Microgrids: Integration for power cost and control

Context: Microgrid and data center synergies

Autonomous energy networks that integrate distributed energy resources, matching this with local electric loads to service localized demand, microgrids are perhaps best described in opposition to the supergrid – or national grid systems built by the utility companies. In contrast to the super or macro grid, which features centralized generation and distribution of electricity to customers over very long distances, microgrids operate at the local level on a much smaller scale, taking advantage of multiple on-site energy inputs, including renewable energy resources, fuel-based generation, storage technologies, and utility grid energy as required, to facilitate both energy consumption and power delivery over much shorter distances. Microgrid self-sufficiency is one of the technology's key value propositions: defined at a high level by Jon Jaeger, application engineer for ABB's microgrid group, as "islandible power systems that can operate either connected to the utility or independently of it," microgrids provide a power option in remote regions that cannot access primary grid systems or in cases of macrogrid failure, as well as an opportunity for technology users to maximize their energy financials by using on-site generation to meet a portion of their energy consumption. Microgrids can operate like demand response systems, using utility pricing data to signal to the user when to turn on their local generation resources in order to avoid consumption at peak times.

Touted as a feasible solution to broad contemporary energy supply issues, such as energy security/supply and climate change mitigation, microgrids are also receiving increased attention as a means to power commercial enterprises – and the data center in particular. Back in 2009, researchers at the Lawrence Berkeley National Laboratory in California concluded that of three types of enterprises, data centers could realize the most potential value, measured in terms of increased reliability and power quality, from microgrid adoption, a conclusion that has since inspired a number of important demonstration projects at university campuses across North America. Microgrids and data centers are well aligned on a number of levels. As Jaeger pointed out, "even with standard diesel generators, you could argue that the data center structure could be called a microgrid," as it is a source of energy production and consumption. In addition to backup generation, like a microgrid, a data center typically has energy storage capability, a robust electrical infrastructure for power management, and often a smart power metering systems that might be harnessed in a microgrid implementation, in addition to experience with 'islanding', moving on or off the grid to ensure uninterrupted power. And as mission critical enterprises, data centers also have a requirement for reliable, conditioned power. These synergies make the data center an ideal platform for the advance of microgrid technology.

Business issues: Energy cost and reliability concerns create case for microgrid adoption

The central grid has served the electricity needs of developed regions for over a century, a fact that is both laudable and a liability. Much of the primary infrastructure across North America was installed in the mid-1960s, and while many utilities are undertaking significant modernization programs, aging equipment has left much of the grid unstable. Additionally, grid interconnection in the macrogrid presents another risk: failure in one part of the system typically translates into cascading failure – wide-scale outages as experienced by large areas of the North American northeast back in 2003, for example. Traditional universal service is also under pressure from our seemingly unquenchable thirst for electricity in productive and daily life: in the digital realm, this pressure is exacerbated by increasing demand for power quality and reliability (PQR) needed to deliver many applications.

Grid modernization is having the logical consequence – an increase in energy pricing in many jurisdictions to fund

CAPEX-intensive network enhancements. Rate increases are exacerbated by the growing cost of generation, and of fossil fuels in particular, which are likely to be subject to additional fees associated with the institution of carbon legislation. While the recent discovery and exploitation of additional natural gas reserves in the US, and the shift towards more economical gas-based generation should mean cost adjustment, in its Short-Term Energy Outlook for March 2015, the US Energy Information Administration is forecasting slight price increases and a resurgence of industrial electricity consumption by 50 million kW hours/day in 2015 and a further 40 into 2016, following collapse in 2014. For the data center industry, this increased cost, combined with significant and growing consumption, as reflected in annual power costs of $60 billion and overall market growth[1] are a critical concern. In the New York region, energy costs account for just under 30 percent of total data center operating budgets[2].

To address these cost and reliability issues, governments, consumers and businesses are turning to use of renewable energy resources (renewables accounted for 21.7 percent of worldwide electricity generation in 2013), and data centers, which increasingly are responding to environmental pressures, air quality regulations and the increasing cost burdens of diesel fuel (for on-site generators) are no different. However, inherent characteristics of renewables present their own challenges: while wind power is available when the wind blows, solar photovoltaic energy is a daytime phenomenon that is especially vulnerable to climactic conditions – a cloud passing over the sun could drop power generation from 5 MW to 100 kW in a matter of seconds. So while limitless reserves of free energy have appeal, high capital costs incurred in installation and the variable power profiles associated with renewable intermittency, represent hurdles to broader adoption, especially in data centers which cannot compromise on power quality and availability.

Implementation challenges: Renewable intermittency a key consideration

Critics of the microgrid approach point towards limitations on the ability of renewable energy to generate 100 percent, or even adequate capacity due to space or cost constraints, or to ensure a steady supply of directed power, an important requirement in data center environments. To solve for this, microgrid implementations may rely on natural gas or other fossil fuel generation to compensate renewables. To maintain a 60 hertz frequency, which is required for grid stability, microgrids must continuously adjust for fluctuations in demand and generation, and interruptions can lead to power quality issues, such as brownouts, or even blackouts.

