A BACKPACK PORTABLE POWER STATION FOR HUMANITARIAN MEDICS IN POST CONFLICT AND DISASTER ZONES

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Abstract - The purpose of this research was to develop a highly portable and rugged renewable energy storage and power management module for use by humanitarian medics. Built to be shoulder portable (≤30lbs) and capable of powering critical medical equipment, this device is intended for use in developing and disaster regions where power sources are either limited or non-existent prior to arrival of aid organizations. Construction was accomplished using carbon fiber composites and testing showed the unit to be capable of providing power in-situ such that enhanced onsite medical care can be provided by humanitarian medics to internally displaced peoples.

Keywords - Internally Displaced Peoples (IDP), Jungle Medic, LiFePo4, Backpack Power Supply

I. INTRODUCTION

As of 2016 there were approximately 1.1 billion people worldwide without access to a reliable source of electricity, with approximately 85% of this group living in rural areas [6].

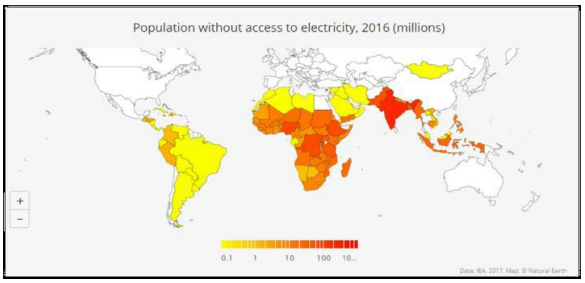


Figure 1-1[9]

In a war torn and rural region of the globe, the need for access to electricity is no less important than the need for such access in the more stable regions of the world. Access to electricity has been shown to improve healthcare services, aid in economic empowerment (especially for women), enhance educational opportunities, and increase technological access[1].
As the primary stakeholders for this research operate in Burma and provide humanitarian aid predominately to oppressed ethnic minorities, research and design was conducted accordingly. At present, the situation in Burma is very dire for ethnic minorities, like the Karen people. They face a constant threat of genocide and oppression from the current regime operating under the banner of Myanmar (formerly called Burma). In addition to living in a rural developing context, the Karen people and IDP's are forced to relocate their villages and homes frequently, in order to escape death or imprisonment[2]. Humanitarian aid organizations such as The Free Burma Rangers[3], Earth Mission Asia[4], Backpack Medics[5], and many others provide some measure of relief to the IDP's in a variety of ways, including medical aid by way of jungle medics. The term jungle medic, for the purposes of this paper, will be used to describe a humanitarian medic, typically of an ethnic minority within Burma, who provides medical aid to the IDP's of Burma wherever they are found.



Figure 1-2 IDP's in the jungle [3]

At times, this means several days of travel on foot through rugged jungle terrain where temperatures can exceed 110°F and heavy rains occur. The jungle medics work tirelessly to serve the medical needs of the IDP's, but they are often limited in the level of care they can provide, due to an absence of electricity on site. When electricity is available, jungle medics can use portable devices such as oxygen concentrators, ultrasound, and LED lights to provide a higher level of medical care to their patients. This led to the development of a portable power station that would enable jungle medics to provide enhanced onsite medical care to the IDP's of rural Burma.

II. PROTOTYPE DESIGN AND CONSTRUCTION

A. Design Overview

To meet the jungle medics need for a portable source of electricity, research was undertaken to determine if a complete solution existed. Upon determining that the existing portable power stations were incapable of meeting all the needs of jungle medics, specifically with regards to transportability, acceptance of solar

input, and protection of onboard electronic hardware against water ingress; a new and unique design was determined to be necessary. As a result, the Ambassador was developed and tested for use by jungle medics with the following capabilities and features: A 12V nominal rechargeable battery with 41.76Ah of capacity, onboard MPPT solar charge controller, 362W of DC power, a 350W 120Vac/60Hz inverter, overcurrent protection, carbon fiber construction, an integrated backpack harness, and water resistant design. An overview of the mechanical and electrical systems can be seen in Fig.2-1 and Fig.2-2 respectively.

