PV Based SEPIC Converter Fed Electric Vehicle

NEELAPU ASHA REDDY

Department of Electrical and Electronics Engineering, Andhra University College of Engineering for Women, Visakhapatnam, Andhra Pradesh - 530017

ABSTRACT

These A high gain SEPIC Converter operated hybrid photovoltaic PV/battery Electric Vehicle to improve the power transfer capability and efficiency of the power conversion stage. The bidirectional flow of power fed to brushless DC motor from the solar system. The proposed system using with SEPIC Converter is to improve the power flow from the photovoltaic (PV) system. The grid is connected with DC bus to supply the power which generated from PV and when the power is not needed to load. The reliability of the Electric Vehicle is increased by using PV as well as the power conversion of SEPIC Converter. The voltage source inverter of DC bus is supplying the energy to Electric Vehicle. Utilization of single phase VSI is used to feed the bidirectional power flow control in between VSI and grid. In this system, switching losses are reduced by using the fundamental frequency used. The proposed PV based SEPIC Converter fed Electrical Vehicle results are obtained using MATLB/SIMULINK.

Keywords: PV, SEPIC Converter, Electric Vehicle, MATLAB/SIMULINK.

1. INTRODUCTION

In the recent years, the global warming has increased the awareness on the reduction of carbon dioxide (CO2) emission from the transportation vehicles, which has a strong impact on the global warming. The emissions of CO2 are mainly due to the usage of internal combustion (IC) engines in the transportation vehicle. A study carried out in 2017 reported that, India is the fourth highest emitter of CO2 in the world, accounting for 7% of global emissions. Figure 1 shows the percentage of emission of CO2 by the countries such as China, United States, European Union, and India in the year of 2017. The study also projected that the growth of the CO2 emission in India will be 20% in 2021. In order to reduce the emission of CO2 and global warming, all the countries in the world have initiated the installation of renewable power generation and electric vehicles (EVs). The EV is used as a one of the alternatives to reduce the emission of CO2. However, the increased use of battery operated EV increases the demand for electricity production and increases the load on the electricity grid. The integration of any one of the renewable power generating system such as fuel cell, photovoltaic (PV), and wind power generation system with the EV helps to reduce the burden of the electricity grid. Many authors have worked on the development of hybrid EV (HEV) to increase the transportation capability of the EV and to reduce the cost of the charging. A lot of PV-supported EVs have been proposed according to the standard driving cycle. Among the other source of power generation, PV power generating systems offer more advantages by providing clean and abundant energy. The power management algorithm based on the vehicle dynamics has been designed to distribute the torque of engine and motor to the driving shaft. It helps to increase the energy efficiency of EV.

The proposed system using with SEPIC converter is to improve the power flow from the photovoltaic (PV) system. The grid is connected with DC bus to supply the power which generated from PV and when the power is not needed to load. The reliability of the BLDC motor is increased by using PV as well as the power conversion of SEPIC converter. The voltage source inverter of DC bus is supplying the energy to BLDC motor. The control method of sliding mode controller is used to improve the system stability and response. Utilization of single phase VSI is used to feed the bidirectional power flow control in between VSI and grid. In this system, switching losses are reduced by using the fundamental frequency used. The efficiency of the BLDC motor is high and the density of power, maintenance less, small in size and lifelong service due to these merits the BLDC motors are more preferred in industrial consumers. In the PV system based power generation the BLDC motors introduced to reduce the cost as well as improve the performance of the system. Due to the climatic changes and variation in the temperature caused to the performance of the BLDC which is not able to work under its full capacity. In the mean time, the sunlight unavailability is caused to the system shunt down due to night time. To store the energy the storage systems are available such as battery. The PV power is used to charge the battery by using the controller after that the charged energy in the battery is discharged to BLDC motor through the inverter circuit. The power converters are utilized to converts the power from one form to another one. In the conventional system, the sepic converter is used to system performance improvement. The high voltage gain and system stability can be controlled by the DC link voltage which is achieved by the power converter system. Control schemes are currently used for the switching signals provision through that the power conversion from the source to load can be achieved.

2. PHOTO VOLTAIC ARRAY

2.1 SIMULATION USING MATLAB OR SIMULINK:

In this paper, the simplified PV module and array models have been used for the PV modeling using Matlab / Simulink. The main reason for choosing this model is that the other two models experience algebraic loop problem in Matlab /Simulink simulation, as the output current is required to be an input to the equations of output current in these models. Iterations may be needed for solving this problem which in many cases ends up with simulation break.

The simplified PV model has been simulated using two methods,the mathematical modeling and the physical modeling.These models are used for monitoring and assessing the non -linear I-v and P-V output characteristics of the PV module/array.

As shown in the above figures, using Simulink SimPowerSystem toolbox, the simplified model of the PV cell has been simulated using a controlled current or photocurrent, diode, and output ports.

