DIRECT FAST CHARGING OF ELECTRIC VEHICLE USING SOLAR PANELS

Mr. R. RAMANJAN PRASAD, M.Tech, Assistant Professor, prasad243@gmail.com
S. SAI SANTHOSHI LAKSHMI, BTech, Department of EEE, santhoshisappa@gmail.com
S. SAI TEJA, BTech, Department of EEE, saiteja.as15@gmail.com
A. MANOJ RAJ, BTech, Department of EEE, manojandekar@gmail.com
P. SAI MANI HARSHA, BTech, Department of EEE, pendemmani143@gmail.com
Vignan Institute of Technology & Science, Near Ramoji Film city, Deshmukhi Village.

ABSTRACT:

In present, environmental problems which originate from the consumption of fossil fuels caused emission of polluting gases into the atmosphere creating the need for change in mobility habits in today's daily life. Thus, companies and governments had made strong investments in the automotive sector especially in the development of electric vehicles (EVs) and the technologies associated with them. One of the technical issues that had been highlighted is the fast charging of EV batteries. Particularly, the usage of renewable energy systems to fast charge EV and lower the power demands from the grids are encouraged. This project aims to alleviate the current state of fast charging and environmental problems by proposing a high performance DC-DC boost converter controlled by PI controller. The proposed converter is able to generate different output power level based on the desired preset reference voltage value. For simplicity, EV batteries are being replaced with one resistor as a load whereas the input source of the converter is attained from PV panels. Keysight Technologies measurement tools will be utilized to measure and validate the experimental results with the simulation one.

Keywords : electric vehicles (EVs), photovoltaic (PV).

I INTRODUCTION

Ever since the beginning of industrial revolution, humans sought for better means of transport leading to the indefinite evolution of automobile industry. The demand for EVs began to rise in the 90s leading to the start of strong investments in the development of EV technologies and the energy production from renewable sources, with emphasis on the batteries [1]-[3]. Generally, EVs are powered up using electric energy stored from its batteries. Although EVs are presented as zero emission cars, the public are yet to accept it due to several factors, mainly, the long charging period. In present, most EVs can charge with three charging systems as describe below [4]: Level 1 A cord-set made through monophasic alternate current (AC) that connects to a regular household outlet with charging time of 7 to 30 hours depending on the battery size. Level 2 AC charging mode to charge a mid-sized EV in 4 to 5 hours. This usually uses three-phase outlets that can be found in public places. Level 3 DC Fast Charger. It is characterized by using direct current (DC) delivers up to 120kW to fill a Li-ion battery to 80 percent state-ofcharge in about 30 minutes. Lack of charging stations for EVs is another huge challenge for EV industries as installing large numbers of charging stations is not economically feasible and will lead to largedisturbances to the existing grid such as peak load demand and voltage magnitude malfunctions [5]. Hence, the optimal solution to those issues is to implement and utilize PVpowered fast charger as illustrated in Fig. 1.

