Portable Solar/Battery Power For Emergency Response and Management

By
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When disaster strikes or there is a terrorist attack, the ability of first responders to save lives depends robust and reliable communication and monitoring systems to support cross-agency situational awareness and coordination of emergency response and management activities.

Often in disaster situations, first responders are left without communications or power because there has been significant damage to the infrastructure. Resources can be marshaled to establish a central command and control center but it is much more difficult and time consuming to extend the reach of the command and control center into the wider community.

Some of the obstacles to the rapid deployment of communications and monitoring equipment throughout the community are the lack of power when and where it is needed and having the appropriate equipment without any ‘missing pieces’. One approach to this problem is to deploy a self contained purpose designed modular equipment to meet the short term needs. It would be ideal to walk/drive to one of more locations and simply drop off one or more communication or sensor modules that could be used for form a command and control network.

Clearly battery powered equipment can enable rapid deployment of equipment but it is likely that power storage capacity of the equipment would not be sufficient to operate for days or weeks as required. While it is possible to use generators to extend the operating period they do require refueling and constant attention.

A better solution is a renewable resource such a photo-voltaic solar system. Although solar power is growing in popularity most development has focused on ‘on grid’ systems and to some degree small fixed installations for lighting, communicating and monitoring. A minimum amount of development has been done on truly portable solar power systems except for the military.

Emergency response applications place additional requirements on a solar system design.

1. Multi-mode power operation, AC, DC or Solar. Rapid charge from AC or generator when solar is not available.
3. A self contained single package design that is easy to transportable (hand carry, dolly) and set up.
4. High efficiency system components (controllers, chargers and regulators) combined with low power equipment.
5. Modular system functionality to support multiple requirements with additional features to support remote monitoring and maintenance of the solar power system.

Typical Solar Powered Emergency Response Systems
1. Solar power command and control work station - Provides a low power laptop (10W-20W-DC) mounted on a stand up dolly with shade for outdoor use, Wi-Fi/ EVDO back haul, battery, AC charger, removable solar panel. Cost - TBD

2. Solar Powered Portable Wi-Fi Hotspot – Provides an instant Wi-Fi bubble that gives instant Internet access to personnel. Support data, voice and video. Utilizes the EVDO high data rate cellular system for Internet backhaul.

3. Solar power 4.9 Ghz Public Safety Mesh Network, Utilizes new 4.9 Ghz / Wi-Fi dual band access points, demo the potential of the new 4.9Ghz band (less interference) and allows comparison with 2.4G /5.1Ghz Wi-Fi band, deployed as a multi node network across a region, EVDO or wired back haul, with portable solar/battery powered nodes. Cost - TBD

4. Solar powered communications tower – Medium sized Solar power system (100W-AC) deployed in a semi permanent location to support a Wi-Max base station or repeater link. May have a small generator with auto start. To increase reliability and reduce battery size – Cost - TBD

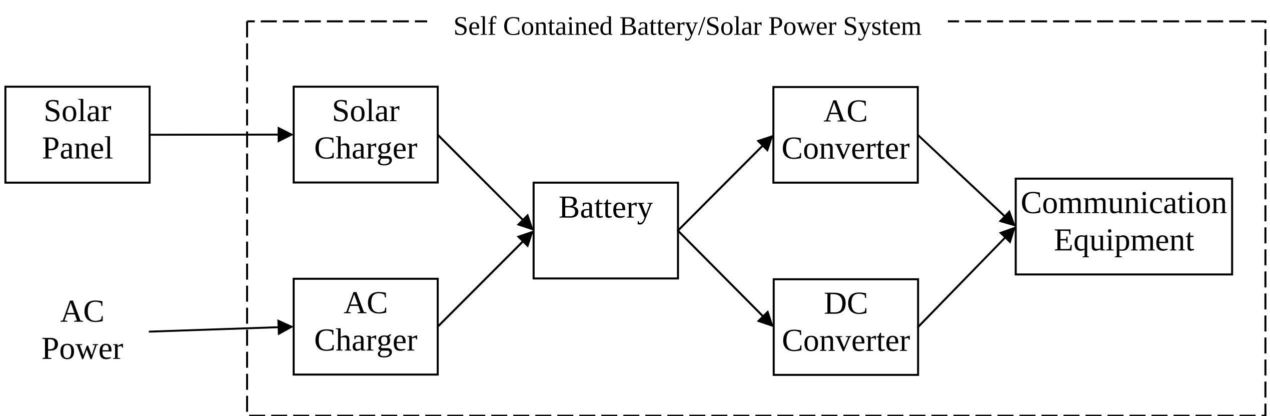
5. Solar powered portable video camera can be deployed to any location for an extended period of time. Wi-Fi / EVDO back haul. Cost – TBD

Portable Solar System Design Guide

One of the things that you learn when you set out to design a solar powered system is an appreciation of the cost of power consumption.

