

Powering medical equipment during a utility blackout

By Michael Hackleman

Most people consider blackouts a nuisance. However, for some folks, a blackout can be paralyzing or even deadly, particularly if a critical piece of medical equipment lacks electricity. A standby generator is not always a good or practical undertaking, particularly for folks living in the city, an apartment building, or retirement home. For these applications, a small battery pack and inverter interconnected with the utility grid offers a low-profile and cost-effective measure against the impact of a blackout. Designed and installed correctly, it is kept in constant readiness and ready to go to work immediately (even instantaneously) when grid power goes off.

The process of designing such a system is within the capacity of anyone who wishes to tackle it and can do some simple math. To illustrate the process, I'll relate the experience of a recent consulting job.

The initial contact

"I saw an article online that you wrote entitled "What if the electricity goes off?" (BHM, Jan-Feb'99, and BHM web page). I have two friends who are dependent on medical equipment for their basic needs. We've already had a couple of blackouts where they had problems associated with the loss of this equipment. Because they live in a condominium development, solar, wind, and hydro adaptation and additions are not allowed. Generators also represent a problem because of their installation, maintenance, fuel, noise, and size limitations. I consid-

ered a UPS (uninterruptible power supply) but was told they run their load continually from the time the power goes out until they are exhausted—even if you're not using it to run anything. To me, this means if the battery stores an hour's worth of energy and the blackout goes two hours, then you won't have energy past the first. I don't want to invest in several really heavy UPS units in order to get 5 hours worth of energy.

So (correct me if I'm wrong), I figured a battery-powered inverter system attached and charged through the circuit breaker box would work best. If I understand correctly, the energy stored this way is not used during a blackout unless you actually run something on it. So, my friends could use it on and off during any length of blackout until they've used up the stored energy. Even an hour's worth of electricity would get them up and down their stairlifts about six times each.

The medical equipment they depend on is as follows:

Handicapped stairlifts (2). One to upstairs bedroom and only bathroom, and one to basement bedroom. Each has a 15A (amp) spike on start-up and 9A running, at 120Vac (60-cycle). These stairlifts are needed for several runs up and down the staircase during a blackout.

Oxygen Concentrator. Make oxygen. It is not life threatening because they can use portable backup tanks and can go short spurts without it. However, it is definitely necessary to have unit back online as quickly as possible. Unit draws 5A at 120Vac. It'd be good if this could run continuously for 2-5 hours (usually length of blackout).

If you have the time or resources, could you suggest someone in my area that could expertly install such a system or help with any other backup plan you might suggest?

Thanks, Lynda S.

Gathering the info

Lynda did a good job of describing the three loads (two stairlifts and an oxygen concentrator). The power consumption of a load is defined by volts, amps, and wattage. Since wattage equals amps multiplied by volts ($W = VA$), you only need two of these values to compute the third. By law, two of these values must be printed on a plate or otherwise detailed somewhere on the unit itself. It may also be found in any product literature or manual.

A critical piece of information was missing in Lynda's initial contact. How long does it take for the stairlifts to go up and down between floors? The analysis of the power consumption of any load essentially involves wattage and time. I immediately e-mailed Lynda and she supplied the information.

"It takes 30 seconds for a stairlift to go up or down."

This was all the information I needed.

The load chart

The first step in finding the overall load on a system is to build a load chart. There's a line for each load—light, appliance, tool, refrigerator, etc.—and columns for various entries (Fig. 1). This arranges all the information in a way that makes it easy to record the values, do the needed math, and add up the results.

Fig. 1 Load Chart

AC Load	Volts	Amps	Watts	kW	Cycle	Freq.	kWh
Stairlift Surge	120	9	1,080	1.08	1(m)/0.017(hr)	1	0.018
	120	15	1,800	1.8	<1 sec	Start-up	
						6 12	0.108 0.216
Oxygen Concentrator	120	5	600	0.60	1 (hr)	Constant	0.60
					5 (hr)	Constant	3.0

A. Load Analysis

Application definition: Provide electricity for routine use of two stairlifts and continuous operation of medical equipment (an oxygen concentrator) for a blackout with a duration of 5 hours.

