Converting Data Centers from Diesel to Gas Power Generation

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INTRODUCTION

The energy needs of the data center (DC) industry continue to grow at a brisk pace. In the past, preferred DC locations were near inexpensive, reliable power sources. Today, such locations are more difficult to come by, and pressure is mounting to find alternate solutions that will be less demanding on the grid, particularly when electrical demand is high.

Despite many DCs having sufficient self-generation capacity from their diesel standby units, the viability of running those units to relieve the grid is neither economically feasible (operating cost would be prohibitive due to high cost of fuel) nor allowable by current air board restrictions that put limits on yearly hours of use. The function of diesel emergency units is purely for backup power at the DC during utility outages.

On the other hand, gas-based generation has a much lower environmental impact and the cost of fuel is significantly reduced compared to diesel power generation. Additionally, some utilities provide financial incentives to reduce consumption at times of grid congestion. Under these conditions, it becomes economically and environmentally viable for a DC to use gas generator sets for cogeneration during non-emergency periods. How much cogeneration would be needed depends on specific scenarios, but it could be as little as supporting noncritical loads to powering the entire DC facility.

It is needless to say that for an industry that must provide the highest level of resiliency, the idea of switching from diesel power to gas power would be a technical leapfrog that may be viewed by some as too radical. If so, an evolutionary approach through incremental steps may be preferable.

The DC transition from diesel power to gas power could be achieved in a number of ways. A few options are outlined below. Note that even solutions that would be generally unattractive could be the right solution in special cases.

BUILD A PEAKING POWER PLANT COLLOCATED WITH THE DC

The first option would be the least disruptive to DCs. The peaking plant would be dispatched when DC electrical demand on the utility would need to be curtailed. Whether the plant would provide additional grid support functions or not would be up to the owners. If the plant is to support the grid, it would need to comply with the respective country's grid codes (e.g. IEEE 1547 in the U.S.).

On the other hand, if the peaking plant is purposed to just support the DC and offset the load on the utility, the grid codes would not apply in most cases, simplifying the installation, connection approval process, and lowering capital cost.

CONVERT DIESEL UNITS TO DUAL FUEL UNITS

Converting diesel units to dual fuel (diesel and gas) is a technically attractive solution. It would yield a generator set that has the response of a diesel engine but nearly the fuel cost of a gas engine. Unfortunately in the current regulatory environment, the units would need to meet the regulations of a prime power diesel engine and would require extensive exhaust aftertreatment at a substantial cost.

POWER NONCRITICAL LOADS WITH GAS UNITS

The third option of powering noncritical loads with gas units would provide a partial answer to offsetting some of the DC burden on the utility. Generally, noncritical loads account for less than a quarter of the total DC load. If that would be enough relief, this may be an acceptable solution. Additionally, if the DC could use some of the heat generated by the gas units as a combined heat and power (CHP) solution, it could be put in place to further improve thermal efficiency.

REPLACE DIESEL UNITS WITH GAS UNITS THAT HAVE HIGHER LOAD ACCEPTANCE CAPABILITIES

Direct replacement of diesel generator sets with gas generator sets is an ideal solution. While it's a common perception that gas units would fall behind in their load acceptance capabilities compared to their diesel counterparts, recent developments in gas engine technology have led to numerous breakthroughs in engine performance and have significantly improved their ability to accept load.

