

How to size a genset: Proper generator set sizing requires analysis of parameters and loads

> White paper

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While most sizing exercises are best done with sizing programs or with the help of a manufacturer's representative, it is still important to understand the factors that affect the operation of your generator set so you can be confident you have the right equipment for your application.

Project parameters

The first step in sizing and selecting a generator set is to establish project parameters.

- **Minimum generator set load/capacity:** Running a generator set under light load can lead to engine damage, reducing reliability. Cummins Power Generation does not recommend running generator sets at less than 30 percent of rated load. Load banks should supplement the regular loads when loading falls below the recommended value.
- **Maximum allowable step voltage dip** (starting and running): As you reduce the maximum allowable step voltage dip during initial startup, when loads cycle under automatic controls or when high peak loads operate, you need to increase the size of the generator set specified. Choosing lower allowable voltage dip requires a larger generator set.
- **Maximum allowable step frequency dip:** As you reduce the maximum allowable frequency dip, you increase the size of the generator set needed.
- **Altitude and temperature:** Based on the site location, the size of the generator set must increase for a given level of performance as altitude and ambient temperature rise.

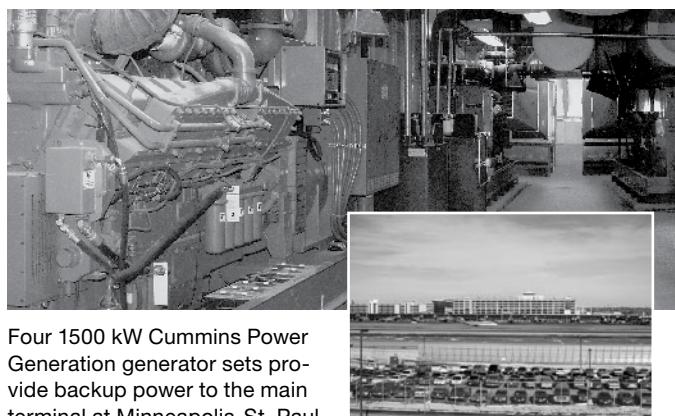
- **Duty cycle:** Generator set size is also influenced by whether the application is for standby power, prime power or utility paralleling. Standby power systems generally have no overload capability. Prime power systems generally have a minimum of 10 percent overload capacity. Generator sets that are intended to operate extended hours at steady constant load should not be operated in excess of the continuous rating.

- **Fuel:** The preference for gas, diesel, or LP will affect generator set choices. Often, generator sets running on gas or LP must be oversized due to derating. Emergency systems typically must be supplied by fuel stored locally.

- **Phase:** Select either single- or three-phase. The three-phase selection permits single-phase loads but the assumption is that the single-phase loads will be balanced across the three phases.

- **Frequency:** Either 50 Hz or 60 Hz.

- **Voltage:** Voltage choices are usually a function of selected frequency.



Four 1500 kW Cummins Power Generation generator sets provide backup power to the main terminal at Minneapolis-St. Paul International Airport.

Loads

The next and most important step in sizing a generator set is to identify every type and size of load the generator set will power. In general, when non-linear loads are present, it may be necessary to oversize the alternator.

Following is a general discussion of how various loads and electrical factors affect the sizing of generator sets.

- Power factor (PF):** The inductances and capacitances in AC load circuits cause the point at which the sinusoidal current wave passes through zero to lag or lead the point at which the voltage wave passes through zero. Capacitive loads, overexcited synchronous motors, etc. cause leading power factor, where current leads voltage (FIGURE 1). Lagging power factor, where current lags voltage, is more generally the case and is a result of the inductance of the circuit. Power Factor is the ratio of kW to kVA and is expressed as a decimal figure (0.8) or as a percentage (80%). Three-phase generator sets are rated for 0.8 PF loads and single-phase generator sets for 1.0 PF loads. Lower PFs require larger alternators or generator sets to properly serve the load. Caution should be used whenever applying generator sets to leading power factor loads. Only slightly leading power factor can cause generator sets to lose voltage control.