At the risk of telling the whole story in the first paragraph here is a quick look at a solar powered system design. A small load of 10W consumes 240 W-h per day. This requires a battery with a minimum storage of 40A-h (32 lbs) and an 80W (8 sq. ft) solar panel if you are in Las Vegas. Other locations could require a much larger panel and battery. A 100W such as a desk top computer would be limited to 2.4 hours of operation per day. Clearly power consumption is critical issue that must be considered when developing operating requirements (hours/day) and the selection of equipment (very low power).

The following is a step by step guide for designing portable solar systems for emergency response applications. Here are the components in a typical portable power system



There are 4 key issues that must be considered when designing a transportable solar power system.

1. Size of the solar panels
2. Size and weight of the batteries
3. The efficiency of the charging and converting equipment
4. The actual daily energy consumption of the equipment to be operated.

A good way to start a design is first make a rough estimate of the daily energy requirements (watt-hours) by defining the hours of operation and power requirements of the equipment. Next, take a first pass through the size and weight of the solar panels and batteries.

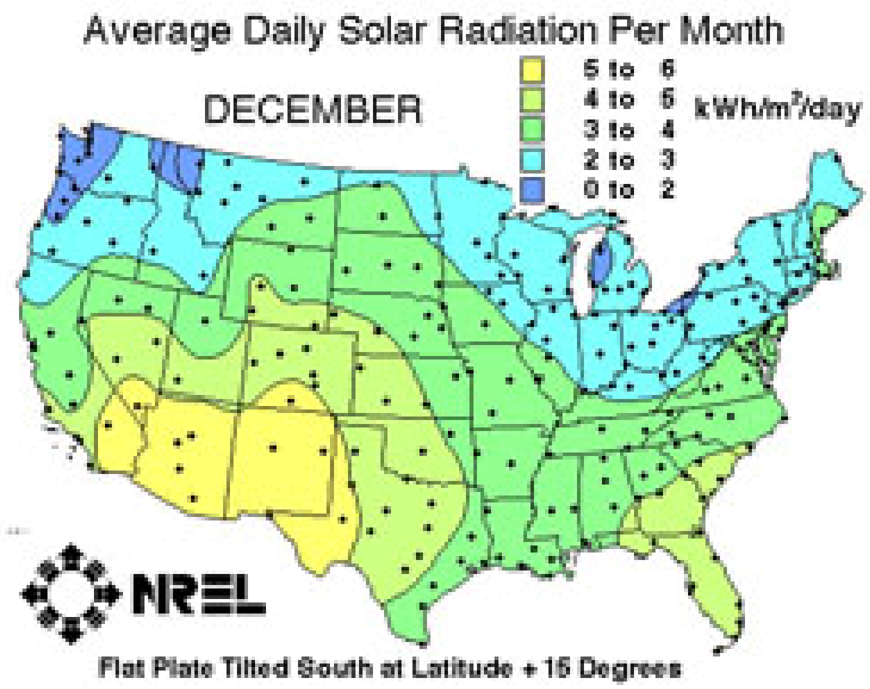
The size of the solar panels and batteries can be estimated separately as they are some what independent. The solar panel must on average provide all the energy for operating the equipment plus an amount to make up for the losses in the charging and conversion equipment. The batteries must store enough energy to operate the equipment between charging cycles and to provide a few days (2 – 5) of autonomous operation if solar power is not available. Sizing the battery for 1 day operation is not recommended as this would discharge the battery 80%-90% each day which would greatly shorten the battery life and the loss of a partial 'solar day' of energy with cause the system to shut down.

Solar Panel Selection
The power that a solar panel generates is primarily a function of the size and orientation of the panel and the solar energy available at a geographic location at a given time of the year. Panels are rated on the based of watts generated at a sun irradiance power of 1000W/m2 (ie the Standard Test Condition (STC). power).

The solar radiation data for a geographic location can be found in 'Insolation' tables and maps provided by the National Solar Radiation Data Base (NSRDB) http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/.

This data base contains hourly solar energy data for 20 years at 237 NWS stations across the US. The values in the tables show the average, minimum and maximum daily solar energy (kW-h/m2/day) and range from 0 to 9. Some people refer to these numbers as 'hours of sun' per day.

A sample map is provided below.