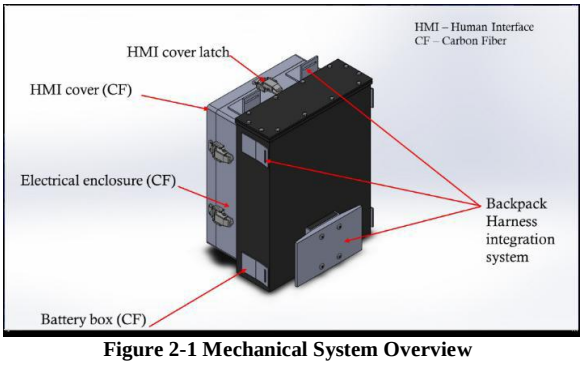


Figure 2-1 Mechanical System Overview

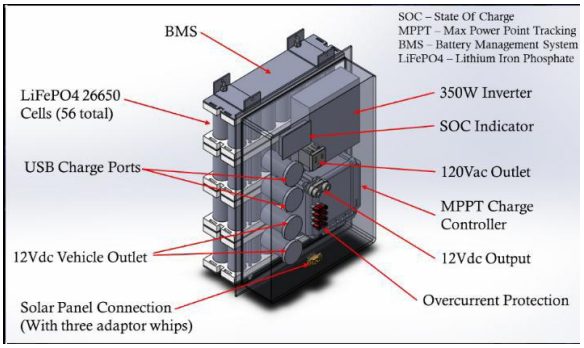


Figure 2-2 Electrical System Overview

B. Prototype Construction

Using composite materials in conjunction with mechanical fasteners and electrical hardware, a functioning prototype was built for proof of concept and testing. All composite pieceswere formed using custom molds and vacuum bagging while the part was cured. To provide additional strength and rigidity to crucial parts while minimizing weight added, Nomex honeycomb was used to produce sandwich core parts. Where attachment of electrical components and mechanical hardware was necessary, threaded brass inserts were potted into the composite structure to provide mounting points for threaded fasteners. To accommodate the insertion of threaded inserts to thinner regions such as the electrical enclosure walls, material thickness was added by way of 3mm laminate. The use of the threaded inserts served to provide greater ease of assembly/disassembly and negated the need for any through hole fastening, thereby reducing the risk of water ingress into the electrical enclosure and battery box through fasteners. Protection against water ingress at mating surfaces was accomplished with rubber gasket material and a silicone sealant.

The backpack harness brackets,which serve to secure and stabilize the unit during transit, were built as separate pieces from carbon fiber and then laminated with epoxy onto the surface of the battery box and electrical enclosure. This method of attachment provides an interlaminar shear strength approaching 14ksi[6], resulting in robust loading points for the backpack harness.

III. RESULTS AND DISCUSSION

A. Testing Overview

Validation of the prototype was carried out by conducting an in-situ test for three days in the Ouachita National Forest. Prior to the in-situ test, the battery was load tested using a battery analyzer to establish functional capacity and verify safe operation under electrical load.

B. Battery Load Test

Testing of the complete assembled battery was done with a West Mountain Radio CBA IV. Per the battery analyzer, a capacity of 41.76Ah was measured with a cutoff voltage of 9.5Vdc. The total watt hour capacity was calculated to be 526Wh by dividing the discharge graph into two sections and calculating the area under the curve for each section using an average value for voltage. However, a voltage drop of approximately 0.15Vdc between the analyzer and battery terminals was observed throughout the test. This amounts to a 6.26Wh discrepancy from measured vs. actual, which brings the total battery capacity to 532.8Wh.

