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Diesel Generators in the Data Center—When is the Bigger the Better?

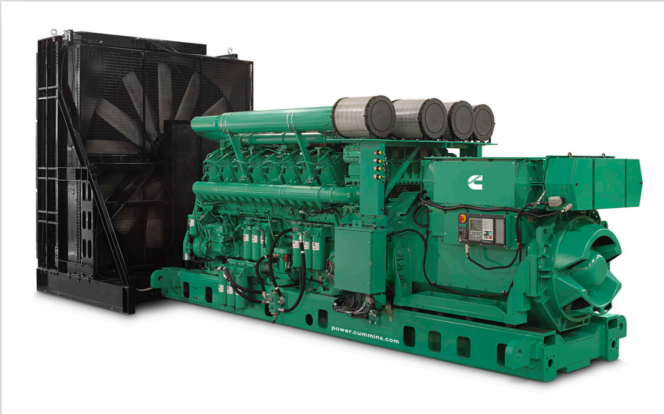
■ White Paper

By David Matuseski, PE, Mission Critical Technical Leader

There are many factors to consider when designing the generator system for your data center. Two of the most important items to consider in your design are the optimal size of the generator and the architecture of how your generators integrate into the overall power system. This paper will concentrate on these two major items with a focus on:

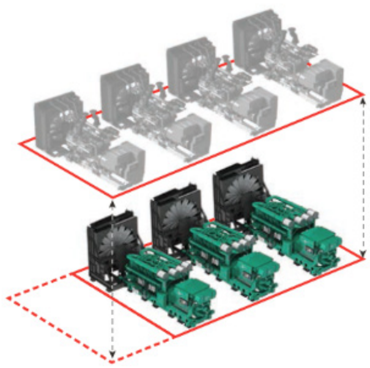
1. Using the largest possible generator.
2. Using a paralleling architecture design.

We will review the benefits of using large generators and the benefits of paralleling generators and then discuss ways to combine the two for an optimal design for your data center.



What Do You Gain When You Choose a Larger Generator?

1. Reduced footprint and installation costs
2. Reduced maintenance costs
3. Increased reliability



Reduced Footprint and Installation Costs

In some installations you have no choice but to go with a larger generator due to the size constraints of the site. This can be especially true when installing additional power generation into an existing building. Here is an example in a downtown metropolitan area where an existing building was in many ways the ideal place to locate a data center (see Figure 1). One challenge was the need for additional onsite backup power generation. The diesel generators needed to be installed outdoors, in a very tight area. By using fewer,

Figure 1: Metropolitan Installation

large generators and a unique stacked configuration, the data center now has enough backup power to provide full operation with full power redundancy. Using a greater number of smaller generators would not have been a good option in this example. The higher power density of large generators was the better choice.

In addition to the unique challenges in metropolitan areas, sometimes the footprint advantages of using large generators is also desired in new construction. We will compare two different sized generators in a common layout of backup power generation for a 10 megawatt data center. The generators are in outdoor enclosures and located just outside of the main structure. We assume the switchgear is located inside the main structure. In Figure 2, the layout using 3.5MW generators is shown in red and the layout using 2.0MW generators is shown in green. As you can see using the

