www.revistageintec.net
ISSN: 2237-0722
revista GEINTEC
Gestão, Inovação e Tecnologias

Smart Power System for Electric Vehicles Using Three Port Bi-Directional Converter

M. Perarasi[1]; J. Vignesh[2]; V. Srish[3]; S. Vishnu[4]; Siva T Lalith Kumar[5]; M. Athavan[6]

[1]Department of Electrical and Electronics Engineering, R.M.K Engineering College.
[1]mpi.ee@rmkec.ac.in
[2]Department of Electrical and Electronics Engineering, R.M.K Engineering College.
[2]vign17331.ee@rmkec.ac.in
[3]Department of Electrical and Electronics Engineering, R.M.K Engineering College.
[3]sris17314.ee@rmkec.ac.in
[4]Department of Electrical and Electronics Engineering, R.M.K Engineering College.
[4]vish17334.ee@rmkec.ac.in
[5]Department of Electrical and Electronics Engineering, R.M.K Engineering College.
[5]siva17310.ee@rmkec.ac.in
[6]Department of Electrical and Electronics Engineering, R.M.K Engineering College.
[6]vathavshanthi@gmail.com

Abstract

The proposed system is used to deliver an uninterrupted power supply to the motor in electric vehicle with reduced switching losses. A PV Panel is combined to the load as a secondary power source in addition to the primary Energy Storage System (ESS) which is connected together using a three port DC-DC converter. The converter boosts output from the respective sources and regulates constant supply to the load in a single stage of transmission. Phase shifted Pulse Width Modulation (PPWM) technique reduces the harmonics which in order reduces the switching losses and makes switching instant, resulting in fast dynamic response. The secondary source can also be used to charge the battery through bidirectional converter. A fuel cell connected to a converter which is interfaced with the load through a separate circuit acts as an additional backup at situations to maintain continuous power supply in case of failure in both the primary power source and the panel circuits.

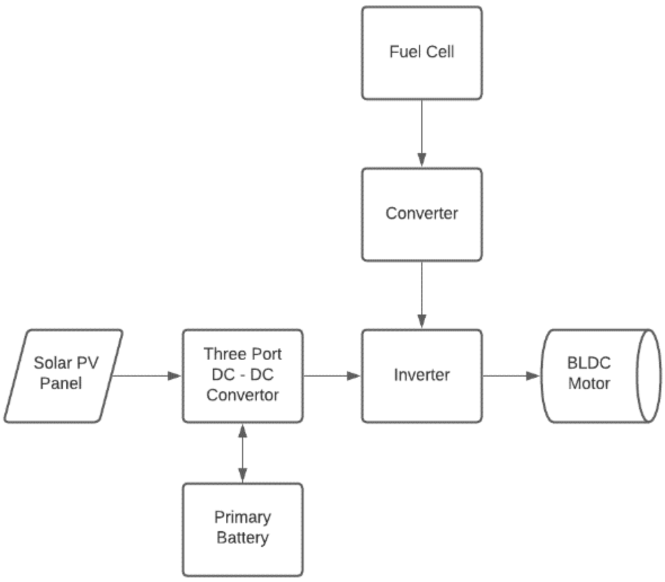
Key-words: Solar PV Panel, DC-DC Converter, PPWM, Fuel Cell.

1. Introduction

Electric Vehicles are now an emerging alternative for existing vehicles and their utilisation is keep on increasing tremendously. Electric Vehicles uses energy from battery or other sources to function and does not produce any harmful gases, thus it is eco-friendly. It uses minimum mechanical and movable parts, which makes it a smooth operating machine with increased durability and less maintenance. The problem with Electric Vehicles is the limited operating range and the time for charging which is a hindrance for its growth. Existing Electric Vehicles uses number of converters which leads to switching losses and slow dynamic response which leads in poor efficiency. To overcome the limitations and to improve the efficiency a power system with a backup is proposed.

This proposed system consists of a converter which is three port bidirectional. The converter uses phase shifted PWM technique whose advantage is to reduce the harmonics to small value during boost up. The motor used is BLDC motor as it has high efficiency compared to others. Here the battery will be acting as the primary source which can be charged externally and as well as through solar panel. During the daytime when sufficient amount of radiation falls on the panel the supply will pass through the converter which would boost it to require amount to run the motor. At times when solar energy is not sufficient the battery circuit immediately connects and the supply to motor would be given through this circuit, that is this circuit acting mainly at night times. The breakers control the switching of power input circuits by turning them on or off instantly as required. When the total circuit that gives supply through solar and battery fails which may occur at rare situations the supply would be given through the additional backup provided by the fuel cell. Thus, the system provides uninterrupted power supply throughout, to the motor while it is running thereby reducing the charging issues and enhances the driving range. This also increases the battery performance and extends its lifetime.