Average Daily Solar Energy (kW-h/m2/day)

	June	Dec
San Diego	5.8	5.0
Dagget	7.4	5.6
Las Vegas	7.4	5.4
Portland	5.3	1.6
Chicago	5.7	2.6
Boston	5.5	3.1

The total daily energy generated by a solar panel (W-h) can be computed by multiplying the solar irradiance data (kW-h/m2/day) by the panel power rating (W/kW/m2). For example an 80W panel in San Diego in December (5.0 kW-h/m2/day) will generate 80 * 5.0 = 400 W-h per day. Generally this is discounted by 40% - 50% by a number of system factors (and who you talk to), leaving 240 W-h which will support a load of 10W for 24 hours. A typical 80W solar panel is 50" x 20" x 2" and weighs about 20 lbs. Solar panels may be connected in parallel up to the capacity of the solar controller.

CAUTION - FULL SUN REQUIRED - Another major consideration for solar panels is shadows and cloud cover. A shadow on a single cell will reduce the output of the panel by 90%. In addition, solar panel output goes to zero quickly when the solar radiation falls below 20% of the STC. Light cloud cover will easily absorb/reflect 50% of the solar energy.

Battery Selection

For small to medium solar systems the battery of choice is a 12V Sealed lead acid (SLA) battery because they provide the best compatibility, value and performance. Lithium batteries offer a weight-saving (1/10th) alternative but they are expensive (10 times) and there are voltage compatibility issues. The SLA battery provides a nominal 12V output while lithium batteries come in a variety of ranges, none of which are compatible with the SLA voltage. Further, most panel controllers and AC and DC output converters are design for SLA batteries making the Lithium option even more expensive.

Batteries are rated by their amp-hours (A-h).storage capacity. It is generally more accurate to analyze solar system performance based on amp-hours but we will use watt-hours for simplicity. The battery rating can be converted to energy (W-h) by multiply by the battery amp-hours (A-h) by the voltage (V). For example a 12 V - 40A battery will provide 480 W-h of energy. This is enough energy to operate a 10W load for 48 hours (2 days). For most solar systems, 2 days is the bare minimum as it implies that only one 'solar charge cycle' is missed (ie a storm or clouds). Realistically 3 days of storage is better. For reference, permanent solar installations are designed with 7 days of autonomy. Another consideration is the reduction of battery capacity with age. A battery is considered at end of life when it has lost 50% of it's capacity. If the system is designed with 2 – 3 days of battery capacity, the batteries will need to be replaced at 25% - 50% of the rated life.

In some cases a generator can be used as an alternative to increasing the battery size to support 7 day autonomous operation. See AC charger below.

DC Converter Selection

The output power converter is an important part in determining the overall system efficiency, Generally DC operation of all equipment is recommended because it is the most efficient. Some equipment will run directly on 12V but be sure to verify that with the equipment will run on unregulated +12V-14.5V battery voltage. If in doubt use a 12V regulator or 'car adaptor'. Regulators are available for +5V or 24/48V for POE. Be certain to select a 'switching' type regulator and it is a good idea to actually test it's efficiency under normal load. A good quality 12V to 5 volt switching converter delivering 4 W will typically consume an additional 1W. The efficiency could approach 85% - 90% at higher loads. Clearly it is important to actually test the equipment and converters under normal operating modes before selecting solar panels and batteries.. Power requirements can vary as much as 2:1 from stated spec. Once you know you actual load in watts you can continue.

AC Converter/Inverter Selection

AC based systems are used because they are compatible with virtually all equipment. They do however consume 30%-60% more power than DC based systems. This is because the DC battery voltage must be converted to 110VAC and then the equipment then converts the AC back to DC. For full compatibility you will likely need a 'true' sine wave inverter because some equipment will not run on low cost (square wave) inverters. Again test all components and measure the actual power consumption.

Typical Solar Powered System Designs

Here are some sample DC based systems operating in Las Vegas.. If the system is located in Boston the panels will need to be twice as large. AC based systems will also require larger solar panels

Sample Battery/Solar DC Powered Systems
(Operating in Las Vegas in December)

Load (W)	Operation (Hrs)	Panel (W)	Battery (2 day) (A-h)	(Lbs)	Application
5	24	40	20	16	Wi-Fi access point
10	24	80	40	32	Wi-Fi EVDO Bridge and camera
50	12	200	100	80	Small Laptop
100	6	200	100	80	Desktop with LCD monitor

Below there are some charts to support a first pass system design. A final design should be based on the actual power requirements of all system components and an A-h based analysis of the solar and battery components.

First determine your panel power requirements from the table below. For example if your load is 8W for 24 hr/day and you are in San Diego in December you will need an 80W panel. Then select your battery storage. For a 10W load and 2 days of storage a 40 A-h battery is required. (3 days will require 60 A-h.)