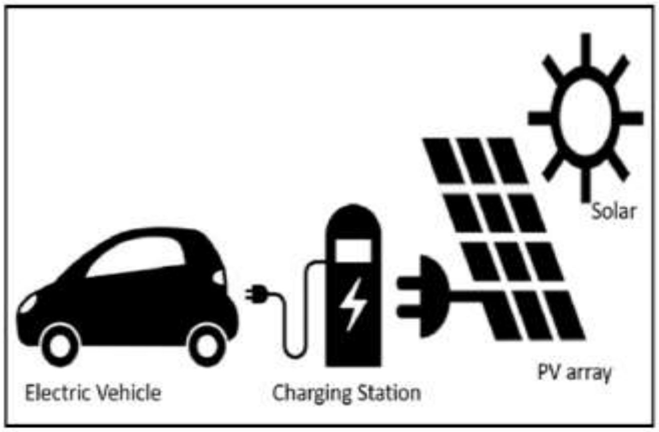


Fig. 1. General scheme of the power system for EV

II. SYSTEM CONFIGURATION

Solar Photovoltaics

The conversion of solar radiation occurs by the photovoltaic effect which was first observed by Becquerel. It is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system. Energy conversion devices which are used to convert sunlight to electricity by the use of the photo-voltaic effect are called solar cells. Single converter cell is called a solar cell or more generally photovoltaic cell and combination of such cells designed to increase the electric power output is called a solar module or solar array and hence the name ‘Photovoltaic Arrays’. Solar cells can be arranged into large groupings called arrays. These arrays, composed of many thousands of individual cells, can function as central electric power stations, converting sunlight into electrical energy for distribution to industrial, commercial and residential users. Solar cells in much smaller configurations are commonly referred to as solar cell panels or simply panels. Practically, all photovoltaic devices incorporate a P-N junction in a semiconductor across which the photo voltage is developed. The solar panels consist mainly of semiconductor material, with Silicon being most commonly used.

Basics of Solar Cells

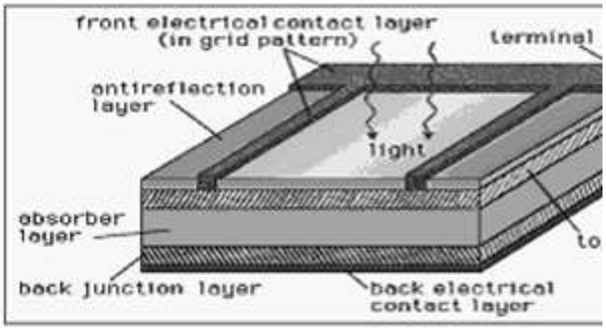


Fig 2. Solar cell system

The overwhelming majority of solar cells are fabricated from silicon with increasing efficiency and lowering cost as the materials range from amorphous (non-crystalline) to polycrystalline to crystalline (single crystal) silicon forms. Unlike batteries or fuel cells, solar cells do not utilize chemical reactions or require fuel to produce electric power and unlike electric generators, they do not have any moving parts.

Light enters the device through an optical coating, or antireflection layer that minimizes the loss of light by reflection; it effectively traps the light falling on the solar cell by promoting its transmission to the energy-conversion layers below. The antireflection layer is typically an oxide of silicon, tantalum or titanium that is formed on the cell surface by spin coating or a vacuum deposition technique.

The three energy-conversion layers below the antireflection layer are the top junction layer, the absorber layer, which constitutes the core of the device, and the back junction layer. Two additional electrical contact layers are needed to carry the electric current out to an external load and back into the cell, thus completing an electric circuit. The electrical contact layer on the face of the cell where light enters is generally present in some grid pattern and is composed of a good conductor such as a metal. Since metal blocks light, the grid lines are as thin and widely spaced as is possible without impairing collection of the current produced by the cell. The back electrical contact layer has no such diametrically opposed restrictions. It needs to simply function as an electrical contact and thus cover the entire back surface of the cell structure. Because the back layer also must be a very good electrical conductor, it is always made of metal. Since most of the energy in sunlight and artificial light is in the visible range of electromagnetic radiation, a solar cell absorber should be efficient in absorbing radiation at those wavelengths. Materials that strongly absorb visible radiation belong to a class of substances known as semiconductors. Semiconductors in thicknesses of about one-hundredth of a centimeter or less can absorb all incidents visible light; since the junction-forming and contact layers are much thinner, the thickness of a solar cell is essentially that of the absorber. Examples of semiconductor materials employed in solar cells include Silicon, Gallium Arsenide, Indium Phosphide and Copper Indium Selenide

CONVERTERS

Dc-Dc Converter Basics

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc.

Boost Converter

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (adiode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

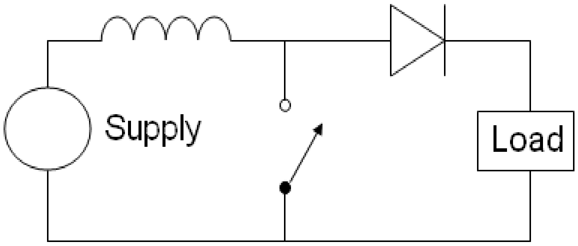


Fig 3: source

Power can also come from DC sources such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it “steps up” the source voltage. Since power (*P* = *VI* or *P* = *UI* in Europe) must be conserved, the output current is lower than the source current.