As shown above,PV cell model has been used as a sub-system and then was masked as a Simulink block PV custom icon to facilitate the integration of the PV module model in any application.Also,the user can input the PV module block parameters according to the datasheet of desired PV module and then illustrate and verify the Nonlinear I-V and P-V characteristics.Mathematical modeling:

As shown in the figures, using Simulink math operations toolbox,the simplified model of the PV cell has been simulated using math function block for the equations of the PV simplified model.The inputs and the parameters are the same in the physical model with additional parameters such as,the quality factor,semi-conductor band-gap energy, and number of cells in parallel.

The mathematical PV cell model that is illustrated in figure has been used as a sub-system to be integrated into other system simulation and provide an easy way to input the parameters of the PV module. The mathematical model has more advantages than the physical model because additional parameters as quality factor and semi-conductor band gap energy can be varied or controlled. Moreover, parallel and series PV cells combinations can be formed without the need for repeating the block diagrams. On the other hand and in order to make a parallel combination in the physical model, the block of the PV cell has to be duplicated, which add more complexity to the model.

The results are obtained by varying two main solar cell parameters as described below:

I. Effect of varying solar radiation
II. Effect of varying Temperature

2.2 SIMULATION RESULTS:

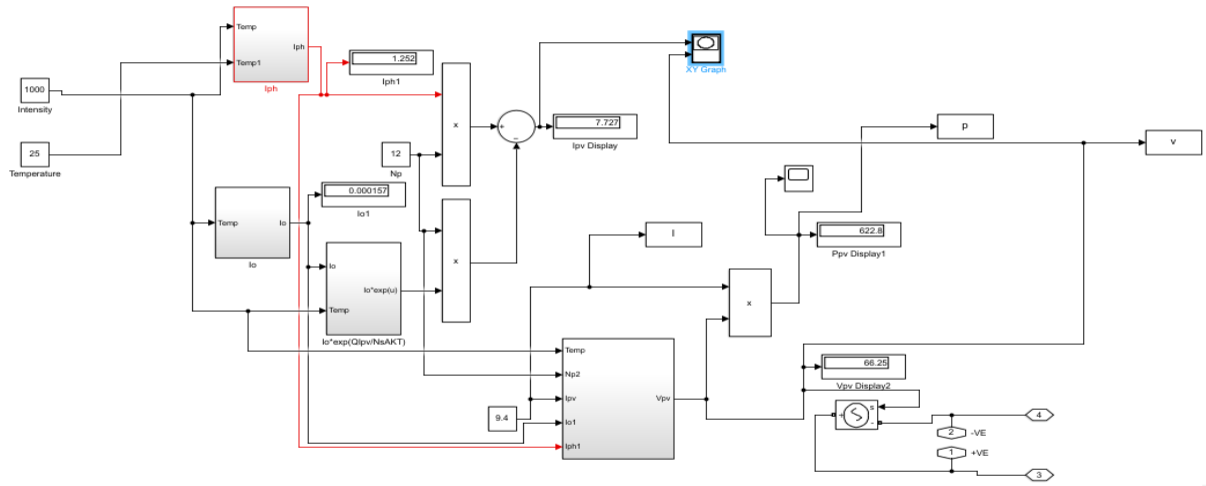

Fig. 2.1 SIMULINK model PV Array

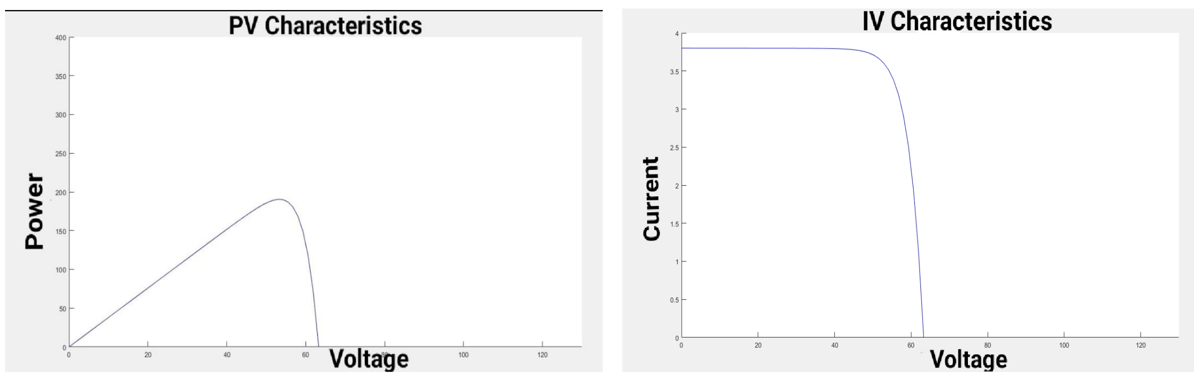

Fig. 2.2 SIMULINK output PV and IV characteristics of PV Array

3. SEPIC Converter

A single ended primary inductor converter (SEPIC) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than, less than or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control switch (S1).

