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Multiple Renewable Input and Output Emergency Portable Power Supply

(Bekalan Kuasa Kecemasan Pelbagai Masukkan dan Keluaran yang Boleh Diperbaharui)

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ABSTRACT

Currently portable power supply unit either powered by diesel generator or solar powered are only able to supply for alternating current (AC) or single direct current (DC) loads. In this work, multiple renewable input and output emergency portable power supply (E-PPS) prototype were developed and the functionality were explored. The developed prototype usage duration was determined by varying electrical loads. Verifications were carried out to demonstrate E-PPS functionality and usage during emergency with Malaysian Health-care Department, Malaysian Civil Defence Agency, and Malaysian Royal Signals Regiment. It was found that E-PPS managed to successfully supply simultaneous power for both alternating current (AC) and various direct current (DC) loads at an average of 88% efficiency.

Keywords: Portable; multiple renewable; emergency power supply

ABSTRAK

Pada masa ini, unit bekalan kuasa mudah alih sama ada digerakkan oleh penjana diesel atau tenaga suria yang hanya mampu membekalkan beban arus ulang alik (AC) atau arus terus tunggal (DC). Penyelidikan ini berfokuskan kepada pembangunan prototaip bekalan kuasa kecemasan pelbagai masukkan dan keluaran yang boleh diperbaharui serta fungsi prototaip tersebut diterokai. Tempoh penggunaan prototaip yang dibangunkan ditentukan oleh beban elektrik yang berbeza-beza. Pengesahan dilakukan untuk menunjukkan fungsi dan penggunaan E-PPS semasa kecemasan dengan Jabatan Kesihatan Malaysia, Agensi Pertahanan Awam Malaysia, dan Rejimen Isyarat Diraja Malaysia. Hasil pengujian mendapati, E-PPS telah berjaya membekalkan tenaga secara serentak untuk kedua-dua arus ulang alik (AC) dan pelbagai arus terus (DC) pada purata kecekapan 88%.

Kata kunci: Mudah alih; pelbagai boleh diperbaharui; bekalan kuasa kecemasan

INTRODUCTION

Electricity is one of the most important blessings that science has given to humankind. It has also become a part of modern life and one of the necessities for living. One could not imagine a world without electricity especially with the introduction of electric cars and electricity powered transportations.

Numerous reports show in the absence of electricity or any power failure, the impact on the society is very huge, which causes not only discomfort but also major chaos as well as fatality. Health care industry and aviation industry are some of the critical electricity users, in need of continuous electricity supply. Since both industries play a major role in human life as most of the health equipment and aviation’s radar uses electricity to ensure its functionality, the continuity of power supply is very crucial. Apart from this, the search and rescue team also needs power supply to power up some of the equipment to save countless innocent life during any natural disaster or in any emergencies. With the changes of global climate, natural disaster such as hurricane, tsunami, flood, earthquakes etc., has become unpredictable and causes wide-scale power failure (Joo et al. 2014).

For instance, as reported in Cable News Network (CNN), eight patients died in a hospital due to lack of treatment provided since there was power failure triggered by the Irma hurricane in Florida, 2017 (McNoldy 2017 & Smith-Spark & Brocchetto 2017). Hence, it is very vital to have a backup power generator or supply especially at places that need power attention for critical usage such as in an ambulance, fire engine, search and rescue unit etc. On the other hand, the need for portable power supply for the usage in defence sector as an asset in counterterrorism and peacekeeping missions is also rising. The trend for future soldier program also acts as catalyst in increasing the need for portable power supply as most future soldier sensors needs electricity to function.

Portable power supply or generators have been serving in the power industry for a very long time through conventional generators using either petrol or diesel. However, this technology has many drawbacks in terms of pollution and harming the environment through its exhaust gas, noise, and the need to refuel for power generation. Currently, the trend for green and renewable portable power supply increases in the power market as more worldwide government initiatives in promoting green energy. This is as a measure for greener earth as well as addressing the global climate change due to greenhouse gases contributed by the previous carbon fueled energy. Besides that, the current generator is only able to supply in Alternating Current (AC) mode, which needs additional power converter in the case of Direct Current (DC) supply needed (Siasho et al. 2013 & Trotman & Pollock 1992).