A boost converter may also be referred to as a 'Joule thief'. This term is usually used only with very low power battery applications, and is aimed at the ability of a boost converter to 'steal' the remaining energy in a battery. This energy would otherwise be wasted since a normal load wouldn't be able to handle the battery's low voltage.*

- This energy would otherwise remain untapped because in most low-frequency applications, currents will not flow through a load without a significant difference of potential between the two poles of the source (voltage.)

Block Diagram

The basic building blocks of a boost converter circuit are shown in Fig 4.

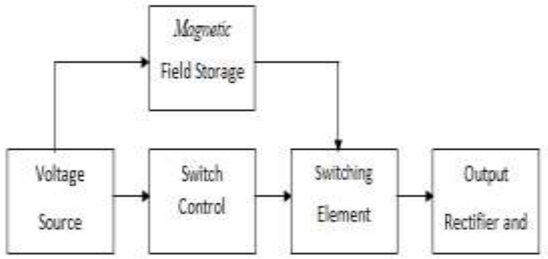


Fig 4. Boost converter Block diagram

The voltage source provides the input DC voltage to the switch control, and to the magnetic field storage element. The switch control directs the action of the switching element, while the output rectifier and filter deliver an acceptable DC voltage to the output.

Operating principle

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor), when being discharged, it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.

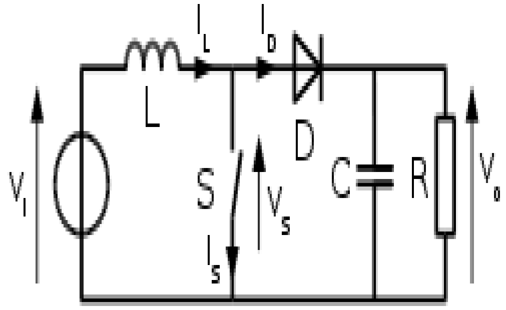


Fig 5:Boost converter schematic

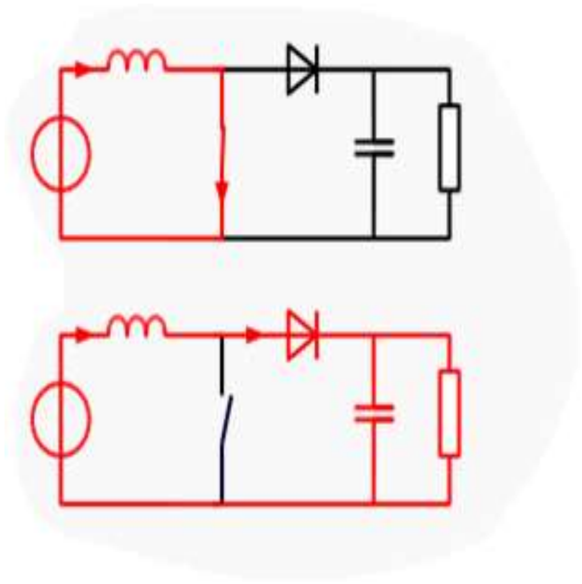


Fig 6. The two configurations of a boost converter, depending on the state of the switch S.

The basic principle of a Boost converter consists of 2 distinct states (see figure):

- in the On-state, the switch S (see figure) is closed, resulting in an increase in the inductor current;
- In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.

The input current is the same as the inductor current as can be seen in figure. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

Continuous mode

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e. using components with an ideal behavior) operating in steady conditions:

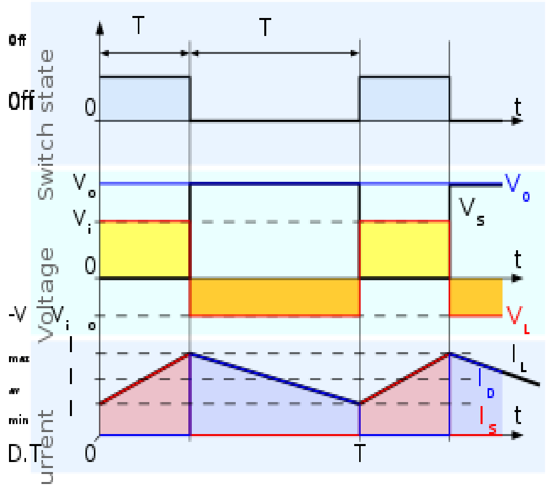


Fig 7:Waveforms of current and voltage in a boost converter operating in continuous mode.

