Theoretical case study of portable solar power unit

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1 Introduction

In today's world, energy has become critical. Energy price fluctuations can have an impact on daily anthropogenic activities that help to maintain peace and stability [1]. This is related to the fall in fossil fuel energy sources [2]. Fossil fuel pollution wreaks havoc on the ecosystem and raises global temperatures [3-4]. With the advancement of technology, the amount of energy required to maintain a high level of life has risen dramatically. As a result, we need to develop a means to gather energy via alternate techniques, as traditional methods such as burning deplete natural resources over time and pollute the environment. (Figure 1)

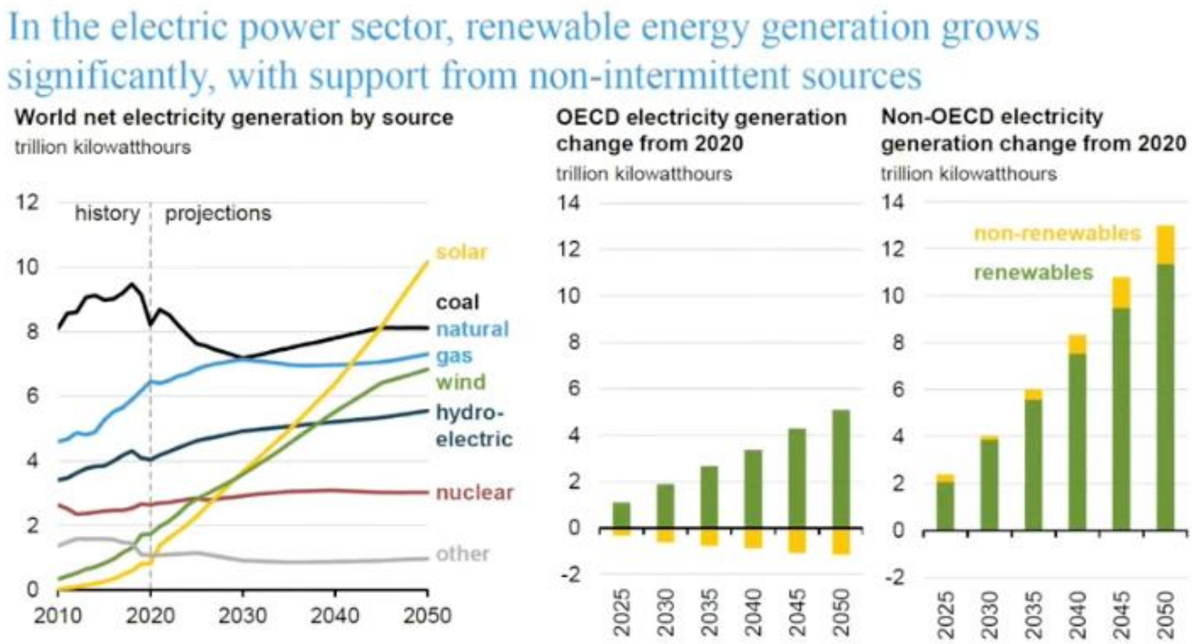

Figure 1 Growth and future projection of renewable energy for Electricity generation, OECD: Organisation for Economic Co-operation and Development, Image credit: International Energy Outlook 2021 [7]

Owing to its ability to mitigate climate change and meet CO2 target of reducing imposed by countries and international agreements, photovoltaic solar energy, or the acquirer of solar irradiance through photovoltaic panels to generate power, is viewed one of the most attractive opportunities in the investment of renewable energies. Solar energy, on the other hand, is not widely used in many poor nations. In 2018, fossil fuels and hydropower accounted for almost 92 percent of total energy consumption [5]. The biggest issue with solar systems is that they are still expensive when compared to other energy sources [6].

1.1 Growth of solar power industry

The output volumes of solar photovoltaic energy have increased virtually tenfold in recent years, as seen by the developing networks of solar installations and financing schemes throughout the world. Worldwide total installed PV capacity has reached almost 512 GW in 2019, accounting for around 2.5 percent of global power generation [8]. Global capacity might reach 2850 GW by 2035, and 8550 GW by 2050, according to estimates [9]. Other factors being constant, and assuming a solar panel's average lifetime is 24 years, photovoltaic deployment is expected to accelerate.

