A REAL-TIME ENERGY MANAGEMENT APPROACH AND ITS POWER CONVERTER FOR PV POWERED PLUG-IN ELECTRIC VEHICLES

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Abstract: *A huge inrush of Electric Vehicles (EVs) is anticipated in the near future. As a new generation of transport, electric vehicles have several advantages compared with conventional vehicles in the aspects of energy conservation and emission reduction and human dependence on traditional fossil fuel. As there is an increase in Electric Vehicle (EV) around the world, making EVs user-friendly becomes more significant. The main challenge in the usage of EV is the charging time required for the batteries used in EV, lack of charging stations and therefore charging within existing distribution system infrastructure. In order to provide the comfortable power system for the EV battery system. The power converter must be relate with input power and EV battery power rating state of charge (SOC). Hence the high power converter is needed to give the high voltage and continuous conduction for helping fast and regular charging. The proposed converter is combines the simple boost and cuk-converter and proving the high voltage gain and discontinuous conduction mode. The proposed converter is capable of charging EV in variable PV condition. The SOC is measured through Arduino UNO and according to EV battery SOC, the microcontroller is giving the voltage gain to the proposed converter. With the Android application, the users will be able to save time and plan their ways accordingly.*

Keywords: *Electric Vehicle (EV), State of Charge (SOC), DC-DC converter, Charging Stations (CS).*

1. Introduction

Electric vehicles (EVs) usage is started to increasing in the current era as an eco-friendly and cost-effective alternative nature [1]. They have lower operational charges with respect to ICE vehicles and can be also charged with renewable energy sources (RESs) such as PV and wind power plant. [2]. Connection to the electric power grid allows opportunities such as ancillary services, reactive power support, tracking the output of renewable energy sources, and load balance. The important issue about EV charging is to deploy an efficient smart grid network that can effectively and conveniently charge the EVs. The secondary batteries are the main sources of electric vehicles. Thus, the energy management and the battery capacity plays a vital role in the development of hybrid electric vehicles (HEV). [3] The main challenge in the HEV is the charging time required for the batteries and insufficiency of charging stations (CS)[4].

Battery management systems (BMSs) on the EV is an important part of the battery system. The power given to the battery system is done by power converters. Particularly the solar power charging stations are providing more attention to EV consumer. Here the power demand is mainly concentrated for changing the battery in fast charging (level-1 charging method). Based on the converter voltage gain and stability of the battery system, the efficiency is increasing and the battery system is maintained in an accurate and reliable operational condition. Recently, many DC/DC converters are proposed by the researchers based on the high gain and continuous current conduction mode operations. Basically, converter providing voltage bucking/boosting is required in many applications such as PV systems and fuel cells [5–8]. Many situationsare a kind of practices, an additional DC/DC buck–boost converter is needed to regulate the output voltage. Several converter types are accomplished by providing both step-up and step-down [9]. The converters are basically classified into isolated and non-isolated. The isolated converters are cuk, sepic and zeta converters and flyback converter [11]. Some DC/DC buck–boost converters are recently proposed by using the KY converters [11–14].Nevertheless, these converters are having more number of four power switches have been used in these converters. The BMS does baseon measuring the system current, voltage, and temperature, and the cells’ state of charge (SoC), state of health (SoH) and remaining useful life determination, protecting the cells, thermal management, controlling the charge/discharge procedure, monitoring, storing historical data, data acquisition, communication with on-board and off-board modules (may be charger), and most importantly is the cell balancing [10].A level 1 household charger (120V, 50Hz, 15-20A) is more than 15 hours. [15] In future, the number of electric vehicles will be increasing to a greater extent, these electric vehicles have to re-charge their battery in a place (i.e.) charging station, and therefore there will be a growing need for public accessing charging stations. [16] This will have a considerable impact on the power systems like transformers, protection devices etc. With respect to the varying load, it will have an impact on the consumers and vendors due to the traffic at this station, waiting time for charging the vehicles will increase etc. Consequently, to progress all these factors there should be suitable monitoring systems to manage them, like the smart grid technologies monitoring the load on the power grids [17-19]. Therefore both the consumer and vendor will get assistance from a communication system which shares useful data regarding the charging station, whether the charging slots are free, the rate at which charging is done and the cost per unit. This is basically what is known as a vehicle to grid communication (V2G) [20].