Fig. 1 - Block Diagram of Proposed System



ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 13.06.2021 – Accepted: 15.07.2021

2. Components

1. SOLAR PANEL - The solar PV Panel is the secondary power source which is used for the backup. The Solar Panel which ingests the sun's beams and converts them into power. The cells are masterminded in grid like framework on the panel surface. The solar panel has a capacity of 50W,12V.
2. BATTERY - Battery is used as primary energy storage system. The progression of electrons from one electrode to another through outer circuit gives an electric flow. The battery has the limit of 12V,1.3Ah.
3. THREE PORT CONVERTER - The three-port converter consists of MOSFET- IRF840, Driver IC- IR2112, Capacitor- 470uF (25V); 1000uF, Regulator- LM7805; LM7812, Diodes- N4000; 1N5408, Inductors- 100uH; 200uH; 1mH and two batteries of 24-V and 48-V batteries used as input source and backup energy respectively. The converter can screen both battery voltages all the while. At the point, when one battery is utilized exorbitantly the other battery can charge it, along these lines keeping the stable power supply. It works with consistent input current and low voltage stress, and it gives input current recuperation.
4. FUEL CELL - Fuel cell is used as an additional backup in-case of a failure of primary and secondary power sources. Fuel cell is chemical cell that producing the power through electrochemical response. In this, hydrogen and oxygen are consolidated to create the power. This electricity will be filtered to constant rate to run the motor. Typical fuel cell works by passing hydrogen through the anode and oxygen through the cathode.
5. BLDC MOTOR - Brushless DC motor is electronically commutated DC motor which gives a precise speed. In brushless DC motor, the perpetual magnets are on the rotor, and the electromagnets are on the stator. PC at that point charges the electromagnets in the stator to turn the rotor entire 360-degrees. The motor has the capacity of 1400KV.

3. Operation of Converter

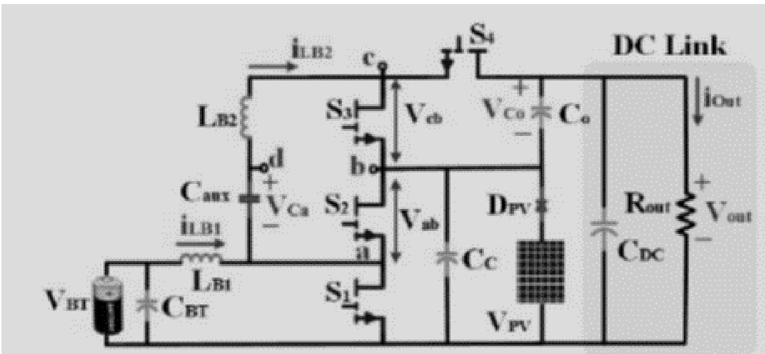
A TPC is a well-established means of realizing a highly regulated dc-link bus in systems with multiple sources. Since the input port is connected to a RES such as PV, TPC has to have the maximum power tracking capability**.** Because of the unpredictability of environmentally friendly power sources, presence of an energy stockpiling component is important to supply the confused force. In this part, the proposed STPTLC is completely considered.

Stacking converters such as that depicted in Fig.3 aims at improving the efficiency and voltage gain without requiring any extra component. Clearly the force can move among three ports straightforwardly without utilizing any transformer.

The clamp circuit limits the voltage stress of switches; hence switches with smaller on-resistance RDS(ON) can be used, leading to lower conduction loss. Compared to other TPC, STPTLC offers the soft-switching for a wide range of power and input voltage and needs a smaller number of switches and inductors to achieve high voltage gain. Symbols are characterized as follows: channel inductors LB1, LB2, power switches S1, S2, S3, S4, assistant capacitor C aux, clasp capacitor CC, and yield capacitor CO.

Vout denotes the voltage of high-voltage port (HVP), which is equal to summation of voltage of clamp capacitor and output capacitor, VCc+ VCo. In Fig.3, the battery is emulated by a voltage source VBT. Also, the solar panel is modelled as an ideal voltage source VPV in series with a diode DPV.

