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Design of Solar and Battery Hybrid Electric Vehicle Charging Station

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Abstract

Microgrids have emerged as a new way to integrate and use large-scale distributed power to provide electricity to isolated locations, such as islands and villages. A utility engineering microgrid structure is designed to provide fast response and efficient operation by analyzing hybrid power systems and fuzzy-PI-based control techniques. This project aims to design a solar photovoltaic (PV)-battery-diesel generator-based hybrid power system employing a Sepic converter. The Perturb and Observe algorithm is used for maximum power extraction from solar panel. A lithium-ion battery is utilized as a storage battery in this system, which may be charged by the PV source. When the storage battery is depleted and PV generation is unavailable, the charging station uses the grid and a diesel generator. The generated voltage is synchronised at the Point of Common Coupling (PCC) to achieve continuous charging. The simulation is done in MATLAB/Simulink. The simulation output of using the PI control strategy is compared with the fuzzy-PI control strategy. This demonstrates the efficacy of the fuzzy-PI control method.

Keywords: Solar PV array, converters, maximum power point tracking, backup battery, diesel generator set, grid, synchronization

1. Introduction

Electric Vehicles (EVs) are now one of the most fuel-efficient ways of transportation, emitting zero pollution. If the energy required to charge EVs comes from renewable sources only it is sustainable. As a result, using renewable energy sources can reduce emissions while also benefiting the environment. Solar PV-based generation is the most practical alternative for EV charging among the different accessible renewable energy sources, including solar

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energy, wind energy, hydro energy, and fuel cell-based energy. Despite the vast number of these fuels available, they will run out in a few years due to the daily drop in fossil fuel and oil levels. As a result, demand for renewable energy sources rises because they are environmentally favorable, lowering greenhouse gas emissions.

As a result, an EV charging station based on solar photovoltaic (PV), battery, and diesel generator is proposed. The proposed charging station is primarily intended to charge electric vehicles using a solar photovoltaic (PV) array. For voltage regulation a sepic converter is used. MPPT is a technique for extracting the maximum energy from fluctuating power sources. Here, Perturb and Observe algorithm is used.

A lithium-ion battery is utilised as a storage battery in this system, which may be charged by the PV source. When the storage battery is depleted and PV generation is unavailable, the charging station uses the grid and a diesel generator. The generated voltage is synchronised at the Point of Common Coupling (PCC) to achieve continuous charging. The objectives of this work are:

- To convert solar energy into electrical energy for charging electric vehicles in the charging station.
- To use MPPT with P&O algorithm to maximize energy extraction for solar energy conversion.
- To use PI and Fuzzy controller to synchronize grid parameters with Point of Common Coupling (PCC).

2. Literature Review

In [1] B. Singh discussed the implementation of a solar PV-battery and diesel generator-based electric vehicle charging station. In the event that the storage battery is depleted and solar PV generation is unavailable, the charging station draws power from the grid and a DG (Diesel Generator) set. In [2] B. Preetha Yesheswini discussed solar for charging electric vehicles. It supports multiple-port charging.

In [3] F. Chiou discussed EV charging with solar energy, the expanding number of EVs creates a significant demand for electric power, which has an impact on power grid. As a result, an alternate and clean source of energy to charge EV are necessary. In [4] B. Revathi discussed solar chargers for electric vehicles; the use of solar energy in conjunction with electric vehicle (EV) charging reduces our dependency on fossil fuels significantly. A converter is used for voltage regulation and MPPT is done to maximize the extraction of solar energy.

In [5] M. Akmal discussed the solar grid-connected chargers for electric vehicles, in this paper, the charging station is supplied with solar energy hence it reduces the problem of the additional load on the grid. In [6] A. M. Alsomali discussed the charging strategy for electric vehicles using solar, a charging network technique based on category prioritizing is presented. The power supply acts as a time multiplexer employing controllers, which is the fundamental component of this network logic, allowing the network to manage the time length for which the EV is supplied with power and overcoming charging bias.

In [7] D. Oulad-abbou discussed there are numerous topologies for a solar based charging station, increasing the use of converters. The primary goal, in this case, is to reduce the number of converters. In [8] M. Grosso discussed the photovoltaic system for EV charging, it provides numerous issues related to efficiency and storage. The challenge was further investigated, and an efficient battery management system was implemented.