A SEPIC is essentially a boost converter followed by an inverted Buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage Polarity as the input), using a series capacitor to couple energy from the input to the output(and thus can respond more graceful to a short-circuit output), and being capable of true shutdown: when the switch S1 is turned off enough, the output (Vo) drops to 0V, following a fairly hefty transient dump of charge.

SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a lithium ion battery typically discharges from 4.2 Volts to 3 Volts; if other components require 3.3 Volts, then the SEPIC would be effective.

CONSIDERATIONS:

3.1.1. Duty Cycle Consideration

For a SEPIC converter Operating in a Continuous conduction mode(CCM), the duty cycle is given by Vo is the forward voltage drop of the diode D1.

$$D = \frac{V_{OUT} + V_D}{V_{IN} + V_{OUT} + V_D}$$

3.1.2. Inductor Selection

A good rule for determining the inductance is to allow the peak to peak ripple current to be approximately 40% of the maximum input current at the minimum input voltage . The ripple current flowing in equal value of L1 and L2 is given by

The inductor value is calculated by

$$\Delta I_L = I_{IN} \times 40\% = I_{OUT} \times \frac{V_{OUT}}{V_{IN\,(min)}} \times 40\%$$

$$L1 = L2 = L = \frac{V_{IN\,(min)}}{\Delta I_L \times f_{sw}} \times D_{max}$$

3.1.3. Power MOSFET Selection

The RMS Current through the switch is given by

$$I_{Q1\,(peak)} = I_{L1\,(peak)} + I_{L2\,(peak)}$$

$$I_{Q1\,(rms)} = I_{OUT} \sqrt{\frac{(V_{OUT} + V_{IN\,(min)} + V_D) \times (V_{OUT} + V_D)}{V_{IN\,(min)}^2}}$$

3.1.4. Output Diode Selection

The output Diode must be selected to handle the peak current and the reverse voltage. In A SEPIC, the diode peak current is the same as the switch peak current IQ1(peak). The minimum peak reverse voltage the diode must withstand is:

$$V_{RD1} = V_{IN\,(max)} + V_{OUT\,(max)}$$

3.1.5. SEPIC Coupling Capacitor Selection

The selection of SEPIC capacitor, Cs, depends on the RMS current, which is given by

The peak to peak ripple voltage on Cs(assuming no ESR):

$$\Delta V_{Cs} = \frac{I_{OUT} \times D_{max}}{Cs \times f_{sw}}$$

A capacitor that meets the RMS current requirements would mostly produce small ripple voltage on Cs. Hence, the peak voltage is typically close to the input voltage.

3.1.6. Output Capacitor Selection

In a SEPIC converter, when the power switch Q1 is turned on, the inductor is charging and the output current is supplied by the output capacitor. As a result, the output capacitor sees large ripple current. Thus the selected output capacitor must be capable of handling the RMS current. The RMS current in the output capacitor is

$$I_{Cout\,(rms)} = I_{OUT} \times \sqrt{\frac{V_{OUT} + V_D}{V_{IN\,(min)}}}$$

3.1.7. Input Capacitor Selection

Similar to boost converter, the SEPIC has an inductor at the input. Hence, the input current waveform is continuous and triangular. The inductor ensures that the input capacitor sees fairly low ripple currents. The RMS current in the input capacitor is given by