III PROPOSED TOPOLOGY

FAST CHARGING OF ELECTRICAL VEHICLES

Fig. 8 below shows the future concept and perception of the fast charging EV:

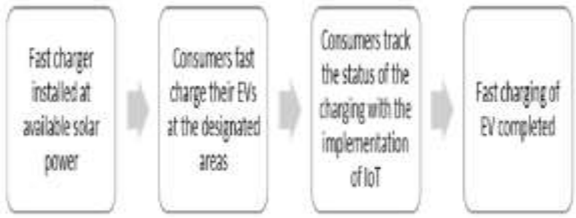


Fig. 8. Pipeline of fast charging the EVs

The proposed fast charger will be installed at the designated areas nearby the available PV power to allow consumers to charge their EVs for a short period of time. With IoT implementation, consumers are able to track the charging status of their EVs using mobile devices.

The pipeline to design the PV-powered fast charger is illustrated in Fig. 9 below:

This work is divided into four different phases.

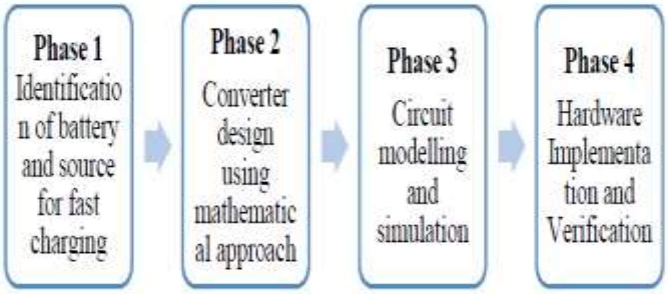


Fig. 9 The pipeline to design the PV-powered fast charger is illustrated in

A. Identification of battery and source for fast charging In Phase 1, EV battery specification and its charging characteristic is identified and investigated. The capability and the availability of using PV energy to charge EVs is also examined in view of the power level adequacy to achieve fast charging.

B. Converter design using mathematical approach Fig. 10 shows the conceptual design of the proposed PVpowered fast charger established for this work.