Stairlifts

Stairlift motor wattage is defined as:

Surge* = 15A x 120V = 1,800 watts, or 1.8kW
 Run = 9A x 120V = 1,080 watts, or 1.08kW

*The surge rating describes the inrush of current as any motor starts to spin and operates something. The surge lasts for, at most, a few seconds. Surge must be considered for its effect on other loads, the circuit itself (“nuisance” trips of a circuit breaker), and any inverter that must supply this burst of energy.

The stairlift, as the Load Chart reveals, consumes 0.018 kWh for each cycle (go and return) where the frequency of use is:

6 cycles consumption is = 0.108kWh
 12 cycles consumption is = 0.216kWh

Oxygen concentrator

Oxygen concentrator wattage is defined as:

Run = 5A x 120V = 600 Watts or 0.6kW

The oxygen concentrator, as the Load Chart reveals, works at a rate of 0.60kW (600W) and, in one hour’s time, will consume 0.60kWh. At other rates:

3 hrs = 1.8 kWh
 5 hrs = 3.0 kWh
 12 hrs = 7.2 kWh

Observations

The stairlifts are big loads that run very briefly. Their wattage, individually or combined, will determine the inverter’s maximum wattage rating. The oxygen concentrator is a relatively small load which runs continuously and hogs the energy requirement. Its usage will dictate the size of the battery pack.

Why? Compare the energy consumption of the oxygen concentrator after one hour (0.60kWh) versus the energy consumption of 6 cycles (12 one-way trips) of the stairlift (0.108kWh). The oxygen concentrator has consumed 6 times the energy as a whole day’s worth of stairlift use and has four more hours of work to do. This is the classic case of the small-and-long load taking the lion’s share of the energy pie over the big-and-short load.

I highly recommend taking the time to build such a chart for two reasons. First, it’s a good way to avoid mistakes, since they can’t easily hide from view. And, secondly, it’s one way to get in touch with how much of the energy pie specific loads consume. For example, small loads that are on for a long time often take a bigger slice out of the available energy than a big load operated briefly, as this particular load analysis will tend to bear out.

The analysis

On the load chart, I listed the two devices—stairlift and oxygen concentrator—and the info Lynda had given me. Some notes:

1. **Wattage** is expressed both in watts and kilowatts. Which one do we use? In idle conversation, probably wattage. In low-voltage (i.e., 12V) systems *without* an inverter, the Ah (Amp-hour) is a good standard. However, in utility-tied systems, the standard of measure is the kWh (kiloWatt-hour), where:

kWh = kiloWatts x hours

[Note: Your current utility bill will tell you how many kWh of electricity you used during the last month.]

For the math of the load chart to work correctly, then, we must adopt a standard measure and convert any values to the appropriate expression. Math folks say this helps the terms to cancel out. Teachers say it helps if everyone is on the same page. Since 1kWh equals 1,000W, we can convert any wattage to a kWh value by dividing it by 1000.

For example, the 600W load (oxygen concentrator) is equal to 0.6kW (600 divided by 1000).

2. **Duration** (of the load) is given in both minutes and hours. If the load is operated briefly and this time is defined in minutes, you must convert this value to hours for the math to work correctly.

For example, each stairlift takes 30 seconds to go between floors (up *or* down). Reasoning that the start and stop point of the lifts each day are the same, I've defined a *cycle* of operation as an up and down (go and return) which takes 1 minute (60 seconds).

Now, let's define the cycle duration of this load in hours. Since one hour equals 60 minutes, the 1 minute duration of a stairlift cycle is 0.017 hours (1 divided by 60).

3. If you're making up your own load chart and have listed the wattage and duration (in minutes) of each load of concern, make your *next* task the conversion of these values into kWh and hours.

4. Converting values of wattage and time into kWh and hours is the challenging part of any load chart. When you're done, you are over the hump.

The inverter

An inverter is an electronic device that converts dc electricity—usually from battery pack voltages of 12V, 24V, 48V, etc.—into 60-cycle, 120Vac like that available from the utility grid.

Most of today's inverters are designed to supply their rated wattage continuously and will briefly handle the surge (startup) current when inductive loads such as motors are first started. Nevertheless, it's best to include such information on the load chart since simultaneous startups (rare but possible) of several motor loads may exceed the capacity of a specific inverter to handle such a combined surge. Most inverters have overload protection, shutting down automatically to prevent damage, but the result is a blackout to the loads they supply.

