Advanced Un Interruptible Power Supply

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Abstract Tulkarm city experiences an unreliable electricity supply from the grid, making it crucial to explore options for enhancing the supply in areas that are most adversely affected by these issues. Power outages or disturbances in power lines can have negative consequences on critical loads, such as computer systems that control important processes or medical equipment. Additionally, due to the COVID-19 pandemic, education in Palestine has shifted towards electronic learning, making it imperative to have an alternative power source that guarantees a consistent energy supply for educational facilities. Although UPS technology has advanced significantly, it is still not widely used in residential electric systems in the region. The use of both solar power and UPS is on the rise, with solar energy being driven by cheaper solar cells, making it economically viable for a wider range of applications. This thesis concentrates on designing a UPS system that uses solar power for residential consumers. The study is comprised of two sections. The initial section is a computer simulation that utilizes MATLAB Simulink, which employs an exploratory approach and seeks to simulate a combined system before conducting physical experiments in order to verify the system's proper operation. The second section entails experimentation on a physical prototype system that utilizes fundamental UPS and solar power components. The findings from the prototype system indicate that integrating solar power into a UPS system does not significantly disrupt UPS functionality. The solar panels, which serve as an additional power source, can improve system performance under specific operational circumstances.

Keywords Tulkarm · UPS · PV

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1 Introduction

In Tulkarm, The infrastructure is in many areas deficient which have led to a devalued Network effectiveness with unstable power distribution throughout the region, due to the Israeli occupation's control over energy resources in the region. Power outages in these areas are therefore occurring many times per month. The vulnerability for power outages differs depending on which part of the society is struck. The hospitals, Educational facilities, homes, and small offices are notably vulnerable due to the importance of their operations. Many facilities get hurt, as well as some sensitive and expensive electronic devices that break down due to this sudden power cut every time.

An Uninterruptible Power Supply (UPS) acts as a secondary source of energy that safeguards loads during a main utility fault. The term "uninterruptible" refers to the primary objective of a UPS, which is to always be available and thus uninterrupted. Moreover, a UPS can also function as a filtering system that suppresses fluctuating frequencies and voltage spikes that may occur in the main grid. The UPS is composed of various power electronic components, each with a specific purpose. These components include a rectifier that converts incoming AC power to DC, an inverter that converts DC power back to AC, filters that suppress fluctuating frequencies or elevated voltages, and a backup power source, usually a battery. To achieve synergy within the UPS system, multiple switches direct the system between different modes [1].

Solar photovoltaic (PV) technology encompasses a wide range of applications and technologies. It is an electrical device that transforms the energy from sunlight, captured by photons, into electricity—a remarkable feat of nature and human innovation. A solar panel, which is a combination of separate cell units connected to a frame module, can be used to harness this energy. PV panels are made up of several solar cells, arranged in a unified set and located on the same plane. The panel is typically covered with a glass layer, which allows sunlight to pass through while safeguarding the semiconductor plate inside the casing [2, 3].

The primary advantage of utilizing solar power is its renewability and long-term viability, which can be optimized by proper orientation at the appropriate location. Additionally, solar energy doesn't produce any atmospheric pollution from nitrogen oxide, carbon dioxide, or other pollutants. Solar power is an endless, cost-free source of energy, unlike harmful fossil fuels, which are both expensive and damaging [4, 5].

The aim of the uninterruptible power system with solar cells is to offer an affordable solution for providing electricity to people living in areas with no access to power. It is easy to transport and lightweight, making it a convenient option for portable energy. What sets this device apart is its ability to charge the battery using two different sources—the first being traditional electricity from generators, and the second being solar energy harnessed through its solar cells [6].

Poor infrastructure leads to a decrease in network efficiency and unstable power distribution, resulting in frequent power outages that can disrupt critical processes

