International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-8, Issue-6, November 2021
https://doi.org/10.55524/ijirem.2021.8.6.20
www.ijirem.org

Design of a Solar Charger for Electric Vehicles

Owais Nazir Lohar
M.Tech Student,
Power System,
Department of
Electrical Engineering,
RIMT University,
Mandi Gobindgarh, Punjab, India

Dr. Satish Saini
HOD, Department of
Electrical Engineering,
RIMT University,
Mandi Gobindgarh,
Punjab, India

Prof. Krishna Tomar
Assistant Professor
Department of
Electrical Engineering,
RIMT University,
Mandi Gobindgarh, Punjab

ABSTRACT

The current global trend towards electric vehicles is growing as governments and automobile manufacturers are focusing on agendas such as "going green", fighting climate change etc. The electric vehicle design is a core part for these. The Electric vehicles themselves run on electrical energy derived from an energy source, commonly batteries. These batteries need to be charged. For this purpose, a charging station needs to be provided. The charging stations or points convert the energy available to them through various sources to electrical energy in DC form for the vehicle. These chargers have to be able to accept user input, such as the amount of power to be delivered, such that the user can pay for as per requirement. In this paper a solar charging station with a local battery reserve is simulated for charging of an electric vehicle. This simulation lays the ground work for solar based designs for Electric Vehicle (EV) chargers.

Keywords

Feedback, Boost Converter, MPP, Solar Array.

1. INTRODUCTION

The advancement of electric vehicles began in the late 19th century, however were easily overtaken by the internal combustion system-based vehicles introduced in early 20th century. This was due to the inefficiencies and poor battery technology.

However, with the advent of more advanced lithium based high energy density batteries, EVs again became a viable option. It is predicted that EVs will eventually replace the current Internal combustion engine (ICE) technology completely by the end of this century. However, the electric grid and generating sources will be greatly stressed by the increased addition of these vehicles, as there energy demand on the grid is very large.

The Electric vehicle will replace the ICE based vehicles, means that eventually tens of millions of EVs will need to be charged. The energy for charging them cannot come solely from the current generating capacity.

There are several ways to counter this, such as using the micro-grid based designs and distributed generation and use of renewables. In this report the use of solar photovoltaics will be explored using a simulation in Simulink the block programming part of the MATLAB software from Math-Works.

2. LITERATURE REVIEW

The drastic change in weather patterns in the last hundred years is being attributed to a phenomenon called global warming. This is, as told by studies an effect of changing human technology especially the increase in the release of gases which trap the heat in atmosphere such as carbon dioxide, nitrogen oxides etc. [1-2]. The use of renewables has been proposed as a means of reducing the influx of these gases into atmosphere, to limit the damage. The cost of these renewable sources has also drastically come down in the past decade and they are now a very beneficial alternative to traditional energy generation methods. [3] The idea of charging electric cars using these renewable sources is not new. However, the design of the chargers has not been yet explored in detail. They have explored locations, timings and the effect of climate on the use of these renewable sources for charging. [4-10]

Earlier researches have mostly focused on using the traditionally available sources for charging electric vehicles, like thermal power, hydro power etc. and optimizing those sources. [8][11]

The reason we are exploring solar photovoltaic (SPV) based charging is because sun is the largest source of energy for earth, with energy received by earth being above 100TWh. This can drastically reduce the stress on the grid which might be induced by the increased electric vehicles in road. [12-13].

3. OBJECTIVES

The objective of the simulation is to make a working model for charging an EV battery using a combination of photovoltaics and battery storage and also design a means for monitoring the energy flow as well as the flow control for power.

3. SYSTEM ANALYSIS

Solar PV or SPV systems rely on the incident light from sun, on specially designed panels, which are made from engineered silicon to convert the incident light energy into electricity. This process works by absorbing the energy of photon to generate charge pairs which are forced to flow through an external circuit path to obtain electrical energy. This effect of charge generation is called as photoelectric effect or PEE.

The use of these panels has been growing and they have been becoming cheaper as a result of improved manufacturing techniques and economy of scale. However there use in distributed generation is still in its early stages of infancy.