Solar Panel - vs Load (W) in Region
(24 hour/day in December)

Panel watts	Las Vegas	San Diego	Port-land	Boston
20	2.8W	2.2W	1.9W	1.2W
40	5.2	4.0	3.4	2.3
80	10.3	8.0	6.9	4.6
160	20.6	16.0	13.8	9.2
240	30.9	24.1	20.6	13.8

Load vs Battery Storage (A-hr)

Load watts	1 day A-hr	2 day A-hr	7 day A-hr
2.5	5	10	35
5	10	20	70
10	20	40	140
20	40	80	280
50	100	200	700
100	200	400	1400

Now that you have defined your system, you can evaluate the size and weight from the tables below. The 40 A-hr battery will weight about 30 lbs and the 80W panel will be about 50” x 21” and weigh 17 lbs.
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Battery Size

A-hr	W-hr	lbs	L	W	H
7	84	6.2	5.9	2.6	3.7
18	216	13.2	7.1	3.0	6.6
35	420	26.4	7.6	5.2	6.7
70	840	53.0	13.8	6.5	6.9
110	1320	68.2	13.0	6.8	8.5
200	2400	143.0	20.6	9.5	8.6

Panel - Physical Size

Watts	lbs	L	W	T	Impp
20	5.3	15.2	12.9	1.4	1.25
40	10.0	21.3	25.8	2.0	2.31
80	16.7	47.2	20.8	1.3	4.76
160	33.4	47.2	41.6	1.3	9.52

Solar Charger/Controller Selection

The solar controller provides the connection between the solar panel and the battery. Like an AC charger, it protects the battery for being overcharged by the panel during the day. At night the controller prevents the battery from discharging back through the ‘dark’ panel. The controller often has a low voltage disconnect (LVD) that protects the battery from excessive discharge by disconnecting the load when the battery falls below a present level. The most popular solar controllers for small systems use pulse width modulation (PWM) to regulate the charge current to the battery. This switching technology results in minimum power dissipation in the controller and generally supports fast charging of the battery through a three step process (constant current, constant voltage, float). PWM however does not actively seek the maximum power out of the panel and is not an optimum solution for all panels. Additional analysis is required especially for panels with a high peak power voltage rating (Vpp). Watch out for specsmanship among the panel manufactures. An A-h based evaluation avoids most pitfalls.

For systems with solar panels greater that 60W the Maximun Power Point (MPP) controllers are an attractive alternative. The MPP controllers are significantly more expensive ($200 min) however they can get up to 30% more power out of a panel. This means that an 80W panel may work with an MPP while a PWM controller would require a 100W panel and since panels cost about $5-$10/W some of the cost can be covered.

AC Charger Selection
A multi-mode fast AC charger should be selected with enough capacity to operate the load and charge the battery in 3 - 5 hours. This is important in emergency response applications because time is the most important commodity. A 4A charger is a good choice for an 18 A-h battery. This will allow the battery pack to be recharged quickly by a generator or other source should solar power not be available. The charger should support a Standby or Float charge mode to allow the battery/solar pack to be charged on a continuous basis and be ready for immediate deployment.

Summary
With proper design and component selection, solar power offers some unique advantages for rapid deployment of a communication and monitor networks in emergency response and management applications.

Although not ideal for all applications or all equipment, the recent trends toward lower power communication gear and lower cost solar equipment should enable wide spread adoption and deployment of portable solar/battery powered equipment.

Solar Powered
Sensor-net Gateway

Battery Powered
Wi-Fi – EVDO Router or
Wi-Fi to WiMax Bridge

Pre-staged Portable Equipment

Search and Rescue Deployment

About the Author

David Ahlgren is President of Entrée Wireless a leading provider of wireless technology solutions that support first responders and mobile workers and protect critical infrastructure. www.entreewireless.com

He has more than 20 years of entrepreneurial business experience and an extensive technical background. David was the founder and CEO of a well known engineering consulting firm and three high-tech product companies. Though out his career he has had in-depth experience in both the commercial and government sectors including the department of homeland defense and the military.

His technical experience includes both hardware and software development for products ranging from software defined radios, to mobile ad hoc networking to business applications. He has worked on digital video, broadband and wireless networking, telecommunications, sensors, instrumentation and process monitoring/control products and systems.

Recent projects include strategic planning for a high speed software defined radio and directional MANET technology, program management and ConOps for the Homeland Defense BioNet program, the analysis of opportunities in transformational Net-Centric military programs such as FORCEnet, ConstellationNet and LandWarNet. He also developed products for mobile video security and battery/solar powered 3G CDMA/Wi-Fi hotspots.