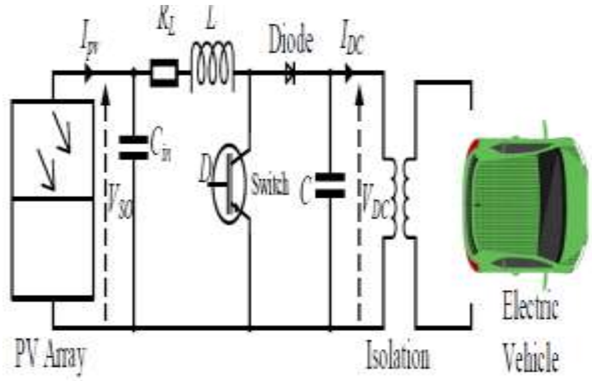


Fig. 10. Boost converter associated with PV array for charging EV

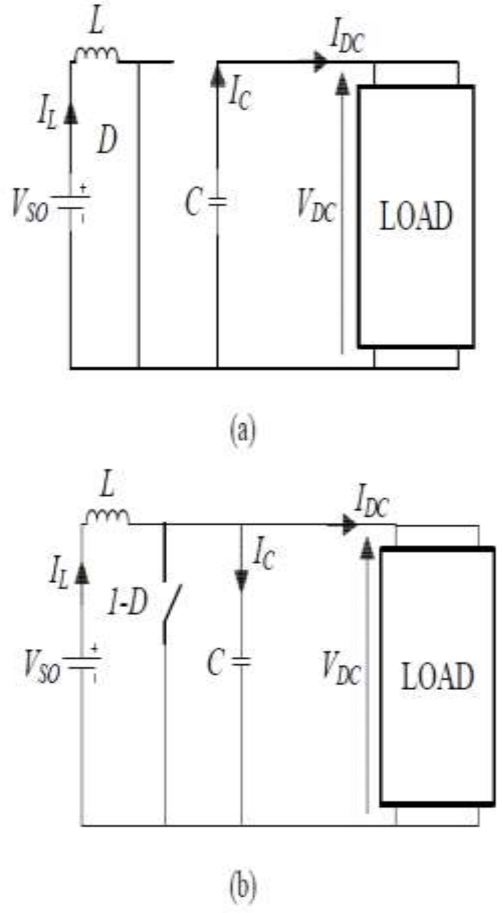
The initial step of designing the DC-DC boost converter is to derive its transfer function and state-space equations [6]-[17]. After that, the size selection of passive components is carried out based on the vendor stock availability. Once accomplished, the selection and development of suitable controller, in this case the PI controller, is conducted to determine its gain values via the root locus diagram.

C. Circuit Modelling and Simulation MATLAB/Simulink is utilized to ensure that the proposed PV-powered fast charger can achieve power regulation and DC-link voltage stabilization according to the desired preset reference voltage value. The performance of the proposed topology is examined and measured based on the dynamic and transient responses as well as the conversion efficiency.

D. Hardware Implementation and Verification A prototype of the proposed topology will be developed in future to validate the optimality and the real-time behaviour of the aforementioned works to identify the discretization issues, modelling issues, and the accuracy of data supplied to the model.

MATHEMATICAL MODELLING

The principle of operation of the proposed PV-powered fast charger based on DC-DC boost converter is illustrated in Fig. 11. From Fig. 11(a), the switch is on causing charging of the inductor L via the input source VSO and discharging of the capacitor C to the load. In contrast, when the switch is off (see Fig. 11(b)), the energy stored in the inductor L discharges. This energy is summing with the input source VSO to produce a much higher DC output voltage VDC when compared withVSO; simultaneously charging and driving the capacitor C and load, respectively.



(a)

(b)

Fig. 11. The proposed boost converter with switch (a) on and (b) off

The size of the capacitor C, inductor L, and the load plays an important role to determine the overall power rating of the converter as well as the voltage ripple and current ripple content produced by the converter. The equations to determine the size of inductor L and capacitor C are defined in (1) and (2), respectively, below:

$$L = \frac{V_{SO}}{\Delta I_{L_{max}}} D T_{SW} \quad (1)$$

$$C = \frac{V_{DC}}{\Delta V_{DC_{max}} R} D T_{SW} \quad (2)$$

IV.SIMULATION RESULTS

The proposed PV-powered fast charger based on DC-DC boost converter is investigated through extensive simulation work using MATLAB/Simulink software package [18] to study and investigate its dynamic and transient performances. For simplicity, the EV batteries are being replaced with one resistor as a load whereas the input source of the converter is attained from PV panels. A. Simulation Results The simulation study of the proposed PV-powered fast charger based on DC-DC boost converter.

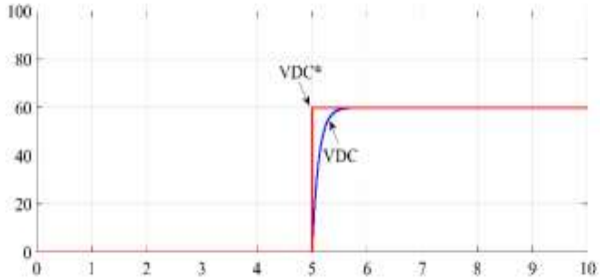


Fig. 12. Simulation result of the proposed voltage loop feedback control for boost converter