In supporting renewable energy initiatives, many green portable power supplies have been introduced in the market mostly using solar power. However, the dependencies of solar power towards the natural sun light and the environment would reduce the reliability of the continuous electrical supply. Hence, multiple renewable inputs to charge the portable power supply would be preferred in order to ensure the reliability of the power supply. In other words, the developed prototype with combined multiple renewable input from solar, hand crank, and vehicle alternator would be suitable in various occasions than just the dependency on one source alone (Abdullah et al. 2017; Wang et al. 2014; Shyba et al. 2016). Moreover, the combination of green energy utilization would increase the power source availability and certainly more environmentally friendly (Singh et al. 2014). User-friendliness and portability are some of the main feature seek by the user for portable power supply as it involves logistics and provides plenty of advantages to the user during emergency and usage in the field (Ziadi & Ojidin 2015; Dolanc et al. 2014).

In recent development, solar powered portable emergency supply is the most popular renewable power supply. However, this system is only able to produce single AC and DC output with single input charging system such as solar or direct charging and stores the energy in either Lithium Ion or Lead Acid Battery. Therefore, this paper presents the developed prototype of multiple renewable input and output emergency portable power supply (E-PPS) using Lithium Ion (Li-Ion) battery. The charging and discharging of E-PPS were also explored through various experiment and presented in this paper.

TECHNOLOGY

RELATED TECHNOLOGY

The most popular portable power supply used is known as the diesel generator set. Although it is robust and able to supply electricity, yet this technology exhibits many drawbacks. Diesel or petrol as its fuel with noisy operating condition found to be some of its major disadvantages. Current instability in the global crude oil price adds up as major challenge to the users as this technology is fueled by either diesel or petrol. The cost of generation using this technology are even higher in the rural areas where the availability of diesel or petrol found to be limited.

Due to the drawbacks of diesel/petrol generator as well as with the increase of emphasis in the clean energy, many new portable power supply using solar power were introduced in the market. Although solar energy is fully weather dependent, the introduction of battery with its recent technology advancement made solar powered portable power supply more promising. The current solar powered portable power supply is able to supply up to 240 V_{ac} and some with either 24 V_{dc} or 5 $V_{dc.}$ On the other hand, one of the setbacks of solar powered technology is the initial cost of investment compared to conventional generator. The initial cost of investment found to be higher due to the solar type with battery and power inverter technology.

The current solar powered portable technology has limited output as well as limited charging input with lower power delivery capacity. In the case for same power delivery capacity (4000 W), the initial investment cost using solar powered technology increases 10 times compared to using the conventional generator. This can be seen clearly from Table I. Yet, in terms of portability, Z brand represented by diesel generator weighs nearly two times more than solar powered technology. This is logical as the generator consists of motor and lots of moving mechanical parts.

Table 1 compares the developed E-PPS prototype against existing products. Table 1 shows clear comparison whereby E-PPS is able to charge its batteries not only using solar but through various other renewable sources such as hand-crank and vehicle alternator. Although, Malaysia lies in the equatorial zone where there is abundance of sun-light made available yet Malaysia also receives equal rainfall too. During these rainfall, solar power would be unreliable, hence that is the inspiration behind the design of incorporating other renewable energy sources as charging input. Apart from that, with the design of internal battery charging, it enhances the ability of E-PPS to deliver power up to 4 kW at an affordable price and set to be competitive with diesel generator. Table 1 clearly defines the multiple input charging for E-PPS compared to other existing products as well as E-PPS capability to deliver various commonly used DC voltages to reduce the need for any additional DC converters.