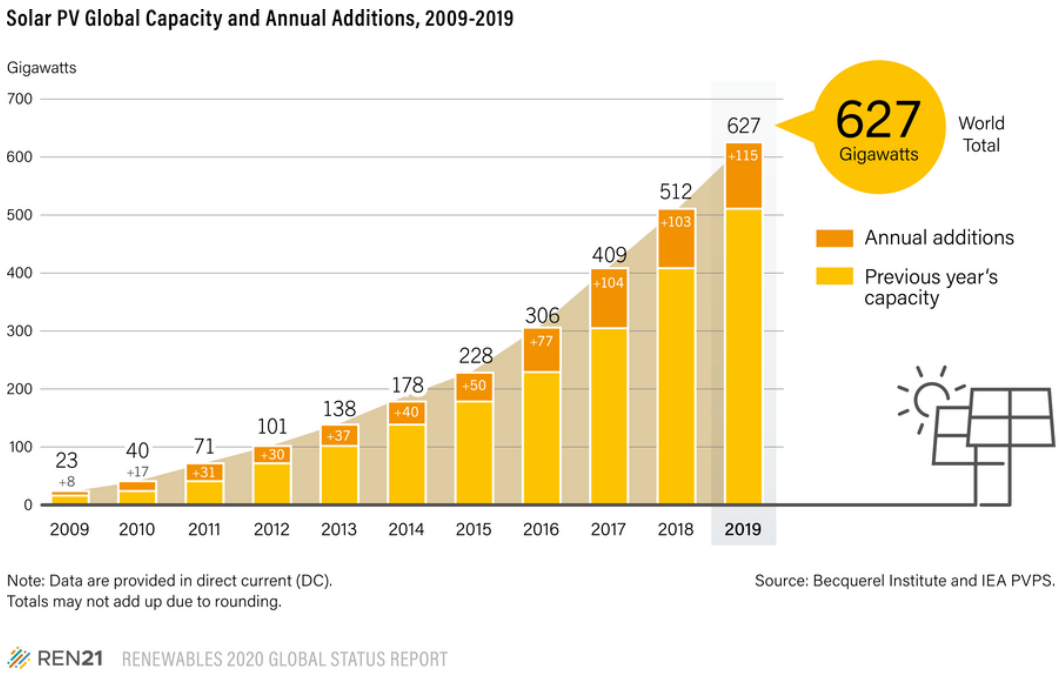

Figure 2 Solar PV global capacity, Image credit: Becquerel Institute and IEA PVPS [10]

2 Project objective

The objective of this report is to perform the theoretical case study of the design of portable solar power unit to generate electricity with means of solar energy. It has the potential to replace petrol generator, widely used by peddlers at night markets.

3 Solar cell

Solar energy is converted to electricity using solar cells. A photovoltaic panels is a p-n circuit device that does not receive direct voltage. A solar cell's basic concept is to transform light energy into electrical energy. Photons are little packets of light that convey light energy, which is mostly derived from the sun. Figure 3 [11] shows how photons of sufficient energy (higher than the material's bandgap) form mobile electron–hole pairs in a semiconductor. As a result, a solar cell transforms light energy, which is represented by a flow of photons, into electrical energy, which is represented by a flow of electrons. The photoelectric effect is the name for this phenomenon. Minority carriers created by light will be gathered at the p-n junction, where excited electrons will be collected.