Based on the above discussions, the power converter designs with respect to the battery management is important for the consideration of PV fed EV charging system. This paper deals with the high boost ratio DC-DC converter and power measuring system for EV. The system model is tested with real-time PV system and the tested results are verified with power management test bench. Chapter 2 is discussing the battery management system and EV on DC micro grid and chapter 3 deliberate the proposed converters and its operation. In chapter 4, the battery power measurement of EV is explained. The chapter elucidate the experiment results.

2. DC Microgrid Power Architecture

Typically, a DC micro grid has structured the combination of PV and wind power with battery storage. The major loads on the DC micro gridare home appliances and EVs. The roof top based PV power system is the best option of feeding power to EVs. The voltage on DC bus required to guarantee power share and prevent current leakage with more sources [24]. When the loads are added to the micro grid, the voltage balancing control and energy management become thought-provoking. The Fig.1 shows the simple DC Microgrid Power Architecture. EV power feeding is a major task here since the EV load is flooding and the power converters (DC-DC) are performing the power conversions based on the available solar power and energy storage devices. According to the charging station nature, the EV are getting charged either in fast or slow changing. The EV charging management is mainly grouping in two technology; 1. Power converters with charging and battery power management

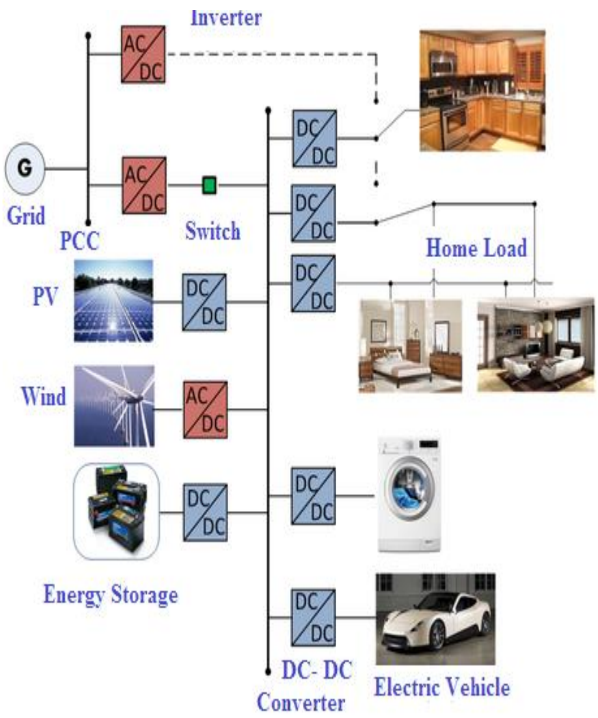


Fig.1 DC Micro grid Architecture

2.1. EV Charging module:

The EV changing station are essential can categories in the following point

2.2 House- hold charging point:

Level-1 charging (fast charging) equipment is standard on vehicles and therefore is portable and does not require the installation for charging equipment [25].

2.3 Public Charging Stations: The public charging equipment offers to charge through a 240V, AC plug and requires the installation of home or public charging equipment. Depending on the battery technology used in the vehicle, public charging generally takes 4 to 6 hours to completely charge a fully depleted battery [24,25]. Charging time can increase in cold temperature. Lithium ion batteries support the charging temperature of 0˚C to 45˚C (32˚F to113˚F) and discharging temperature of -20˚C to 60˚C (-4˚F to 140˚F).

2.4. Range Prediction

It provides guidance to the CS with the possibility of reserving a charging slot using the range charging assistant function. Based on the battery state-of-charge (SOC) [23], and remaining distance, the system can calculate the minimum energy required in the batteries and it indicates the driver whether the destination can be reached or not with the present SOC. So that the users can make it possible to reach the desired destination or they can plan to reach the nearest CS. The range prediction can be estimated using the formula given in Distance estimation in Chapter III.

2.5 Emergency charging

When the EV's battery SOC is very low, the EV's location will be sent to the mobile charging stations [26]. The SOC describes the Battery's remaining power. The SOC and DOD is defined by the following equations (1) and (2)

$$\mathrm{SOC} = \left(\mathrm{Q_{total}} - {}^{\mathrm{Q_{out}}}/_{\mathrm{Q_{total}}}\right) * 100 \quad (1)$$

$$\mathrm{DOD} = 1 - \mathrm{SOC} \quad (2)$$

Where Q_{total} is the charge available before discharging of the battery

Q_{out} is the charge during discharging of the battery.