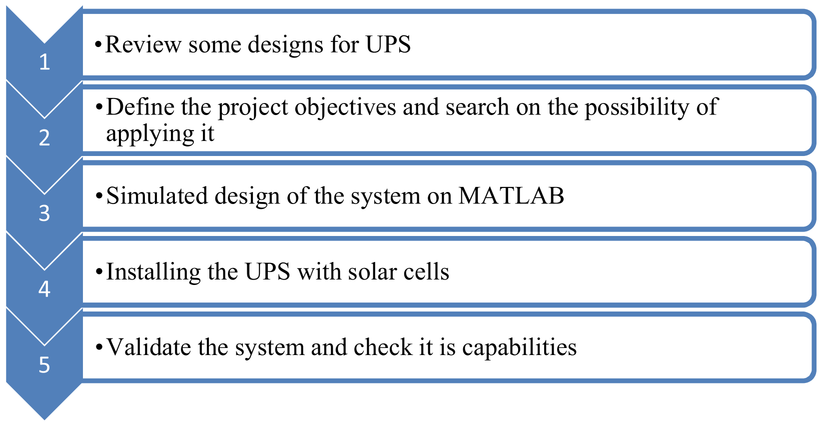

Fig. 1 Flow chart of the research methodology

such as education and healthcare. This can cause significant damage to facilities and expensive electronic equipment that can be adversely affected by sudden power cuts.

If a UPS be successfully combined with solar energy systems, many UPS system users may consider using their own solar energy. This would benefit the users, the general energy system and the environment [7].

Our research objectives can be summarized as:

1. Computer simulation using MATLAB Simulink to simulate a combined system before experimenting physically with it to ensure the correct functioning of the system.
2. Design prototype system based on basic UPS and solar power components.

2 Methodology

Figure 1 shows the flow charts of project methodology. The main overview of the prototype system is shown in Fig. 2.

One of the most important project stages is selecting the available and suitable hardware equipment. The system comprises of one outdoor solar panel RoHS TUV Tsolar/SP-10W. Mppt solar charge controller (efficiency 94–99%) and UPS MAKELSAN 2KVA. Two 12 V and 9AH Lead-Acid Batteries. After that, we build up a prototype of the system; Fig. 3 shows the main blocks used in the system.

3 MATLAB Simulation

MATLAB is an advanced analysis software with the ability to model power system components using the Sim Power Systems toolbox within the Simulink package. The toolbox includes a range of power system components, such as three-phase

