Generators as a Backup Power Source

Richard Perez

Generators driven by engines offer one big advantage—lots of power available on demand. This advantage has made the engine-generator or alternator the most popular backup power source for RE systems. This article focuses on choosing the right generator and then how to effectively and efficiently employ it as a backup power source.

Analyze the Situation

Every situation is different. Some folks employ generators as backup to their regular utility power. Other folks use the generator (or genny) to recharge their batteries when the sun or wind sources have not kept up with their energy consumption. The amount of power required varies from application to application. The climate and physical accessibility varies from system to system. All of these factors need to be analyzed before deciding on a specific genny. Make the wrong decision at this early stage of the process and you are doomed to unsatisfactory gennny performance.

Let's look at *Home Power* Central's system here on Agate Flat. We are eight miles for the nearest electric utility service. Our office and home are sourced by a 2,000 Watt photovoltaic array and a 1,000 Watt wind generator. Our battery, while large enough to have its own room, only stores enough power for about three days of cloudy, windless weather. And usually this is more than enough. For the last three years we have only used our little 12 Volt backup generator (see HP#42, page 28) for about five or ten hours each winter. When we expanded our office, the additional computer equipment consumed more power. Over time, our energy consumption has grown to over 10 kiloWatt-hours daily. This fall we experienced the worst cloudy weather we have seen in 25 years of living on Agate Flat. We had about two full sun days in two, windless months. We were in big trouble. *Home Power Magazine* has solid deadlines. We need power for computers to keep this magazine on schedule. I went shopping for a generator and here is what I found.

Backing Up the Grid

Consider the situation of a household wishing to back up their utility power during blackouts. The most common reason given is the freezer full of food. A blackout of four or five days will certainly ruin all the refrigerated food. In fact, most utility power outages in the USA are less than a few hours in duration. If the utility did fail for durations of five days, the cost of buying and running the generator would be paid for by five to seven long-term outages. This situation doesn't occur to many folks. In some grid-connected homes the heating system, even though fired by natural gas or oil, requires electricity to operate controls, pumps, and/or fans. Outages of as little as one day may make the home cold and uncomfortable. Power outages of several days may freeze the home's plumbing. If your home could be damaged or severely inconvenienced by a power outage of longer than three days, then the genny is your logical choice for backup power. RE sources with battery backup are not cost effective if all you wish is power during infrequent, short-duration, utility power outages. If you are grid connected, then you will probably run the generator less than 50 hours yearly. This means that buying an expensive generator is not cost-effective. Even the cheapest generator will run about 500 hours and this means ten years of use.

Backing Up PV and Wind Systems

Since renewable energy systems are designed with days of energy storage in their batteries, only prolonged cloudy or windless periods are a problem. The best way to deal with energy shortages in RE systems is conservation. If the system is low on energy, then put off energy intensive jobs like doing the wash. Inevitably, most RE systems will experience infrequent periods of extreme power shortage. It is just too expensive to size the RE system for the absolute worst case scenario. If these low power periods cannot be met with conservation, then the genny is the most cost-effective backup power source. Of the 3869 PV systems listed in our subscribers' database, 1941 or 50% use gennies for backup power. Of the 623 wind systems listed in our subscribers' database, 372 or 60% use a generator for backup.

The energy deficit in RE systems is deeper than the grid connected system. We not only want to run the household, but also need to recharge the depleted battery. This means more power is demanded from the generator. Recharging large batteries is a long procedure requiring more generator operating time. Backup gennies in RE systems will typically run between 100 and 200 hours yearly.

Please note that I am talking about backup power here. The genny is not suitable as a prime power source for stand-alone systems. It is too expensive to operate at levels of over 200 hours per year. If you are operating a generator over 200 hours yearly, then you need to expand your PV and/or wind system. There are exceptions to this rule. Consider systems located in Alaska, for example. Here the generator is the only power source for much of the winter.

Types of Engine-Generators

It's easy to be confused by the large selection of generators available. Not only are they available in different sizes, but they also consume a variety of fuels and most importantly, they have widely varying price tags. Let's look at some of the choices we make when buying a generator.