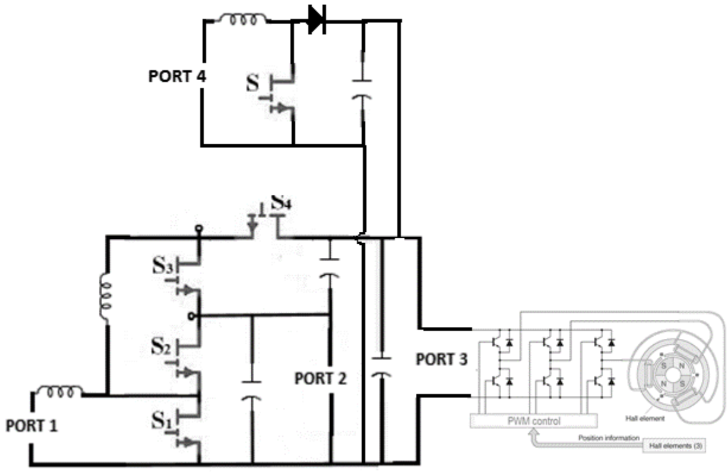
Fig. 2 - Operation of Converter



The voltage across switches S2 and S3 are symbolized by Vab and Vdb, respectively. The gate pulse of switches S2 and S4 are complementary to that of switches S1 and S3, respectively. The inductor LB1 is adopted as a filter to reduce the battery current ripple, and the inductor LB2 is used to form a resonant circuit to realize ZVS performance and confine the peak current of HVP switches. The main switches S1 and S3 can transfer the power from PV to the battery and the load, respectively. While no extra voltage stress is added across the switches, an auxiliary capacitor is added to the circuit to extend the range of soft-switching performance, which forms a resonant tank with the inductor LB2. This auxiliary capacitor stores the magnetic energy of inductor LB2, and released it to the output capacitor Co.

4. Methodology

Fig. 3 - Circuit Diagram of Proposed System



The three-port bidirectional DC/DC converter in which Phase-shifted PWM technique is used to boost up the incoming DC supply. The PWM technique improves the voltage output and reduce the harmonic distortion that occurs during conversion. The PWM uses suitable cascade method and hall element to invert the input energy to boost accordingly. Here the port one and two resembles the battery and panel input lines, port three resemble the load and port four resembles the fuel cell circuit. The amount of each supply power is being rectified to required level and boosted up accordingly by the converter to run the BLDC motor. The switches turn on or off the circuits. All the power supply ports will be represented through 3 switches in the proposed system.

5. Modes of Operation

In this proposed system there would be totally five modes of operation.

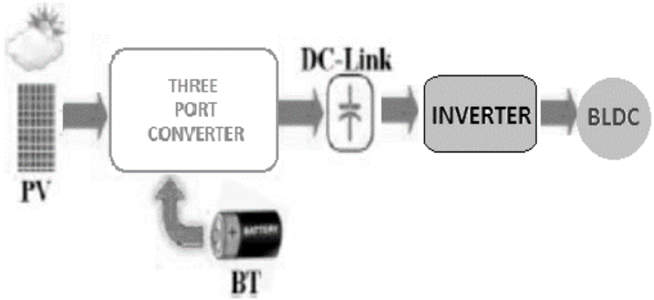
Mode 1 & 4

During the mode one and mode four the panel supply does not meet the required level due to the low radiation, and so the battery circuit connects and battery discharges and supplies power to the

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 13.06.2021 – Accepted: 15.07.2021

motor through the converter when required gate pulse is given to the converter for boosting up the power. Switch 2 will be used to show that the battery circuit has been connected to the system.

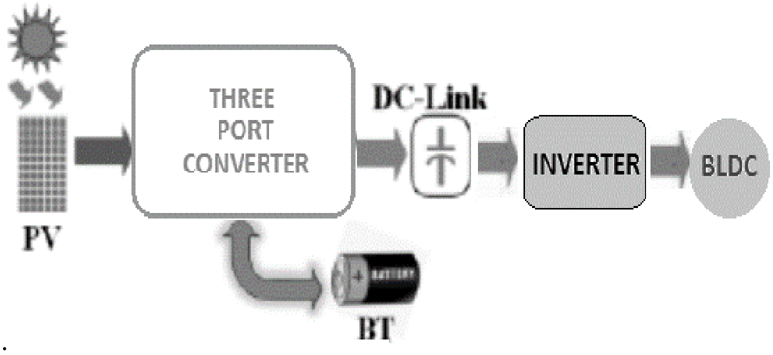
Fig. 4 - Mode 1&4 Operation



Mode 2 & 3

During mode two and mode three the radiation that falls on the panel is high and hence panel starts discharging power to the motor through the converter which after being given the required gate pulse boosts up the power supply, and sends it. Also, the panel will act as source by means of which the battery can be charged in this mode. Switch 1 in the proposed system shows that panel circuit has been connected to the system.