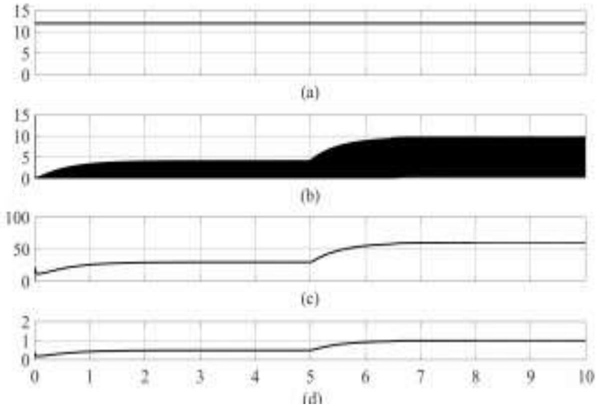


Fig. 13. Simulation results of boost converter (a) input voltage VSO, (b) input current IL, (c) output voltage VDC, and (d) output current IDC

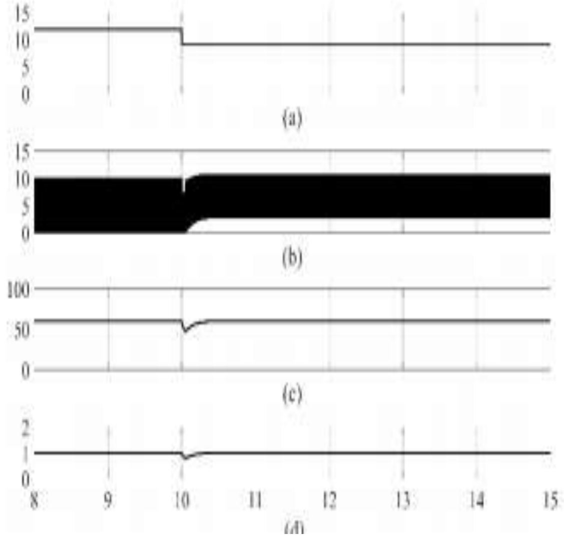


Fig. 14. Simulation results of boost converter (a) input voltage VSO, (b) input current IL, (c) output voltage VDC, and (d) output current IDC

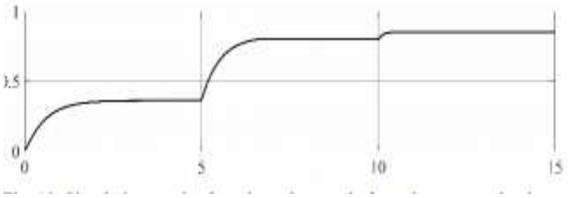


Fig. 15. Simulation result of resultant duty cycle from the proposed voltage loop feedback controller

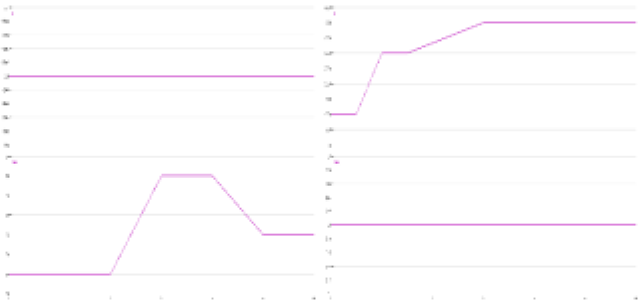


Fig. 16 PV panel with (a) constant irradiance variable temperature and (b) variable irradiance constant temperature

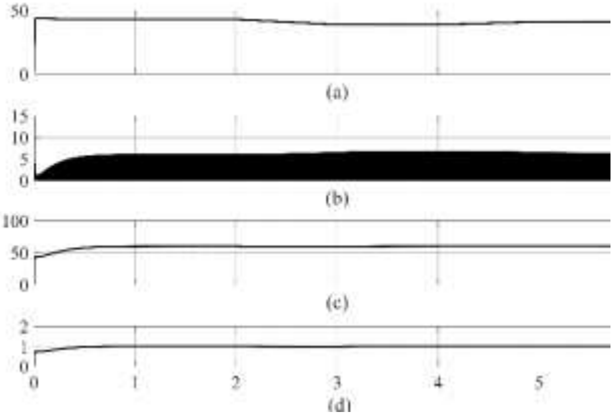


Fig. 17. Simulation results of boost converter at constant irradiance variable temperature (a) input voltage VSO, (b) input current IL, (c) output voltage VDC, and (d) output current IDC