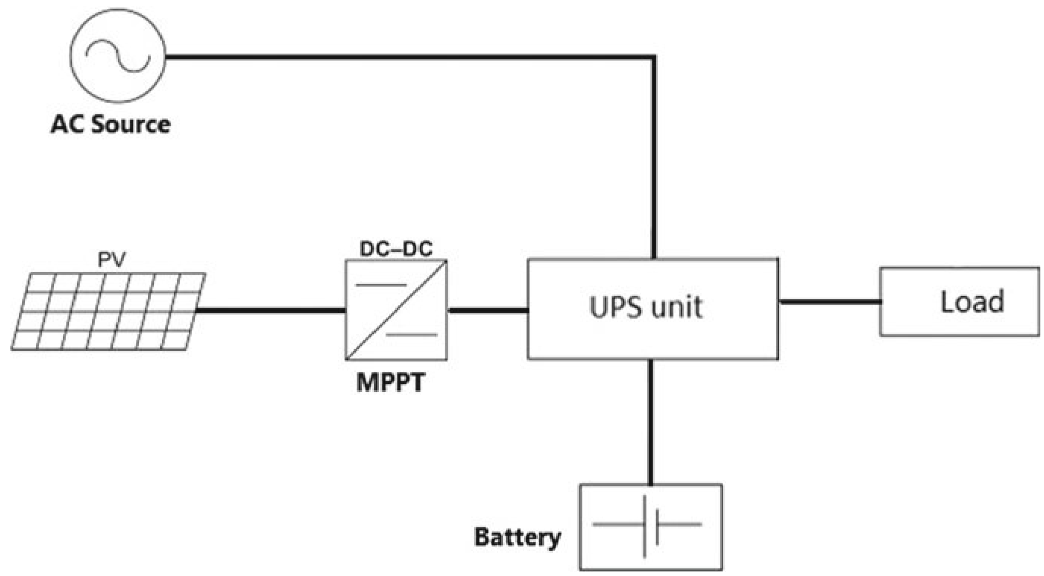

Fig. 2 Block diagram of the prototype system

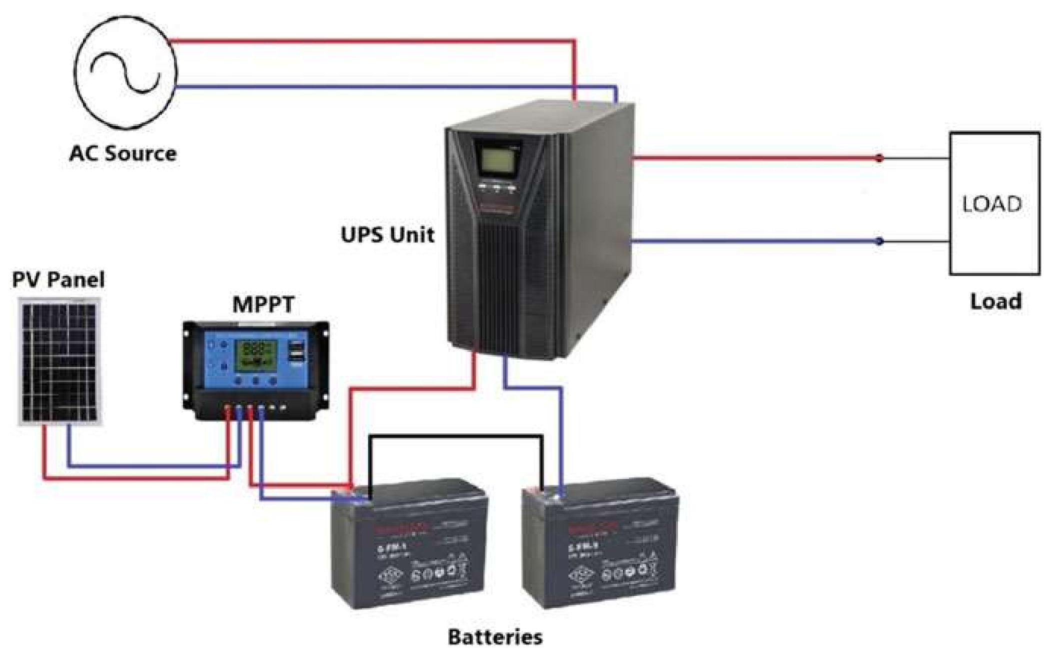

Fig. 3 The prototype of the proposed system

transformers, loads, distributed parameter lines, sources, circuit breakers, and more, that can be used for both AC and DC applications. These components are readily available and easy to use, as users can simply drag and drop them into their model file and input the relevant parameter values.

By creating a subsystem for the developed model, only one block set is required. This helps to minimize the use of space within the file, especially for complex

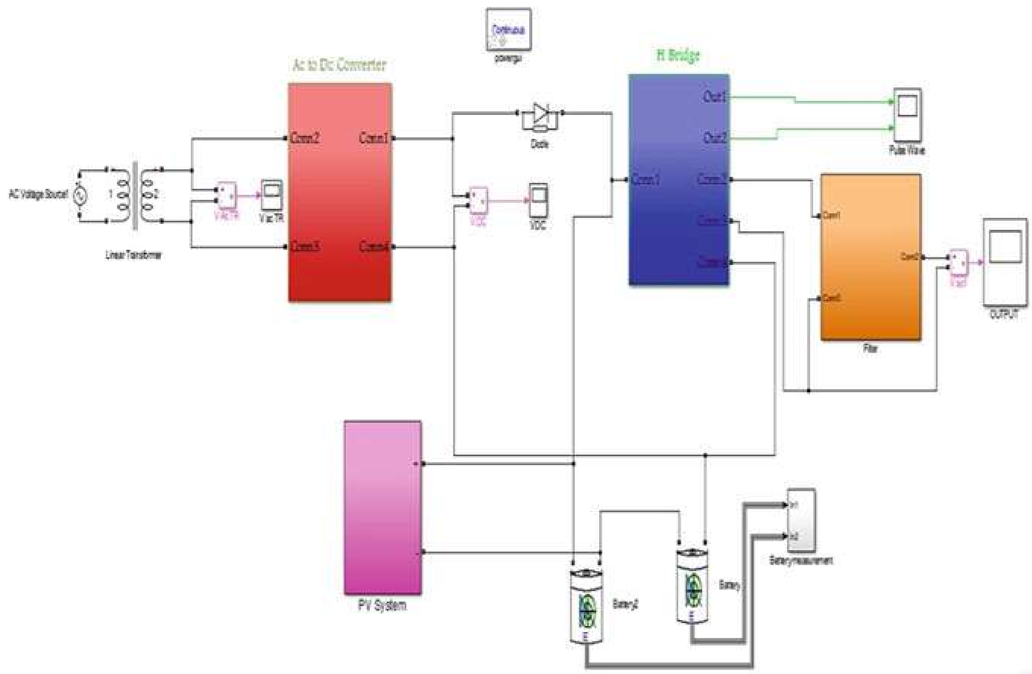

Fig. 4 Simulated system in Matlab Simulink

systems. Additionally, the created subsystem block set can be easily copied and pasted into any space or file, eliminating the need to build the model multiple times [8].