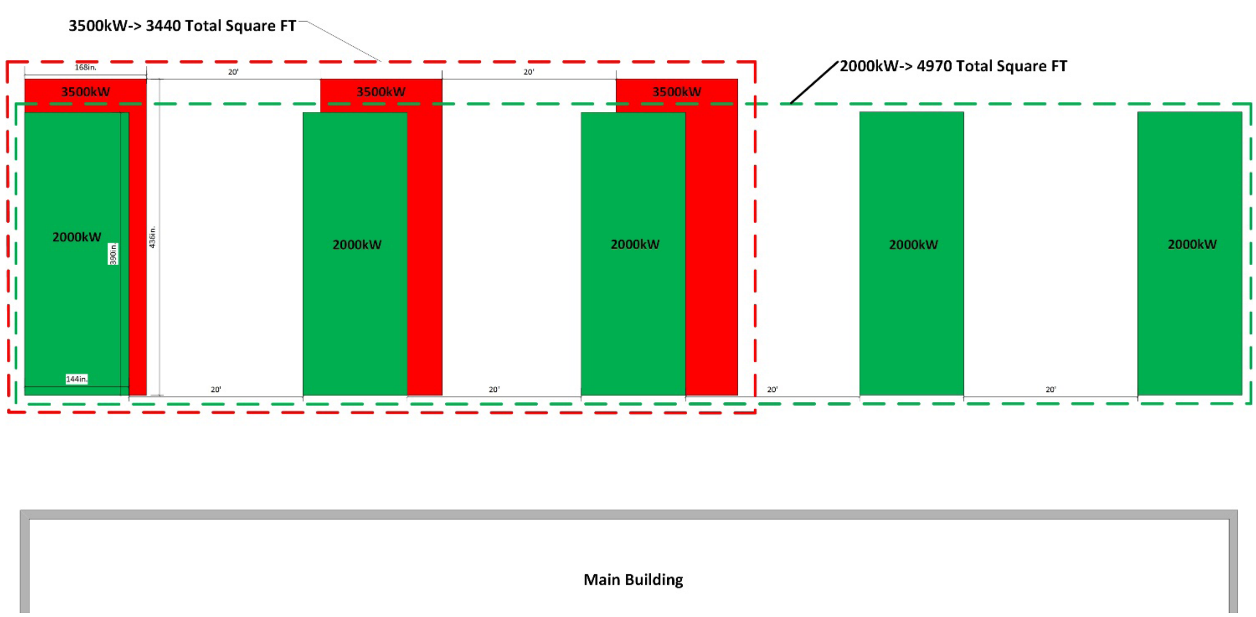


Figure 2: Outdoor 10MW Installation comparing 3.5MW gens to 2.0MW gens.

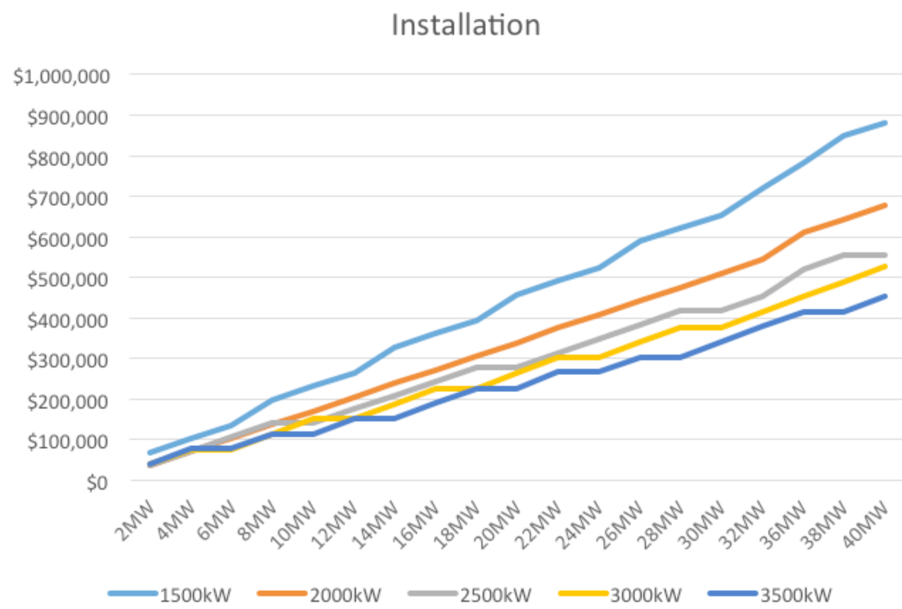


Figure 3: Installation Costs

3.5MW generator design requires two fewer generators and 1500 fewer square feet (140 square meters) of land to achieve the 10MW of required power.

The land savings achieved when comparing the 3.5MW generator site to the 2.0MW site may or may not be a significant cost reduction, depending on different land costs. But, one advantage you will definitely gain with the larger generators is a reduction in the overall installation costs. Figure 3 shows an installation cost comparison for various sized power plants using various sized diesel generators. This analysis did not include the real estate savings you might get with a smaller footprint. As you can see, the bigger the megawatt size of the power plant, the more you save in installation costs. The overall capital expenditure (CapEx) costs will also depend on the generator cost and this should be included into your calculations.

Reduced Maintenance Costs

Seeing the reduced maintenance costs is straightforward. If you have fewer generators to maintain it stands to reason that your maintenance costs will be lower. There are some maintenance trade-offs when comparing large and smaller generators, but overall you will see a cost reduction. Table 1 shows a comparison of annual maintenance costs for various sized generators.