In [9] F. G. Martínez explained the implementation of electric vehicle charging station using solar for small vehicles. The proposed system analyses varying loads on the battery bank of an EV, obtaining energy from the photovoltaic panel and backup batteries. Further, a prototype is built to understand the performance in detail.

3. Proposed System

Figure 1 shows the proposed system. The proposed system is to design a solar photovoltaic (PV), battery, and diesel generator-based hybrid electric vehicle charging station. It is primarily designed to use the solar energy to charge the electric vehicle (EV). This system employs a Sepic converter for solar panel voltage regulation. The Sepic converter acts as both buck and boost converter. Perturb and Observe (P&O) algorithm is used for maximum power extraction. Here, a lithium-ion battery is used as a storage battery. It is connected with a bidirectional converter so that it can be charged by the PV source and also charges the vehicle in the charging station. In the event that the storage battery runs out of power and there is no PV generation, the charging station draws power from the grid and a DG (Diesel Generator) set. The excess PV generation can be fed into the grid. The injected voltage is synchronized to the grid voltage at the Point of Common Coupling (PCC).

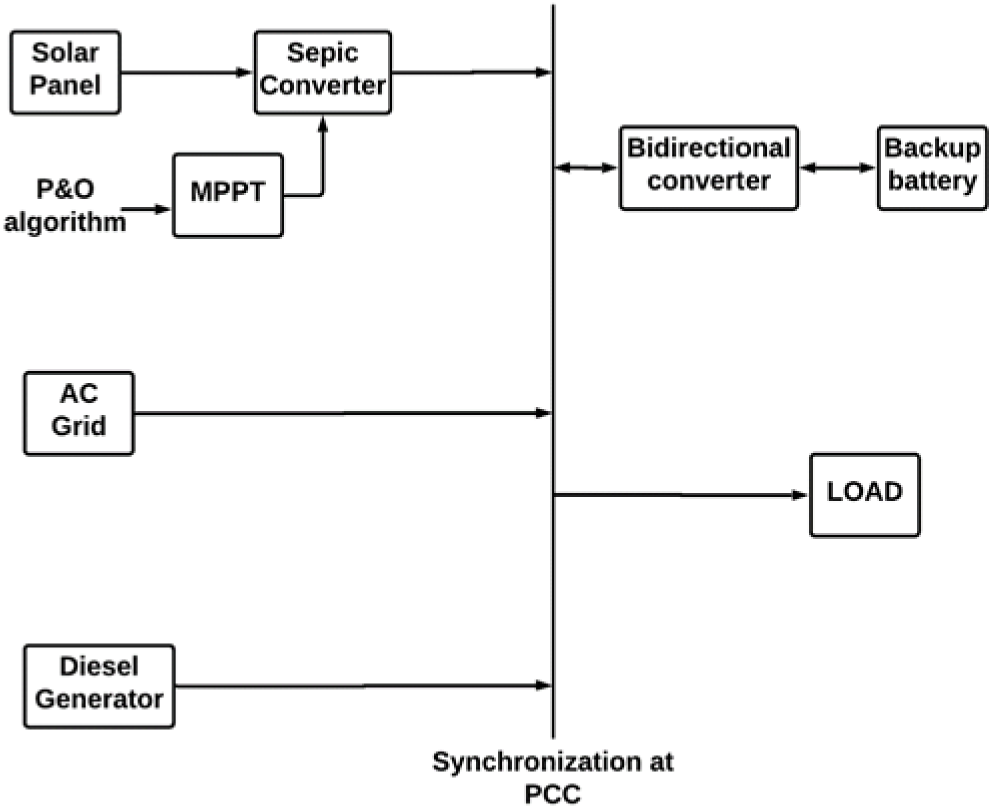

Figure 1. Block diagram of the proposed system

4. Control Algorithm

The synchronization algorithm of the proposed charging station is discussed below. The control is categorized into two parts,

- Off-grid operation.
- On-grid operation.

When the power of the solar PV array and the storage battery is adequate to meet the load's demand, the off-grid mode is activated. The PV panel voltage is synchronized with the grid voltage by comparing the phases of the two voltages using a PI and fuzzy controller. The errors are minimized and a new frequency is obtained. According to the new frequency, voltage is modified. In addition to the modified voltage, the PCC voltage is used to generate a gating pulse. The conditions checked before synchronization are,

- Whether the PV panel voltage is equal to grid voltage and
- Whether the phase error is within the standard limits.

Thus, the generated PV panel voltage is synchronized with the grid voltage.