Fig 2 shows a possible distributed generation style solar array mounted on a parking lot.

Figure 1: Solar Panel

Figure 2: Solar Tracking Array

The power from an array can be obtained by determining the product of the voltage (obtained by the number of panels connected in series) and current (obtained by the number of panels connected in parallel).;

P-array = (n*V) * (p*I)

Where;

n – Is the number of panels connected in series

p – Is the number of panels connected in parallel

V – Is the voltage of a single panel (open circuit or maximum power)

I – is the current of a single panel (open circuit or maximum power)

For the purpose of this simulation around 63kW is the design of the solar array, note however that the battery is substantially larger in capacity for the buffering purpose.

3.1 Battery

The lithium-based batteries are formed from several individual lithium-based cells, whose typical output voltage can be 3V. For an electric vehicle several such batteries are connected in series and parallel to make a high power Battey pack. There is also a dedicated controller for charging and discharging as well monitoring the health of battery packs, cells groups or even individual cells called a battery management system or BMS. Fig 3 shows a typical EV battery pack and BMS. The individual blocks are the cells blocks which contain multiple cells and these blocks are connected using the orange cables to form the high voltage battery pack. This board is a BMS board for a single cell block. It controls and monitors individual cells.

Figure 3: EV battery Pack and BMS

3.2 Chargers

Electric vehicle chargers are for this design a type of DC-DC converters such as boost converters and buck converters or other types of DC-DC topologies. Fig 4 shows a typical EV charger. The charger is the blue box with cable below. The charger cables for commercial points are designed to be thick because they typically support high speed charging which might use current in the range of kiloamperes, wither continuous or pulsed. The design presented in this work uses pulsed charging by taking advantage of the discontinuous conduction mode of a DC-to-DC converter.

Figure 4: EV Charger

4. SIMULATION DESIGN

The following now describes the simulation design in MATLAB Simulink and the results obtained. Fig 5 shows the full simulation design.

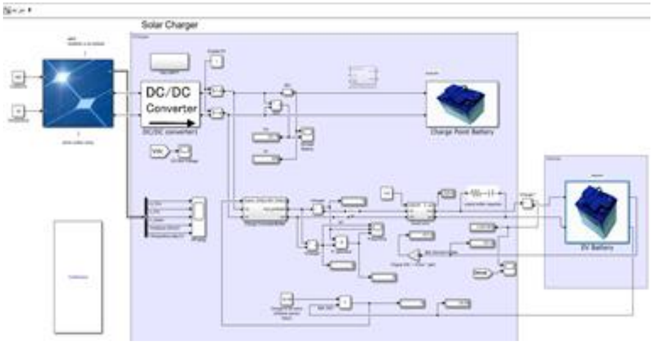


Figure 5: EV Charger

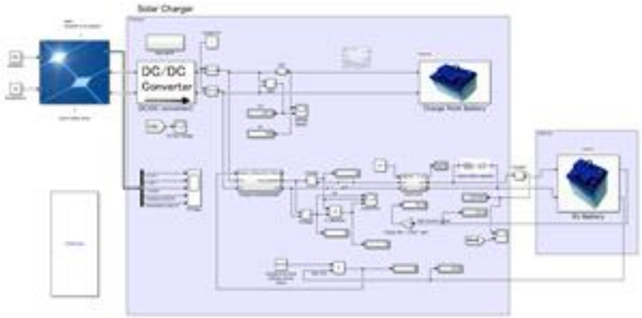


Figure 6: Buffer Battery

On the top left is the solar array block. Then the central block is the charger and the right-most block is the EV battery. The battery in the central block is the buffer battery for the charging station. The detailed picture is shown in Fig 6.

Fig 8 shows a MATLAB solar array bloc which is configured here to generate maximum power of about 63.94kW. The irradiance and temperature are set to 950W/m^2 and 30 degrees Celsius.

To form the desired power ratings, the panels are connected in series and parallel as per Fig 9. 30 parallel strings and 10 series strings.