$$I_{Cin\ (rms)} = \frac{\Delta I_L}{\sqrt{12}}$$

3.3 SIMULINK MODEL:

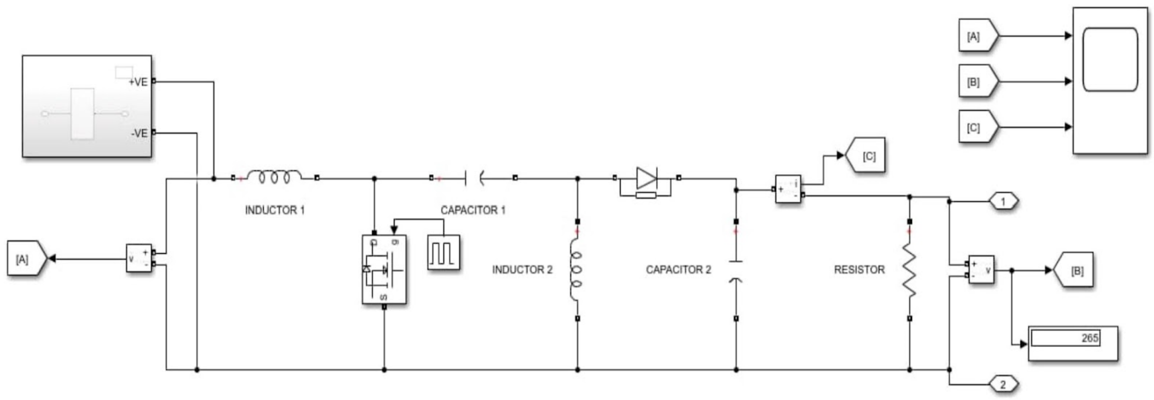

Fig. 3.3 SIMULINK model of PV based SEPIC Converter

3.4 SIMULATION RESULTS:

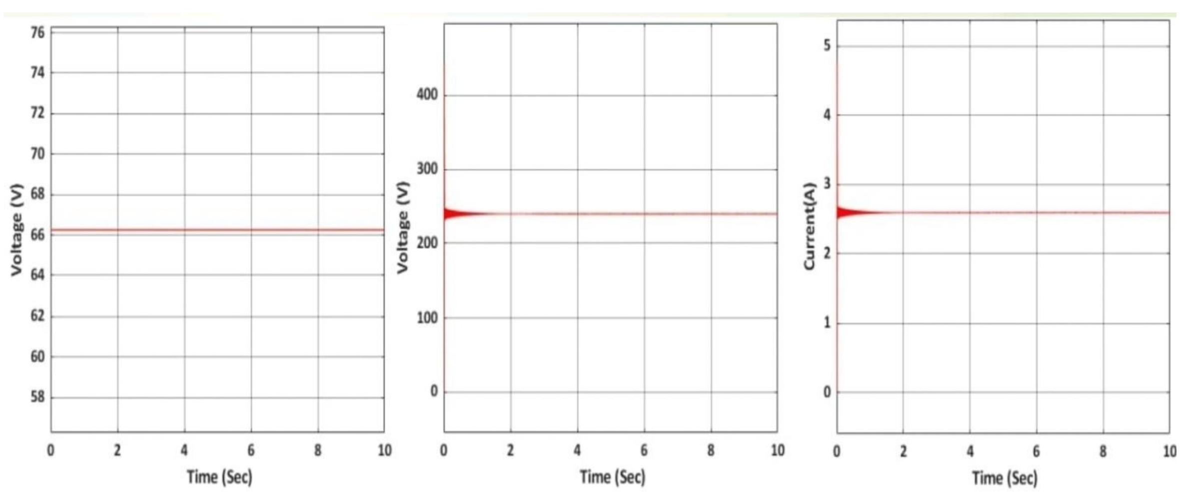

Fig. 3.4 Simulation results

4.ELECTRIC VEHICLE

4.1 INTRODUCTION:

In the recent years, many existing automobile manufacturers and new dedicated companies have put a remarkable effort in transforming the conventional vehicle into an electric vehicle that provides green and reliable solutions. In terms of market share, EV demand is rising. It has started replacing conventional vehicle in USA, Europe and Asia. With revolutionized perspective and competitive price (Entry range), EV is a smart choice for any end user, however an extra effort is required to enhance the range of autonomy and vary applications.

An electric drive vehicle, or simply electric vehicle (EV), is a vehicle based on one or multiple motors (electric or traction) to ensure propulsion. The degree of electrification varies from one vehicle to another.

An electric car is a car which is propelled by one or more electric motors, using energy stored in rechargeable batteries. The first practical electric cars were produced in the 1880s. Compared to internal combustion engines cars, electric cars are quieter, have no exhaust emissions, and lower emissions overall.

Charging an electric car can be done at a variety of charging stations, these charging stations can be installed in both houses and public areas. Several countries have established government incentives for EV, tax credits, subsidies, and other non-monetary incentives. Several countries have established a phase out of fossil fuels vehicles, and California which is one of the largest vehicle markets has an executive order to ban sales of new gasoline powered vehicles by 2035.

The Tesla Model 3 was the world's best selling EV from 2018 to 2021 and had a maximum electric range of 500 km (310 miles) according to the EPA. The model 3 became the world's all time best selling car by 2021.

Electric vehicles (EV) are increasingly becoming a part of modern life; its tremendous fuel economy, eco-friendliness, and smooth driving feel have appealed to many conscious modern consumers. EVs are quite different from traditional vehicles with internal combustion engines. From the basic mechanism diverge in many, many aspects. Understanding those differences would be the first step of a consumer beginning to gauge his or her interest in EVs. A venture into a new field of knowledge is always a challenge, but given the unmistakable trend towards the electric, there is no reason to shy away.

4.2 MODELLING OF AN ELECTRIC VEHICLE USING MATLAB/SIMULINK:

The below diagram shows the simulink model of electric vehicle.

