite power generation assets are applied in data centers – the quest to decarbonize data centers, and the challenge of an insufficient power grid. Today, diesel generator sets are the predominant standby power source in a typical data center and run only a few hours per year to meet emergency grid outages and equipment exercising regimens; but also because their operation may be limited by national and local air quality regulations. As such, data center operators are assessing how onsite power generation systems can be leveraged beyond conventional use and contribute to meeting their sustainability goals and address the challenges of an insufficient grid. In this paper we will discuss these forces, the evolution of design and application of onsite power, and present viable alternative power generation technologies that may be deployed to address these challenges.

MARKET FORCES

While there are several forces at play impacting the data center industry, two prominent forces are shaping the way we think about powering data centers.

Data centers are under pressure from both internal and external stakeholders to improve sustainability. While many industries and government entities are subject to the same pressure, most do not experience it to the extent that data centers and particularly Hyperscalers do. This is primarily because data centers consume a lot of power. Various sources estimate that data centers use between 2% and 3% of power in the world today. Additionally, data centers are large, visible companies making them an impactful target for environmental groups and regulators who are putting in place mandates. But even more so, data centers are keen to be good stewards of the environment and recognize how impactful actions from the collective industry can be. As such data centers have set aggressive sustainability and decarbonization targets that in many ways far exceed regulatory push and have become pace setters. Simply put, for the data center industry at large, sustainability is no longer a “nice to have,” it is core to ‘how’ data centers are built and operated.

In addition to sustainability concerns, data center construction and power needs have outpaced electric grid infrastructure in several parts of the world especially in Europe and North America. Utilities in Northern Virginia and Dublin, among other places, are restricting the ability of new data centers to connect due to power generation capacity or distribution limitations. Grid shortages are becoming more widespread and could be further exacerbated by increased power needs as the industry sees continued growth and AI compute demands takes off as expected by many industry experts. Another compounding factor to the constrained power grid, is the availability of renewable power. While many utility providers and IPP’s have been instrumental in increasing the availability of renewable power, sources still face challenges with insufficiency, intermittency and cost effectiveness.

DATA CENTER POWER SYSTEM EVOLUTION

On site power generation systems in data centers have traditionally been for emergency standby operation – providing power to the equipment only in the event of a utility outage. However, the drive towards decarbonization of energy in data centers and the need to operate data centers in the wake of a constrained grid are inevitably driving a shift in how onsite data center power systems are used.

To understand how the shift may play out it is useful to consider operating hours and carbon intensity of the onsite power sources, as shown in the graph below. Here we are plotting carbon intensity on the horizontal axis, with fossil fuel-based sources on the left and low carbon sources on the right. We plot operating hours on the vertical axis, with low operating hours typical of standby operation at the bottom of the graph, and high operating hours of a prime power source at the top.

The onsite power system of a typical data center today operates in the lower left corner of this graph. The predominant power source is a diesel generator set that operates for a limited number of hours per year to support emergency backup power needs.

The drive toward sustainable decarbonized data centers will cause a shift to the right on this graph, as data centers adopt lower carbon fuels such as HVO. The shift to the right is straightforward and easy to anticipate given the commitment that data centers are making towards sustainability.

However, the need for an upward shift has more recently emerged and evolved quite quickly, caused predominantly by the need to address an insufficient power grid (grid augmentation), but may also play a role in enabling decarbonization.

GRID AUGMENTATION

Where the grid is insufficient, utility providers are unable to guarantee uninterrupted power supply to new or expanding data centers, especially in periods of peak power demand e.g., in the summer when consumer cooling loads exhaust grid capacity. Similarly in this situation, data center operators have to find ways to keep their operations powered during these times of interruptions which can be up to several hours a day. Onsite power generation assets present as an obvious option to meet this need. Many utilities offer financial incentives for operators of onsite power generation assets to provide grid support functions to help keep the grid stable when there is an imbalance between generation and load. In general, data centers have not participated in these programs because the financial incentives were not sufficient to justify the added risk and complexity to a data center's operation, particularly given the favorable tariffs that large data centers typically have with utilities. With grids becoming constrained data center operators are anticipating that they will need to incorporate grid support functions in order to maintain operation. In some cases, utilities are mandating that data centers participate in demand response programs in which an operator takes some of all of their load off the grid based on a signal from a utility.