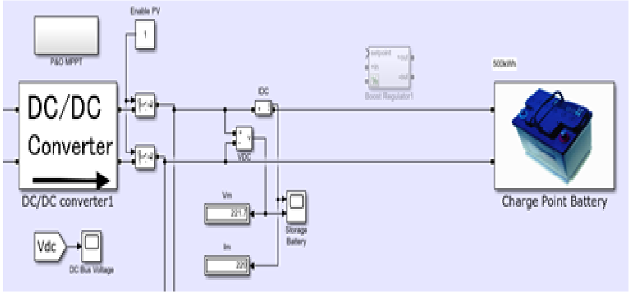


Figure 7: Solar Part

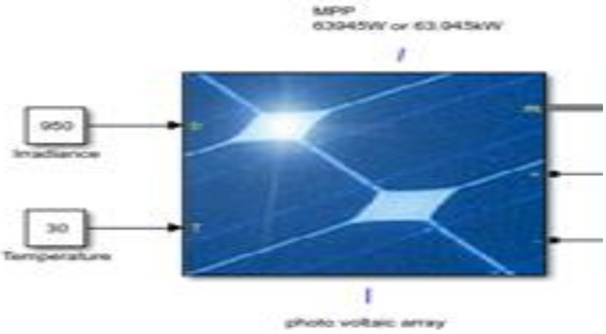
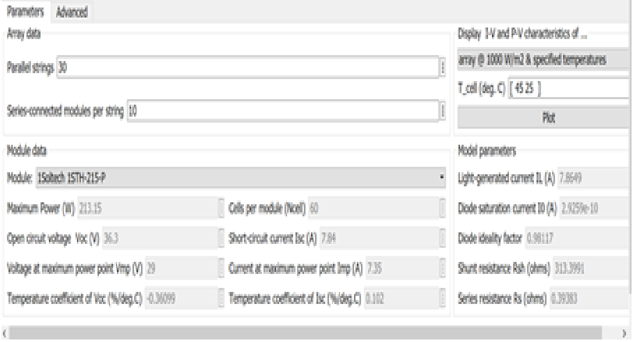


Figure 8: Solar Array Block



Array data

Parallel strings 30

Series-connected modules per string 10

Display I-V and P-V characteristics of ... array @ 1000 W/m2 & specified temperatures

T_cell (deg. C) [45 25]

Module data

Module: 1Soltech 1STH-215-P

Maximum Power (W) 213.15

Cells per module (Ncell) 60

Open circuit voltage Voc (V) 36.3

Short-circuit current Isc (A) 7.84

Voltage at maximum power point Vmp (V) 29

Current at maximum power point Imp (A) 7.35

Temperature coefficient of Voc (%/deg.C) -0.36099

Temperature coefficient of Isc (%/deg.C) 0.102

Model parameters

Light-generated current IL (A) 7.8649

Diode saturation current I0 (A) 2.9259e-10

Diode ideality factor 0.98117

Shunt resistance Rsh (ohms) 313.3991

Series resistance Rs (ohms) 0.39383

Figure 9: Panel Power Ratings

The individual panel ratings are mentioned in the right side of the configuration in the previous picture. To extract maximum power from the panel, maximum power tracking is performed using the “P&O” or perturb and observe algorithm. For that purpose, a dedicated DC-DC boost converter is used; as shown in Fig 10. The MPP technique is programed using state flow block modeling as shown in Fig 11.