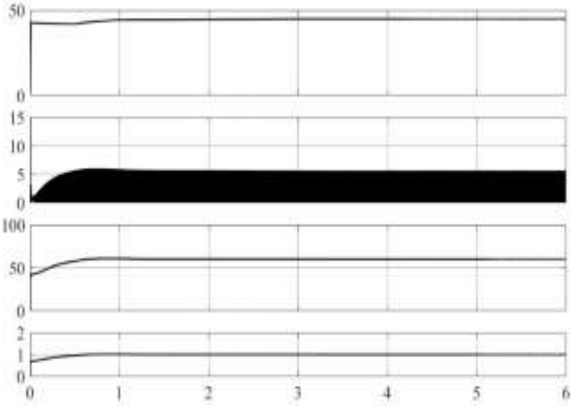


Fig. 18. Simulation results of boost converter at constant temperature variable irradiance (a) input voltage VSO, (b) input current IL, (c) output voltage VDC, and (d) output current IDC

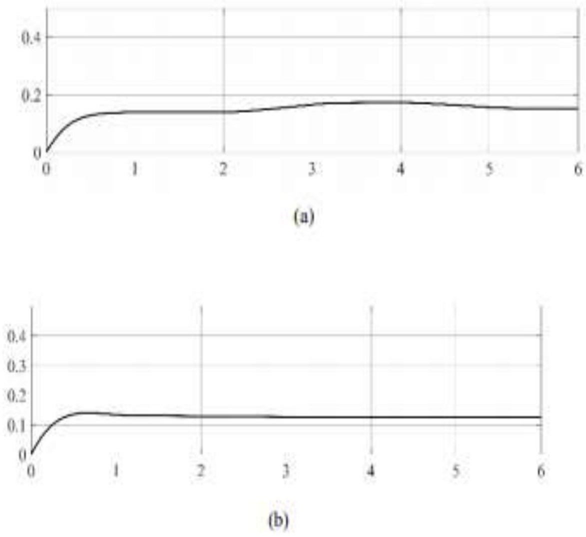


Fig. 19. Simulation results of the resultant duty cycle for (a) Fig. 17and (b) Fig. 18.

V.CONCLUSION

This paper presents the design of a fast charger for electrical vehicles. Different values for different parameters were calculated, derived, and chosen to ensure the design of the fast charger meets the required specifications and needs. Simulations were carried out using MATLAB/Simulink to ensure that the expected results were achieved before proceeding to the next phase (i.e. hardware implementation). Although only simulations and simulation results as considered in this paper, hardware implementations will be carried out in future works to ensure the usability of the designed fast charger and for potential maximization of system efficiency and performance.

Besides, analysis will be made to identify areas of improvement to decrease the amount of charging time using renewable energy. This also include identification of the tool dynamics and better matching values for capacitors used. Lastly, future works will include the implementation and integration of PV power for direct fast charging of EVs to reduce the drop of efficiency in power conversion. The integration of IoT in the fast charger with the electrical vehicle will also be investigated in future works to increase the information consumers are able to view thereby increasing the functionality, reliability and convenience of the fast charger for consumers.

VI. REFERENCES

[1] Y. Segura, L. Chmielarz, P. Kustrowski, P. Cool, R. Dziembaj and E. Vansant, "Preparation and characterization of vanadium oxide deposited on thermally stable mesoporous titania," J. Phys. Chem., vol. 110, no. 2006, pp. 948-955, 2006.

[2] C. Silva, D. M. Sousa and A. Roque, "Charging electric vehicles from photovoltaic generation with intermediate energy storage," in 2017 6th International Conference on Clean Electrical Power (ICCEP), Santa Margherita Ligure, Italy, 2017.

[3] L. Dickerman and J. Harrison, "A New Car, a New Grid," IEEE Power Energy Mag., vol. 8, no. 2, pp. 55-61, 2010.

[4] I. Buchmann, "Ultra-fast Charging," 27 September 2017. [Online]. Available: https://batteryuniversity.com/learn/article/ultra_fast_charging. [Accessed 20 October 2018].