$DOD$is the Depth of Discharge

2.6. External Interface System

The Battery SOC, speed and the temperature must be communicated to the android application via Bluetooth. Bluetooth is preferred because it can communicate up to100 meters. Hence that it can achieve the prediction of reaching the destination.

2.6 EV Charging power converters:

The power converters are preferred to give the boosting power in order to maintain the EV battery charging rate, which is defined by SOC. Based on the SOC level, the EV is deputed either to have fast charging or slow charging.

The Load forecasting is an important aspect, which helps to predict the peak loads. According to the peak load the number of cars that can be charged is estimated [28]. This informationis a boon to predict the EV power needs. The most distinct specifications of batteries are longer recharging time and limited battery cycle life, which badly restrict the development of EV [27]. As for the EV charging station, its main objectives include high decline in recharge time, high charge efficiency and improved battery life. Charge time and cycle life of battery are closely linked with charging pattern. Choosing the right charging pattern based on the actual condition ensures high charge efficiencies and improved cycle life. The PV tied battery charging station involves PV system and power converters and charge control. The converter delivers the required amount of voltage to the EV battery to provide fast charging. Here the converter needs to provide the high boosting naturally [28]. Hence the battery can achieve better SOC characteristics. The double boost converter is proposed in this paper for proving the better voltage gain and stability. The proposed converter is mergesthe simple boost converter with the Cuk-converter. PV connected cuk-converter is connected to charge control unit and proving the power management on the EV battery.

3. Proposed PV tied Cuk-converter

EV is electrical power circuit which is grouped into three major parts such as DC-DC converters, battery and motor [5]. Here, the DC-DC converter plays a vital role in power management to provide the required amount of voltage and current to the battery. However, for increasing the boosting factor, converter need additional switch and energy storage elements. Employing a single power switch reduces the implementation cost and switching power losses. Hence in order to achieve an extra boosting, the proposed converter is the combination of the boot converter and Cuk converter. It has only one power switch with higher voltage gain in a step-up mode in comparison with conventional buck–boost and Cuk-converter. The proposed DC–DC converter controls the dc link voltage using capacitive energy transfer which results in anon-pulsating input and output currents and are operated at a high switching frequency for fast and effective control with the additional advantage of a small size filter. The fig.3 shows the proposed cuk converter

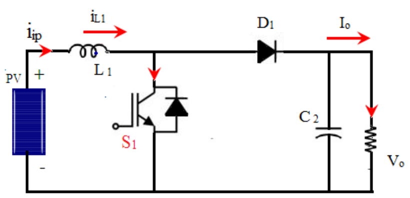


Fig.2 conventional dc-dc boost converter

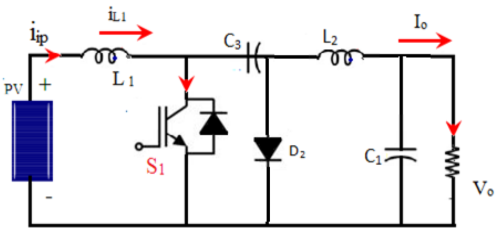


Fig.3 conventional Cukconverter

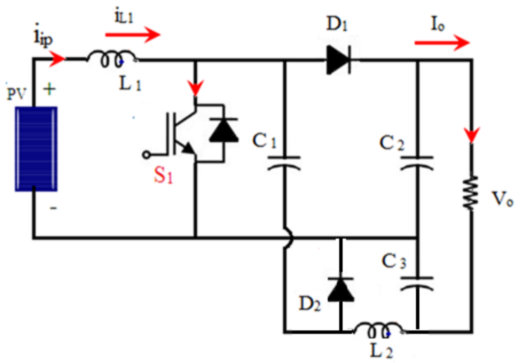


Fig.4 Proposed high gain Cuk-converter

The proposed converter is able to boot two times with single switch. The Mode of operation of proposed cuk-converter is described below. The Fig.5 to 7 illustrate the converter in different modes of operation. The Fig.8 shows the mode diagram for proposed converter.