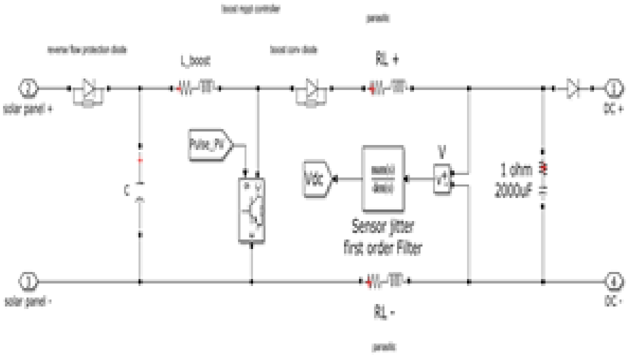


Figure 10: DC-DC Boost Converter

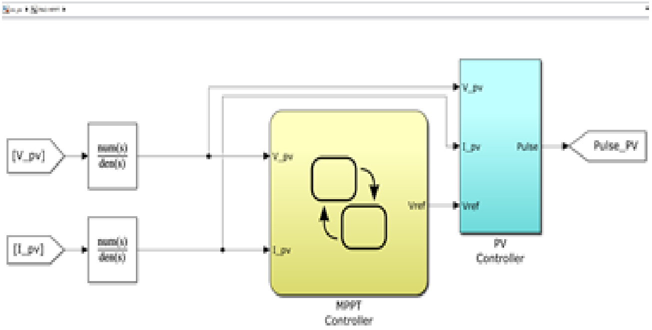
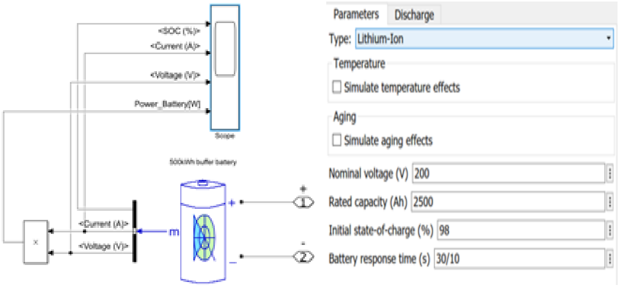


Figure 11: MPP Technique

The buffer battery storage is also shown in Fig 12 along with its configuration. It is rated for a higher capacity to be able to provide multiple charges for multiple or same vehicle, and to also compensate for line losses. The power is measured using a dedicated voltage and current sensor.



Type: Lithium-Ion

Temperature

☐ Simulate temperature effects

Aging

☐ Simulate aging effects

Nominal voltage (V) 200

Rated capacity (Ah) 2500

Initial state-of-charge (%) 98

Battery response time (s) 30/10

Figure 12: Battery Storage and Configuration

The battery is rated for 500kWh. The configuration is shown Fig 12. The charger design is shown in Fig 13.

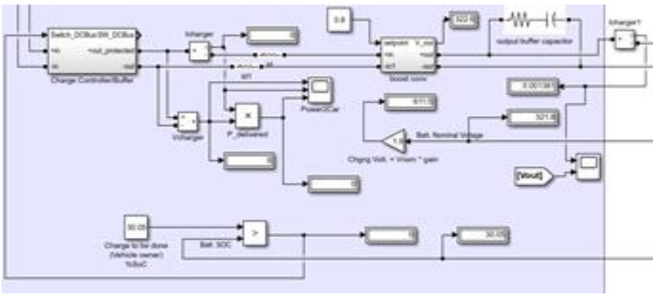


Figure 13: Charger Design

The first block is the switching for charger, it is followed by measurements and on the side from the EV battery several lines are there. 2 of them are the DC power lines and two are the battery voltage and state of charge or SoC feedback lines. The SoC line is compared with the set-point which the user sets (such as charge the vehicle to 60%). Since the EV batteries are typically higher voltage than the buffer battery or the SPV array output a DC-DC boost converter is used.. The SOC target for simulation is set to 0.05 higher than the incidental EV battery SoC to keep the simulation short.