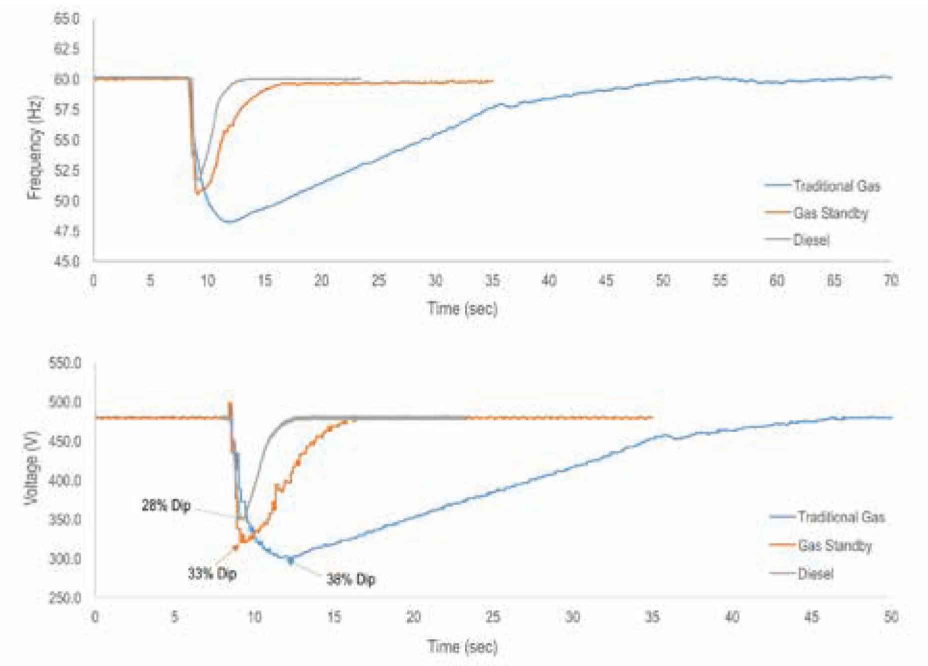

Figure 1: Voltage and Frequency Transient for 75 percent step change in loadbank load

Figure 1 shows the voltage and frequency transients for a 75 percent step change in load. The blue trace corresponds to a conventional gas generator set, the red trace corresponds to a new dynamic response gas generator set, and the green trace to a diesel generator set. As shown in Figure 1, the load acceptance capabilities of the new gas engine technology begins to approach the level of performance expected from a diesel unit – to the point that in some cases a direct replacement of a diesel unit with a gas unit is within reach. Additionally, optimizing loading sequencing, stretching of uninterruptible power supply ramp times, and reducing the size of block loads could shape the DC load profile to be within the load acceptance capabilities of the next generation of gas generator sets, making gas-powered DCs a reality.

USE A HYBRID GENERATION SYSTEM WITH A MIXTURE OF GAS AND DIESEL UNITS

Lastly, there is a hybrid solution where gas and diesel units are combined to offset DC demand on the utility during grid congestion while retaining diesel generator set performance during emergency conditions. This is possible due to the fact that by and large the steady state load in a DC is slow varying and the demands on generator set transient response are not severe. The challenge is presented when there is a transition from one power source to another. Diesel generator sets have historically been able to handle these transitions without incident. Conversely, conventional gas units are not yet able to match the transient capabilities of diesel units. However, a hybrid gas-diesel system would be capable of meeting the transient response requirements and providing nonemergency generation capabilities to relieve load on the utility at times of peak demand.

The simpler rendition of a gas-diesel hybrid DC is a parallel bus configuration with a mix of gas and diesel generator sets. Basically, gas and diesel generator sets are connected to a parallel bus sharing load. Since gas units would typically have lower load acceptance capabilities than diesel units, it would be beneficial to run the gas units in base load mode and the diesel units in load follow mode. The apportioning of how much gas versus diesel should be selected based on the level of non-emergency generation desired while providing sufficient electrical bus stiffness through the diesel generator sets to maintain targeted power quality during emergency conditions. While the ratio between gas and diesel would differ from case to case, a reasonable starting point would be a 50/50 split.

For DCs using modular designs where a single generator set powers DC load through UPS, developing a hybrid configuration requires more extensive trade-off. Typically, modular systems have some level of generation redundancy (N+1 or N+2, etc). The redundant generator set(s) present an opportunity for hybridization. Figure 2 shows a simplified single line diagram of a modular DC. Two distinct opportunities are possible:

1. Gas generator sets are used for redundancy and diesel units are used for primary.
2. Diesel generator sets are used for redundancy and gas units are used for primary.

In the first case, the capacity for utility load relief is 1/N or 2/N depending on level of redundancy. This would be a diesel dominant configuration. The second case is the gas dominant configuration potentially providing all the required power for the DC. The desirability of each case depends on the level of non-emergency self-generation targeted.