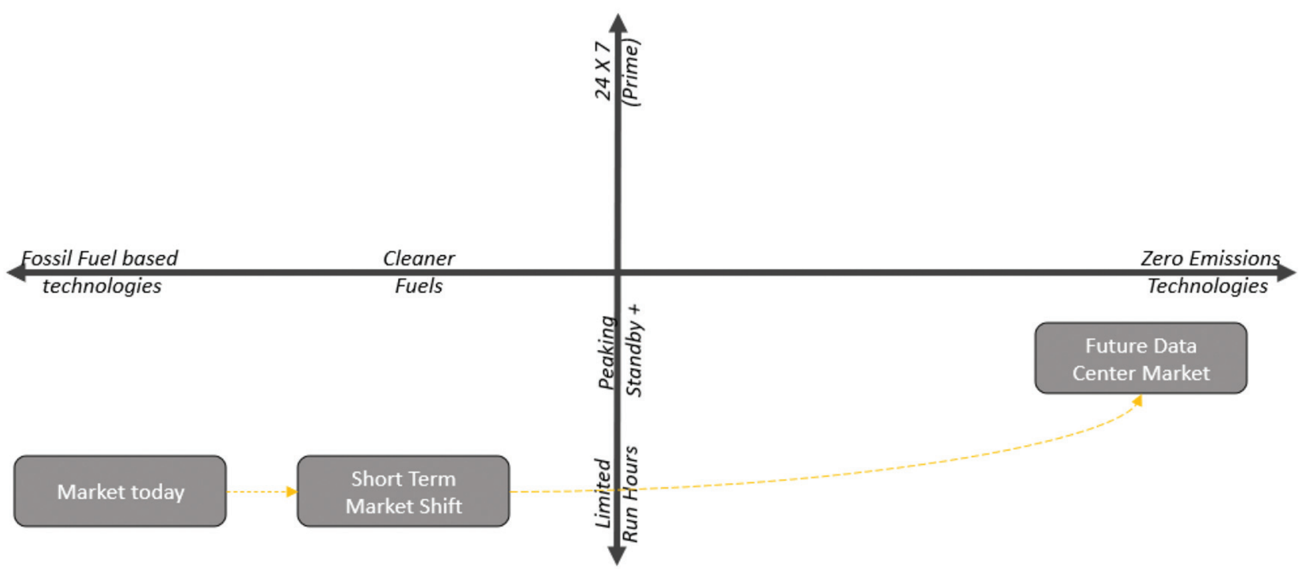

Figure 1 – Power System Evolution

DECARBONIZATION

One of the main challenges data centers face as they seek to decarbonize is access to a reliable, affordable renewable grid. Further, renewable grids bring about unique challenges due to their intermittent nature. Therefore, as cleaner onsite power sources are developed and adopted into data centers there arise opportunities for data centers to leverage these assets for more than emergency backup power; to supplement intermittent renewable energy sources.

With all this at play, data centers will need to move beyond using gensets solely in the event of a grid outage, to dispatching their assets to support a constrained grid. We are referring to this use case as "active standby" where the power generation assets are used for purposes beyond emergency standby but are not the primary source of power for the datacenter. With active standby operation we will have more operating hours for onsite assets as they are participating in grid support functions, so we locate this operating point to the right on the graph (indicating a low carbon source) and higher (indicating greater operating hours) compared with the standby use case. Adoption of active standby operation will depend on the availability at scale of cleaner power sources and on the extent to which utilities are becoming constrained. Today a main barrier to active standby operation is regulations limiting criteria emissions, particularly oxides of Nitrogen (NOx). Engine in-cylinder technological advances, after-treatment solutions and natural gas generators are a few of the technologies that address this to enable active standby operation in the near term. As battery technology matures batteries may be suitable power generation assets depending on the expected duration of demand response events. In the future as the green hydrogen ecosystem matures, fuel cells and hydrogen reciprocating engines may be attractive onsite power assets.

Note that the operating point on the graph is below the center line. This indicates that we are not expecting the onsite assets to operate as a prime power source. Where utilities or Independent Power Producers have sufficient capacities data center operators will choose to purchase power rather than take on the operational burden of producing prime power and will use their onsite assets standby power and for grid augmentation where necessary.

CONCLUSION

The drive for sustainability and the constraints of limited grid infrastructure will cause data center operators to consider new technologies and use cases for onsite power generation. In this paper we've looked at how onsite data center power systems in some markets will migrate from the traditional standby use case to an active standby use case and the key drivers and barriers to that evolution. As power systems evolve in the coming years and as new technologies and ecosystems mature, there will be a variety of power generation technologies and operating modes adopted by the data center market. To ensure solutions that meet the evolving needs of data centers, including the shift to an active standby use case, Cummins is investing in low carbon, low emissions technologies such as Battery Energy Storage Systems (BESS) and fuel cells and are exploring the viability of various low carbon fuels. Additionally, microgrid control technologies will enable integration of future data center power systems which will likely include multiple diverse energy sources.

About the author

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Rich Scroggins is a Technical Advisor on the Data Center market at Cummins. Rich has been with Cummins for 30 years in a variety of engineering and technical marketing roles in the Power Generation business. Rich has been a member of the IEEE 1547 working group and is an alternate member of the NEC and NFPA 110 code panels. Rich received his bachelor's degree in electrical engineering from the University of Minnesota and an MBA from the University of St. Thomas.

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