Power systems typically maintain some amount of operating reserve, or head-room on their generators, in order to meet increases in system loads or the loss of generation. With greater reliance on renewables, this reserve margin must be increased in order to compensate for larger changes in wind or solar output. Some fuel-based generators have constraints on how quickly they can be ramped up or down, and what their minimum loading level is. Furthermore, if the system isn't properly configured, this increased ramping of the generators can lead to increased wear and tear.

Technology capabilities: Squaring the macrogrid and renewables circles

Defined as a subset of load and generation equipment at an enterprise site, microgrid for data center may include electrical grid structures for load or generation optimization, conservation programs, heat and/or HVAC management. Regardless of the use case the key component in microgrid implementations is the master control system, a sophisticated hardware and software solution that aims at efficient management of a diversified mix of onsite generation (wind, solar, thermal power, bio fuel, fuel cells or even heat recovery) and its integration with local load demand. In more sophisticated solutions, the software combines modelling and forecasting capabilities with cost optimization capabilities – advanced modelling to predict fluctuating energy demand and local generation potential which can be offset against real time energy pricing market information from the utility or ISO, generation production costs and local environmental data (for example, site specific interior building and exterior temperatures over a 24 hour period) to support decision-making around the facility's dispatch of local generation (renewable, diesel or natural gas based) vs. access to resources delivered via utility grids. In many cases, this analysis can be automated to take best advantage of the spread between production and consumption costs associated with different resources, and automated demand response applications within microgrid can optimize for cost and for reliability in cases where additional capacity and frequency control are needed – especially in jurisdictions where timely response is a critical factor. Interface capabilities for interaction with the primary grid are another feature of most microgrid solutions.

Another key input in microgrid management of power reliability is advanced battery storage such as Lithium-Ion, which may be marshalled to offset fluctuations in renewable generation or even to participate in voltage or frequency markets where utilities purchase power to regulate their own supply. Given data center focus on power quality, this capability is an important component of microgrid technology. ABB, for example, combines its advanced microgrid integration of renewables and diesel generation with a PowerStore Stabilization system, a flywheel or battery unit that acts as a grid stabilizing generator, with software that controls power flow to smooth out grid frequencies and manage voltage fluctuations.

Interestingly, another approach to resolving issues with renewables hails from the data center industry itself. Researchers are currently investigating ways to apply cloud technologies to shift loads within the data center to address fluctuations in supply. HP Labs, for example, has created a data center architecture that features supply and demand management and the colocation of workloads to shape demand to match capacity: according to HP, the architecture generates an 80+ percent reduction in reliance on utility grid power when used with a manageable renewable infrastructure.

Benefits: Cost, power control and the future of microgrid

Armed with advanced control systems, data center demand management software and new battery technologies, many organizations have been able to manage the intermittency challenges associated with the integration of renewables. According to noted green IT consultant Bill St. Arnaud of St. Arnaud-Walker and Associates Inc., these onsite projects deliver savings through fuel cost reduction, but more importantly, microgrid integration technologies have become so sophisticated that the presence of renewable sources is now viewed as measure of energy reliability, a critical requirement for data center uptime. In addition, the microgrid's ability to deliver power independent of the embedded grid, which has become increasingly vulnerable to wide-scale failure, offers the facility operator a new vehicle for energy security and data center resiliency that up to now have been ensured through costly and carbon intensive diesel generation. Since a microgrid is able to function islanded from the macrogrid, higher reliability can be achieved for all its loads, while management and control systems can deliver heterogeneous power quality and improved reliability levels to applications and end uses with diverse requirements.

Microgrids also offer significant potential to reduce operating costs though integration of renewable resources, which offer limitless supplies of OPEX-free energy, and which are experiencing reductions in CAPEX costs, bringing them closer to parity with traditional grid supplies. Since power travels a shorter distance in microgrid settings than in macrogrid environments, there are less power losses in transmission and distribution lines. This waste reduction may not be transparent to the user, but it does have an impact on overall cost. Most importantly, microgrids allow the data center to balance and shape demand and generation capability, utilizing supergrid resources where energy pricing mechanisms and environmental conditions makes it economically sensible to do so, and maximizing the value of onsite generation by selling excess power back to the grid when utility pricing signals the availability of competitive rates.

Going forward, the potential to further integrate microgrid and data center technologies offers even more profound opportunity for efficiency improvements. Research into "energy routing" or "energy Internet" technology that can integrate renewables and grid energy as well as electric vehicles (for storage sink) in data center applications is now underway. Built on demand management principles and the integration of data and energy platforms at the chip level, this approach promises to power up ICT devices as needed, send workloads to renewable generation sites, or pull power from solar panels and route it via a USB port or other IT channel to servers or other devices that reside on the ICT network. Or, taking advantage of advanced networking, an organization may engage in demand/response arbitrage, leveraging microgrid resource and price information as well as data from building information management systems to determine when and where discrete sites in a data center network should be fired up, fired down or kept online.

References

[1] Global data center power consumption will increase at a compound annual growth rate of 4.3% during the 2015-2020 period. Datacenter Dynamics Intelligence, 2015.

[2] Datacenter Dynamics Intelligence Market Abstract: New York, March 2015.

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