Fuel Source

Gennies can consume either gasoline, diesel, natural gas, or propane. Most of the inexpensive models consume gasoline. Your choice of fuel should be made on the number of hours you plan to put on the generator yearly and on fuel availability. If you are backing up the grid during infrequent outages, then the gasoline generator is the most cost-effective. This scenario simply does not use the generator enough to make the higher price of diesel or propane models cost-effective. In undersized RE systems, increased generator usage makes it cost-effective to purchase the higher quality, more expensive generators.

The major advantage of gasoline or diesel as a fuel is its portability. Some sites are not supplied by natural gas or bulk propane service. For example, our site on Agate Flat is too remote for bulk propane delivery. Our only choices for generator fuel here are gasoline or diesel. The major disadvantages of gasoline as a fuel is storage and flammability. We use small, five gallon gas cans in good condition. We have four stored well away from the house and office in a cool, shady location. Don't store gasoline inside your home or garage, it's not safe. The gennies that consume diesel are usually of higher quality than the gasoline models. We chose a gasoline model so we could syphon fuel from our truck. This makes fuel transportation safer and more convenient. Diesel gennies can be hard to start during very cold weather, which is just about the only time we need to run the generator.

Propane or natural gas is a better choice for generator fuel if it is available. Generators fueled by propane or natural gas will last longer and burn cleaner than their liquid-fueled cousins. Natural gas and propane are more easily and safely stored than liquid fuels.

Size

There are really only two sizes of generator—adequate and too small. Don't buy one that is too small. Gennies are rated in the electric power output in kilowatts. This rating is always the maximum amount of power that you can extract from the generator. It is more efficient on fuel to run the generator at no more than 75% of maximum rated loading. Running the generator at its full load rating will not only be less efficient, but will radically shorten the engine's lifetime.

Gennies are rated for using resistive electrical loads. If you are running reactive loads like battery chargers and electric motors, then the poor power factor of these loads will actually increase the loading on the generator. Since reactive loads are mostly what we want to power, consider derating the generator by an additional 25%. This will compensate for the poor power factors of the reactive loads.

A rule of thumb on generator sizing is to figure out how much power you require then double it. This 2X factor makes sure that the generator can deliver the power you require without straining or browning out the loads with low voltage. We commonly see gennies in the range of 4,000 watts to 10,000 watts being used as backup for the grid or RE sources.

Engine Details

There are many different types of engines driving generators. The more inexpensive models use a single cylinder, air cooled engine. The higher quality units have multiple cylinders and are liquid cooled. It's worth giving the engine the hairy eyeball because it will likely be the first part of the generator to wear out.

If you are running the generator less than 50 hours yearly, then it is a waste of money to buy a multi-cylinder, liquid cooled model. If your generator operating time is in the range of 200 hours yearly, then it is cost effective to consider the more expensive, multi-cylinder, liquid cooled models.

Liquid cooling gives the generator a more stable operating temperature. Since most backup gennies in RE systems are operated during the winter, liquid cooling helps the engine keep a constant temperature while running on cold winter nights. Another advantage to liquid cooling is a substantial reduction in engine noise due to the sound-deadening water blanket surrounding the engine.

Consider the availability of remote engine starting. Some gennies can be started without leaving the house, others require that you actually go to the unit to start it. My personal preference is not to remote start the generator. Consider the following story.

My neighbors had a 7.5 kw propane-fired, two cylinder, air cooled Onan generator. It was demand-started by switching on any electrical appliance in their house.

One afternoon, John drained the generator's oil for an oil change. He went to the barn to feed the horse leaving the generator draining its oil into a pan. Pat, unaware that the genny was having its oil changed, switched on a light. The generator automatically started and fried its bearings in less than five minutes. The damages came to over $700 and the generator was out of service for a week while its owners hauled it to town for repair.

This is why I prefer to have a human visit the generator when it is started. Check the oil level and the coolant level. Listen for strange, unusual, and often expensive noises before the genny self-destructs. If you insist on remote-starting your generator, then it must be equipped with automatic controls which will shut it off if the oil level is low or if the engine temperature is too high.