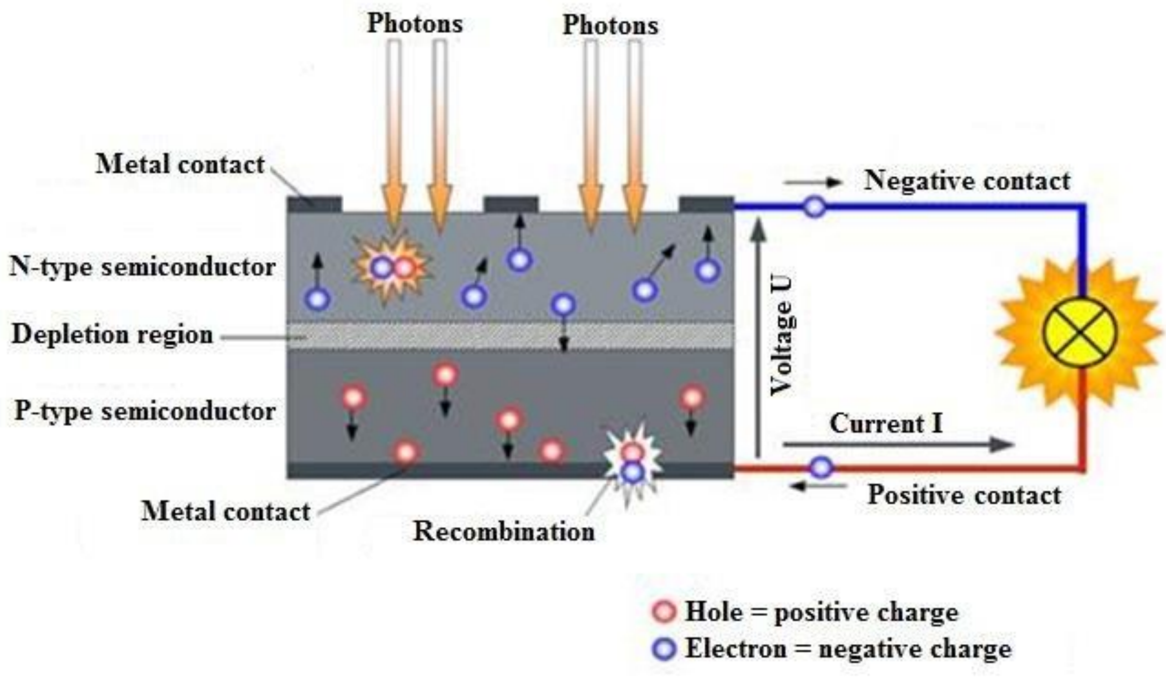

Figure 3 Working of solar cell, Image credit: A Kavaz et al. [11]

The high energy electrons will travel across the exterior circuit to combine with the vacancies in the p-region when an exterior load is connected all across solar cell, as seen in figure 3 [11]. Direct current is the flow of electrons through an external circuit that can be stored in a charging station. To power electrical equipment that require AC power, an inverter might be used to convert direct current (DC) to alternative current (AC). Tahsina et al. [12] built and constructed a micro-inverter for a solar household system as an example.

3.1 Material Used for PV cell

In recent years, photovoltaics have made great strides, garnering the most bizarre uses in our life. The vast availability of silicon, as well as related composite elements such boron and nitrogen, enable the fabrication of such solar panels on a continuous basis. Because of its stability, safety, and long service life, silicon solar cells are suitable for a wide range of applications. Their versatility allows them to be used in more niche sectors such as buildings and automobiles. Figure four, shows the current development in the P technology.

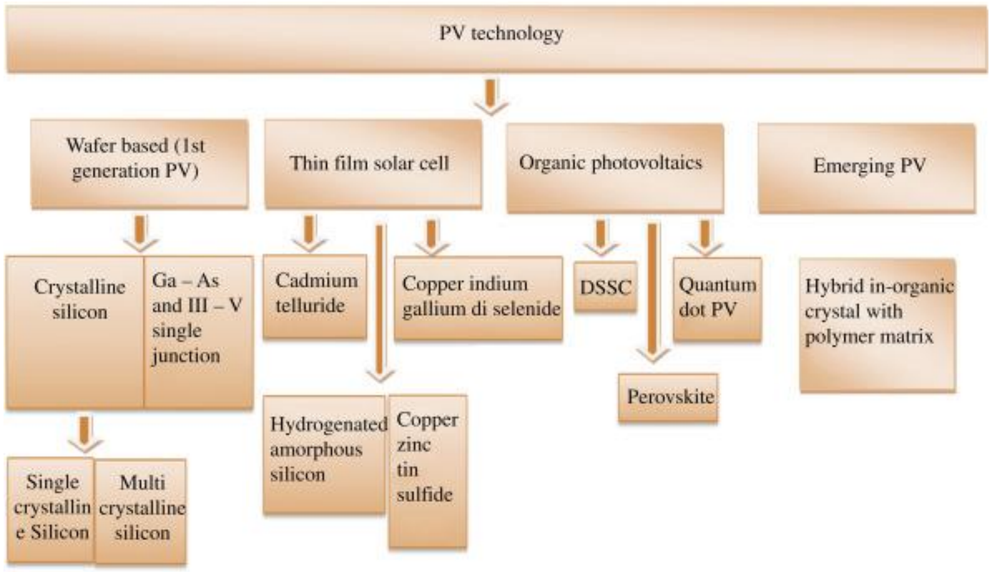

Figure 4 Current development in the PV technology, Image credit: Mustansar et al. [13]

Monocrystalline silicon, polycrystalline silicon, and amorphous silicon are the three types of silicon solar cells now available.