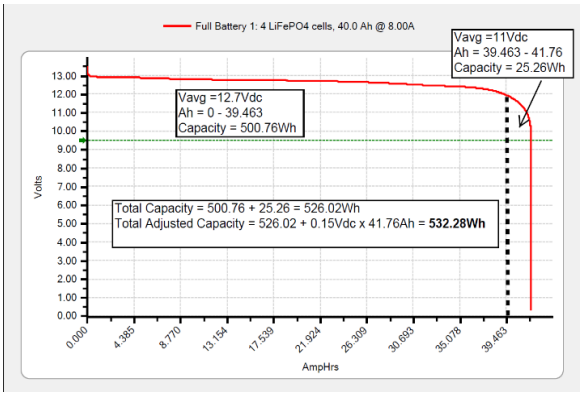


Figure 3 3 1 Battery Discharge Test

C. IPX3 Test

Validation of the unit's ability to protect the electronic components and batteries from ingress of water during transport in rain was done by conducting a modified IPX3 test as it closely emulates rainy conditions. The IPX3 test as outlined in IEC 60529 requires protection from water spray from an angle no greater than 60º from vertical. Duration of the test ranges from five to ten minutes[7] depending on the test apparatus used and the total surface area of the device being

tested.When using an oscillating tube, the test duration is ten minutes total with a 90º rotation of the tested device taking place at the five-minute mark.

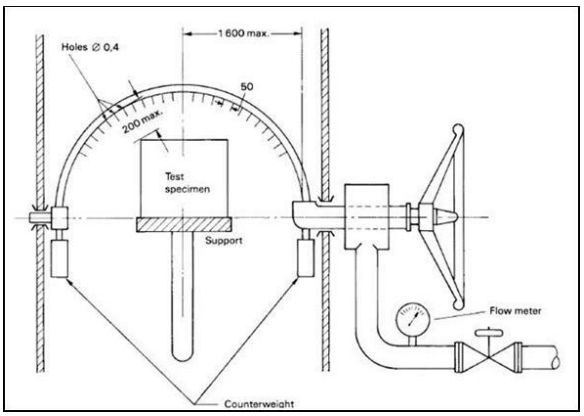


Figure 0-1Oscillating Tube – IPX3 Test

The water flowrate is dependent upon the tube radius, and a full list of flowrates as they correlate to the oscillating tube radius can be found in IEC 60529 [8]. In instances where the oscillating tube is not capable of fully soaking the tested device, a spray nozzle is permissible.