The speed at which the engine runs is a factor in its longevity. Air cooled units operating at 1800 RPM will usually last much longer than those operating at 3600 RPM. This area of distinction has recently been blurred by modern engine designs employing advances engineered for motorcycle engines. For example, Honda makes gennies with engines running at 3600 RPM that will outlast most 1800 RPM models. These high tech gennies use overhead cam shafts and liquid cooling.

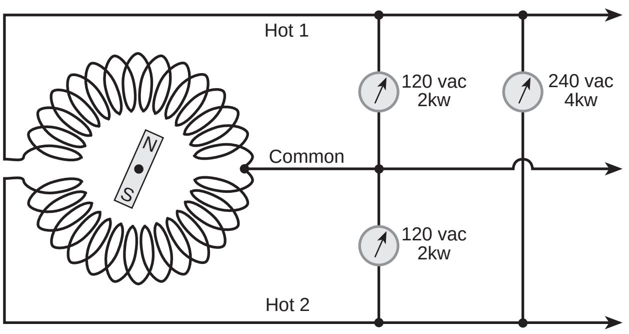
Consider the method of oiling used in the generator's engine. Most inexpensive models use splash lubrication. This means that a bit of metal is attached to the engine's crankshaft. This bit of metal splashes oil around in the interior of the engine thus providing lubrication. More expensive gennies use pressurized oil lubrication, just like an automobile engine. The engine's bearings float on a cushion of pressurized oil, giving the engine a longer lifetime before it requires rebuilding.

Inexpensive air cooled engines will run for around 500 hours before requiring an overhaul, and the genny will cost about $500. Multi-cylinder, liquid-cooled engines will run between 5,000 and 10,000 hours before requiring a major overhaul, and the genny will cost around $3000. Consider that the cost differential between these two types is about six to one, and their longevity differential is about ten to one. In the world of generators, you get what you pay for.

Alternator Details

The generator used in these units is actually an alternator. It is a 2 phase, 120/240 rms volt ac, 60 hz, alternator. While this may seem like technical trivia, the fine print on the alternator determines the performance you will get from the unit.

For example, consider a 4,000 watt alternator constructed to make 120/240 vac. This means that most alternators are actually producing two 120 vac sinusoidal wavefronts that are 180 degrees out of phase. When the output of one phase is positive maxima, the output of the other phase is at a negative maxima (remember, this is alternating current). What this technical detail boils down to is that on a single 120 vac phase only half of the generator's power is available. In order to get the generator's full rated output power, you must use it as 240 vac across the two phases. This nasty technical detail has bitten more first-time generator buyers than any other.



Two Phase AC Alternator

The "you get only half power on 120 vac" rule is another good reason for oversizing the generator. Consider that most of your loads are probably 120 vac. Consider that only half of the generator's rated output power is available on a single 120 vac phase. Buy a bigger generator.

Another technical factor to be considered is peak voltage output. While the alternator is rated at 120/240 vac what this really means is: the alternator makes two 180 degree out-of-phase sine waves that have an individual voltage, if they were rectified and filtered to direct current wavefronts of 117 volts rms (Root Mean Square). Actually the voltage of each 120 vac wavefront should vary from positive 164 volts to negative 164 volts. These positive and negative voltage maxima are known as peak voltage and abbreviated as vpp.

What really counts here is that almost all gennies exhibit low peak voltage. Ideally we would like to see ±164 vpp, but in fact most gennies only deliver ±155 vpp or less (in some cases, much less). What rescues this technical detail from the realm of trivia is that most of the stuff we want to power with the generator is run from the peak, not the rms voltage. Electric motors, transformer-based battery chargers, and many other appliances do most of their work by using the peaks of