Monocrystalline silicon photovoltaic cells have the best conversion efficiency of up to 26% and are growing rapidly in recent years. Researchers have created a variety of solar cell architectures with good attributes by using a thin silicon layer as the light-trapping layer's substrate. Fang et al. presented an extremely thin flexible solar cell using silicon nanowires supported by a monocrystalline silicon substrate [14].

Polycrystalline silicon sun cells & amorphous silicon cells have lesser efficiency than monocrystalline silicon photovoltaic cells, however they are less expensive and produce silicon under less stringent conditions. Monocrystalline silicon also has a greater optical absorbance value, which means it performs better in low-light conditions and costs less.

Plentz et al. claimed to have developed a stretchable solar cell by selectively layering silicon onto glass fibre textiles [15].

4 Types of Solar powered systems

4.1 Grid Connected Systems

Solar panels, panel mounting, wiring, and an inverter are all included in a grid-connected system. DC power is generated when the sun's rays land on solar panels. This DC is sent through an inverter, which converts the voltage to AC. The extra power is then sent into the mains system.

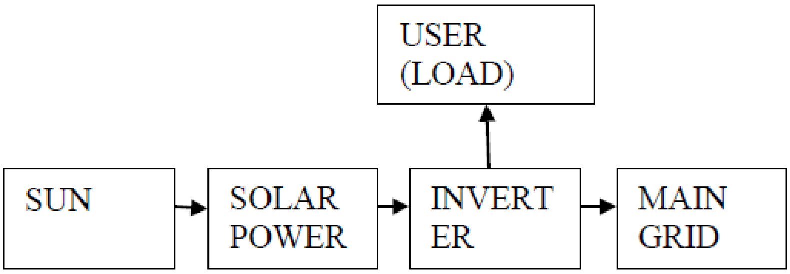

Figure 5 Block diagram of grid connected system, Image credit: [16]

4.2 Stand Alone Systems

The components of a PV stand-alone system are as follows. 1. A solar power system 2.Batteries 3.Inverter 4.Switches. The electricity from the PV rays is transferred to the batteries, which are then transferred to the inverter, which converts DC to AC. The electricity is sent to the base station from the inverter. The PV stand-alone system is depicted in the diagram below.

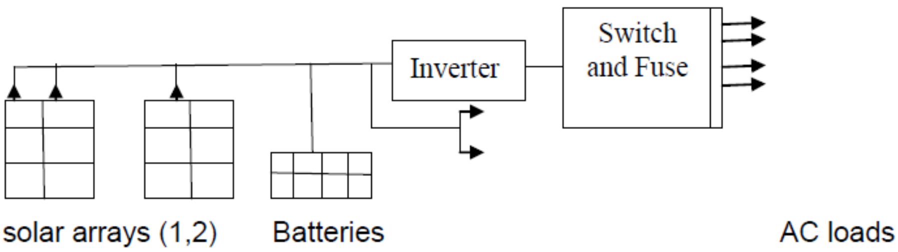

Figure 6 PV standalone power system with battery, Image credit: [16]

4.3 Stand Alone Hybrid System

This system is not reliant on a single source of electricity. A variety of power sources are employed. Stand-alone hybrid systems are divided into two categories. Diesel-powered hybrid system on its own. Fuelled stand-alone hybrid system [16].

4.3.1 Hybrid system with diesel

Because diesel is more cost-effective for generating electricity, diesel generators are combined alongside PV or wind in hybrids. In certain cases, a battery is utilised in conjunction with fuel. When there are daily changes in load, a battery is employed, and a diesel generator will be used for long-term fluctuations [17].

4.3.2 Hybrid with fuel cell

In this technology, a fuel cell replaces the diesel engine in metropolitan areas. Because diesel has a huge carbon footprint. As a result, using a diesel engine is not recommended. Emissions from a fuel cell are quite low. The emissions per MWh are 25gm. Electricity is generated in a fuel cell through a chemical process that does not affect the electrode or electrolyte material. Figure 7 depicts the fuel cell's construction. [18] When hydrogen from the air mix, electricity is produced.

