My 3,600 W inverter-charger is overloading my 6,500 W generator—what gives?

Sizing a Generator for Your RE System

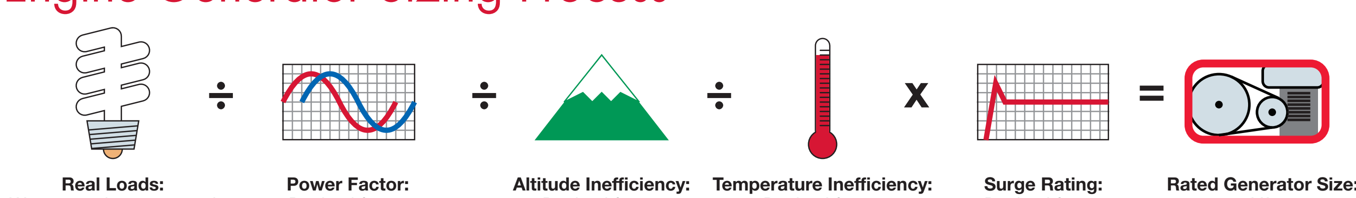
by Jim Goodnight

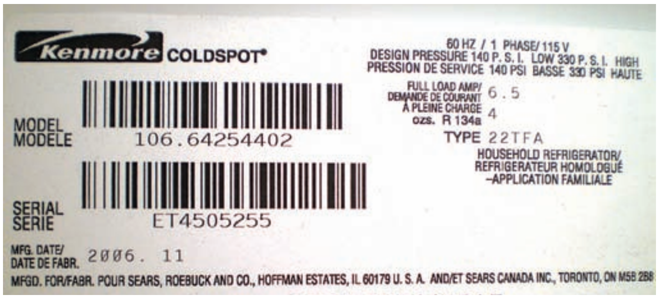
An 1,800-watt, portable Coleman generator (left) is dwarfed next to a 30,000-watt Cummins/Onan unit (right). Your generator needs will probably fall somewhere in between. But where?

Estimating a system's maximum power load and then specifying a generator to match or slightly exceed the load estimate is a common practice, but one rife with problems. The *apparent loads (volt-amperes)* might be larger than the *real loads (watts)*, environmental factors may have been overlooked, and the generator's specifications and features may not live up to the manufacturer's marketing. Common results include an overloaded generator (and circuit breakers), an unreliable system, a dissatisfied system owner, and tarnished reputations.

This article considers the basics of generator sizing: establishing the load requirements, understanding the difference between apparent power and real power, assessing a generator's environment, and clarifying generator specifications and features. We'll also look at some inverter-charger features that can help reduce part of the peak load on a generator, thus reducing generator size (and cost). Understanding these factors can help you correctly size a generator to reliably meet a system's needs.

Engine-Generator Sizing Process





While some appliances use rated watts as a selling point (for power or efficiency), multiplying the amp rating(s) times voltage will give you the generator's apparent load and peak surge.

Power Factor

An AC system's power factor (PF) is the ratio of the load's real power to its apparent power. PF is frequently expressed as a percentage (i.e., 0.8 PF = 80% PF).

Reactive loads—ones that contain capacitors and/or inductors, such as electric motors—store part of the energy supplied to them, and then return it to the power source. This energy is in addition to the energy used to operate the load, and it results in additional current flowing back and forth between the power source and the load.

Real power is the circuit's capacity for performing work over a particular duration. *Apparent power* is the product of a circuit's voltage and current (volt–amps; VA).

A washing machine can have a fairly low PF (about 50%). Contrast this with a PF-corrected battery charger, which can have a PF of about 98%.

In an electrical system, a load with a low PF draws more current than a load with a high PF, for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires, among other things. And, since generators are current-limited power sources, and the low PF loads draw relatively high current, less current is available to power other loads, thereby effectively reducing the generator's functional capacity.

Calculate the Apparent Load

The first step is to sum up the power loads that might be operated simultaneously. For this example, let's say the combination of a well pump, a microwave, a fridge, a washing machine, some compact fluorescent lights, and other loads adds up to 3,600 W.

Although we casually tend to express generator power and loads in watts, generator specifications typically state power in volt-amps (VA). This is an important distinction, as a load with a low power factor may not draw many watts, or "real power," but its VA load, or "apparent power," may be higher. For example, a washing machine with a power factor (PF) of 0.5 (the ratio between "real power" and "apparent power") might consume 500 W, but it'll draw about 1,000 VA (120 V × 8.3 A) from a power source.

Here's an example: A 500 W load with a 0.5 PF will draw 500 W ÷ 0.5 = 1,000 VA. 1,000 VA ÷ 120 VAC = 8.33 A. If the PF was 1.0 (i.e., purely resistive), the load current would be (500 W ÷ 1.0) ÷ 120 VAC = 4.17 A.