STEADY STATE ALTERNATOR REACTIVE POWER CAPABILITY CURVE

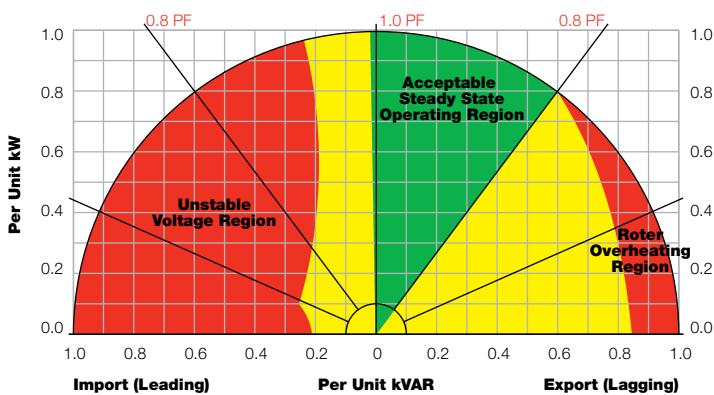


FIGURE 1 –A typical alternator curve of reactive power (kVAR) capability. A reasonable guideline is that a generator set can carry up to 10 percent of its rated kVAR capability in leading power factor loads without being damaged or losing control of output voltage. The most common sources of leading power factor are lightly loaded UPS systems with input filters and power factor correction devices for motors. Loading the generator set with lagging power factor loads prior to the leading power factor loads can improve stability.

- Single-phase loads and load imbalance:** Single phase loads should be distributed as evenly as possible between the three phases of a three-phase generator set in order to fully utilize generator set capacity and limit voltage imbalance.

- Peak loads:** Peak loads are caused by loads that cycle on and off—such as welding equipment, medical imaging equipment, or motors. Taking cyclic loads into account can significantly increase the size of the recommended generator set despite painstaking efforts to place loads in a step starting sequence.

- Motor loads:** Calculating specific motor loads is best handled by sizing software which will convert types of motors into load starting and running requirements. For this discussion, however, it is sufficient to broadly characterize loads as high-inertia or as low-inertia loads for the purpose of determining engine power needed to start and accelerate motor loads.

- Low-inertia loads** include fans and centrifugal blowers, rotary compressors, rotary and centrifugal pumps.

- High-inertia loads** include elevators, single- and multi-cylinder pumps, single- and multi-cylinder compressors, rock crushers, and conveyors.

- Motors over 50 HP:** A large motor started across the line with a generator set represents a low-impedance load while at locked rotor or initial stalled condition. The result is a high inrush current, typically six times the motor rated (running) current. The high inrush current causes generator voltage dip which can affect other systems. The manner in which generator voltage recovers from this dip is a function of the relative sizes of the generator, the motor, engine power (kW capacity) and generator excitation forcing capability. Depending on the severity of the load, the generator should be sized to recover to rated voltage within a few seconds, if not cycles. Various types of reduced-voltage motor starters are available to reduce the starting kVA of a motor in applications where reduced motor torque is acceptable. Reducing motor starting kVA can reduce the voltage dip, the size of the generator set, and provide a softer mechanical start. However, these starting methods should only be applied to low-inertia motor loads unless it can be determined that the motor will produce adequate accelerating torque during starting.

Many factors influence generator set sizing, making it time consuming to manually calculate required generator capacity. Parameters that determine the required generator set size include minimum generator set load; maximum allowable step voltage dip and step frequency dip; altitude and temperature; duty cycle, fuel, phase, frequency and voltage.

Sizing software, such as Cummins Power Generation's GenSize, greatly simplifies this process and allows analysis of alternative to optimize the generator size. Knowing manual calculation methods helps the engineer understand how each factor contributes to a correctly-sized genset.

- **Variable frequency drive (VFD) motors:** Variable frequency drives (or variable speed) are non-linear loads, which are used to control the speed of induction motors, induce distortion in generator output voltage. Larger alternators are required to prevent overheating due to the harmonic currents induced by the VFD and to lower system voltage distortion by lowering alternator reactance. For example, VFD loads on a generator must be less than approximately 50 percent of generator capacity to limit total harmonic distortion to less than 15 percent.