5. Results and Discussion

The simulation is verified using MATLAB Simulink. The overall simulation is shown in Figure 2 which consists of subsystems such as battery system that includes bidirectional converter and storage battery, diesel generator system, MPPT control that consists of P&O algorithm and synchronization control that synchronizes the PV panel voltage to the grid voltage. The ratings of the solar panel are shown in Table 1.

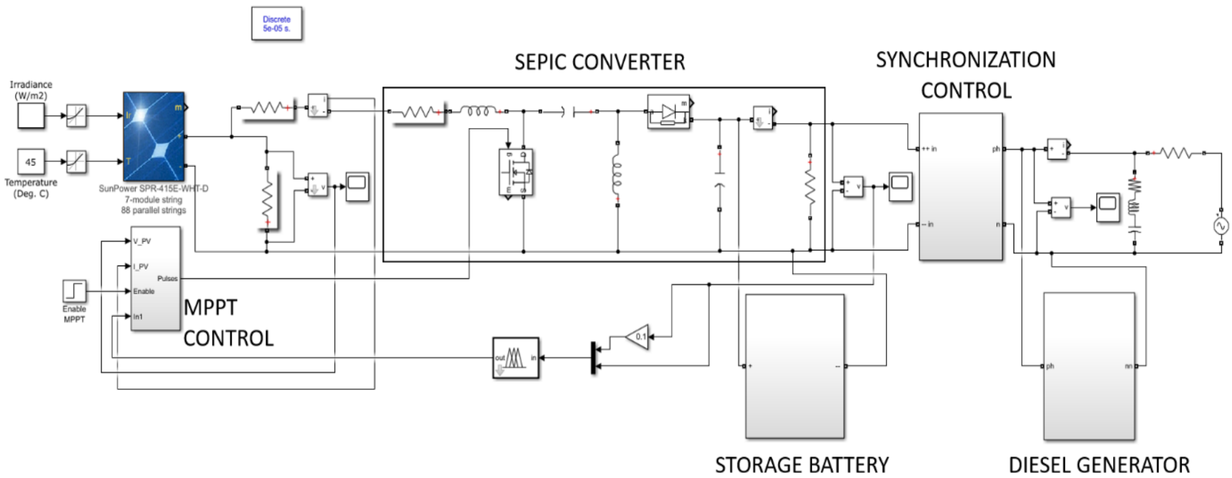

Figure 2. Overall simulation of the proposed system

Table 1. Solar panel ratings

Description	**Ratings**
Model	SunPower SPR-415E-WHT-D
Maximum power (W)	414.801
Open circuit voltage (V)	85.3
Short circuit current (A)	6.09
Voltage at MPP (V)	72.9
Current at MPP (A)	5.69

The temperature and irradiance provided to the solar panel are 1000 W/m^2 and 45^{o}C respectively. The irradiance is provided with a stair generator so that the amplitude is varied from 1000 W/m^2 to 500 W/m^2 which depicts the varying nature of the solar energy. The output voltage of the solar PV panel with MPPT using the P&O algorithm is 194.8 V. The PV panel output voltage is shown in Figure 3.

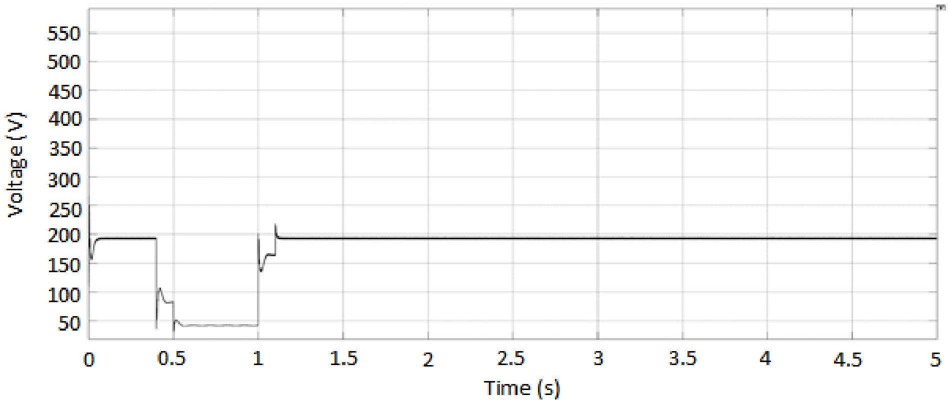

Figure 3. PV panel output voltage

The output voltage of the solar PV panel is fed to the SEPIC converter for voltage regulate based on the requirement of the load. Here, the output voltage of the sepic converter is 299.2 V as shown in Figure 4. The output voltage of the sepic converter is fed to the 300V DC bus.