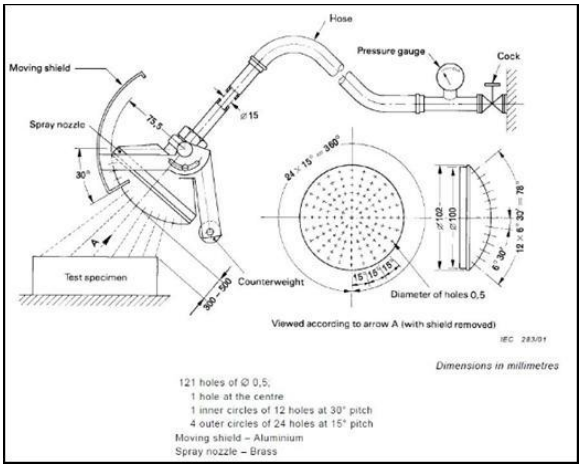


Figure 0-2 Spray Nozzle – IPX3 Test

A flow rate of ten liters/min is required when using the spray nozzle and for every square meter of surface area, one minute of testing is required with five minutes as the minimum time acceptable. Additionally, the attached shield is positioned such that a portion of the spray head is blocked, resulting in approximately 22 of the 121 nozzles having no effect on the test. When testing for the IPX4 standard, the blanking shield is moved out of the way entirely so that all 121 nozzles are used. To pass either test, the device must demonstrate functionality during the test if functionality is desired under the conditions tested. If testing in a mode where the object is not intended to be operated, then no water ingress is permitted, and the unit must function as designed when placed in an operational state. In the absence of an IPX3 oscillating tube or spray nozzle an alternate testing method was developed which emulated the IPX3 test closely. Using a standard flow shower head with a measured flow rate of 7.69 liters/min, a water ingress test was conducted for a total time of twelve minutes in three separate positions relative to the shower head. In the first position the angle of incidence relative to the shower head was varied +/-60º from vertical approximately by steadily tilting fore and aft. The second and third test positions were 90° counterclockwise and clockwise from test position one. Immediately following the conclusion of twelve minutes under water spray, the unit was taken outside for a test of functionality and to check for ingress of water into three key locations, which are the electrical enclosure front panel, the interior of the electrical enclosure, and the battery box interior. Prior to inspecting any of the areas in question, a towel was used to remove residual water on the exterior to ensure no water rolled into the regions being inspected for water ingress. Theelectrical enclosure front panel, which is accessed by removing the HMI cover via six snatch latches, was inspected first. Upon removal, the entire front panel was inspected, and no signs of water ingress were detected. At this point the unit was turned on by pushing the master switch to its on position and the coulomb meter was inspected to verify that the battery voltage was stable and that no unwanted current was being drawn other than the 0.2A that is standard for powering the USB charge port lights. It is important to note that the inverter was switched off for the first portion of the inspection. The next step was connecting the 40W solar panel to verify functionality of the charge controller. With an observed 17-24W of power coming from the attached solar panel, the charge controller was deemed operational. The last item to check was the inverter, which after being switched on began to sound its alarm and the coulomb meter displayed a wildly fluctuating discharge between 2-95W. The inverter was immediately switched off and preparations were made to remove the electrical enclosure to inspect the interior for the presence of water, which was a likely prospect given the behavior of the inverter. Once the EC was removed, water was quickly located inside the EC space and it was observed being in contact with the inverter board and the charge controller.





Figure 3 4a Entry Point 1 **Figure 3 4b Entry Point 2**

The gasket was inspected for signs of water passage but was not a likely suspect as its sealing ability had been enhanced by the application of 100% silicone sealant on both sides of the rubber gasket and the silicone had cured for two days prior to the test.

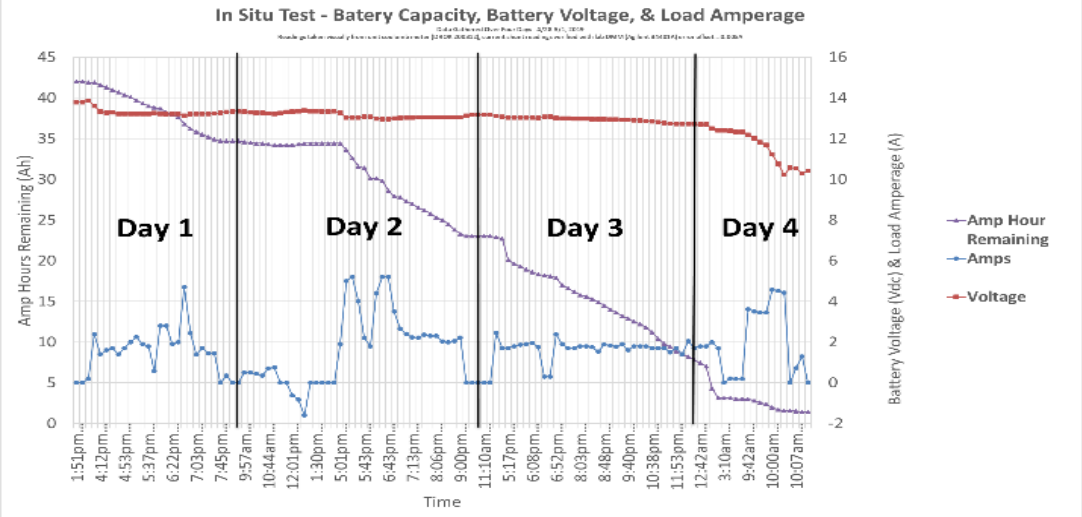


Figure 3-5 In-Situ Test Data

Next the electrical enclosure itself was inspected for possible points of entry and at least two were identified, all on the top side of the electrical enclosure. The final point of inspection was the battery box interior, which displayed no signs of water ingress, despite the presence of water inside the electrical enclosure.