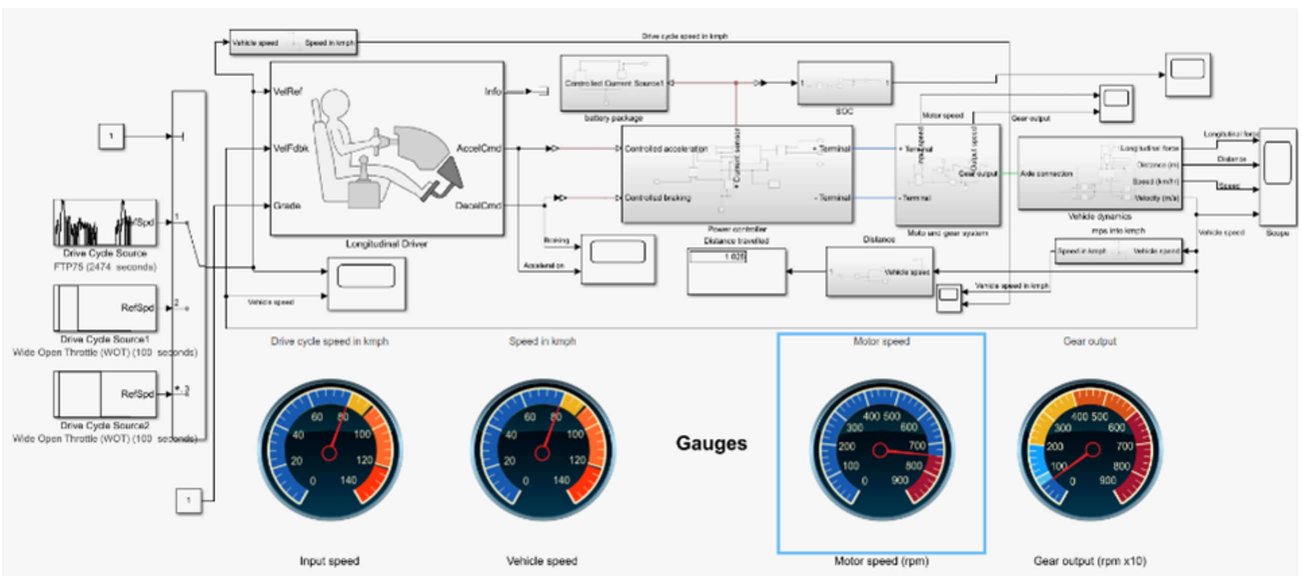

Fig 4.1 Simulink model of Electric

4.3 SIMULATION RESULTS:

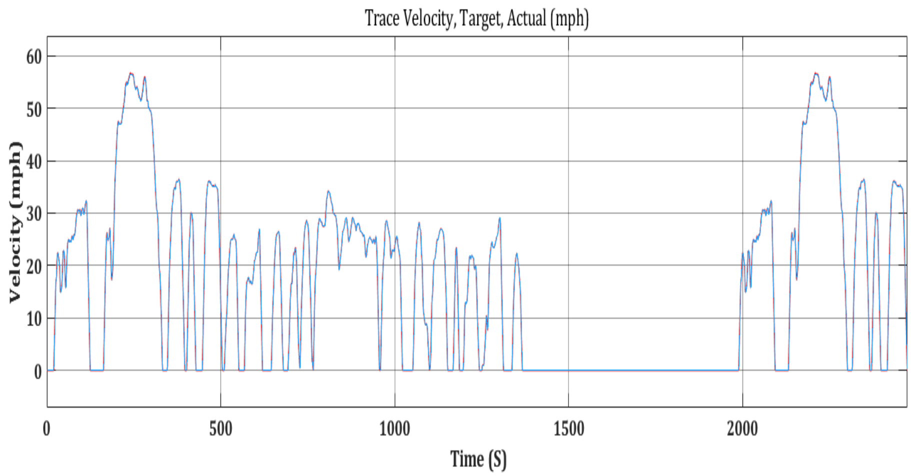

Fig. 4.2 Trace Velocity, Traget, Actual (mph) graph