Mode -I ($t_0 - t_1$): During S in ON condition, the inductors L_1 and L_2 are in charging mode and D_2 is ON, while capacitor C_1 is discharging and D_2 and L_2 are blocked by negative voltages of V_{C2} and V_{C1}.

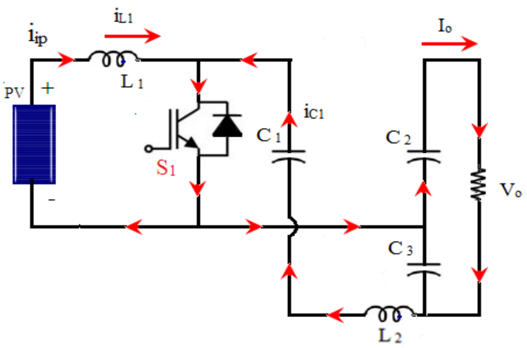


Fig.5 Mode- I (t0 –t1)

Mode -II ($t_1 - t_2$): In this mode of operation S is OFF. Hence the VC_1 is smaller than VC_2. During this period the capacitor C_2will be charged (voltage across C_2 is increasing) and the energy on the L_1 and L_2 starts to decrease, Diode D_1 will stay blocked but diode D_2 will be ON.

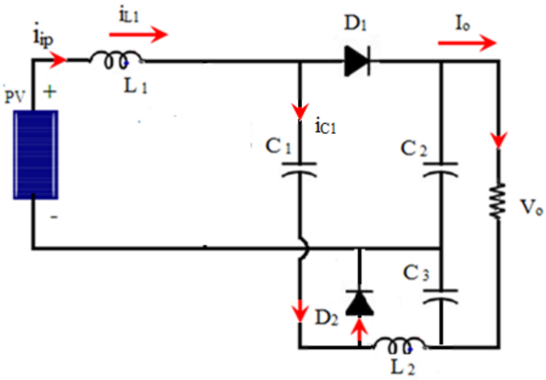


Fig. 6. Mode- II (t1 –t2)

Mode -III ($t_2 - t_3$): This mode is Operating when the power switch S is turned OFF and voltage across capacitor C_2 is equal or smaller than voltage across capacitor C_1. Both inductors are in discharging mode and capacitors C_2 and C_1 are being charged by the current that flows through the inductorL_1. Then both diodes are turned ON.

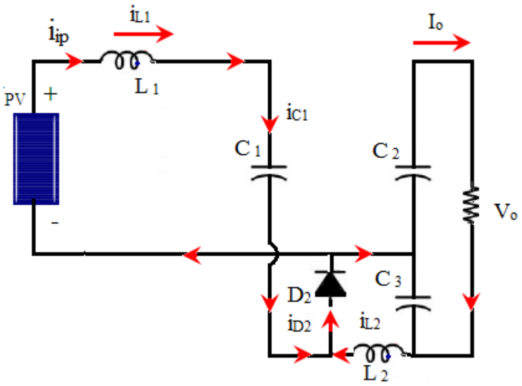


Fig.7. Mode- III (t2 –t3)

The static voltage conversion ratio for the classical boost is$\frac{V_{C2}}{PV}$and$\frac{V_{C3}}{PV}$for Cuk converters IN CCM and switch duty-cycle ∂.

$$\frac{Vc_3}{PV} = \frac{1}{1-\partial} \quad (1)$$

$$\frac{Vc_1}{PV} = \frac{\partial}{1-\partial} \quad (2)$$

The extended statics voltage gain of theDC-DC converter in CCM is the sum of the conventional converters.

$$\frac{V_o}{PV} = \frac{1+\partial}{1-\partial} \quad (3)$$

Average value of the continuous input currentI_{L1}

$$PVI_{L1} = V_O I_O \leftrightarrow I_{L1} = \frac{1+\partial}{1-\partial} I_O \quad (4)$$