GENERATOR CURRENT IN AC AMPERES AT 117 VAC

		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110
R	25	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
O	30	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
U	35	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
N	40	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
D	45	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
	50	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
T	60	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
R	70	14	14	12	12	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
I	80	14	14	12	11	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
P	90	14	14	12	11	10	8	6	6	6	6	6	6	4	4	4	2	2	2	2	0	0	0
	100	14	13	11	10	9	8	6	6	6	6	6	5	4	4	4	2	2	2	2	0	0	0
W	125	14	12	10	9	8	7	6	6	6	5	5	4	4	4	4	2	2	2	2	0	0	0
I	150	14	11	10	8	7	7	6	5	5	4	4	4	3	3	3	2	2	2	2	0	0	0
R	175	14	11	9	8	7	6	5	5	4	4	3	3	3	2	2	2	2	1	1	0	0	0
E	200	13	10	8	7	6	5	5	4	4	3	3	2	2	2	1	1	1	1	0	0	0	0
	225	13	10	8	7	6	5	4	4	3	3	2	2	2	1	1	1	0	0	0	0	0	-1
L	250	12	9	7	6	5	4	4	3	3	2	2	1	1	1	1	0	0	0	0	-1	-1	-1
E	275	12	9	7	6	5	4	3	3	2	2	1	1	1	0	0	0	0	-1	-1	-1	-1	-2
N	300	11	8	7	5	4	4	3	2	2	1	1	1	0	0	0	-1	-1	-1	-1	-1	-2	-2
G	325	11	8	6	5	4	3	3	2	2	1	1	0	0	0	-1	-1	-1	-1	-2	-2	-2	-2
T	350	11	8	6	5	4	3	2	2	1	1	0	0	0	-1	-1	-1	-1	-2	-2	-2	-2	-3
H	375	10	7	6	4	4	3	2	1	1	1	0	0	-1	-1	-1	-1	-2	-2	-2	-2	-3	-3
	400	10	7	5	4	3	2	2	1	1	0	0	-1	-1	-1	-1	-2	-2	-2	-3	-3	-3	-3
in	425	10	7	5	4	3	2	2	1	0	0	0	-1	-1	-1	-2	-2	-2	-3	-3	-3	-3	-3
	450	10	7	5	4	3	2	1	1	0	0	-1	-1	-1	-2	-2	-2	-3	-3	-3	-3	-3	
F	475	9	6	5	3	2	2	1	0	0	0	-1	-1	-2	-2	-2	-3	-3	-3	-3	-3		
E	500	9	6	4	3	2	1	1	0	0	-1	-1	-1	-2	-2	-2	-3	-3	-3	-3			
E	600	8	5	4	2	1	1	0	-1	-1	-1	-2	-2	-3	-3	-3							
T	700	8	5	3	2	1	0	-1	-1	-2	-2	-3	-3	-3									
	800	7	4	2	1	0	-1	-1	-2	-2	-3	-3											

Generator Wire Table

Codes The body of the table contains the Wire Gauge Number (AWG) for the correct size COPPER wire
"0" Wire is designated by 0 "00" Wire is designated by -1 "000" Wire is designated by -2 "0000" Wire is designated by -3
Wiring is specified for a power efficiency of 98% and/or the correct ampacity

the alternating current wavefront. This means that battery chargers and motors will not perform up to spec when powered by a generator with low peak ac voltage.

Noise

Engines are noisy, there is no way around this. You can do three things to minimize the noise pollution: buy a genny with a good muffler and water cooling, locate the genny far from the house, and give the genny a sound-proofed building to live in.

The less expensive the genny, the noisier it will be. If noise is a problem for you, be sure to listen to the unit operate before buying it. There is no substitute for a good muffler and a water jacket for noise suppression. Space is a good silencer, but even 100 feet or more can be too close for a noisy, air cooled unit. If you put your genny in a sound-proofed shed, make sure to allow adequate ventilation.

Maintenance

Over the years you will lavish many hours of care on your generator. Most important is the interval between oil changes. Many inexpensive gennies have an oil change interval of 25 hours on their engine. Better quality units have an oil change interval of 100 hours. Consider the oil change interval when you decide which genny to buy.

Generator to Load Wiring

Once the generator is in place we must still move its electric power by wire to the loads. If most of the work we do with the generator depends on its peak voltage, then wire is one place we don't want to skimp. Oversizing the wiring feeding generator power to the loads is a very good idea. While the NEC specs a 5% voltage drop as acceptable for 120 vac system, I would suggest that 2% or less is better for gennies. At an energy cost of over 80¢/kwh, generator power is more expensive than PV power. Undersizing the current handling conductors is foolish economy and only intensifies the generator's low peak voltage problem. The table shows the proper gauge copper wire for generator connection. Please note that the generator is listed by 120 vac output current. To find the output current of your generator divide its rated single phase wattage (usually half of the genny's total rated wattage) by 117 volts ac and you will get its single phase current. For example our 6000 watt Honda generator delivers about 3000 watts on each 117 volt phase, so single phase current is about 25 amperes. Since our round trip wire length is about 125 feet, we could have used 8 gauge copper wire to hook the generator up to our battery chargers. We actually used 6 gauge because we had it on hand and after all, there is no penalty for being more efficient.