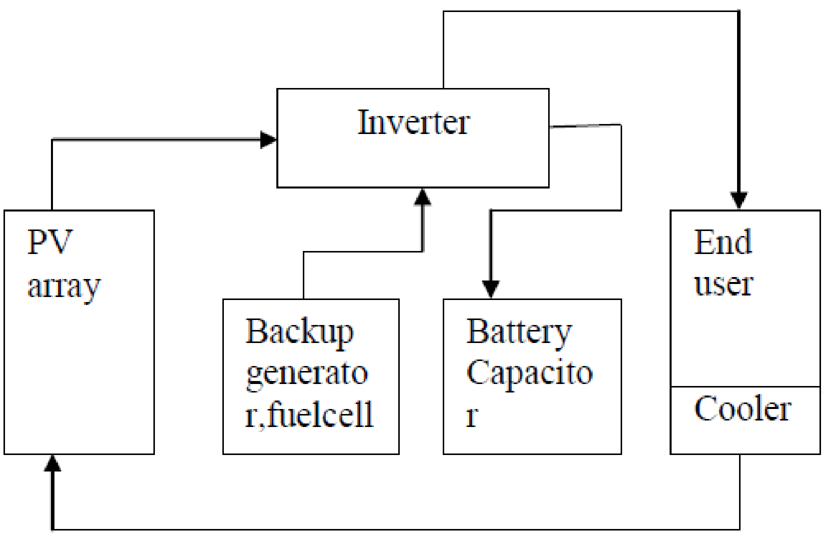

Figure 7 Block diagram of hybrid standalone solar system, Image credit: [18]

5 Components required in portable solar unit

In previous section we discussed about the solar cell and the solar powered system. In this section we will discuss about the different components required for the portable solar unit. The system architecture of the portable solar power unit is illustrated in Figure 8.

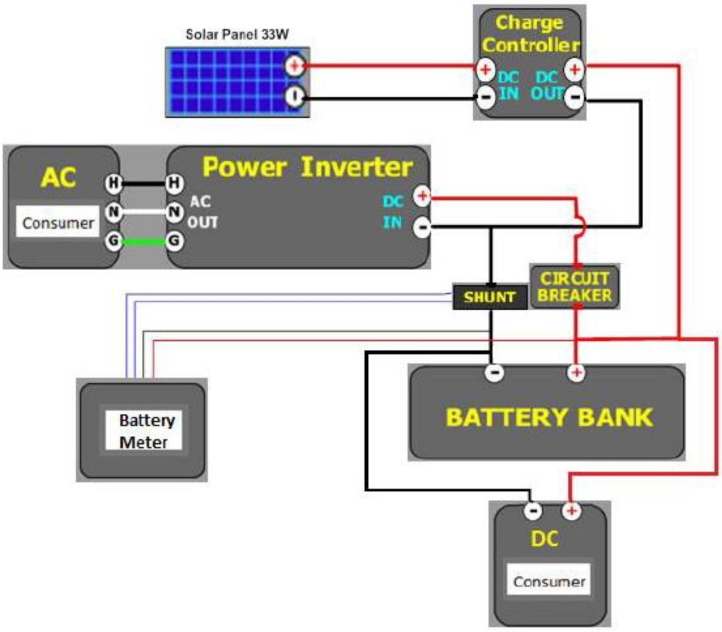

Figure 8 System architecture of the portable solar unit, Image credit: [19]

- Solar panel.
- Charge controller to avoid overcharging, which is bad for the battery's health.
- Voltage regulator for maintaining a consistent DC power supply of 5 volts.
- Inverter for transforming DC to AC power and stepping it up to 230V with the help of a converter should provide AC voltage for low-power household appliances.
- A battery indicator lets the user know how much voltage is remaining in the battery bank.
- A storage box containing all of the electrical circuits to prevent component damage as well as the risk of workers being exposed to excessive AC voltage.

Derrick et al. designed a portable Solar AC & DC Power Supply device. [19] The specification of the components used by them is shown in the following figure. Since, our device works on similar principle, this helps to get an overview of components specification.

Descriptions	Specifications
Input voltage of solar panel	12 Volt – 21 Volt
Inverter output voltage (AC operations)	220-230 VAC
Voltage regulator output voltage (DC operations)	5 Volt
Battery bank	12 Volt
Charge controller	Able to charge 12 Volt rechargeable battery
Battery meter	Display a range of voltage using LEDs

Figure 9 Component specification [19]

6 Hardware Design Theory and Calculations

Before moving on to the hardware design stage, several calculations must be completed. According to Ohm's Law, the current that flows through an electrical component in a circuit ought to be proportional to the voltage supplied while the resistance remains constant. We can now determine the capacity required to run various low-wattage appliances at 230V AC using the principles of Ohm's law. The computed power consumption for chosen hardware components is shown in Figure 9.