Fig. 5 - Mode 2 & 3 Operation



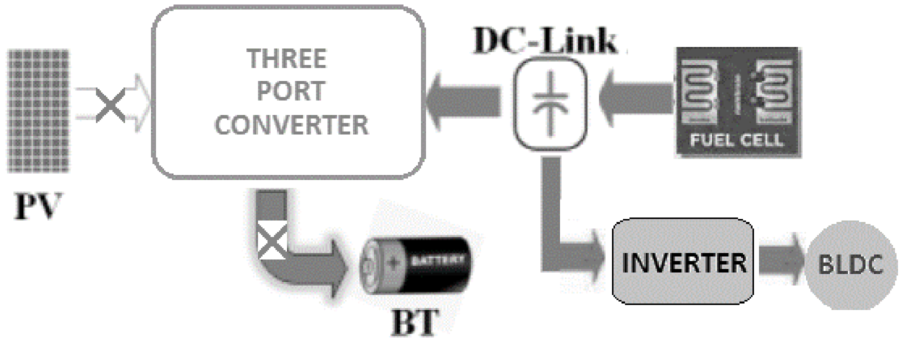
Mode 5

This mode represents the fuel cell circuit that has been connected to the system. When both PV and the battery get faulted which may occur at the rare condition those circuits will be disconnected and immediately the fuel cell circuit connects to the motor. The fuel cell does not need any external source of powering, and therefore this mode can supply power as long as the motor runs

ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 13.06.2021 – Accepted: 15.07.2021

or till the vehicle reaches the destination. The supply from the fuel cell to is boosted up using suitable converter, and then that output is inverted and then it is sent to the motor.

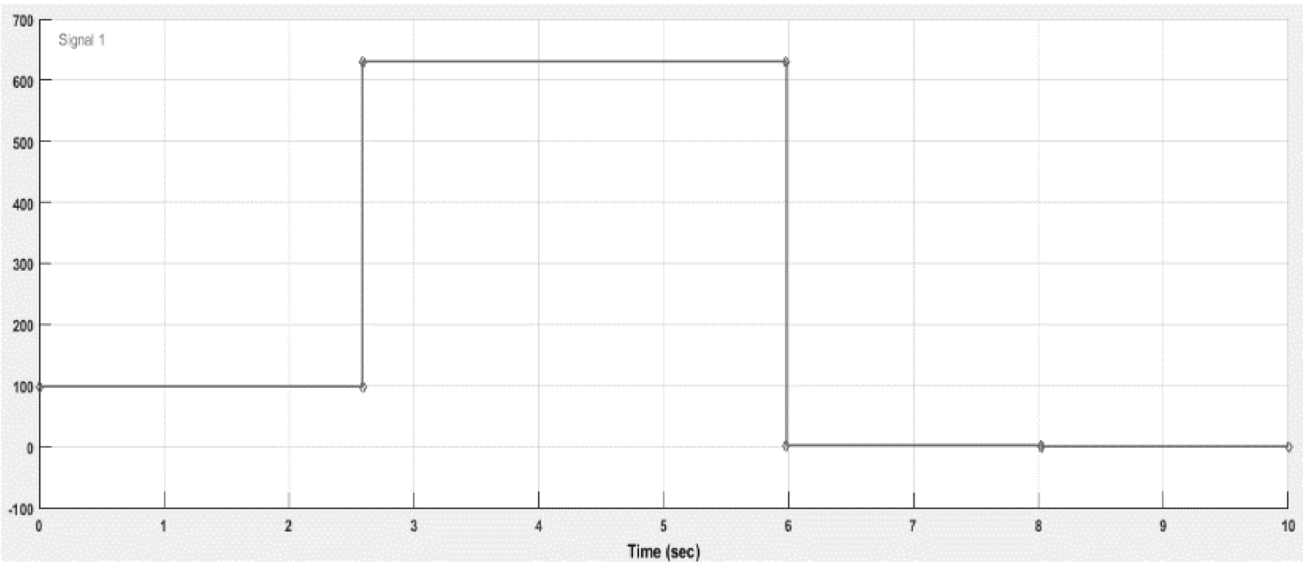
Fig. 6 - Mode 5 Operation



6. Result

The components which give output are studied individually and analysed in MATLAB Simulink.