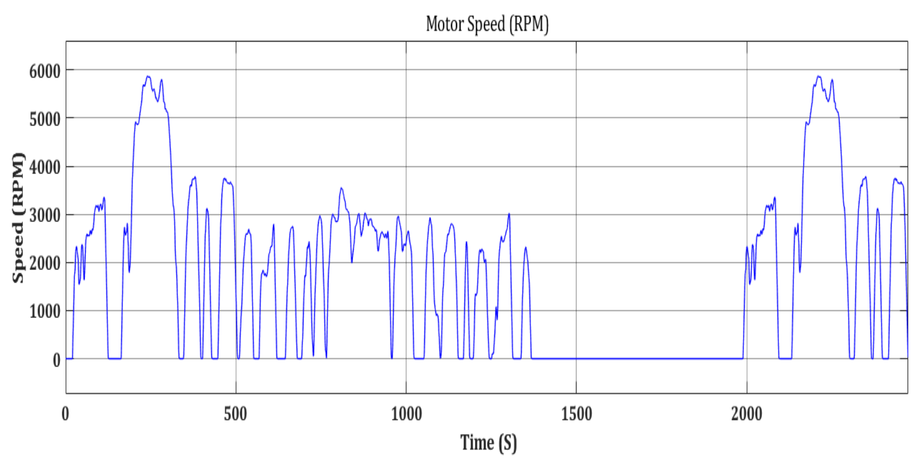

Fig. 4.3 Motor Speed (RPM) graph

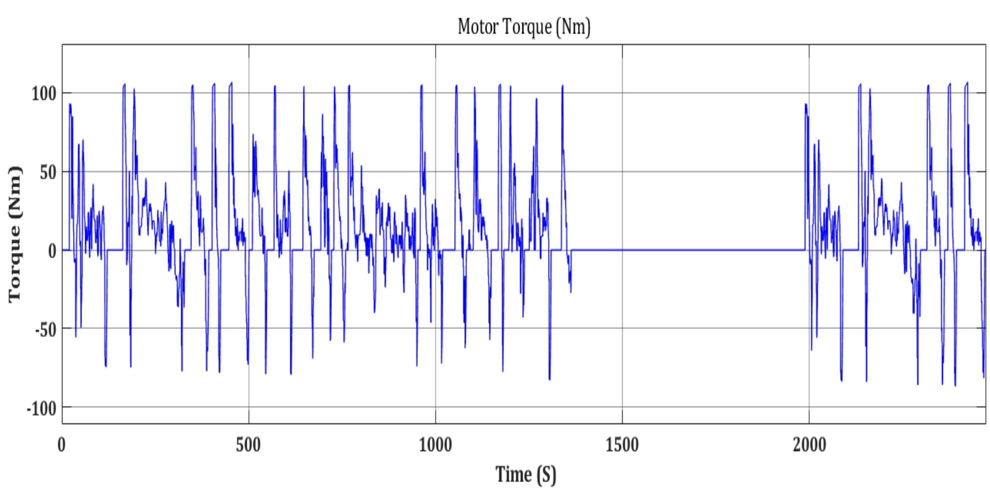

Fig. 4.4 Motor Torque (Nm) graph

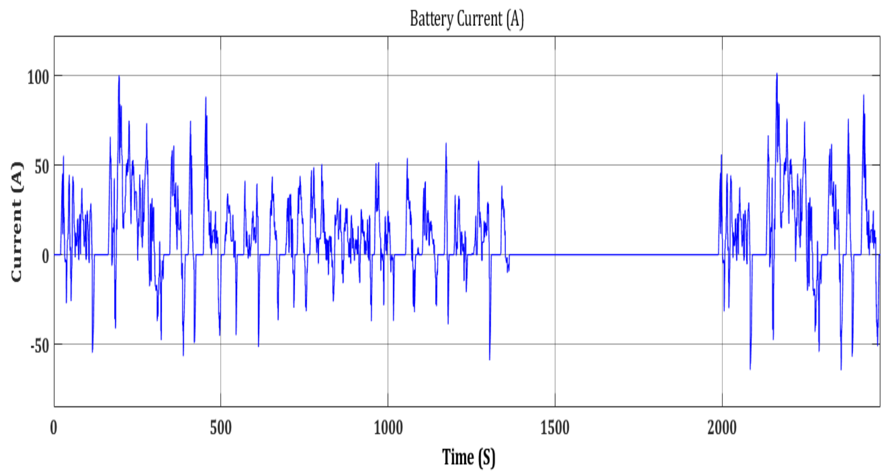

Fig. 4.5 Battery Current (A)