The primary objective of constructing the MATLAB simulation was to gain insight into how the actual system might function and identify potential issues that could arise. As such, the MATLAB system was developed prior to the physical system, which may result in certain limitations in the simulation's accuracy when compared to the prototype system [9].

To build the proposed system in Simulink, different modules are used. The components were taken from Simulink's library and some of these blocks were created as Matlab Functions or individual building blocks. Figure 4 shows the proposed Simulink model. Below these blocks were discussed in detail. The model has four major components: an AC–DC converter, a battery, a DC–AC inverter, and a PV system.

4 Simulation Results

The major task of the results of the MATLAB simulation is the learning obtained from designing and experimentation the system, and not the existing output of the final system. However, some outputs will be presented, that describe some insights gained briefly.

Figure 5 shows the input voltage from the grid which is 220 V RMS, this voltage is converted from 220 V RMS to 36 V RMS as shown in Fig. 6.

The output from the transformer is rectified to 49 V DC as shown in Fig. 7. The DC output from the rectifier will be converted using H-bridge. The blue pulses are used to biasing the MOSFETs 1 and 3, and the red pulses are used to biasing the

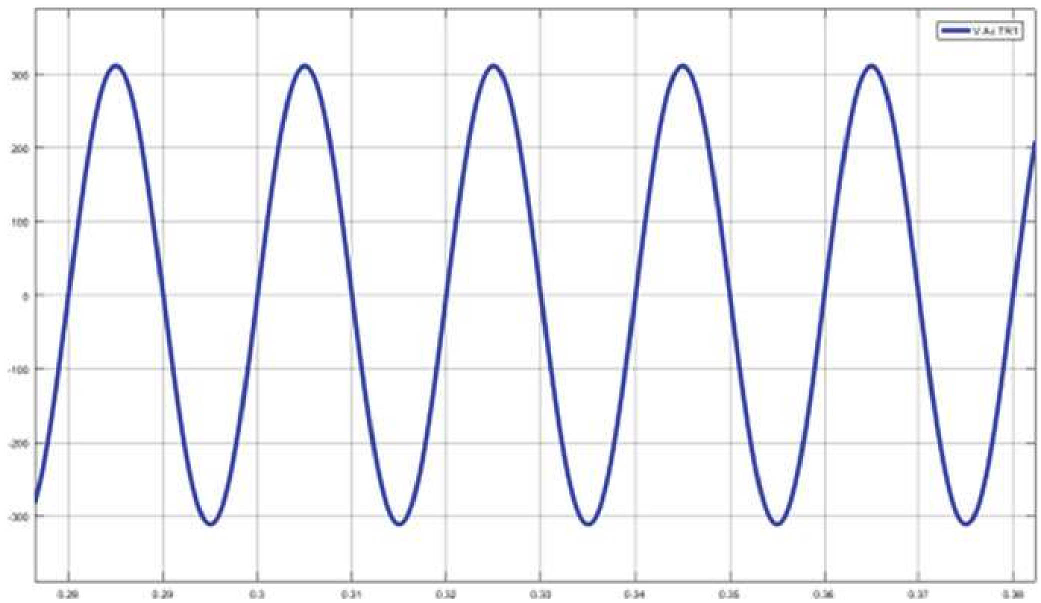

Fig. 5 Input from grid (220 V RMS)