TABLE 1. Comparison between E-PPS and existing products

TECHNOLOGY	 E-PPS	 X BRAND	 Y BRAND	 Z BRAND
COST (RM)	3227.00	2X XXX.XX	2 XXX.XX	2 XXX.XX
RATED POWER OUTPUT	4000W	4000W	120W	4000W
WEIGHT (Kg)	37	3X	7	7X
INTERNAL CHARGING	YES	NO	NO	NO
PORTABLE FRIENDLY	YES	YES	YES	NO
VOLTAGE OUTPUT				
240 Vac	YES	YES	YES	YES
5 Vdc	YES	NO	YES	NO
15 Vdc	YES	NO	NO	NO
24 Vdc	YES	YES	NO	NO
EXTERNAL CHARGING METHODS				
SOLAR CHARGING	YES	YES	YES	NO
HAND CRANK	YES	NO	NO	NO
VEHICLE ALTERNATOR	YES	NO	NO	NO

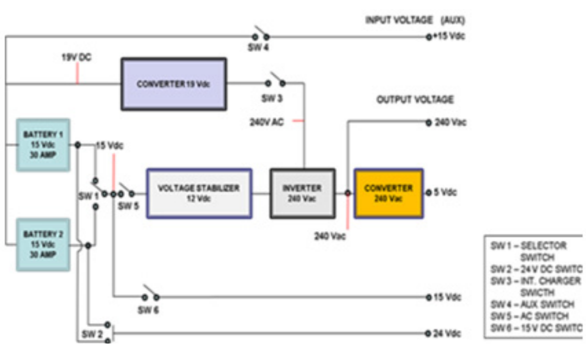

FIGURE 1. E-PPS block diagram

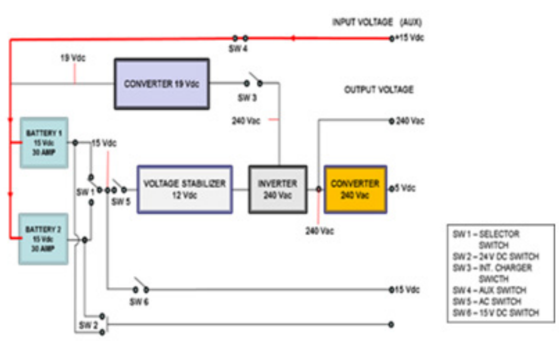

FIGURE 2. E-PPS in charging mode via external charger

Figure 2 shows current flow via auxiliary switch (SW 4) to charge both battery pack 1 and battery pack 2. This configuration functions during external charging mode whereby the input voltage connected to either solar, hand crank, or vehicle alternator. The same input voltage port can also be utilized to charge through wall-mounted plug using adapter. On the other hand, Figure 3 shows current flow in the internal charging mode where battery 1 charges battery 2 through internal charger switch (SW 3). It is not an automated process, when either battery in usage goes lower than 10 V, the voltmeter display will alert the user to switch on SW 3 for internal charging mode to function.

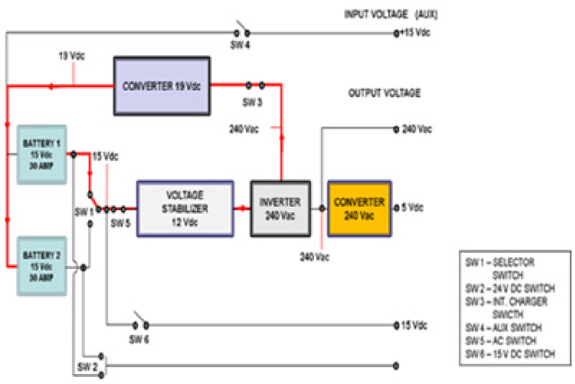

FIGURE 3. E-PPS Charges via internal charging mode

Figure 4 shows the current flow path in the E-PPS for multiple voltage output. In order to produce 24 Vdc, both batteries configured to be in series and switch (SW2) function as can be seen in Figure 4 in red line. Theoretically, 15 V_{dc} battery connected in series would produce 30 Vdc, yet when measured it only produces 24 V_{dc}, due to internal wiring losses configured for series connection. The green coloured line in Figure 4 shows the current pathway in producing 240 V_{ac} through the inverter and 5 V_{dc} through the converter. Referring to Figure 4, it clearly shows the blue pathway on obtaining 15 V_{dc} directly from the either battery connected through the selector switch. SW 1 situated between the batteries and other component known as selector switch used as the manual switch to turn on between batteries when either one goes below 10 V.