D. In-Situ Test

To validate the design and system functionality of the Ambassador pack, a field test was conducted over the course of three days while camping in the Ouachita National Forest at Cedar Lake campground. In addition to using the pack to power a variety of electrical devices at the base camp, the author went on a hike each day of the trip with the portable power station pack to test the ruggedness, ergonomics, and overall suitability for transport through unimproved terrain. Total distance hiked was just over 16 miles with approximately 1,400 feet of elevation gain. While in camp, the portable power station was used to charge cell phones, run LED lights, charge a laptop, and power a 3D printer.This was done to verify system functionality with each circuit loaded simultaneously (5Vdc, 12Vdc, and 120Vac). Additionally, the recharge functionality via solar input was tested using a foldable 40W solar panel.



Figure 3-6 Camp Use of Portable Power Station

The data depicted in Fig. 3-5 was taken by hand with readings from the unit's state of charge (SOC) indicator approximately every ten minutes when any input or output was connected, and every hour when idle.The zero crossing of the amperage line on day two corresponds to when the solar input was greater than the amp draw of loads connected.Upon returning from the Ouachita National Forest the unit's battery was not completely discharged resulting in the continuation of data collection for one more day till the unit battery was at zero percent SOC. Loading of the unit continued in a similar manner while camping, with an oscillating fan being added as a load to accelerate depletion of the batteries charge.

E. Application

While much of the usage of the unit during electrical testing may seem random in the types of loads connected, they provided valuable insight into the run-times of potentially life-saving equipment, such as a portable ultrasound machine. A portable ultrasound machine's power consumption is similar to that of the 3D printer used during testing.

A cell phone is comparable electrically to a satellite phone and running an oscillating fan draws approximately 50W, which is the same amount a portable oxygen concentrator draws while in pulse mode. Table 3-1 outlines run times for a variety of portable medical devices and associated hardware that can be used by jungle medics to provide enhanced medical care in remote developing regions.

An example of how enhanced medical care has been used to save lives recently is told by Dr. Mitch Ryan, who works with Earth Mission Asia. He recently was able to save an infant's life by using an oxygen concentrator for a critical period of 12 hours. Without power to run the oxygen concentrator, the infant could

have developed long-term complications or possibly perished. It is for situations such as this that the research and development of the backpack portablepower station was undertaken, so that more stories like the one told by Dr. Mitch Ryan may come to be in the rural developing regions of Burma.

Run Time For Various Devices (Ambassador Capacity = 532.8Wh)					
Device Description	Supplemental Data	Manufacturer	Part Number	Power Consumption (W)	Min Runtime (Hr)
Portable Ultrasound	N/A	Mindray	DP-30/DP-30T	32	16.7
Portable Ultrasound	N/A	Whale	Sigma P5	43	12.4
Portable Oxygen Concentrator	Pulse Flow Only	Inogen	One G3	50	10.7
Portable Oxygen Concentrator	Continuous Flow - 0.5LPm	Phillips	SimplyGo	32.8	16.2
Portable Oxygen Concentrator	Continuous Flow - 1LPm	SeQual	eQuinox	45	11.8
Portable Oxygen Concentrator	Continuous Flow - 3LPm	SeQual	eQuinox	110	4.8
LED Lights	5W Lights x 2	Various	Various	10	53.3
Satellite Phone	N/A	Iridium	Extreme 9575	3.475	153.3
Laptop	N/A	Lenovo	P1	80	6.7
Cell Phone	N/A	Samsung	Galaxy S10	15.17	35.1

Table 3-1 Medical Device Estimated Run Times

IV. CONCLUSION

It has been shown that a backpack portable renewable energy storage and power management module for deployment in the rural regions of Burma can be designed and built such that jungle medics and IDP's can have access to a source of electrical power for providing enhanced medical care and improving quality of life. The ability to provide reliable power in areas accessible only on foot and over rugged terrain, with the ability to recharge via photovoltaic panels has been demonstrated with service times in the range of five to sixteen hours on a single charge.

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