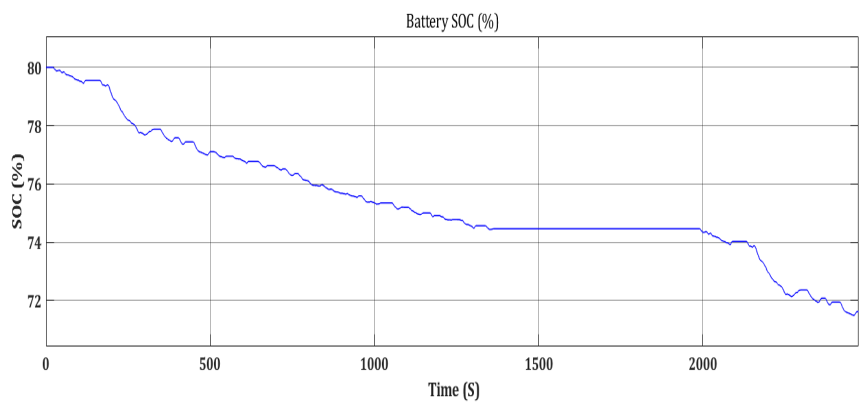

Fig. 4.6 Battery SOC (%) graph

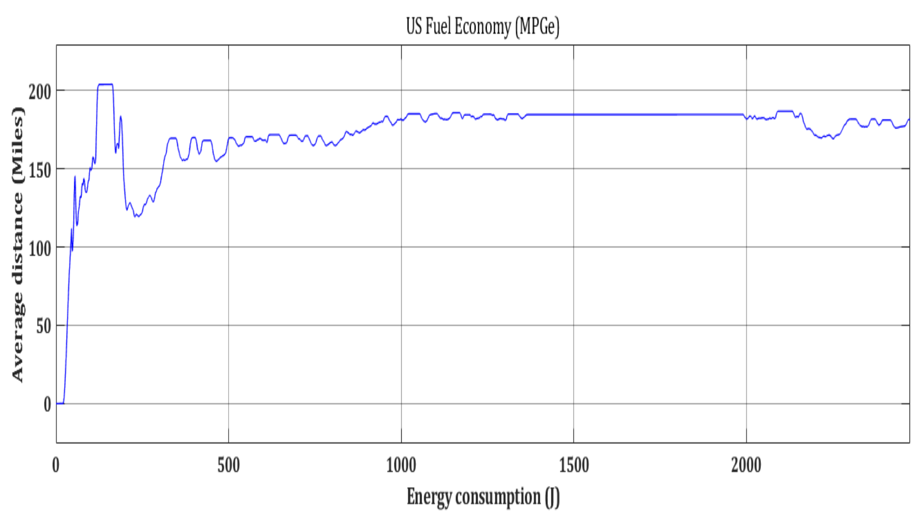

Fig. 4.7 Fuel Economy (MPGe) graph

5. CONCLUSION

A high gain sepic converter operated hybrid photovoltaic PV/battery Electric vehicle to improve the power transfer capability and efficiency of the power conversion stage. The bidirectional power flow fed to brushless DC motor from the solar system.The proposed system using with sepic converter is to improve power flow from the photovoltaic PV system.The grid is connected with DC bus to supply the power which generated from PV when and when power is not needed to load.The reliability of the Electrical vehicle is increased by using PV as well as the power conversion of sepic converter. A PV based SEPIC Converter fed Electric vehicle model created will increase the reliability and reduce the operating cost of Electric vehicle.The voltage source inverter of DC bus is supplying the energy to Electric vehicle.Utilization of single phase VSI is used to fed the bi-directional power flow control in between VSI and grid.In this system switching losses are reduced by using the fundamental frequency used.The proposed PV based sepic converter fed Electric vehicle results are obtained using MATLAB/SIMULINK.

6.FUTURE SCOPE

The future of mobility promises to be silent, efficient, and much better for our environment. Public procurement is expected to be an important driver of growth in the coming years, with the purchase of four-wheeler vehicles for government offices, three-wheeled vehicles and buses for public transport. Investments by fleet operators such as Ola and Uber, as well as some operators of food distribution services, are also expected to boost the initial growth of two and four wheeled electric vehicles. If the government 2030 targets are met, India could save Rs. 8 lakh crore on gasoline and diesel imports for the industry during the period considered, after considering a certain level of batteries. The timely adoption coupled with the electrification of the existing vehicles and growth of charging infrastructure will create a shift, the impact of which will be felt in metropolitan cities especially given that pollution has reached catastrophic levels. With the median age of Indians being 27 years, the younger generation is driven for innovation, sustainability and environmental conservation. At the same time, by manufacturing vehicles, components and batteries together, various established conglomerates and start-ups can ensure indigenous availability of products.

REFERENCES

[1] Patel, H., Agarwal, V.: MATLAB-based modelling to study the effects of partial shading on PV array characteristics. IEEE Trans. Energy Convers. 23, 302-310 (2008)

[2] Tarak Salmi, Mounir Bouzguenda, Adel Gastli, Ahmed Masmoudi, MATLAB/Simulink Based Modelling of Solar Photo-voltaic cell, INTERNATIONAL JOURNAL OF RENEWABLE ENERGY RESEARCH. Tarak Salmi et al., Vol.2, No.2, (2012)

[3] E. Duran, M. Piliougine, M. Sidrach-de-Cardona, J. Galan, and J. M. Andujar, “Different methods to obtain the I-V curve of PV modules: a review,” in proceedings of the 33rd IEEE Photovoltaic Specialists Conference (PVSC ’08), San Diego, Calif, USA, 2008.

[4] M.G. Villalva,J.R.Gazoli,E.Ruppert F, “Comprehensive approach to modelling and simulation of photovoltaic arrays”,IEEE Transactions on Power Electronics, 2009 vol.25,no.5,pp. 1198—1208, ISSN 0885-8993.