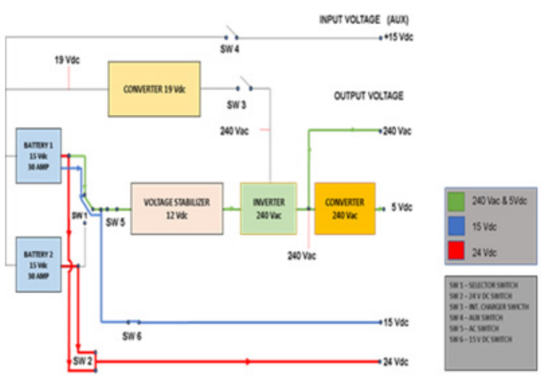

FIGURE 4. Current flow in E-PPS for various voltage output

METHODOLOGY

COMPONENTS

The developed E-PPS prototype consists mainly of 4 kW inverter, 12 V_{dc} and 19 V_{dc} converters, 60 A fuse for protection purpose, and Lithium Ion (Li-Ion) 7.5 Ah batteries. LCD were incorporated to display voltage for AC and DC as user needs to manually trigger the selector switch to select the higher voltage battery for usage. Table 2 summarizes the cost for the relevant components and total cost incurred. All paragraphs must be justified alignment. With justified alignment, both sides of the paragraph are straight.

TABLE 1. Components and cost (RM) for the development of E-PPS

No	Component	Qty	Per Unit Cost (RM)	Total (RM)
1	E-PPS Casing	1	570.00	570.00
2	DC Terminal	6	2.00	12.00
3	4kW Inverter	1	650.00	650.00
4	Converter $12V_{dc}$, 60A	2	13.50	27.00
5	60A Fuse	1	3.50	35.00
6	Converter $19V_{dc}$, 5A	4	35.00	141.00
7	Selector Switch	1	16.00	16.00
`8	LCD Display	2	16.00	32.00
9	Switch	5	5.00	25.00
10	Extension Board	1	20.00	20.00
11	$12V_{dc}$ Fan	2	13.50	27.00
12	Panel Mount Connector	8	5.00	40.00
13	Li-ion 7.5Ah battery	8	204.00	1632.00
	GRAND TOTAL (RM)			3227.00

E-PPS PROCESS AND PROTOTYPE

Prior to the circuitry assembly in the case, the case was drilled to make space for both AC and DC voltage output terminals and the pelican case was smoothened to make sure the edges are safe. The drilling process is shown in Figure 5.

FIGURE 5. Drilling the E-PPS case

Figure 6 shows the process undertaken to smooth the case after drilling process using sand paper. It took four hours to completely smoothen the entire E-PPS case and were rechecked several times in order to ensure the safety of the E-PPS user.

FIGURE 6. Application of sand paper on the E-PPS case

Next, the case was then sprayed with paint to ensure that the E-PPS becomes visually more appealing. The black colour spray was chosen in order to camouflage any disorder caused to the case by the earlier drilling and smoothening process. Spray paint was used in order to have some glossy effect on the case which adds up the aesthetic value to the E-PPS prototype. Later, once the paint dried, the circuitry assembly process was carried out as shown in Figure 7.

FIGURE 7. E-PPS circuitry components assembly

Figure 8 and Figure 9 illustrates the final completed assembly of E-PPS prototype with its exterior and interior view. The exterior view shown in Figure 8 clearly depicts three ports for 240 V_{ac} usage with 2 USB 5 Vdc ports available. On the lower part of the E-PPS, the external charging input 15 V_{dc} and voltage output for 15 Vdc and 24 V_{dc} terminals were located. All the switches including battery selector switch were designed at the top of E-PPS for the easier user accessibility. Both AC and DC voltmeter display were also designed on the top of E-PPS to ensure users comfortability in monitoring the battery usage.