Increased Reliability

When evaluating a diesel generator power plant, data suggests the probability of a generator failure is lower when the plant consists of fewer generators. In other words, fewer large generator sets will have a lower probability of failure than a greater number of smaller generator sets making up the same size power plant. The data in Figure 4 illustrates this fact for a 12 MW power plant with an N+1 configuration. Analysis revealed that the most probable failures of a power system involve auxiliary equipment, not engines or alternators. Accordingly, as the number of generator sets applied increases to reach a certain power plant size, so does the quantity of auxiliary equipment needed in the overall system, increasing the probability of failure. Developed by an independent risk assessment consultancy, the data provides mathematical evidence that applying fewer generators will reduce the probability of a system failure.

Generator Size	Annual Maintenance Cost per Generator	Number of Generators for 10MW	Total Annual Maintenance Cost
1500 kW	$6,802	7	$47,614
2000 kW	$8,788	5	$43,940
3500 kW	$10,618	3	$31,854

Table 1: Annual Maintenance Costs for 10MW installation

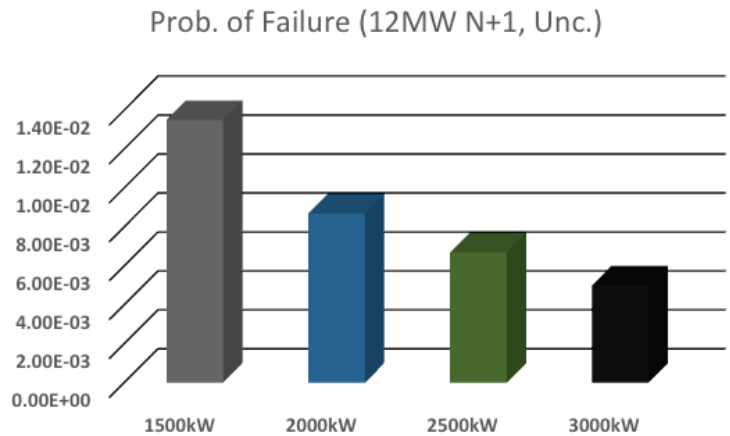


Figure 4: Reliability Comparison

Paralleling Designs

Paralleling generators in a data center design can have many advantages. It does not fit every situation, but paralleling does provide many benefits over a single generator design. Some of the advantages are summarized in Table 2. These advantages have varying degrees of importance in a data center application, but "efficiency" (reducing your stranded generator power capacity), can be the most attractive. The generator system is one of the more expensive systems to procure, install, and maintain. Making this system as efficient as possible will have a significant effect on reducing data center cost.

Concurrent Maintainability

An important challenge in a paralleling system architecture is achieving concurrent maintainability. This is due to the common paralleling bus that is required in a generator paralleling system. Various system architectures have been developed to address this challenge. One of the more common architectures is shown in Figure 5. In this design, tie breakers (or sometimes tie switches) are added to the paralleling bus. These tie breakers provide segments in the bus that allow you to partially shut down the switchgear for maintenance. For example, if you have an N+2 design, you can completely isolate one segment of switchgear for maintenance or repair. In Figure 5 we show that the switchgear sections for gens 5 and 6 can be taken completely out of service without affecting the remaining gear. If desired, you could also perform the require maintenance on the corresponding generators at the same time. While the bus segment or the corresponding generator is serviced, you still have full "N" generator capacity for powering the data center. This design is also used in an N+1 design with tie breakers in between each generator on the paralleling bus. The protective relaying on a segmented bus can be designed to eliminate the paralleling bus as a single point of failure, this is most commonly achieved with a current differential scheme.

1	Efficiency	More efficient use of your generator power. Less chance of having stranded generator capacity
2	Reliability	You are not dependent on a single generator. If one generator fails, you still have all the others to power your load.
3	Redundancy	Creating an N+1 or N+2 configuration is very straight forward in paralleling designs.
4	Performance	A large generator bus will act more like a utility. There will be less frequency and voltage variations during load steps.
5	Scalability/ Expandability	Easy to add generators to a paralleling architecture as power demand increases.
6	Serviceability	A single generator can be serviced while the remaining generators are available to provide power.