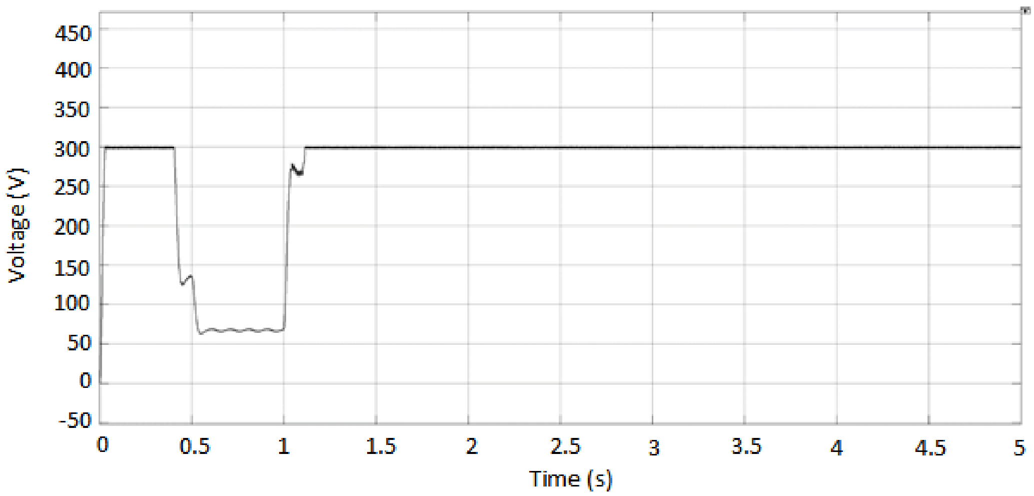

Figure 4. SEPIC converter output voltage

Here, 120V lithium-ion battery is used as a storage battery which can be charged by the excess generation of the PV source. A bidirectional converter is connected to the backup battery so that the battery can be charged when its charge is minimum and when the charge of the battery is maximum it can be discharged to feed the load. In the event that the storage battery runs out of power and there is no PV generation, the charging station draws power from the grid and a DG (Diesel Generator) set. The excess generation of the PV can be fed to the grid. The synchronization of the generated voltage with the grid voltage is done based on the control algorithm.