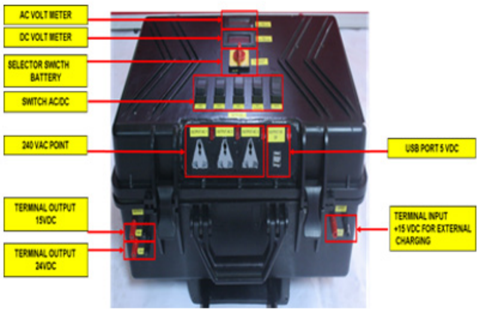

FIGURE 8. E-PPS exterior view

Figure 9 portrays the interior view of the developed prototype. In the earlier design, without the 12 V_{dc} fan, the prototype found to be extremely hot when utilized for more than two hours. Heat generated especially from the power inverter may affect the overall performance of E-PPS. Hence, two fans were incorporated into the design to act as a heat sink. With the introduction of both fans, E-PPS temperature reduced from 60 ºC to 32 ºC. E-PPS also intentionally has similar design to a travelling luggage bag with four wheels and retractable handle on top to increase the portability of it.

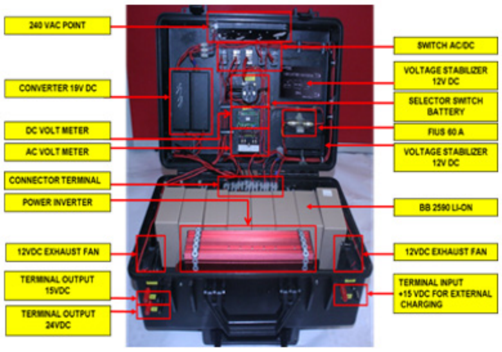

FIGURE 9. E-PPS interior view

CONDUCTED VERIFICATIONS

The developed E-PPS prototype functionality was then tested and verified against most of the health-care equipment available in an ambulance, then for the usage of defence communication equipment, and medical equipment owned by civil defence agency used during emergencies. Results from the performed test presented in the discussion and analysis section.

FIGURE 10. E-PPS tests at Armed Forces hospital (HAT MIZAN)

Figure 10 shows verification conducted with health-care equipment found in ambulance. E-PPS able to supply and operate for all health-care tools such as defibrillator patient monitor, nebulizer kit, Laerdal Suction Unit (LSU), as well as able to power up the oxygen compressor.

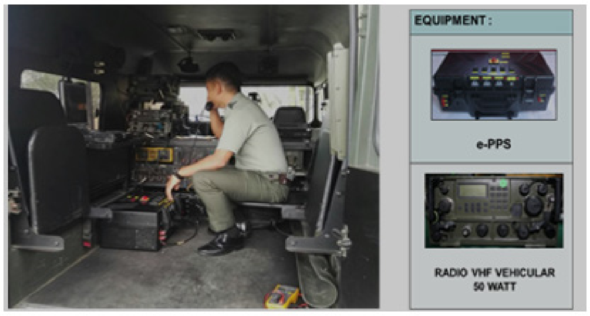

FIGURE 11. E-PPS tests at Royal Signal Squadron (Sungai Besi Army Camp)

Figure 11 shows verification conducted with military communication equipment. E-PPS was able to supply and operate for all communication devices such as vehicular high frequency and very high frequency radio sets.

FIGURE 12. E-PPS tests at Civil Defence Agency

Figure 12 shows verification conducted with civil defence agency equipment. E-PPS was able to supply and operate for all devices such as portable ventilator and communication equipment (GIRN).

RESULTS AND DISCUSSION

Table 3 represents the experimented time duration taken to fully charge the 30 Ah E-PPS battery using multiple charging input. From Table 3, utilizing vehicle alternator was proven to be the fastest to charge all eight Li-Ion batteries. Battery charging duration experiment was also extended by using main source 240 Vac just as reference and the obtained result is shown in Table 3. Detailed submission guidelines can be found on the journal web pages. All authors are responsible for understanding these guidelines before submitting their manuscript.

TABLE 3. Time taken by respective charger to fully charge 30Ah E-PPS

CHARGING TYPE	FULL VOLTAGE	DURATION FOR FULL CHARGE
PANEL SOLAR	24 V dc	54 h 23 min
HAND CRANK	24 V dc	72 h 00 min
VEHICLE ALTERNATOR	24 V dc	36h 00 min
MAIN SOURCE 240-V_{ac}	24 V dc	15h 20 min

In the initial design prior to the verification tests at site for emergency, E-PPS was also tested in the workshop with basic electrical AC and DC load. E-PPS was able to power up AC load of 550 W impact drill at full speed continuously for more than 10 hours and DC load of military radio manpack for more than five hours successfully. Table 4 summarizes the usage of 30 Ah battery for respective load and the estimated duration of supply by E-PPS.