Consider,

$\Delta t_{on} = \partial T$ in (5) and $\Delta i_L = i_{L1}(t) - i_{L2}(t_o)$

$$i_{L1}(t) = \frac{V_{Li}}{L} \Delta t_o + i_{Li}(t_o) \quad (5)$$

$$L_1 = \frac{PV\partial T}{\Delta_{i_{L1}}} \quad (6)$$

$$\Delta t_{off} = (1-\partial)T$$

The inductor L_2

$$L_2 = \frac{V_{C3}(1-\partial)T}{\Delta i_{L2}} \quad (7)$$

P_O is the load power

$$C_2 = \frac{1}{\Delta V_{C2}} \frac{P_O}{V_O} \Delta t_1 \quad (8)$$

$$C_1 = \frac{1}{\Delta C_3} \frac{P_O}{V_O} \Delta t_2 \quad (9)$$

Value of capacitor C_3 is obtained by considering that the charge variation of the capacitor ΔQ is related with the current variation in the inductor$L_2 \Delta i_{L2}$

$$C_3 = \frac{\Delta Q}{\Delta V_{C3}} \quad (10)$$

$$\Delta Q = \frac{\frac{T \Delta i_{L2}}{4}}{2} \quad (11)$$

$$C_3 = \frac{T \Delta i_{L2}}{8 \Delta V_{c3}} \quad (12)$$

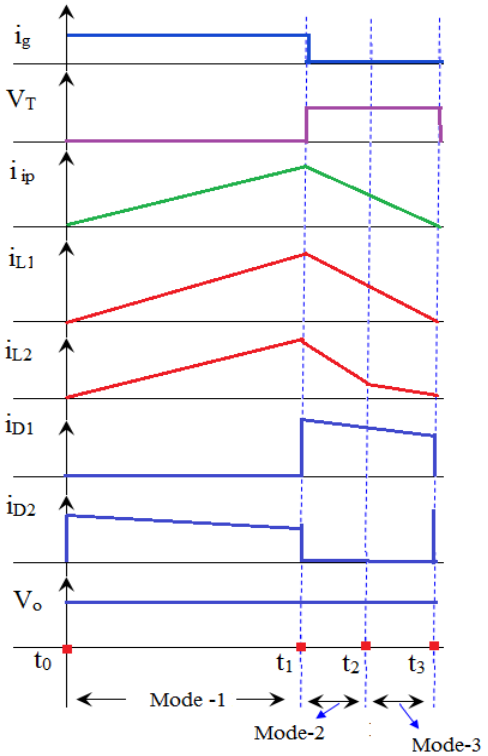


Fig. 8 mode of operation of proposed cuk converter

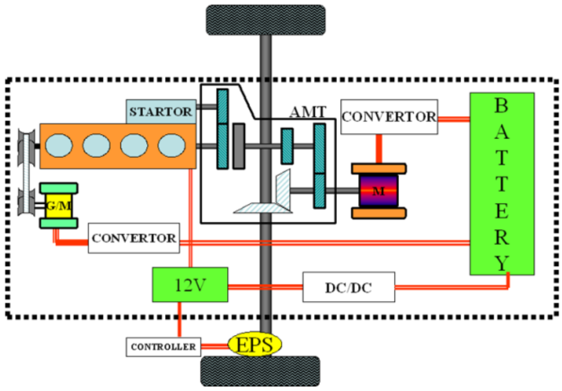


Fig.9. EV power connection setup

In EV the main energy source is assisted by one or more energy storage devices. Thereby the system cost, mass, and volume can be decreased, and a significantly better performance can be obtained. Two often used energy storage devices are batteries and SCs. They can be connected to the fuel cell stack in many ways. A simple configuration is to directly connect two devices in parallel, (FC/battery, FC/SC, or battery/SC) [1]. However, in this way the power drawn from each device cannot be controlled but is passively determined by the impedance of the devices. The impedance depends on many parameters, e.g. temperature, state-of-charge, health, and point of operation. Each device might, therefore, be operated at an inappropriate condition, e.g. health and efficiency. The voltage characteristics also have to match perfectly with the two devices, and only a fraction of the range of operation of the devices can be utilized, e.g. in a fuel cell battery configuration, the fuel cell must provide almost the same power all the time due to the fixed voltage of the battery, and in a battery/super capacitor configuration only a fraction of the energy exchange capability of the super capacitor can be used.

4. Proposed battery power measurement and management

The Charge controller keeps monitoring the details of the electric vehicle and communicates to the charging station server as well as to the requirement of SOC limit. The Fig.10 describes the circuit connections for measuring the SOC of the battery. The current SOC of a battery is simply a maximum charge minus the current, multiplied with time for which it was flowing.