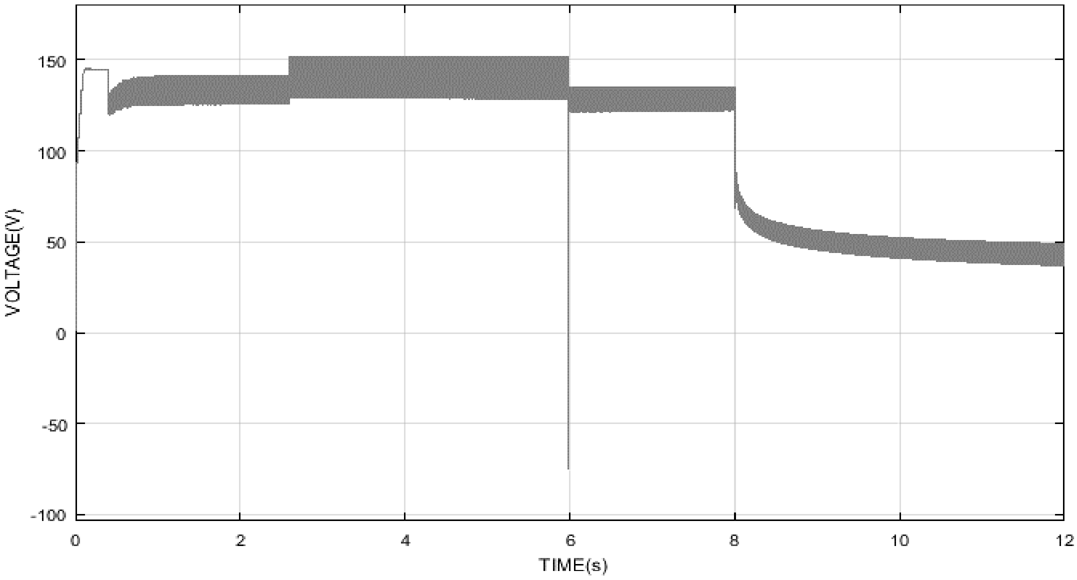
Fig. 7 - Solar Panel Input



The source for solar panel is sun and since the source does not have constant value it is chosen to be in pulse with three different signals, low radiation, high radiation and zero radiation. The converter will take care of delivering constant supply throughout the system.

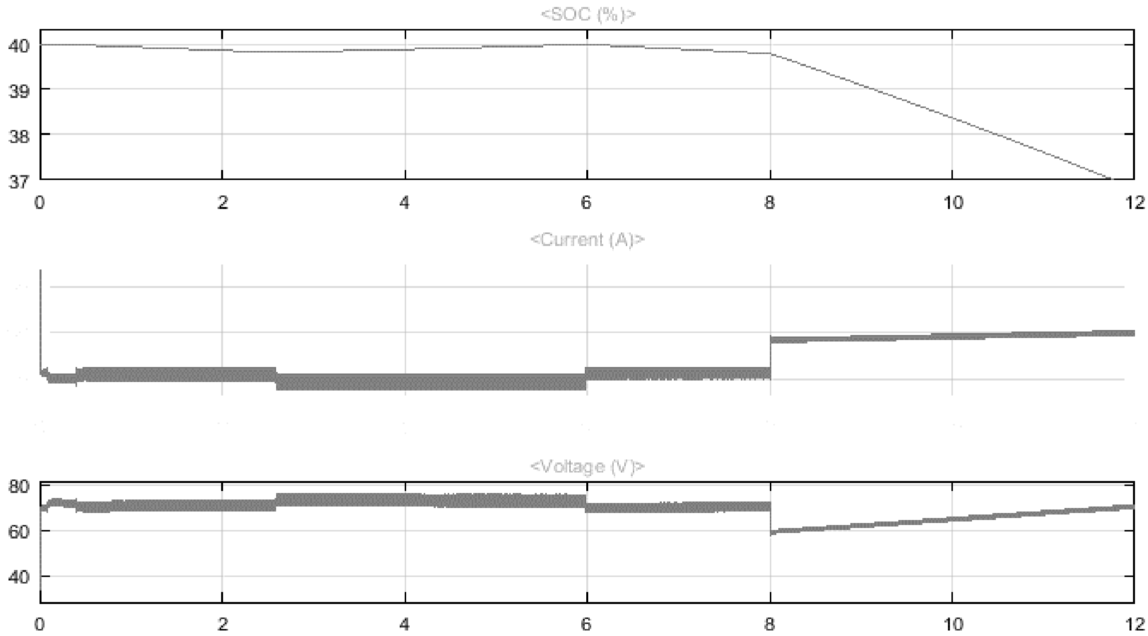
ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 13.06.2021 – Accepted: 15.07.2021