TABLE 4. Functionality estimated duration of E-PPS with various AC and DC loads

BATTERY CAPACITY	LOAD TYPE	MAXIMUM CURRENT	ESTIMATED DURATION
AC LOAD			
30 Ah	40W TABLE FAN – FULL SPEED	0.41 A	73h 00min
30 Ah	40W TABLE LAMP – FULL BRIGHTNESS	0.16 A	187h 00min
30 Ah	550W IMPACT DRILL – FULL SPEED	2.29 A	13h 00min
DC LOAD			
30 Ah	USB PORT	2 A	15h 00min
30 Ah	MILITARY RADIO MANPACK	5 A	6h 00min
30 Ah	MILITARY RADIO VEHICLE	25 A	1h 2min

The developed E-PPS was run with full AC load and data obtained consecutively for two days to obtain its efficiency. Table 5 shows the input and output power obtained for the experiment through Fluke Meter. The overall average efficiency of E-PPS obtained at 88%.

TABLE 5. Experimented E-PPS inverter efficiency

INPUT POWER	OUTPUT POWER	EFFICIENCY
3120Watt	2795Watt	89%
2990Watt	2600Watt	87%

Table 6 tabulates the discharge duration of E-PPS for various load verified for its emergency usage at Hospital Tuanku Mizan, Civil Defence Agency, Royal Signal Squadron, and at Defence Industry. E-PPS was able to power up the equipment successfully as shown in Table 6 and receives testimonial letters from all the respective agencies. E-PPS exhibited the required efficiency, capability to provide AC and DC power simultaneously, and remain portable as well.

TABLE 6. Experimented E-PPS discharge duration in respective test sites

CAPACITY OF BATTERY	LOAD TYPE	MAXIMUM CURRENT	DISCHARGE DURATION
PERFORMANCE TEST ON MEDICAL EQUIPMENT AT HOSPITAL ANGKATAN TENTERA TUANKU MIZAN KUALA LUMPUR			
30 Ah	DEFIBRILLATOR PATIENT MONITOR	5A	5 h 30min
30 Ah	NEBULIZER KIT	1A	25h 00min
30 Ah	LAERDAL SUCTION UNIT (LSU)	2A	14h 20min
30 Ah	OXYGEN COMPRESSOR	1.75A	16h 20min
PERFORMANCE TEST ON MILITARY COMMUNICATION EQUIPMENT AT ROYAL SIGNAL SQUADRON SUNGAI BESI CAMP			
30 Ah	PANASONIC TOUGHBOOK	1.5A	18h 45min
30 Ah	SMART PHONE	1A	29h 00min
30 Ah	RADIO HF VEHICULAR	16A	1h 9min
30 Ah	RADIO VHF VEHICULAR	10 A	2h 45min
PERFORMANCE TEST ON MEDICAL EQUIPMENT AT CIVIL DEFENCE AGENCY			
30 Ah	PORTABLE VENTILATOR	2A	14h 10min
30 Ah	COMMUNICATION EQUIPMENT - GIRN	3A	9h 20min
PERFORMANCE TEST ON MILITARY COMMUNICATION EQUIPMENT AT DEFENCE INDUSTRY			
30Ah	MULTI CHANNEL RADIO SYSTEM (MCRS)	5A	5h 20min
30Ah	ANTENNA MASTWINCHING	10A	2h 45min

CONCLUSION

A working prototype of Multiple Renewable Input and Output Emergency Portable Power Supply (E-PPS) was developed successfully to provide electrical energy up to 4000 W. The developed E-PPS found to exhibit average efficiency of 88% in delivering the power. Experimental results successfully demonstrated the full capability of E-PPS to deliver simultaneously AC and multiple DC supply for various purposes and capable of internal charging between the batteries. This prototype has laid an important milestone in portable and renewable power industry by incorporating multiple charging inputs and various output to suit many requirements that may exist during emergency scenarios.

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DECLARATION OF COMPETING INTEREST

None

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