Many models of inverters today are designed to be interconnected with the utility grid. There are many advantages to this marriage. One is

that as long as utility electricity is available, it feeds through the inverter to power the loads directly. In the same mode, it also works as a battery charger to keep the battery pack at full capacity.

When a blackout occurs, the inverter shifts into full operation. Internally, its transfer switch shuts the battery charger off, turns on the inverter, and directs the energy of the battery pack to all ac loads (up to its maximum rating)—all within a fraction of a second.

Another common feature of today's inverters is the sleep/search feature. When this inverter has no loads to power, it puts itself to sleep while activating a search pulse that looks for newly-activated loads. The most efficient search (slow) setting means that you must wait for a fraction of a second before, say, a light comes on when you've thrown the switch. The search pulse has to see this load and wake up the inverter to deliver the juice. The feature is adjustable if you find the wait some-

B. Inverter Analysis

Continuous rating:

A. All loads operating together.

Stairlift 1 + Stairlift 2 + Oxy. Conc. = Total

$$1,080W + 1,080W + 600W = 2,760W$$

B. Lifts *never* operate at the same time.

$$1,080W + 600W = 1,680W$$

Intermittent rating:

Surge is 6A above the continuous run current of 9A for either stairlift. The surge wattage, then, is 720W (6A x 120V) above continuous rating. This is well within the capability of most inverters to handle for many seconds.

Recommendations

1. An inverter rated at 1,800W (or higher) continuous rating will easily handle the load if the stairlifts are *not* used simultaneously.

An inverter with a 2,500W (or higher) rating will be needed if the stairlifts must be able to operate at the *same* time.

2. Motor surge is not an issue with *either* inverter as they are designed to handle this surge. However, make certain the circuit breaker that feeds utility grid power to the inverter is capable of handling 15A continuously (with surge up to 20A) without tripping.

3. Select an inverter with a battery charger feature built in. It is generally more expensive to buy an inverter *and* a good (separate) battery charger. Also, when combined in one unit, there's better overall regulation and less likelihood of overcharge, undercharge, etc.

4. Inverter should have a load-sensing feature so that it remains in standby until any one of these loads comes on.

5. The electrical code wants the inverter tied into the utility main (or sub-panel) through its own breaker. You may be able to use one of the two (i.e., 15A or 20A units) that presently control the stairlifts. More likely, you'll need to upgrade the breaker slot to a 25A or 30A breaker.

Your running load is 9A (one stairlift at a time) plus 5A (oxy conc), so 14A minimum. This will probably pop a 20A breaker with the surge of motor startup. A 30A breaker will handle this easily.

6. The inverter has three sets of terminals: ac in, ac out, and dc in/out (Fig. 2). The utility grid (or a standby generator) is connected to "ac in." The loads connect to "ac out." The battery connects (through a fuse/switch or dc circuit breaker) to the inverter at "dc in/out." The in/out designation refers to inverting vs charging modes, respectively.

how unbearable at a slow search setting.

It's these two features—line-tie and search mode—in the inverter that make this type of backup system so desirable. It's on the job quickly, sleeps to conserve energy, and keeps the battery pack charged and ready to go—all without any knob-fiddling or attention from you.

What loads will the inverter need to handle? Sizing the inverter looks at continuous and intermittent ratings, singular and simultaneous use of important loads, and any motor surges (Sidebar B).

The battery pack

Many people glare at the thought of investing money in 4 or more batteries to make up a battery pack. Why? I think it's because they think they may have to replace this battery pack as frequently as they do the battery in their car.

Fortunately, this is *not* true. A battery tends to last 2-3 times longer when used in stationary applications. Why? In cars, a battery is exposed to the heat and vibration of engines in

close proximity, road shock, and cold weather. Stock golf cart batteries will last at *least* 5-6 years in an RE system, and ones specifically tailored to RE systems will last ten years and more.