The flowchart for the estimation of SOC is given in the fig.3

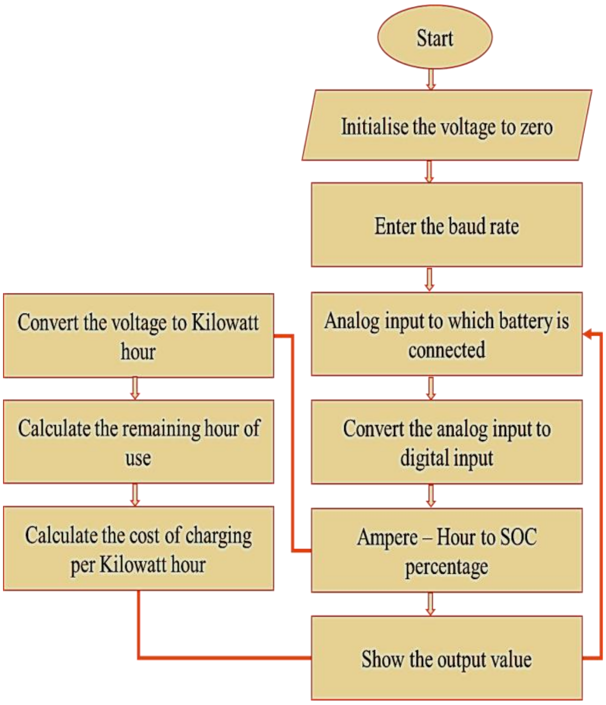


Fig. 10 Flow chart for the determination of SOC

The SOC is measured using the following equations (3), (4), (5) and (6)

$$Amps = \frac{Voltage}{0.060} \quad (3)$$

$$Watts = Amps\ X\ Voltage \quad (4)$$

$$Amphours = \frac{Amps\ X\ Time}{3600} \quad (5)$$

$$SOC = \frac{400-Amphours}{400} X100 \quad (6)$$

3.1 Monitoring the battery SOC

Hardware implementation includes the connection of battery with the Arduino UNO board and then monitoring the voltage of the battery. In this, the battery is connected to one end of the voltage divider and the other end of the voltage divider is connected to the pin A_0 of the Arduino UNO board.

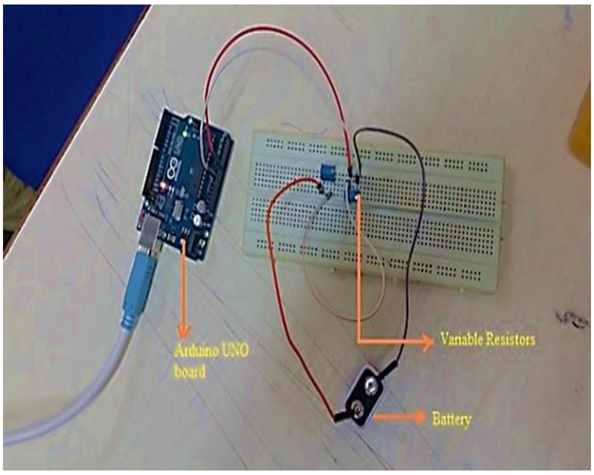


Fig. 11 monitoring the battery voltage

The ground pin is connected to the negative terminal of the battery. The voltage of the9V battery is measured and it is displayed on the PC using the serial port which has the baud rate of 9600. The voltage measured is 8.54V for a 9V battery. The battery voltage is measured using the voltage divider rule. The connection of 9v Battery to the Arduino UNO is shown in the above fig.11