Fig. 8 - Solar Panel Output



The output voltage (V out) is shown. The voltage (V) varies with respect to time (s).

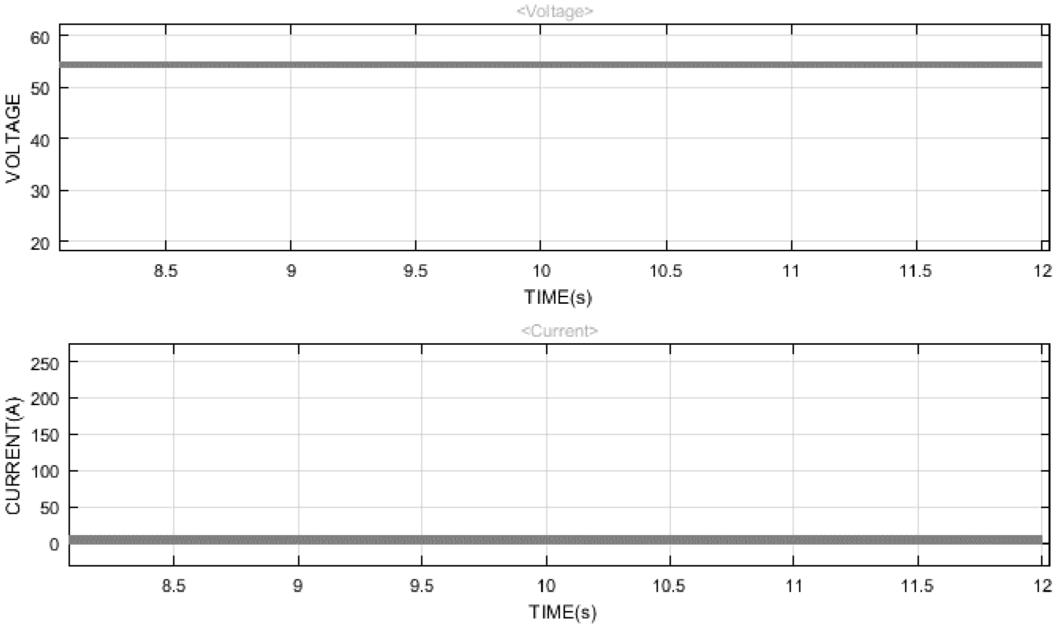
Fig. 9 - Battery Parameters



State of charge is associated with battery tells how much power can it deliver in ampere hours (Ah). At a particular time when battery loses its energy the voltage drops and current raises. In this situation, the bidirectional port is used to recharge the battery. Simultaneously, other source comes in.

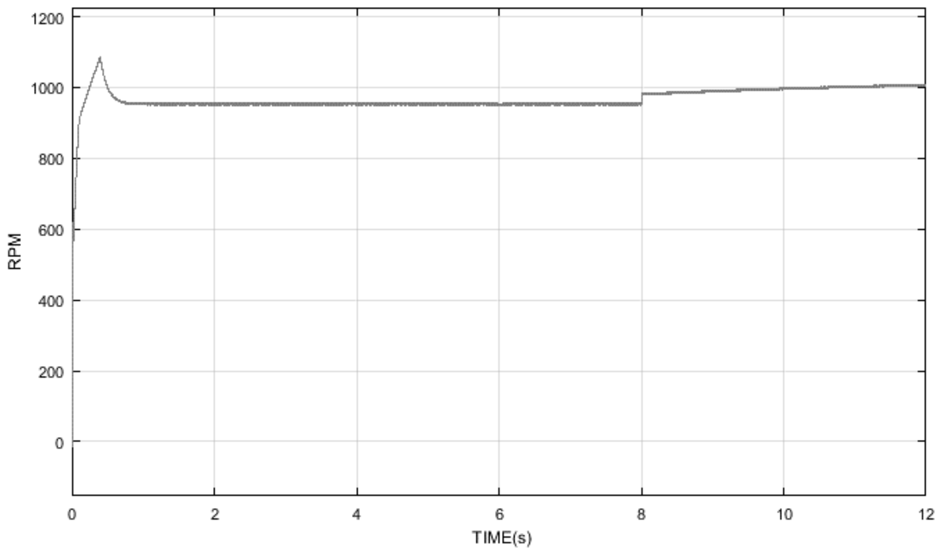
ISSN: 2237-0722
Vol. 11 No. 4 (2021)
Received: 13.06.2021 – Accepted: 15.07.2021