[5] J. K. Sahoo and A. T. Mathew, "Design of a ZCS full amp - Bridge DC - DC converter for PV based electric vehicle fast charging station," in 2017 IEEE Region 10 Symposium (TENSYMP), Cochin, India, 2017.

[6] K. H. Law and M. S. A. Dahidah, “Dc-dc boost converter based mshepwm cascaded multilevel inverter control for statcom systems”, Int. Power Electron. Conf., pp. 1283-1290, 2014.

[7] K. H. Law, M. S. A. Dahidah, and N. Mariun, “Cascaded multilevel inverter based statcom with power factor correction feature,” IEEE Conf. Sustain. Utilization and Develop. in Eng. And Technol., pp. 1-7, 2011.

[8] K. H. Law, M. S. A. Dahidah, G. S. Konstantinou, and V. G. Agelidis, “She–pwm cascaded multilevel inverter with adjustable dc sources control for statcom applications”, 7th Int. Power Electron. And Motion Cont. Conf., pp. 330-334, Jun. 2012.

[9] K. H. Law and M. S. A. Dahidah, “New current control algorithm incorporating multilevel she-pwm approach for statcomoperationunder unbalanced condition,” 5th Int. Symp. Power Electron. forDistrib. Generation Syst., pp. 1-7, Jun. 2014.

[10] K. H. Law, M. S. A. Dahidah, and H. A. F. Almurib, “She–pwm cascaded multilevel inverter with adjustable dc voltage levels control for statcom applications,” IEEE Trans. Power Electron., vol. 29, no. 12, pp. 6433-6444, Dec. 2014

[11] K. H. Law, M. S. A. Dahidah, and H. A. F. Almurib, “A new reactive current reference algorithm for the statcom system based on cascaded multilevel inverters,” IEEE Trans. Power Electron., vol. 30, no. 7, pp. 3577-3588, Jul. 2015.

[12] J. S. X. Ong, K. Y. K. Yong, K. H. Law, W. P. Q. Ng, and M. Dahidah, “CCM and DCM analysis of quasi-z-source inverter," in 2017 IEEE Conf. Energy Convers., pp. 157-162 Oct. 2017.

[13] K. H. Law, W. P. Q. Ng, and W. K. Wong, "Flyback cascaded multilevel inverter based SHE-PWM control for STATCOM applications," Int. J. Power Electron. Drive Syst., vol. 8, no. 1, pp. 100- 108, 2017.

[14] K. H. Law, “An effective voltage controller for quasi z-source inverter based statcom with constant dc-link voltage," IEEE Trans. Power Electron., vol. 33, no. 9, pp. 8137-8150, Sept. 2018.

[15] K. H. Law, M. S. A. Dahidah, S. Y. Sim, W. P. Q. Ng, A. Masaoud, and A. A. Siada, "An Effective Dual Closed-Loop Scheme Based on Lead Compensator and Proportional Controller for Quasi Z-Source Inverter," in 2018 IEEE Region 10 Conf. TENCON, Oct. 2018.

[16] K. H. Law and W. P. Q. Ng, "Dual closed-loop scheme with lead compensatpr and proportional controller for quazi z-source inverter based STATCOM," in 2018 IEEE Int. Conf. Power Energy, pp. 56-61, Dec. 2018.

[17] K. H. Law. S. K. Yong, W. P. Q. Ng, M. Dahidah, "Lead compensator design for single-phase quasi z-source

inverter," J. of Telecommunication, Electron. And Comput. Eng., vol. 10, no. 1-12, pp. 39-44, 2018.

[18] MathWorks. [Online]. Available: http://www.mathworks.com/.

AUTHORS

Mr. R. Ramanjan Prasad, M.Tech, Assistant Professor, Department of EEE, prasad243@gmail.com

S. Sai Santhoshi Lakshmi, BTech, Department of EEE, santhoshisappa@gmail.com

S. Sai Teja, BTech, Department of EEE, saiteja.as15@gmail.com

A. Manoj Raj, BTech, Department of EEE, manojandekar@gmail.com

P. Sai Mani Harsha, BTech, Department of EEE, pendemmani143@gmail.com