It's the 1,000 VA's 8.3 A that count against the generator's current limit, not the 500 W. As a result, the generator is required to supply more current to meet the high apparent power demand.

The power factor of common loads varies from quite low (i.e., about 0.5 for the washing machine), to high (i.e., 1.0 for a resistive load). Applying an average power factor of 0.85 to a group of typical loads is a reasonable rule. In our example, the original 3,600 W peak "real load" estimate translates to an apparent load of about 4,300 VA (rounded up to the nearest hundred).

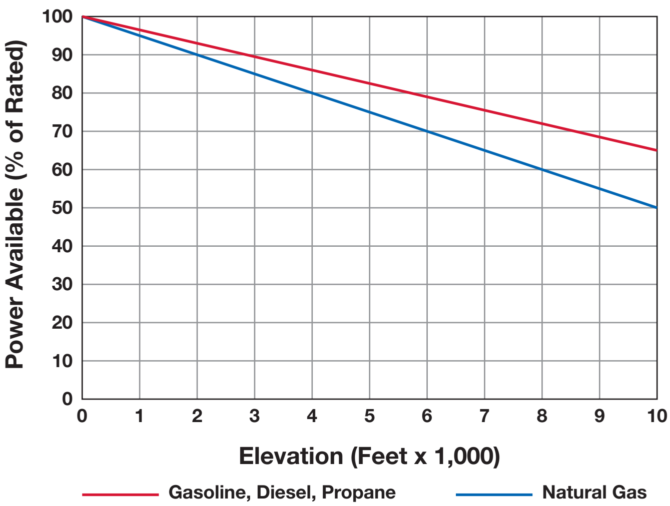
Compensate for Environmental Factors

A generator's power rating is based on its operation at sea level. Generator engine power decreases as altitude increases (thinner air), and a generator's maximum electrical output drops accordingly. A power loss of about 3.5% per 1,000 feet of elevation gain is typical for gasoline-, diesel-, or propane-fueled generators; natural gas-fueled generators may suffer a power loss of about 5% per 1,000 feet. Additionally, the generator's carburetor may need to be modified for high-altitude operation, even to achieve the reduced power rating.

Ambient temperature is a related complication, as typical power derating is about 1 to 2% for each 10°F above its

This engine generator displays its continuous power output rating of 5 kW and its surge capability of 6,250 W. For volt–amps, you'll need to check the documentation.

Engine Generator Efficiency at Altitude



nominal rating. Combining the conditions of high altitude and high temperature may require specifying a generator with a higher continuous rating. For example, say you're in Denver, Colorado (elev. 5,000 ft.), and need a propane generator to deliver 4,300 VA during the summer days with temperatures at 90°F. Compensating for altitude would result in a 17.5% loss. If a generator's "full" power specification is based on an ambient temperature of 60°F, then available output can be expected to decrease by about 3% at 90°F [(90°F - 60°F) × 1% ÷ 10°F]. So the actual rating needed would be about 5,400 VA.

Allowing for Surges

Lastly, generator power specifications also emphasize their "surge" capacity, or the VA that can be delivered for 30 minutes or less. This number tends to be about 20% higher than a generator's continuous VA rating. In this example, a 5,400 VA requirement may necessitate a generator with a surge rating of about 6,500 VA. However, this surge capacity can come in handy when starting motorized loads, whose start-up surge current is often several times the normal running current specification.

So even starting with a 3,600 W load, it's not unusual to need a generator rated for at least 6,500 VA, especially if the loads have low power factors and are operated at high elevation.

While full generator output (7,200 W) can be accessed from the 120/240 VAC, 30 A round receptacle, using the 120 V, 20 A receptacles reduces available output to 4,800 W (2,400 W from each).

Other Considerations

Attention to system voltage, split-phase load balancing, and ratings for circuit breakers and outlets may be required to optimize generator size and performance.

RE systems that operate 120 VAC loads generally require a 120 VAC generator, and systems that operate at split-phase 120/240 VAC typically need a 120/240 VAC split-phase generator. However, there are times when a different configuration needs to be considered, perhaps because an old (but still serviceable) generator is available. For example, a 120/240 VAC split-phase generator can be used to power a 120 VAC system by wiring an autotransformer to the 240 VAC generator output.

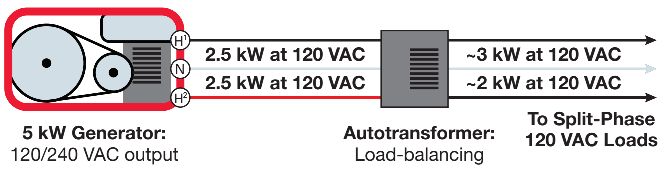
An auto-transformer will allow a 240 VAC generator to power 120 VAC loads, or vice versa.