Fig. 10 - Fuel Cell



Fuel cell has constant voltage supply, irrespective of any changes. When the output voltage (V out) is high, current (I) is low.

Fig. 11 - BLDC Motor Output



This graph shows the final output of our system, that is how to motor runs with various inputs. The rotation per minute is 1000 rpm which is achievable. Thus, it also replicates the normal electric vehicles' output.

7. Conclusion

Backup assistors are developed to support the primary power system. These assistors are operated when primary system fails to meet the load. In that perspective, our backup assistor is designed in way that the primary system is kept as an option in supplying power. So, in this place a **renewable energy source** is equipped as a primary source. The **three-port converter** used here has one two unidirectional switches and one bidirectional switch. Solar panel and battery are the input for three-port converter, and the output is fed to inverter. Battery is connected in bidirectional port because whenever the discharging takes place it needs to be recharged again. The input for the converter is pulse width modulation signals. It offers better efficiency and reduces switching losses. Fuel cell is used in our system in rare situations when both the sources i.e., solar panel and battery are failed. Giving an uninterrupted energy to the vehicle is our ultimate aim.

References

F. Xue, R. Yu and A.Q. Huang, "A 98.3% Efficient GaN Isolated Bidirectional DC–DC Converter for DC Microgrid Energy Storage System Applications," *IEEE Trans. Ind. Electron.,* 64(11), 9094-9103, Nov. 2017.

H. Li et al., "Paralleled operation of high-voltage cascade GaN HEMTs," *IEEE J. Emerg. Sel. Topics Power Electron.,* 4(3), 815–823, Sep. 2016.

D. Reusch and J. Strydom, "Understanding the effect of PCB layout on circuit performance in a high-frequency gallium-nitride-based point of load converter," *IEEE Trans. Power Electron.,* vol. 29, no. 4, pp. 2008–2015, Apr. 2014.

C.Zhao et al., "Design and Implementation of a GaN-Based, 100-kHz, 102-W/in3 Single-Phase Inverter," *IEEE J. Emerg. Sel. Topics Power Electron.,* vol. 4, no. 3, pp. 824-840, Sept. 2016.

X. Zhu, B. Zhang, Z. Li, H. Li and L. Ran, "Extended Switched-Boost DC-DC Converters Adopting Switched-Capacitor/Switched-Inductor Cells for High Step-up Conversion," *IEEE J. Emerg. Sel. Topics Power Electron.,* vol. 5, no. 3, pp. 1020-1030, Sept. 2017.

L. Wang, Z. Wang, and H. Li, "Asymmetrical duty cycle control and decoupled power flow design of a three-port bidirectional DC-DC converter for fuel cell vehicle application," *IEEE Trans. Power Electron.*, vol. 27, no. 2, pp. 891–904, Feb. 2012.

J. Zeng, W. Qiao, and L. Qu, "An Isolated Three-Port Bidirectional DC-DC Converter for Photovoltaic Systems With Energy Storage," *IEEE Trans. Ind. Appl.,* 51(4), 3493–3503, 2015.

J.L. Duarte, M. Hendrix, and M.G. Simões, "Three-port bidirectional converter for hybrid fuel cell systems," *IEEE Trans.Power Electron.,* 22(2), 480–487, March 2007.

V.N.S.R. Jakka, A. Shukla and G. D. Demetriades, "Dual-TransformerBased Asymmetrical Triple-Port Active Bridge (DT-ATAB) Isolated DC–DC Converter," *IEEE Trans. Ind. Electron,* 64(6), 4549- 4560, June 2017.