- This computation is based on the above-mentioned list of goods. Some of the appliances' power ratings were determined via online sites. Because each fluorescent bulb is rated at 20 watts, we used two of them to produce a total of 40 watts. Because the filaments bulb is rated at 30 watts, we used two of them to get 60 watts. Because we know the HP laptop draws 0.20A from a 230V AC supply, we may estimate its power consumption to be around 46W.
- The amount of watt hours needed to run them for two hours is (40+60+46)*2= 292 Watt Hours. The figure is used to determine when the battery needs to be recharged.

- 292*2 = 584 Watt Hours are required to run the devices for two days at a rate of two hours every day. During this, we'll assume that the consumption is solely from the battery, as there will be no solar energy available from the sun for the two-day period.
- We must double the consumption for two days by a factor of two to avoid depleting batteries to less than 50% of the full charged value, assuming no solar light is accessible for that period of two days. The battery's total Watt Hours need is consequently 584*2 = 1168 Watt Hours. This is significant because the battery's lifespan and performance can be improved if it is always charged at a level greater than 50% of full charge.
- For the time being, we must establish the size of the battery bank required for this design in ampere hours. Because the battery we'll be utilising is 12V, the estimated ampere hour need is 1168/12 = 97 Ampere Hours. If a 30 Ampere Hours pack is used, 97AH/30AH = 3, implying that three 40AH batteries are required.
- The final stage is to figure out what kind of solar panel you'll need. Because we want this model to be portable, we'll only utilise one solar panel. Humans estimate that we receive around eight hours of solar radiation every day. The daily usage, which is 230 Watt Hours in this example. To calculate the needed wattage of the solar panel, multiply 230 by 8*(watts of solar panel), which equals 230/8 = 28.75. As a result, while contemplating this design, a 30W solar panel will suffice.

7 Detailed schematic diagram of portable solar power unit

The schematic diagram of the system is shown in Figure 10. The power output of the system can be used to power the (direct current) DC and AC load simultaneously. The DC output is 12 Vdc and protected by a 15 A fuse. The AC output is a single phase 220 Vac modified sine wave using a 150 Watts peak power inverter with a 200 Watts surge and is protected by a 0.5 A fuse.