5. RESULTS AND OBSERVATIONS

Starting with the SPV

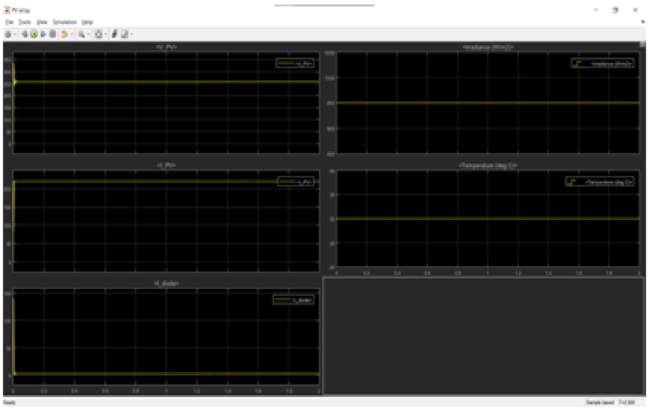


Figure 14: Voltage and Power

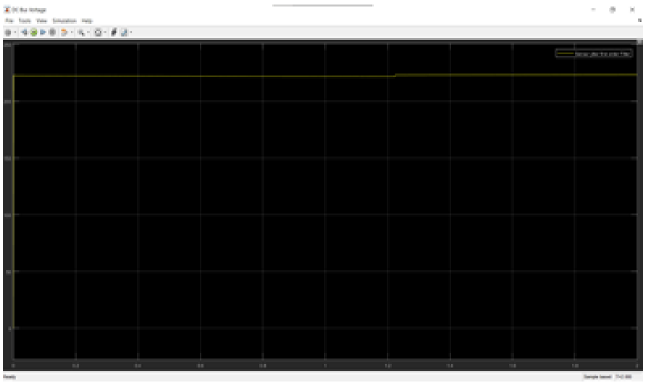


Figure 15: Voltage on the DC Bus

Figure 16: Storage Battery

Note that the negative current means it is discharging and the dip or decay in the voltage signifies the same, since the SPV is also charging the EV battery. The green curve shows the power flow and the y-axis is 10^5 multiplied. The negative power shows charging. The power going to the car after charge controller is shown in Fig 17.

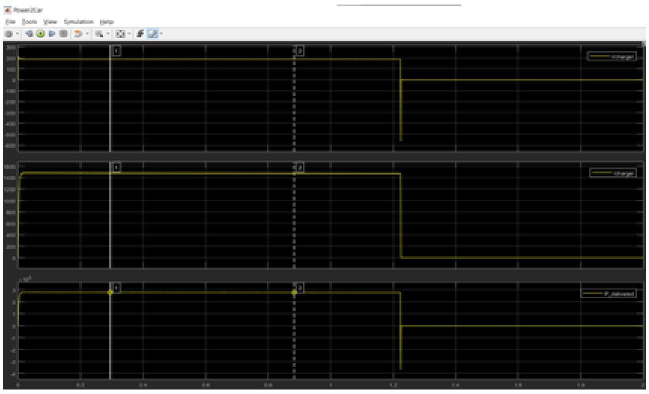


Figure 17: Power to the car

Figure 18: EV Battery current

The first one is the V charge, followed by I charge and lastly Power delivered. After charger cutoff, the voltage, current and power become zero. The actual current going to the EV battery is shown in Fig 18. The same when zoomed in is shown in Fig 19.

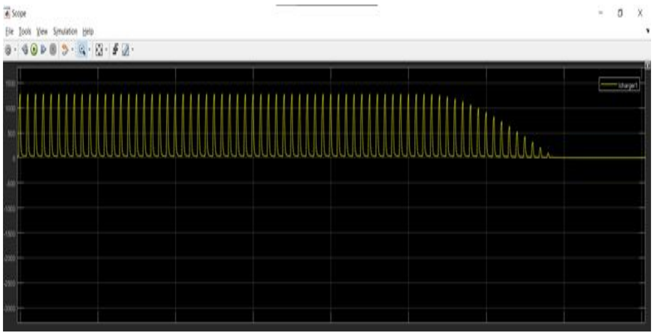


Figure 19: EVBatteryZoomed

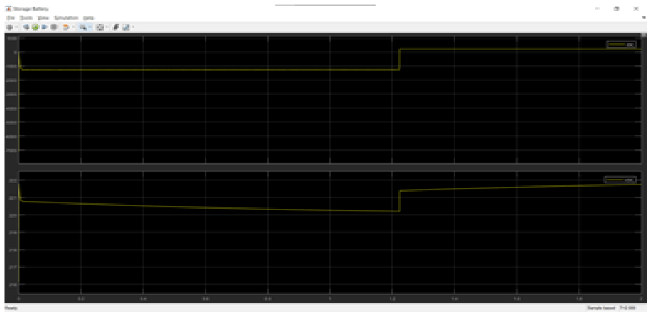


Figure 20: Charger Battery.