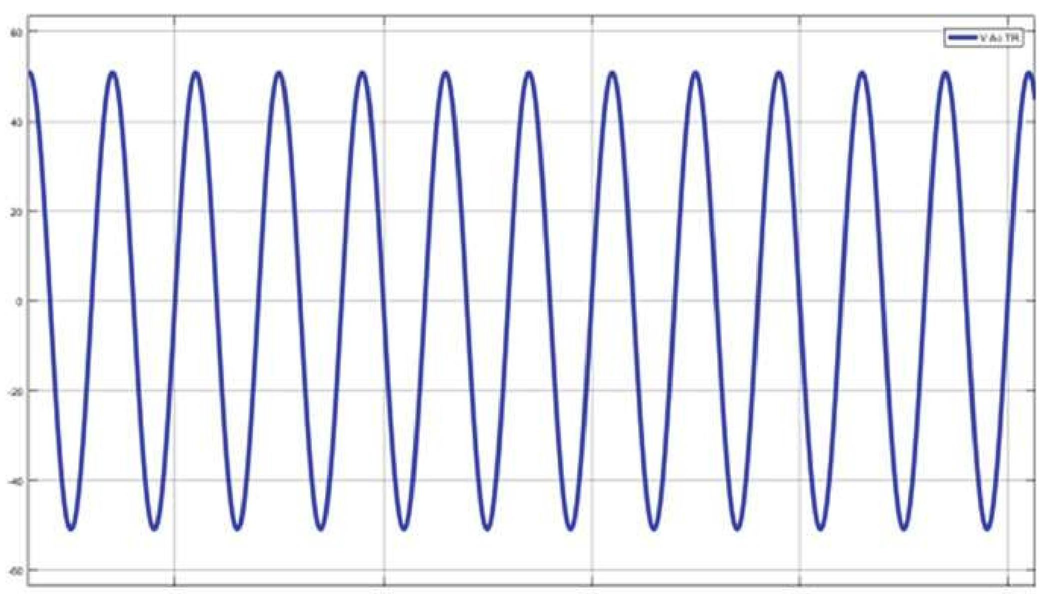

Fig. 6 Output from transformer (36 V RMS)

MOSFETs 2 and 4 as shown in Fig. 8. The output AC voltage from H-bridge is shown in Fig. 9.

The rectified DC voltage is connected with the output from the PV system and the terminals of the Lithium-acid battery. Figure 10 shows the output voltage from PV system that connected to DC bus.

This simulation work composed of two cases, First case simulates when the voltage supplied from the AC source is 220 V. Figure 11 shows the output voltage from the system for this case.

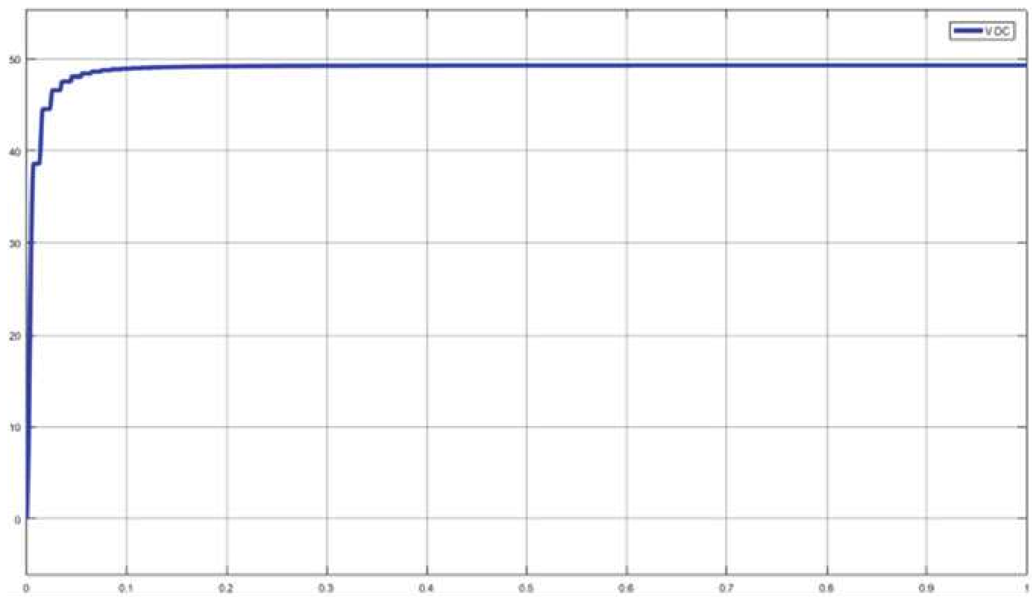

Fig. 7 Output from rectifier (49 V DC)