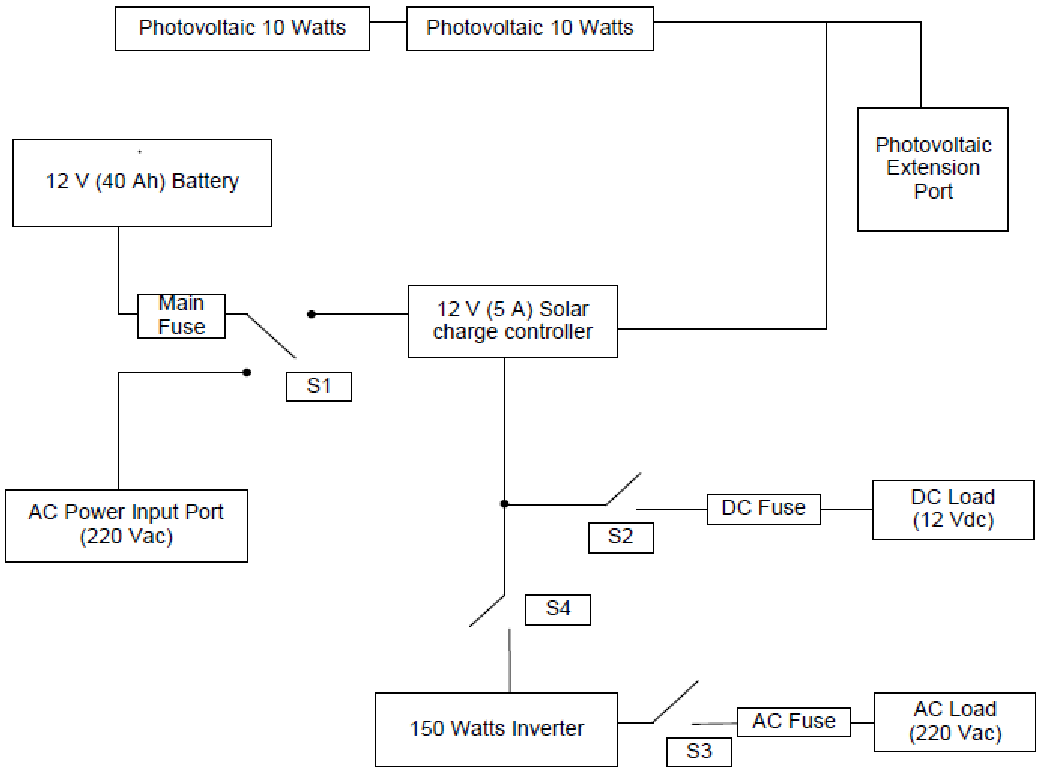

Figure 10 Detailed schematic diagram of portable solar power unit [19]

8 Conclusion

The theoretical case study of the construction of a small-scale, cost-effective portable solar power source is presented in this research. A solar panel is included with the device to absorb and transform solar energy into electrical energy. The electric power was collected in a battery pack that was regulated by a charge controller. To keep track of the battery storage capacity, a battery level indicator was installed.

9 Reference

1. Abdul Majid Z A 2011 Sistem pengering pam haba terbantu suria dengan pengumpul suria multifungsi. PhD Thesis, Universiti Kebangsaan Malaysia.

2. Sopian K 2006 Bringing Renewables into the Mainstream Proc. of the Malaysia Chemical Congress (MCC) Int. Conf. on Green Chemistry (Kuala Lumpur, 19-21 September 2006) pp 234-241.

3. Yatim B 1995 Inovasi Menghadapi Cabaran Bekalan Tenaga (Bangi: Penerbit Universiti Kebangsaan Malaysia) pp 31-32

4. Sopian K 2008 Tenaga Keterbaharuan – Laluan Masa Depan Bebas Karbon (Bangi: Penerbit Universiti Kebangsaan Malaysia) pp 14-15

5. Suruhanjaya Tenaga 2008 Industri Pembekalan Elektrik di Malaysia – Maklumat Prestasi & Statistik 2008. Kuala Lumpur Suruhanjaya Tenaga p 151

6. Henden L, Rekstad J and Meir M 2002 Thermal performance of combined solar systems with different collector efficiencies Solar Energy 72(4) pp 299–305.

7. Eia.gov. (2018). International Energy Outlook 2018. [online] Available at: https://www.eia.gov/outlooks/ieo/.

8. IRENA. Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects. Glob. Energy Transform. Pap. 2019.

9. IRENA. Global Energy Transformation: A Roadmap to 2050, 2019 ed.; IRENA: Abu Dhabi, United Arab Emirates, 2019.

10. Anon, (n.d.). In 2019 the solar PV market increased an estimated 12% to around 115 GW | REVE News of the wind sector in Spain and in the world. [online] Available at: https://www.evwind.es/2020/07/05/in-2019-the-solar-pv-market-increased-an-estimated-12-to-around-115-gw/75561.

11. ResearchGate. (n.d.). (PDF) Solar Tree Project. [online] Available at: https://www.researchgate.net/publication/322628682_Solar_Tree_Project.

12. Tahsina Hossain Loba & Khosru M. Salim, “Design and Implementation of a Micro-Inverter for Single PV Panel based Solar Home System,” 2013 International Conference on Informatics, Electronics and Vision (ICIEV 2013).

13. Handbook of Nanomaterials for Industrial Applications. (2018). [online] Elsevier. Available at: https://www.sciencedirect.com/book/9780128133514/handbook-of-nanomaterials-for-industrial-applications.

14. Fang X., Li Y., Wang X., Ultrathin interdigitated back-contacted silicon solar cell with light-trapping structures of Si nanowire arrays,Solar Energy , 2015, 116 , 100-107.

15. Plentz J., Andrä G., Pliewischkies T., Amorphous silicon thin-⍰lm solar cells on glass ⍰ber textiles, Materials Science andEngineering, 2015, B, 34-37.

16. Wind and Solar POWER SYSTEMS Design, Analysis, and Operation, Mukund R.Patel.

17. www.utilityfree.com/powerstation2.html

18. Cost Analysis on Solar Powered Radio Base Station with cooling Demand, by Christer Olsson.

19. Building of A Portable Solar AC & DC Power Supply Luo-Qi Soh, Chee-Chiang Derrick Tiew, 2014 Fifth International Conference on Intelligent Systems, Modelling and Simulation.