A. Nahavandi, M.T. Hagh, M.B.B. Sharifian and S. Danyali, "A Nonisolated Multiinput Multioutput DC–DC Boost Converter for Electric Vehicle Applications," *IEEE Trans.Power Electron.,* 30(4), 1818-1835, April 2015.

C.C. Chan, "The State of the Art of Electric Hybrid and Fuel Cell Vehicles", *Proceedings of the IEEE*, vol. 95, no. 4, April 2007.

I. Staffell, P. Balcombe, D. Scamman, P. E. Dodds, A. Velazquez Abad, P. Ekins. "The role of hydrogen and fuel cells in the global energy system", *This journal is The Royal Society of Chemistry,* 2018.

A. Flah, S. Lassaad and C. Mahmoudi, "Overview of Electric Vehicle Concept and Power Management Strategies", *Conference Paper,* November 2014.

G. Vacheva and N. Hinov, "An Overview of the State of Art of Fuel Cells in Electric Vehicles," 2019 *International Conference on Creative Business for Smart and Sustainable Growth (CREBUS), Sandanski*, Bulgaria, 2019, pp. 1-4, doi: 10.1109/CREBUS.2019.8840075.

S. Sadagopan, S. Banerji, P. Vedula, M. Shabin and C. Bharatiraja, "A Solar Power System for Electric Vehicles with Maximum Power Point Tracking for Novel Energy Sharing," *2014 Texas Instruments India Educators' Conference (TIIEC), Bangalore,* 2014, pp. 124-130, doi: 10.1109/TIIEC.2014.029.

T. Sarkar, M. Sharma and Suresh Kumar Gawre, "A generalized approach to design the electrical power system of a solar electric vehicle," *2014 IEEE Students' Conference on Electrical, Electronics and Computer Science,* Bhopal, India, 2014, 1-6, doi: 10.1109/SCEECS.2014.6804490.

S. Mohd, S.A. Zulkifli, R.G.A. Rangkuti, M. Ovinis, and N. Saad, "Electric vehicle energy management system using National Instruments' Compact RIO and LabVIEW," *in Proceedings of the 2013 IEEE International Conference on Smart Instrumentation, Measurement and Applications, ICSIMA* 2013, Malaysia, November 2013.

G. Suciu and A. Pasat, "Challenges and opportunities for batteries of electric vehicles," 2017 10th *International Symposium on Advanced Topics in Electrical Engineering (ATEE),* Bucharest, Romania, 2017, pp. 113-117, doi: 10.1109/ATEE.2017.7905058.

J. Zhang, H. Wu, X. Qin and Y. Xing, "PWM Plus Secondary-Side Phase-Shift Controlled Soft-Switching Full-Bridge Three-Port Converter for Renewable Power Systems," *in IEEE Transactions on Industrial Electronics, 62*(11), 7061-7072, Nov. 2015, doi: 10.1109/TIE.2015.2448696.

P. Shamsi and B. Fahimi, "Dynamic behavior of multiport power electronic interface under source-load disturbances", *IEEE Trans. Ind. Electron.,* vol. 60, no. 10, pp. 4500-4511, Oct. 2013.

T.V. Thang, N.M. Thao, J.H. Jang and J.H. Park, "Analysis and design of grid-connected photovoltaic systems with multiple-integrated converters and a pseudo-DC-Link inverter", *IEEE Trans. Ind. Electron.,* 61(7), 3377-3386, Jul. 2014.

H. Oman, "New electric-vehicle batteries,*" Proceedings of Northcon '94, Seattle,* WA, USA, 1994, 326-330, doi:10.1109/NORTHC.1994.643374

F.W. Colliver, W.D. Wesson and L.L. Grigsby, *"Microprocessor control of an electric vehicle," 28th IEEE Vehicular Technology Conference,* Denver, CO, USA, 1978, 82-87. doi: 10.1109/VTC.1978.1622514.

T.J. Maloney and F.L. Alvarado, "A Digital Method for DC Motor Speed Control," *in IEEE Transactions on Industrial Electronics and Control Instrumentation, IECI-23*(1), 44-46, 1976. doi: 10.1109/TIECI.1976.351346.

A. Paredes, H. Ghorbani, V. Sala, E. Fernandez and L. Romeral, "A new active gate driver for improving the switching performance of SiC MOSFET," *2017 IEEE Applied Power Electronics Conference and Exposition (APEC),* Tampa, FL, USA, 2017, 3557-3563. doi: 10.1109/APEC.2017.7931208.