For the charger battery as shown in Fig 20, note that after cutoff of the EV battery, the energy from the SPV is directed towards the charger battery and it starts charging, this is quite visible in the second graph, which shows the charger battery voltage increasing.

7. CONCLUSION

The main objective of presenting a design and simulating it in Simulink was accomplished and the results obtained showed that the design works. Further work may be carried out in extending the simulation to multi-vehicle scenario, reducing losses, improving vehicle-charger communication etc.

REFRENCES

[1] Q. Liu, “Electric car with solar and wind energy may change the environment and economy: A tool for utilizing the renewable energy resource,” Earths Future, vol. 2, no. 1, pp. 7–13, Jan. 2014.

[2] M. Z. Jacobson and M. A. Delucchi, “Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials,” Energy Policy, vol. 39, no. 3, pp. 1154–1169, Mar. 2011.

[3] P. S. G. A. Putrus, “Impact of electric vehicles on power distribution networks,” 5th IEEE Veh. Power Propuls. Conf. VPPC 3909, pp. 827– 831, 2009.

[4] W. Zhang, W. Ge, M. Huang, J. Jiang, W. Zhang, W. Ge, M. Huang, and J. Jiang, “Optimal Day-Time Charging Strategies for Electric Vehicles considering Photovoltaic Power System and Distribution Grid Constraints, Optimal Day-Time Charging Strategies for Electric Vehicles considering Photovoltaic Power System and Distribution Grid Constraints,” Math. Probl. Eng. Math. Probl. Eng., vol. 2015, 2015, p. e765362, Mar. 2015.

[5] Z. Salam, M. J. B. A. Aziz, and K. P. Yee, “A critical review of electric vehicle charging using solar photovoltaic,” Int. J. Energy Res., vol. 40, no. 4, pp. 439–461, Mar. 2016.

[6] M. A. Lange, S. J. Cohen, and P. Kuhry, “Integrated global change impact studies in the Arctic: the role of the stakeholders,” Polar Res., vol. 18, no. 2, pp. 389–396, Dec. 1999.

[7] Gurkaynak Y, Khaligh A. Control and power management of a grid connected residential photovoltaic system with plug-in hybrid electric vehicle (PHEV) load. In: 2009 Twenty-fourth annu IEEE appl power electron conf expo, IEEE; 2009. p. 2086–91.

[8] Tesfaye M, Castello CC. Minimization of impact from electric vehicle supply equipment to the electric grid using a dynamically controlled battery bank for peak load shaving. In: 2013 IEEE PES innov smart grid technolconf, IEEE; 2013. p. 1–6.

[9] Hong-Yi Yang, Tse-Hsu Wu, Jiann-Jong Chen, Yuh-Shyan Hwang and Cheng-Chieh Yu, "An Omnipotent Li-Ion Battery Charger With Multimode Controlled Techniques", Power Electronics and Drive Systems (PEDS) IEEE 10th International Conference, pp. 531-534, 2013.

[10] Hao Nguyen-Van, Thang Nguyen, Vu Quan, Minh Nguyen and Loan Pham-Nguyen, "A Topology of Charging Mode Control Circuit Suitable for Long-Life Li-Ion Battery Charger", Communications and Electronics (ICCE) IEEE Sixth International Conference, pp. 167-171, 2016.

[11] Naotaka Kawamura and MitsuharuMuta, "Development of Solar Charging System for Plug-in Hybrid Electric Vehicles and Electric Vehicles", Renewable Energy Research and Applications (ICRERA) International Conference, 2012.

[12] H. Suresh et al., "Efficient charging of battery and production of power from solar energy", 2014 International Conference on Embedded Systems (ICES), pp. 231-237, 2014.

[13] Mousazadeh, Hossain; et al. "A review of principle and sun-tracking methods for maximizing" (PDF). Renewable and Sustainable Energy Reviews 13 (2009) 1800–1818. Elsevier. Retrieved (30 December 2012).