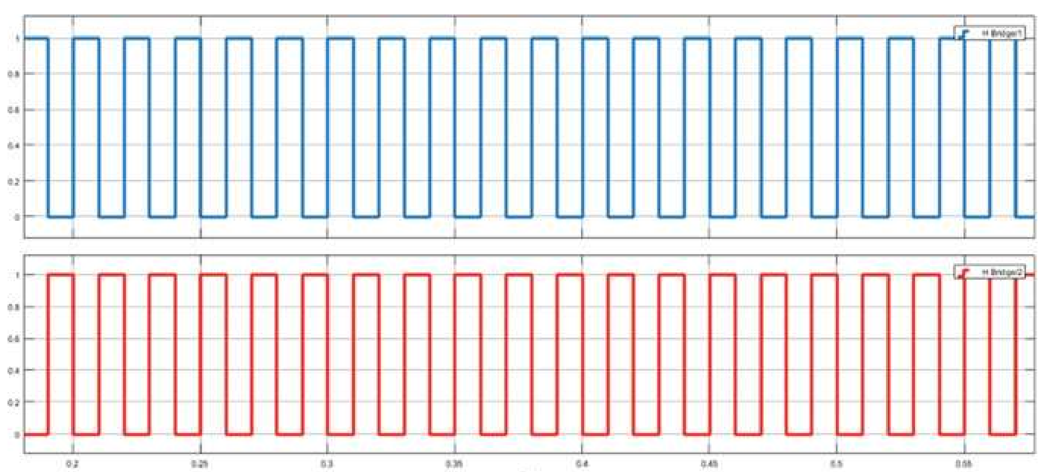

Fig. 8 Pulses wave to the MOSFET

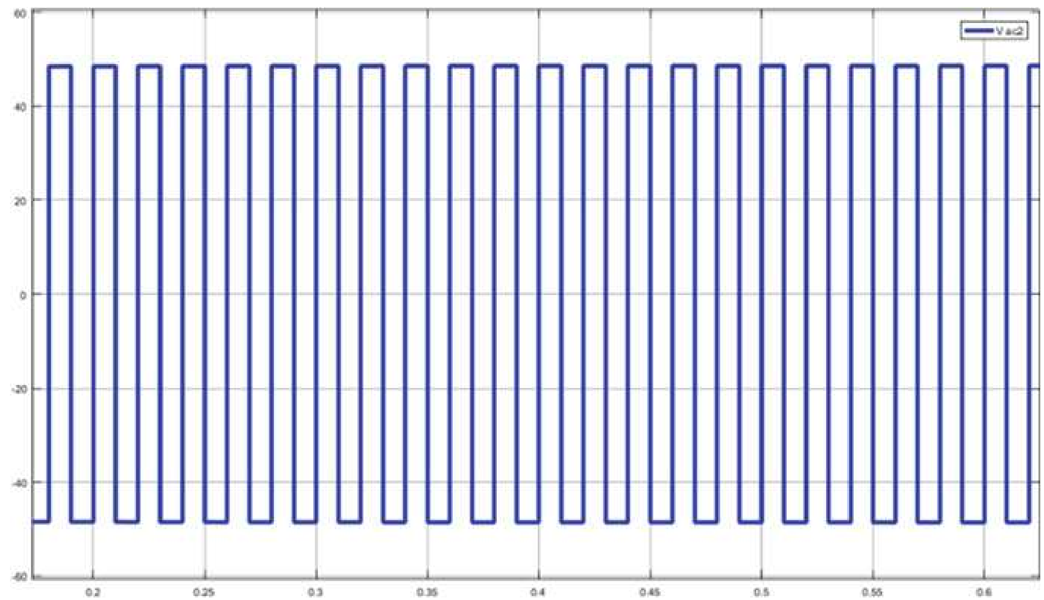

Fig. 9 Output from H-bridge

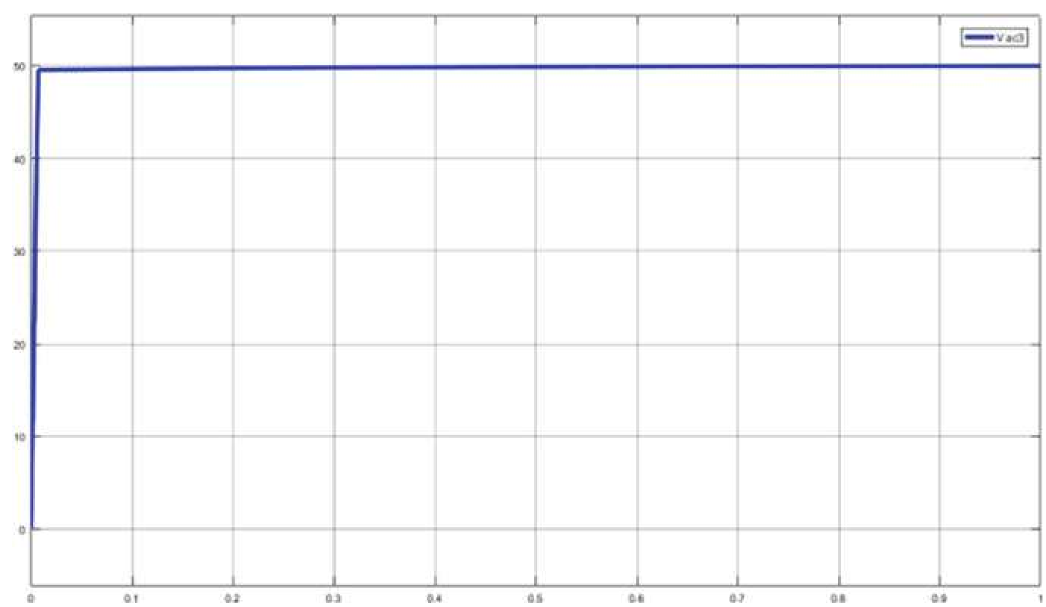

Fig. 10 Output from PV system (50 V DC)

The second case simulates when the network is interrupted (we put the voltage of the power supply to