Table 2: Paralleling Advantages

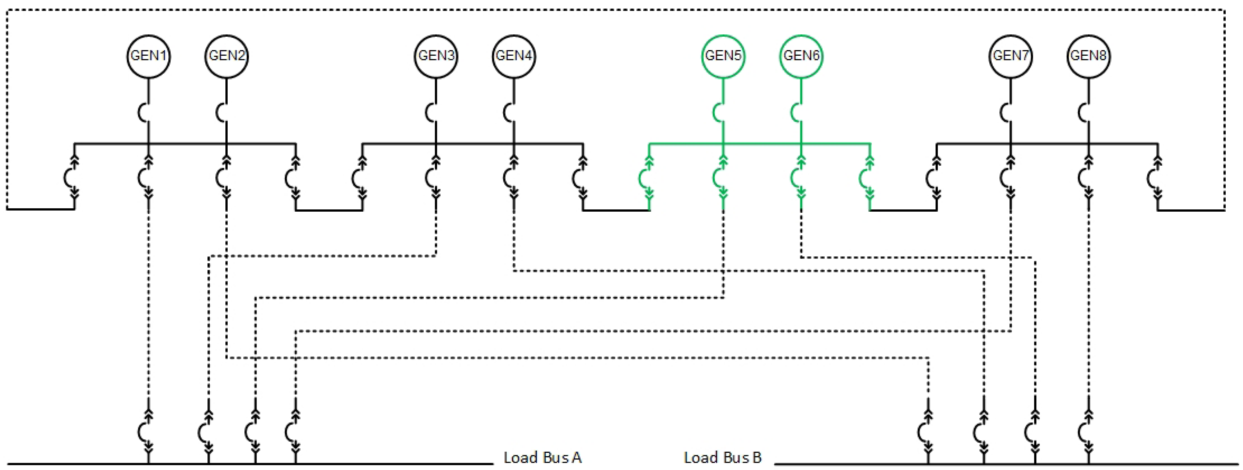


Figure 5: Segmented Paralleling Bus

Another way to achieve concurrent maintainability is shown in Figure 6. In this design, each generator can be switched from one paralleling bus to an alternative paralleling bus. In an N+1 design, there would be one additional generator and corresponding transfer switch. Any one component, including the paralleling bus, can be shut down for maintenance and there will still be the full "N" capacity available from the generator system.

There is another architecture for paralleling generators being used in data centers. This is sometimes called 3 to make 2 (or 4 to make 3, etc.). An example is shown in Figure 7. In this example, the data center needs two generators to meet the "N" capacity. So this is an N+1 design. The generators actually parallel down at the load bus level, which is shown as load bus A and load bus B. This design allows any one generator or any one piece of switchgear to be taken down for maintenance while still providing "N" generator capacity to power the data center.

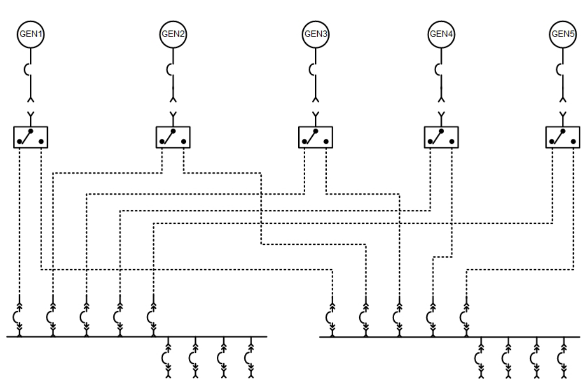


Figure 6: Dual Bus Architecture

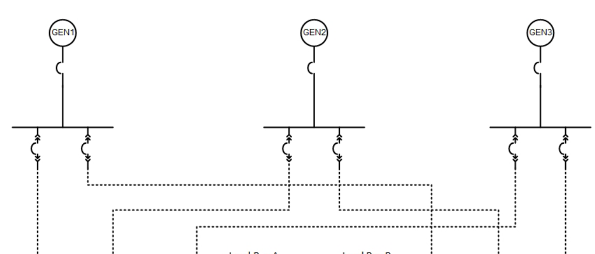


Figure 7: Three to make Two

About the author

David Matuseski is the Mission Critical Technical Leader for Cummins in the Strategic Accounts group specializing in the data center segment. He provides technical expertise on the implementation of generator systems and total power systems. Dave has been working in the power industry since 1996 and is a registered Professional Engineer in the state of Minnesota. He graduated from the University of Minnesota with a Bachelor of Electrical Engineering. Within Cummins, Dave has held the positions of Design Engineer, Project Manager, Engineering Manager and Chief Engineer.

Optimizing Your Design

Finding the best combination of generator size and system architecture is a goal for all data center designers. Many times, a larger generator can provide you with unique advantages as described in this paper. When you combine large generators into a paralleling system, you can achieve a whole new level of advantages. The data center designer should carefully analyze all options to optimize the generator system design.

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