Other loads

- **Uninterruptible power supply (UPS) loads:** A UPS system uses silicon controlled rectifiers or other static devices to convert AC voltage to DC voltage for charging storage batteries and are another type of non-linear load. Larger alternators are required to prevent overheating due to the harmonic currents induced by the rectifiers and to limit system voltage distortion by lowering alternator reactance. Past problems of incompatibility between generator sets and static UPS devices lead to many misconceptions about sizing generator sets for this type of load. Most UPS manufacturers have addressed these issues and it is now more cost effective to require UPS devices to be compatible with the generator set than to significantly oversize the generator for the UPS. Use the full nameplate rating of the UPS for determining load to allow sufficient capacity for generator set battery charging and accommodating full UPS load capacity.

- **Battery charger loads:** A battery charger is a non-linear load requiring an oversized alternator based on the number of rectifiers (pulses)—up to 2.5 times the steady-state running load for three-pulse; to 1.15 times the steady-state running load for 12-pulse. These loads are typically found in telecommunications systems.
- **Medical imaging loads:** These include CAT scan, MRI, and X-ray equipment. The generator set should be sized to limit the voltage dip to 10 percent when the medical imaging equipment is operated with all other loads running in order to protect image quality.
- **Lighting loads:** In addition to lamp wattages, ballast wattages and starting and running power factors should be considered.
- **Regenerative loads:** For loads such as elevators, cranes and hoists, the power source is often relied upon for absorbing power during braking. That is usually not a problem when the utility is supplying power because it can be considered as an infinite power source with many loads. A generator set, in comparison, is able to absorb far less power, especially with no other loads connected. Generally, the regeneration problem can be solved by making sure there are other connected loads which can absorb the regenerative power. Excessive regenerative load can cause a generator set to over-speed and shut down.

About the author



Jim Iverson is a senior applications engineer for Cummins Power Generation, with an M.S. in Engineering Science, and a B.S. in Electrical Engineering. Since 1976, he has managed Transfer Switch Design, Systems Engineering, Switchgear &

Controls, and Technical Marketing & Sales. Jim provides technical direction to Commercial Marketing & Sales, contributes to domestic industry codes and standards development, offers sales and service training, offers technical input for published literature and software, publishes technical papers on industry topics, and provides application engineering support to customers.

Load step sequencing

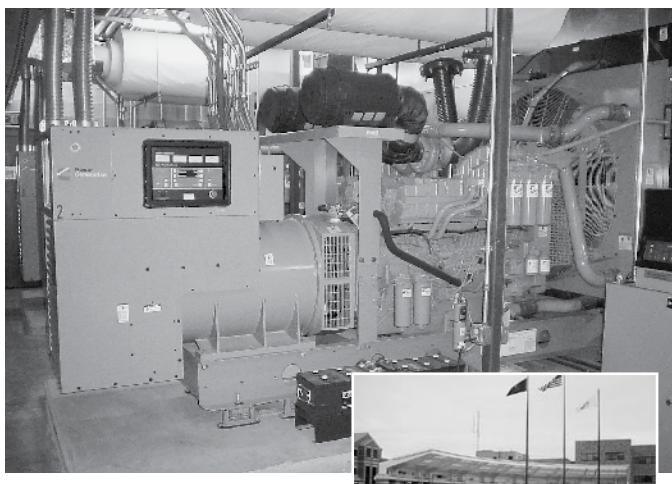
In many applications the generator set is sized to pick up all loads in one step. In some applications it is advantageous to start up the loads which cause the largest starting surge first and then the rest in multiple steps—the “largest motor first” rule. Codes may require sequenced load starting to start emergency and life safety loads within as little as ten seconds, while allowing other loads longer periods of time. In general,

sequenced startup allows the smallest generator set in relation to the steady state load. When cycling motor loads exist, it will still be necessary to size the generator set to start the largest cycling motor last, with all other loads connected.

Future needs

One last step in the sizing equation has to do with future needs. Power use is not fixed and tends to grow over time. Therefore, any generator set sizing exercise needs to take system expansion into consideration. Even with sophisticated software solutions, the final decision on generator set size needs to be tempered with judgment. And, the more you know about the parameters that affect sizing, the better that judgment will be.

For additional technical support, please contact your local Cummins Power Generation distributor. To locate your distributor, visit www.cumminspower.com.



Two 1 MW generator sets provide full redundancy to three power branches at Hancock Hospital, Greenfield, Indiana.



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