While there are many choices for batteries to use in this application, a good standard to start with is the conventional 6V, 220Ah (amp-hour) lead-acid battery like that used in golf carts. It has a maximum capacity of 1.3kWh (6V x 220A) at an 8-hour discharge rate. This means the battery will deliver 27.5A (220Ah divided by 8 hours) for an 8-hour period. Be careful. The math suggests that this battery will deliver 110A (27.5 times 4) for 2 hours because the product equals 220Ah. It won't. At discharge rates higher than the 8-hour rate, the chemistry is strained and the losses get big fast.

In the industry, then, the capacity of this battery is *adjusted* to a more realistic 0.75 kWh capacity (or lower) *per* battery to account for the higher discharge rate (in this application, a 150-200A rate) and the fact that no battery pack should be dis-

charged completely. By adhering to the recommended 50% depth of discharge, the owner/builder can be ensured of a good, long service life for the battery pack.

How big a battery pack is needed for this system? Let's consider two blackout scenarios: 5 hours and 10 hours (Sidebar C).

The battery pack may be rated at either 12V or 24V. If wired as a 12V pack, two sets of the 6V batteries will be wired in series and then parallel-wired together (Fig. 2). If wired as a 24V pack, all four batteries are wired in series.

Choosing a 24V arrangement generally has the advantage of lower line losses for a given size of wire if there's a big distance between the battery pack and the inverter. There are two advantages in this application for the pack to be wired for 12V instead of 24V. One, it's easier to tap a 12Vdc pack directly for emergency lighting because there are more products available at 12V than 24V. This strategy avoids the use of an inverter for this function. Two, if it is to be increased in capacity (now or later),

C. Battery Pack Analysis

Let's size the battery pack for the indicated loads for a 5-hour and 10-hour blackout.

1. A 5-hour blackout. The stairlift system needs 0.018 for each cycle (up/down). Let's figure 5 cycles, or 0.09kWh (5 x 0.018kWh).

The oxygen concentrator needs 0.6kWh for each hour of use. Let's figure 5 hours of continuous use, or 3.0kWh (5 x 0.6kWh).

The total demand, then, is the stairlift load plus the oxygen concentrator load, or 3.09 kWh (0.09 + 3.0)

At a capacity of 0.75kWh for each 6V, 220Ah battery, four batteries will store 3.0 kWh (4 x 0.75kWh). This *pack capacity* is a close match to the *load requirement* of 3.09kWh.

2. A 10-hour blackout. If the load conditions are the same—five additional cycles of the stairlifts and full time operation of the oxygen concentrator—the battery pack needs only to be doubled in size (eight 6V, 220Ah batteries).

Recommendations

1. Avoid a bigger battery bank (\$440) by minimizing operation of the oxygen concentrator during a blackout. Avoid a larger inverter (\$1,000) by never operating the stairlifts together.

2. The electrical code wants a DC disconnect between the batteries and inverter. This is high current at low voltage (12V). It's more than 10 times the current at 120Vac for the same wattage. Only 15A of 120Vac

loads will draw 150A of dc current from the 12V battery pack.

3. Electrical code requires automatic *and* manual shutdown of the battery-inverter circuit. So, a big fuse and power switch *or* a dc breaker (works like standard circuit breakers, popping with a big load or shutting off with a pull on the switch) is needed. Fuses are expensive and no fun to change in the dark. However, in this system of *fixed* loads, the fuse/switch idea has merit. A breaker-type DC-disconnect switch is best overall, but a more expensive option.

You'll need miscellaneous connectors and fittings in this installation, i.e., the big cables that run between inverter and batteries (Fig. 3).

a 12V battery pack will take a 50% increase in capacity whereas a 24V pack will need a 100% increase. That's because the 12V pack will need a minimum of 2 more batteries (two 6V batteries wired in series) added in parallel with the first set(s)—a 50% capacity increase. A 24V pack will need a minimum of 4 batteries (series-wired 6V batteries) added in parallel with the first pack of 4—a 100% capacity increase. The point? It's less expensive to add capacity in a 12V pack than a 24V one.

The battery pack and inverter should be next to each other since they're interconnected with a big electrical cable. However, the inverter and battery pack may be located either near the loads or near the sub-panel to which they're presently wired.