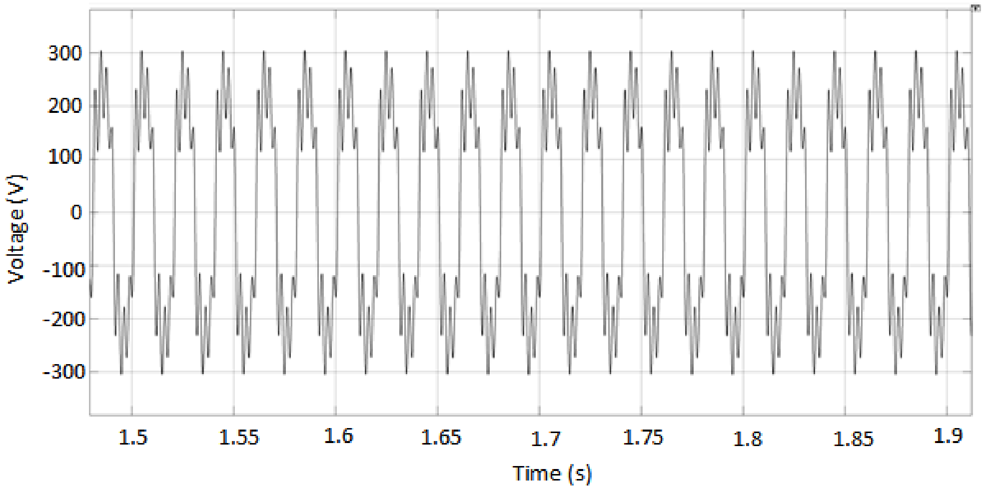

Figure 5. Grid injected voltage with PI controller

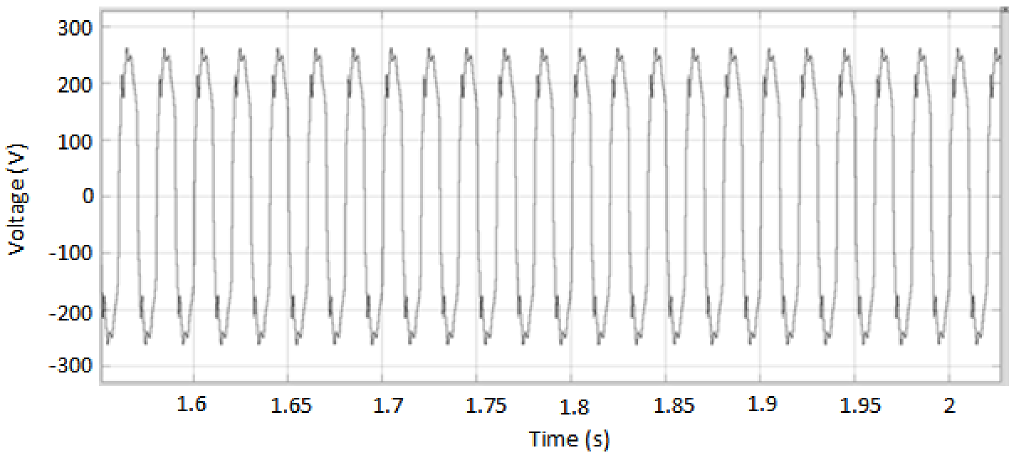

Figure 6. Grid injected voltage with PI and fuzzy controller

Here, the synchronization is done in two ways i.e., PI controller and a hybrid PI and fuzzy controller. On comparing the results of the grid injected voltage with PI controller shown in Figure 5 and grid injected voltage with PI and the fuzzy controller is shown Figure 6 clearly shows that the PI and fuzzy controller combination minimizes the voltage harmonics effectively.

6. Conclusion

The proposed system converts solar energy into electrical energy for charging electric vehicles in the charging station. For maximum solar energy extraction MPPT with a P&O algorithm is used. PI and Fuzzy controller combinations are used to synchronize the generated PV parameters to the grid parameters at Point of Common Coupling (PCC). Comparing the simulation results of the grid injected voltage with PI controller and the grid injected voltage with PI and fuzzy controller clearly shows that the combination of PI and fuzzy controller minimizes the voltage harmonics effectively.

References

[1] B. Singh, A. Verma, A. Chandra, and K. Al-Haddad, "Implementation of Solar PV-Battery and Diesel Generator Based Electric Vehicle Charging Station," in IEEE Transactions on Industry Applications, vol. 56, no. 4, pp. 4007-4016, July-Aug. 2020.

[2] B. Preetha Yesheswini, S. Jai Iswarya, B. Amani, P. Prakash, and M. R. Sindhu, "Solar PV Charging Station for Electric Vehicles," 2020 International Conference for Emerging Technology (INCET), 2020, pp. 1-7.

[3] F. Chiou, "Solar energy for electric vehicles," 2015 IEEE Conference on Technologies for Sustainability (SusTech), 2015, pp. 234-238.

[4] B. Revathi, A. Ramesh, S. Sivanandhan, T. B. Isha, V. Prakash, and S. G., "Solar Charger for Electric Vehicles," 2018 International Conference on Emerging Trends and Innovations In Engineering And Technological Research (ICETIETR), 2018, pp. 1-4.

[5] M. Akmal, A. Jawad, and A. A. Tarabsheh, "Design and Simulation of Solar Grid-Connected Charger for Electric Vehicles," 2018 UKSim-AMSS 20th International Conference on Computer Modelling and Simulation (UKSim), 2018, pp. 108-113.

[6] A. M. Alsomali, F. B. Alotaibi and A. T. Al-Awami, "Charging strategy for electric vehicles using solar energy," 2017 Saudi Arabia Smart Grid (SASG), 2017, pp. 1-5.

[7] D. Oulad-abbou, S. Doubabi, and A. Rachid, "Solar charging station for electric vehicles," 2015 3rd International Renewable and Sustainable Energy Conference (IRSEC), 2015, pp. 1-5.

[8] M. Grosso, D. Lena, A. Bocca, A. Macii and S. Rinaudo, "Energy-efficient battery charging in electric vehicles with solar panels," 2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 2016, pp. 1-5.

[9] F. G. Martínez, G. L. Magaldi and F. M. Serra, "Solar Charging Station for Small Electric Vehicles," 2018 Argentine Conference on Automatic Control (AADECA), 2018, pp. 1-6.