One-half of the total power available from a 120/240 VAC split-phase generator is available from each leg. But too many loads connected to one leg may overload part of the generator—even though the total load is less than the generator's rated power. An autotransformer connected between full, 240 VAC output and the loads will balance the load across the generator's 120 V legs. Popular autotransformers are available from Schneider Electric (formerly Xantrex), OutBack Power Systems, and others.

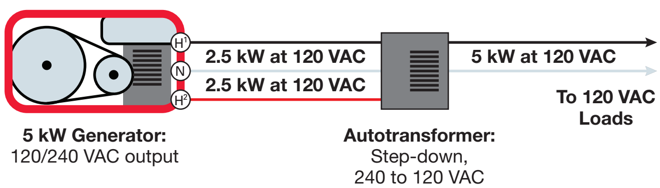
Sizing for Battery Charging

A critical load to consider when sizing a generator for an off-grid system is an inverter's built-in battery charger. Assuming 85% efficiency and a 95% power factor, a battery charger rated at 25 amps DC delivering 1,450 W to a 48 V nominal battery

Balancing High/Uneven Loads Across a Split-Phase Generator Output



Full Output at 120 VAC with an Autotransformer



bank (charging voltage is actually 48 V) equals a 1,800 VA load. Adding this load to a peak combination of essential loads can dramatically increase a generator's size calculation.

Carrying the example through, adding 1,800 VA to the original 4,300 VA load estimate results in a new estimate of 6,100 VA. Applying the same deratings and surge multipliers, the revised generator "rating" is increased to 9,200 VA!

At the high end, a 9,200 VA generator could simultaneously meet projected load demands and operate the battery charger at full capacity, leading to reduced generator run-time and less noise. However, because peak loads (i.e., microwave ovens) can be short duration and charging loads taper off as the battery fills, much of a large generator's capacity may go unused, reducing its fuel efficiency. Large generators are also relatively expensive.

Generator Sizing Example

	Factor	Adjusted Loads	Loads with Battery Charger
Peak real power estimate		3,600 W	3,000 W + 1,450 W
÷			
Power factor adjustment*	0.85	4,300 VA	6,100* VA
÷			
Altitude derating	3.5% per 1,000 ft. 5,000 ft. = 0.825	5,212 VA	7,394 VA
÷			
Temperature derating	1% per 10° over 60°F 90°F = 0.97	5,373 VA	7,623 VA
x			
Surge rating	120% = 1.20	6,448 VA	9,148 VA
=			
Generator rating		6,500 W	9,200 W

* 0.95 power factor × 85% efficiency = 0.81 for battery charging through an inverter: 1,450 W ÷ 0.81 = 1,800 VA; 4,300 VA + 1,800 VA = 6,100 VA

Current-limit settings on an inverter–charger allow maximum use of generator output without overloading.

At the low end, a 6,500 VA generator could meet projected AC load demands, but operating the battery charger at the same time could create an overload. Fortunately, some inverter–chargers include useful features to manage such a load combination. For example, built-in chargers typically include settings that can limit battery charge current to reduce the charger's load.

A more sophisticated tool is an inverter-charger's AC source input current-limit setting, which limits the total current that will be drawn from the generator. If the sum of the home's AC load current and the charger's AC current exceeds the setting, the charger "backs off" the AC current it draws. In effect, the charger becomes a variable, "opportunity" load.

This solution allows a smaller, less-expensive generator to be used, although battery charging time (and therefore generator run time) will likely be increased due to the lower battery charge current. For example, if the household loads draw 30 A (AC) and the charger is set to draw 25 A, but the input current limit setting is 30 A, the inverter will reduce the charger load from 25 A to 0 A to keep the *total* load current at the limit setting. However, if a 15 A load is turned off, reducing the downstream AC load total from 30 A to 15 A, the inverter will automatically increase the charger load from 0 A to 15 A, and the generator's total load current will still be at or below the 30 A input limit.

Choosing a Generator

Understanding how to accurately estimate VA requirements, accounting for environmental factors, and knowing how to work with generator ratings and inverter–charger settings can help ensure that a generator can provide the power needed for your system. A little up-front computation will save you dollars (and headaches) in the long run and ensure that you buy right from the get-go.

Access

Jim Goodnight (james.goodnight@us.schneider-electric.com) has more than 35 years of design and project management experience in a broad range of technical fields. He has been designing and optimizing PV systems since 2002, and providing technical and field support since 2004. In 2010, Jim joined Schneider Electric as a senior sales application engineer.