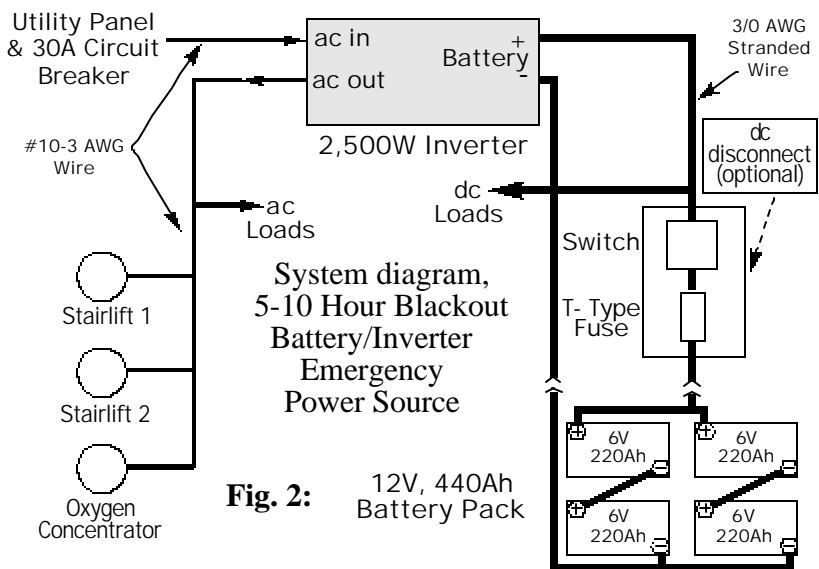
Additional questions

I sent Lynda my findings—load chart, load analysis, the sizing info on inverter and battery pack, and a system block diagram (Fig. 2)—for her review. I had a few questions of my own. Did the users have a way to illuminate their surroundings during a blackout at night or should a few lights be added to the system? Were the stairlifts wired into a sub-panel?

Below, I answer the questions Lynda asked of me in response to what I sent her.

1. How often do we need to replace batteries, parts etc.? What kind of maintenance does this system require? Can we put them on the floor or do they have to be on a shelf? Should they be in a vented, insulated (w/ what?) casing (wood?) or can they stand on their own? Is it safe to have near a bedroom? (The breaker box is on the unfinished side of the basement/bedroom).

You can expect deep-cycle, off-the-shelf golf car batteries (lead-acid) to last at least 5-6 years. For 30% more



money, you can get ones that will last *twice* that long (10-12 years).

Flooded cells will need to have water added periodically (twice a year, or more often). For a little more money, you can get sealed lead-acid or batteries which have virtually no maintenance. These are a better choice for any system where the batteries are located in the house.

An inexpensive way to safely store batteries inside a house is in a plastic tub with a cover (same type of plastic and lids as are used in trashcans) located near an outside wall. These are available from hardware or home improvement centers. If you can't get one big enough for the entire battery pack, get two tubs and place them side by side. Install a fitting at the lowest point in each (bottom or side) that will let you run a drain hose outside. It's also recommended that you add a vent (same as used with clothes dryers) in the side (near top) for carrying off any gases (oxygen and hydrogen) produced during heavy charge or discharge to the outside. Flooded batteries may "spray" out some electrolyte during heavy charge or discharge. If you use the tub-and-drain fixtures I've specified, you can literally hose off the batteries (turn off the breaker switch first)

inside their enclosure, further diluting an already weak electrolyte solution and letting it drain away harmlessly onto the ground outside.

The batteries should be located as close to the inverter as possible because of the big wire (00 or 000) used to interconnect them. It's expensive (\$1-2/ft), so you want a minimum run of it. If both of the stairlifts are connected into the same breaker box, this might be the best location for the batteries. The battery pack and inverter can also be located elsewhere (at a distance from the existing breaker box), i.e., a closet, utility room, or even near the stairlifts. If located outside, the batteries will want to be insulated to protect them against the cold your region (New Hampshire) experiences. Wherever you put them, keep the inverter and battery pack close together.

Plan on a #10-3 (awg) wire set between the utility panel and inverter *and* between the inverter and the loads. The #10-3 insulated wire has three wires—black (power), white (common), and green (ground)—and can be run inside EMT (electrical metal tubing) or plastic pipe. Or use romex-type wire. This wire will handle the combined load (9A stairlifts,

5A oxygen concentrator, plus lights) with no more than a 5% loss.