zero). Figure 12 shows the output voltage for this case.

The Simulink simulation conducted in this thesis led to the conclusion that significant knowledge was gained about the behavior of the system prior to its physical construction and experimentation.

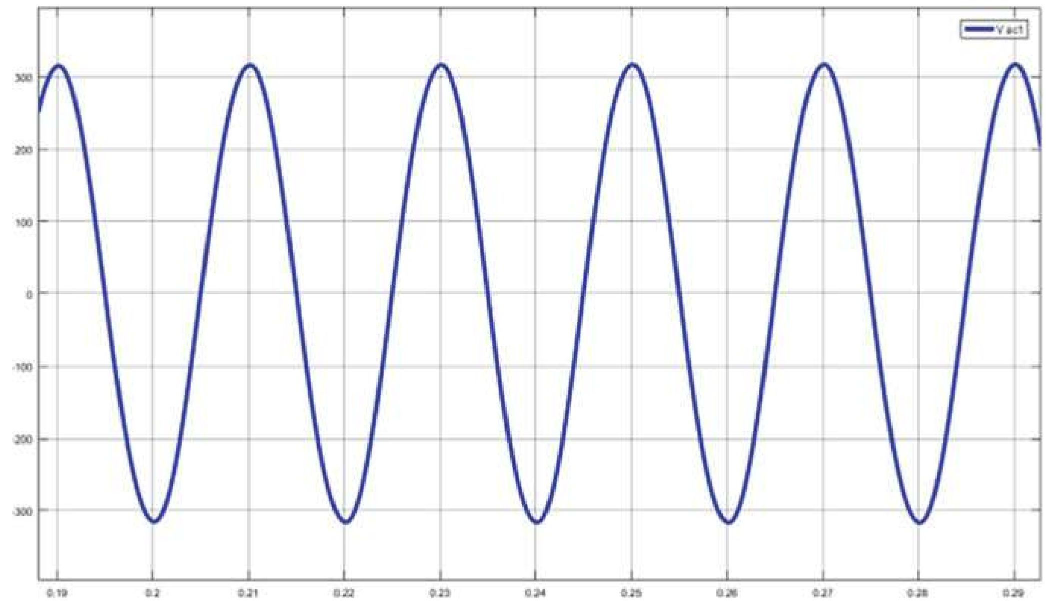

Fig. 11 Final output from grid (226 V RMS)