[5] M.G. Villalva, J.R. Gazoli, E.Ruppert F,”Modelling and circuit-based simulation of photovoltaic arrays”, Brazilian Journal of Power Electronics, 2009 vol.14, no.1, pp. 35—45, ISSN 1414-8862

[6] R.Sridhar, Dr.Jeevananathan, N.Thamizh Selvan, Saikat Banerjee, “Modelling of PV Array and Performance” IJSER 2015 https://www.ijser.org

[7] Enhancement by MPPT Algorithm, International Journal of Computer Applications (0975-8887) Volume 7-No.5, September 2010.

[8] Hairul Nissah Zainudin, Saad Mekhilef, “Comparision study of Maximum Power Point Tracker Techniques for PV Systems”, Cairo University Egypt, December 19-21, 2010, Paper ID 278.

[9] Katherine A.Kim and Philip T.Krein,”Photovoltaic Converter Module Configurations for Maximum Power Point Operation”, University of Illinois Urbana-Champaign Urbana, IL 61801 USA.

[10] Huan-Liang Tsai, Ci-Siang Tu,and Yi-Jie Su, “Development of Generalized photovoltaic Model Using MATLAB/SIMULINK”, proceedings of the world congress on Engineering and Computer Science 2008 WCECS 2008, October 22-24,2008, San Francisco, USA.

[11] Chen YM, Huang AQ,Yu X.A high step-up three-port DC-DC converter for stand-alone PV/battery power systems. IEEE Trans Power Electron.2013;28(11):5049-5062.Janu

[12] Lin BR, Chu CW.Hybrid DC-DC converter with high efficiency, wide ZVS range, and less output inductance. Int J Circuit Theory Appl.2016;44(5):996-1011.July

[13] Dung NA, Hieu PP, Hsieh YC, Lin JY, Liu YC, Chiu HJ. A novel low-loss control strategy for bidirectional DC-DC converter. Int J Circuit Theory Appl.2017;45(11):1801-1813.June.

[14] Faraji R, Farzanehfard H. Soft-switched non-isolated high step-up three-port DC-DC converter for hybrid energy systems. IEEE Trans power electron.2018;33(12):10101-10111.Janu

[15] Dobakhshari SS, Milimonfared J, Taheri M, Moradisizk H.A quasi-resonant current-fed converter with minimum switching losses. IEEE Trans power electron.2017;32(1):353-362.Febr

[16] Gules R,Santos WMD,Reis FAD,Romaneli EFR, Badin AA. A modified SEPIC converter with high static gain for renewable applications. IEEE Trans Power Electron. 2014;29(11):5860-5871.Nov

[17] Babaei E, Saadatizadeh Z, Heris PC. A new topology for non-isolated multiport zero voltage switching dc-dc converter. Int J Circuit Theory Appl.2018;46(6):1204-1227. February

[18] Saadatizadeh Z, Heris PC, Babaei E, Sadikoglu F. Expandable interleaved high voltage gain boost DC-DC converter with low switching stress. Int J Circuit Theory Appl.2019;47(5):782-804.March

[19] Mahmoudi M, Ajami A, Babaei E. A non-isolated high step-up DC-DC converter with integrated 3 winding coupled inductor and reduced switch voltage stress. Int J Circuit Theory Appl. 2018;46(10):1879-1898.May

[20] Muranda C, Ozsoy E, Padmanaban S, Bhaskar MS, Fedak V, Ramachandaramurthy VK.Modified SEPIC DC-to-DC boost converter with high output-gain configuration for renewable applications. In Proc IEEE Conference on Energy Conversion in Malaysia, Oct 2017, pp.317-322.

[21] Park KB, Moon GW, Youn MJ. Nonisolated high step-up boost converter integrated with SEPIC converter. IEEE Trans Power Electron. 2010;25(9):2266-2275.March

[22] Yang JW, Do HL. Bridgeless SEPIC converter with a ripple-free input current. IEEE Trans Power Electron. 2013;28(7):3388-3394.July

[23] Kanagraj N, Ramasamy M, Rezk H, Manesh T.Modified bi-directional DC-DC boost converter fed three-phase four-wire PV-DVR. J Test Eval.2018;48(4):1-29.May

[24] Kircioglu O, Unlu M, Camur S.Modeling and analysis of DC-DC SEPIC converter with coupled inductors. In Proc of International Symposium on Industrial Electronics in Bosnia Herzegovina, Nov 2016, pp. 1-5.

[25] Chiu HJ, Lo YK, Tseng PJ, et al. Design and implementation of a high-efficiency LiFePO4 battery chager for electric vehicle applications. Int J Circuit Theory Appl.2014;42(7):759-768. July

[26] Li L, Coskun S, Zhang F, Langari R, Xi J. Energy management of hybrid electric vehicle using vehicle lateral dynamic in velocity prediction. IEEE Trans Vehicle Technol.2019;68(4):3279-3293.Janu

[27] Malan J, Kamper MJ. Performance of a hybrid electric vehicle using reluctance synchronous machine technology. IEEE Trans Ind Appl. 2001;37(5):1319-1324.Sept