By the way, electricians are *not* accustomed to working with batteries and dc systems. Still, even a skillful layperson can do this wiring or direct the installation of this system.

Finally, adding more batteries is not necessarily difficult, or something you have to do right away. That is, put in a 3kW battery pack and check out its operation, then decide if more batteries are dictated or desired. It's easy enough to add them, particularly if you're using tubs.

(Never place batteries directly on concrete. It adversely affects the electrolyte levels between battery cells. Result? Bad chemistry.)

2. *What is needed to add, say, 4 small lights—one in each bedroom, one in the kitchen, and one in the living room?*

The system as designed should be able to handle a lighting load *without* additional battery capacity *if* small, low-wattage, efficient fluorescent (12Vdc or 120Vac) or LED-based (cluster) lamps are used and operated minimally.

Avoid incandescent lights. They typically use 4 times more power than a low-wattage incandescent (light) bulb. The LED cluster lights are 4-10 times more efficient than even fluorescents, thus worth every penny of their cost. The lamps use clusters of red and yellow standard LEDs (light-emitting diodes) to the desired illumination level. More expensive than other lighting systems, they use little power and last forever.

Wires for 120Vac lights can branch off the stairlift wiring, either at the stairlifts or directly from the inverter. Any 12Vdc lights can use romex wire (usually a no-no for dc electricity) since LEDs draw virtually no current.

Fig. 3 Inverters, batteries, connectors, and dc disconnects

I asked Steve Willey at Backwoods Solar, a reputable RE dealer, for quotes on the components—inverters, batteries, dc disconnects, and cables—for this installation.

Inverter The requirement here has the greatest option as to quality and type. Requirements seem to match well with the new ProSine 2000, a 2kW true sine wave unit with 100A charger (built-in), 12V only, \$2,000. ProSine also makes a 2,500W available for 12V (\$909) or 24V (1,000). Trace DR1512 (12V, \$1,029) or DR1524 (24V, \$979) will do it with little margin, whereas DR2412 (12V) and DR24 (24V), each \$1,395, will work with plenty of margin. These are all combined battery charger/transfer switch units (work with line-tie or standby generators).

Battery Pack. As you suggested, 4 Trojan T-105 (golf cart type),

3. *If the inverter must handle 3000 watts, did you mean to recommend a 2000W inverter? (Probably something I don't know, but thought I'd ask.)*

Sorry for the confusion. If the loads are managed somewhat, the cost of the system will be \$1,000 *less* than if the users wish to have the option of running both stairlifts at the *same* time. The difference is in either using a 2,000W (managed) or a 3,000W (unmanaged) inverter—and a dollar per watt price tag.

Note that in the final analysis of how this system will perform in a 5-hour blackout that I was generous with the number of stairlift trips. That's because they are such a *small* drain on the batteries due to the brevity of their use. Conversely, these folks could easily stretch their power availability in a prolonged

220Ah, 5-6 year lifespan, \$300 total. Or use two L-16HC 395Ah, 10 year lifespan, \$440 total. Generally, we can supply batteries through local Trojan newtwork for customer pick-up, therefore no shipping and tax involved outside of Idaho.

Cables. Between battery pack and inverter, size 4/0, 10 foot length, \$70. Battery interconnect: 2/0 cable. Single (for 10-year pack) is \$6, or 4 (for 5-year pack) are \$16 total.

DC Disconnect/Fuse. Can be a simple in-line fuse, \$69. The class T fuse may be more suitable for this compact system since it's unlikely to ever be blown. Trace DC breaker box, \$329.

All of these components are usually available within two weeks, most within a few days.

(Backwoods Solar, 1395 Rolling Thunder Ridge, Sandpoint, ID 83864. Phone: (208)-263-4290 Fax (208) 265-4788 Website: www.backwoodssolar.com)

blackout by minimizing the operation of the oxygen concentrator. It is such a big drain on the system. True, they can *buy* their way into extra reserve with the batteries but conservation is cheap *and* effective if they've enough cylinders charged up to help them manage. It's just one of many strategies.

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