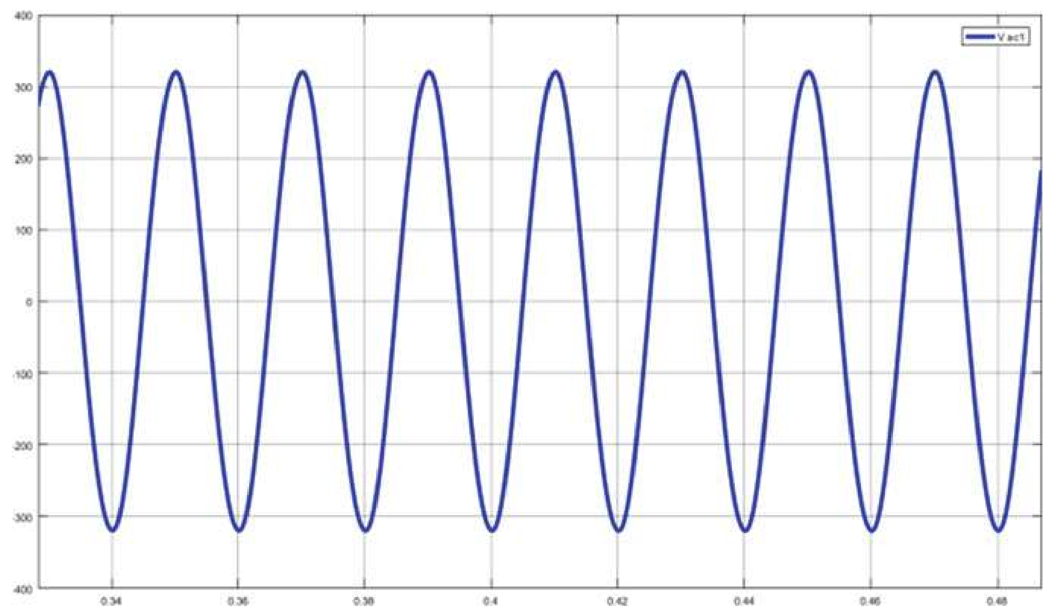

Fig. 12 Final output voltage from battery with power outage (220 V RMS)

5 Hardware Results

Table 1 represents the results from the prototype system when the solar output is varied from 13.3-V to 13.8 V, the output from the inverter is tabulated.

It is noticed that, when the solar panel is exposed to Sunlight the voltage developed across the solar charger circuit varies due to the solar irradiation. Figure 13 shows the

Table 1 Results from the prototype system for various ambient temperature

Solar output in DC	Inverter output in AC
13.8 (30 °C)	220-V (RMS)
13.3 (26 °C)	220-V (RMS)
13.0 (24 °C)	220-V (RMS)

output from PV when the ambient temperature is 30 °C, and when the temperature decreased to 26 °C and then to 24 °C the output from PV for the two cases are shown in Figs. 14 and 15.

Fig. 13 The output from PV when the ambient temperature is 30 °C

Fig. 14 The output from PV when the ambient temperature is 26 °C

Fig. 15 The output from PV when the ambient temperature is 24 °C

6 Conclusion and Recommendations

Based on the findings, it can be concluded that it is technically feasible to combine solar energy and UPS systems on a common DC line with only minor modifications. The addition of solar energy does not have a significant impact on the power quality of the UPS system. Moreover, in case of power outages in the electricity grid, solar power can benefit the system with less impact on power quality at the point of disconnection from the grid and also increase the autonomy time of the UPS. The project holds promising potentials for important social and environmental advantages. As solar cell technologies and power electronics continue to improve, such projects will become even more valuable and should receive more attention and support.

In future work, these options can be applied:

- To combine different renewable energy sources with UPS, an additional renewable energy sources such as wind energy can be combined.
- Add a control system would need to be able to handle more complex charging algorithms in order to optimize the system.
- Add protection device to save the system.

References

1. Skilbred, M., Rohlén, S.: Strategy for Designing Solar Powered UPS Systems-in Hospitals in Eastern Africa (2016)
2. Khamisani, A.A.: Design Methodology of Off-Grid PV Solar Powered System (A Case Study of Solar Powered Bus Shelter). East Illinois University, Goolincoln Avenue, Charleston (2019)

3. Foqha, T., Alsadi, S., Refaat, S.S., Abdulmawjood, K.: Experimental validation of a mitigation method of Ferranti effect in transmission line. IEEE Access **11**, 15878–15895 (2023)
4. Singh, S.K., Madhuraj, R., Kamat, R.K., Arya, V.P., Kumar, V., Roy, S.K.: Solar Powered UPS Systems
5. Alsadi, S., Foqha, T.: Mass Flow Rate Optimization in Solar Heating Systems Based on a Flat-Plate Solar Collector: A Case Study (2021)
6. Alsadi, S.Y., Nassar, Y.F.: Estimation of solar irradiance on solar fields: an analytical approach and experimental results. IEEE Trans. Sustain. Energy **8**(4), 1601–1608 (2017)
7. Nassar, Y.F., Abuhamoud, N.M., Miskeen, G.M., El-Khozondar, H.J., Alsadi, S.Y., Ahwidi, O.M.: Investigating the applicability of horizontal to tilted sky-diffuse solar irradiation transposition models for key Libyan cities. In: 2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA), pp. 9–14 (2022)
8. Maji, P., Ghosh, G.: Designing over-current relay logic in MATLAB. Int. J. Sci. Eng. Res. **8**(3), 40–43 (2017)
9. Bengtsson, T., Hult, H.: Combining Solar Energy and UPS Systems (2014)