Battery Chargers

If your are using RE sources, then the main load for your generator is your battery, or more properly your battery charger(s). You will be using some type of power supply which converts 120 vac (or 240 vac) into either 12 or 24 Volts DC for your battery. This battery charger is a critical link in the power chain between your generator and your battery. In most systems, the battery charger limits the amount of power delivered to the battery. This results in much longer generator operating time, reduced efficiency, and wasted money.

Battery chargers are rated in terms of output current into the battery. In all cases this rated current is delivered only into a discharged battery with low voltage. As the battery voltage rises during recharging, the current output of the battery charger decreases rapidly. Expect the charger to deliver about half of rated current into the battery when it is about half way recharged. As the battery reaches a full state of charge, charger current will decrease to about 20% of its full rated output.

60 Hz Transformers

Battery chargers which use a 60 Hz transformer do most of their work using the peak voltage of the incoming ac wavefront. Expect any 60 Hz transformer-based battery charger to run at 40% to 70% of its rated current when it is powered by a generator. This includes the battery charger built into many inverters. This classification of chargers also includes almost all units sold for operation from grid power, including the large 60 Ampere gas station chargers that roll around on wheels. Sorry, but the laws of Physics are at work here. It's the voltage peaks that do the work in this type of charger and they are anemic on all generators.

Switching Power Supplies

The answer to battery charging from a generator is to use a 120/240 vac switching power supply. These types of battery chargers virtually ignore the peak incoming voltage and do most of their work using the average (or rms) voltage. A brand very popular with *Home Power* readers is the Power Source made by Todd Engineering. At Home Power, we use three of these Todd 70 Ampere battery chargers to recharge our batteries from the generator.

I wish I could say that these inexpensive (about $260 each) Todd chargers were perfect, but they aren't. While the combined current output of our three Todd chargers is over 200 Amperes into a battery at less than 12 Volts, the output current radically decreases as the battery voltage rises. At 13.78 VDC these three Todd chargers only deliver about 124 Amperes to the battery. At 15 VDC or higher the output of the three chargers is down to a measly 40 Amperes. Worse yet, the three chargers we own show considerable variation from one to the next. One of the chargers almost meets its maker's specification, while the other two fall far short of delivering their rated power.

The bottom line is that we also need to derate the performance of battery chargers in addition to derating the output power of the generator. All this combined derating means purchasing equipment that has much higher ratings and higher costs. I think its evident why using the generator/battery charger is a poor choice for a primary power source.

Effective Use of Generator Power

If the generator is running, then it is most effective to load it to within 75% of it rated maximum power. Go ahead and recharge the battery, but also do the wash, pump water, and do any other power-intensive chores.

A distinct advantage can be had by balancing the power factors on each of the generator's phases. For example, we here at Home Power gain about a 15% current increase from our chargers if we plug our 120 vac deep well pump into the generator at the same time it is powering the battery chargers. The inductive load of the well pump balances the capacitive load of the chargers. The result is the generator sees a combined load that is closer to resistive and therefore delivers more usable power to all of the loads. Check this out for yourself on your generator. Power factor is a reality for generator (and inverter) users just the same as with mega public utilities.

Are we happy with our new generator? Well, I'd rather see the sun shine or the wind blow. But if our RE sources don't provide the power when needed, it's nice to know that we can keep on producing this magazine with the help of our new Honda ES 6500 generator. It delivers about 3000 watts per phase, is very quiet, and recharges our depleted batteries in about five hours of operation. Karen, after years of jerking the starting cord on our homemade 12 Volt engine/alternator, loves the electric start. I like not having to put off work because the system is running low on energy.

All in all, I'd rather have sunshine. While our new backup generator is powerful and reliable, it still feels like a giant step backward every time I pour dead dinosaurs into it….

Access

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