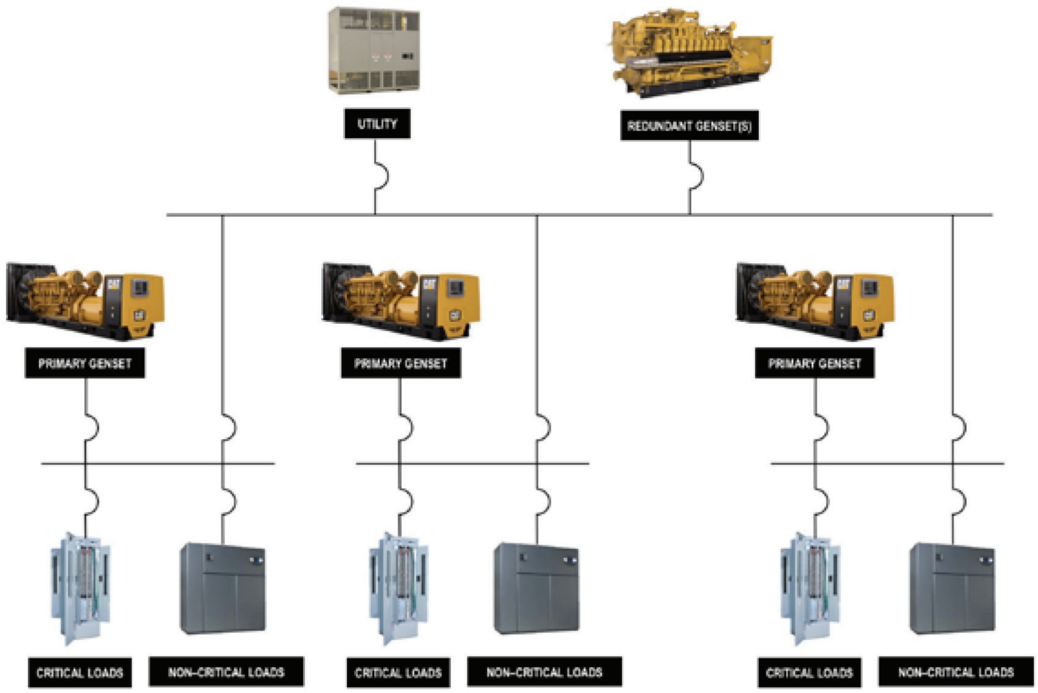

Figure 2: Example of Modular DC Configuration

Under the assumption that gas generator sets are not fully capable of matching the load acceptance transient response of diesel units, let us review how those needs would be met by the hybrid system. In case 1 where redundant units are gas units, these generator sets could be used to reduce the load on the utility during non-emergency conditions. The gas generator sets would be operating in base load mode. In the event of utility loss, the diesel units would start up and restore power to the UPS as usual, whether the gas units were running or not. In the rare case that one of the diesel units fails to start, the gas unit would be available to substitute the diesel unit, but the UPS walk-in onto the gas generator set would need to be slowed down to the load acceptance capability of the gas unit. Alternatively, if there was more than one gas unit to substitute for a failed-to-start diesel unit (e.g., N+2 system), it could be well within the load acceptance capabilities of the pair of gas units to take on the UPS walk-in.

In the second hybrid configuration where the redundant generator set is diesel and the primaries are gas, there is sufficient non-emergency generation capacity to fulfill the entire DC electrical consumption with no load put onto the utility. It would still be advantageous to remain connected to utility to stiffen up the electrical source and add additional redundancy. Preferably, the startup sequence would occur while connected to the utility, so that the gas generator set can ramp up to a level where the DC load is fully carried by the gas unit and no current flows through the associated utility breaker. In the event that the gas generator set would need to be started in the absence of the utility, the redundant diesel generator set would provide the necessary electrical bus stiffness to transfer the DC load on to the gas unit. This process would need to be repeated sequentially until all gas units are up and running from a black start condition. This process would extend the UPS run time, particularly on the last unit to be walked in. However, for battery UPS with multiple minutes of discharge time capability, it would not be a limitation as indexing the generator set walk-in priority would even out UPS run time on all units. This last approach allows the DC to reduce utility consumption to near zero levels at times of grid congestion, and it would enable DC owners to capitalize on economic incentives utilities may provide.

CONCLUSION

In summary, this white paper has outlined multiple options for converting a DC from diesel to gas power generation. This migration could be incremental to full conversion. The decision of how far to go would be primarily driven by the extent of grid relief needed in times of high electrical demand and by the economic incentives for curtailing DC external electrical consumption through the use of cogeneration. Current trends indicate that grid congestion will continue to rise as legacy power plants are being decommissioned and the penetration of renewables and variable generation resources increases. To counter the emerging volatility in the electric energy market, gas power generation provides a resilient, environmentally and economically sound solution for DC facilities. Cost of natural gas is at a historical low point and the supply is abundant.

A study[1] commissioned by the U.S. Department of Defense concluded that the natural gas system is generally robust enough to handle two-week to three-month outages in the electricity grid. Historically, there have been very few outages in the natural gas distribution system, with firm delivery contracts exhibiting greater than 99.999% reliability. In short, natural gas is a viable option for fueling a DC.

[1] *Source: U.S. Department of Defense: "Interdependence of the Electricity Generation System and the Natural Gas System and Implications for Energy Security", 2013*

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