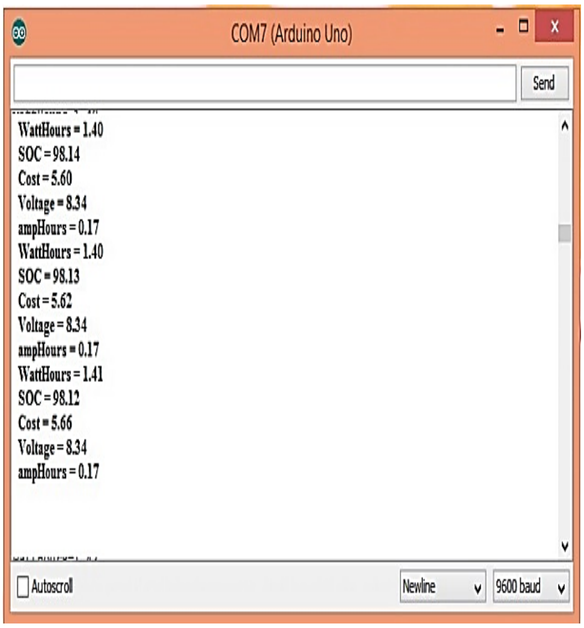


Fig. 12 Battery Voltage - Display

B. Arduino – Bluetooth Interface

The fig. 12 shows the interfacing of the Bluetooth Module to Arduino for receiving the battery voltage and SOC from the Arduino to android mobile. The key pin of the Bluetooth module is connected to the 3.3V of the Arduino board, the VCC pin is connected to the 5V pin of the Arduino.

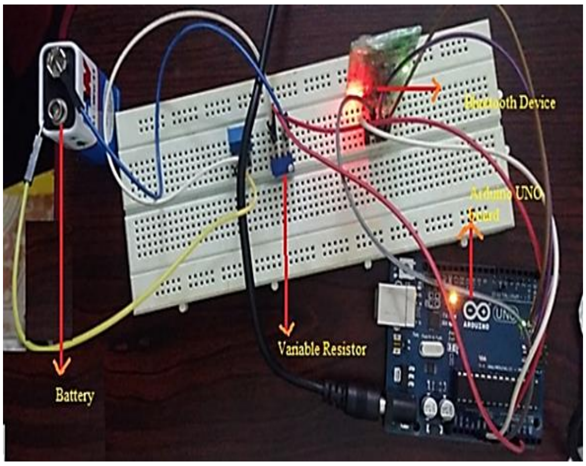
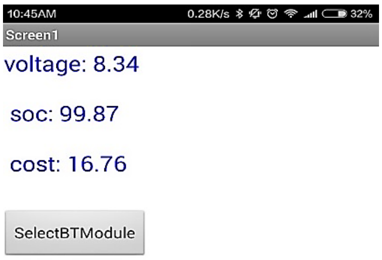


Fig. 13 Arduino – Bluetooth Interface



The TX pin of the Bluetooth module is connected to the RX pin of the Arduino board. The RX pin of the Bluetooth module is connected to the TX pin of the Arduino board. The battery voltage is communicated to the android via the Bluetooth module. The Bluetooth module used here is HC – 05. It supports the baud rate 9600. The Voltage is then displayed in the android is shown in fig. 13

5. Experimental Verification

To verify the operation of the proposed converter with charge controller, the experimental setup is developed for solar tied Cuk-converter connected to EV battery. The experimental setup of proposed DC-DC converter is shown in Fig. 14.The set the different PV voltage value a 100 W, 42 V PV panel is utilized to test the proposed converter for EV changing requirement. The test bench has carried the results for low irradiation to maximum irradiation of PV installation. The converter gains the voltage in all the stages of PV power generation. The PWM pulse is delivered from PIC microcontroller. Initially, the converter is tested with 45V. The 90 W power and the DC link of the converter is fixed and the results were analyzed.

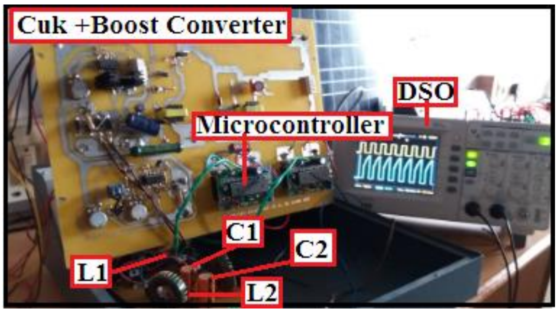


Fig.14 Excremental setup of proposed cuk converter

The fig. 15 and Fig.16shows current waveforms of the inductors L_1 and L_2. Fig. 17 shows the experimental results of the proposed converter operating in acontinuous mode with 65% duty cycle. As it is shown in Fig.18, the output voltage is 102 V when the input power is 45V for d=0.65.

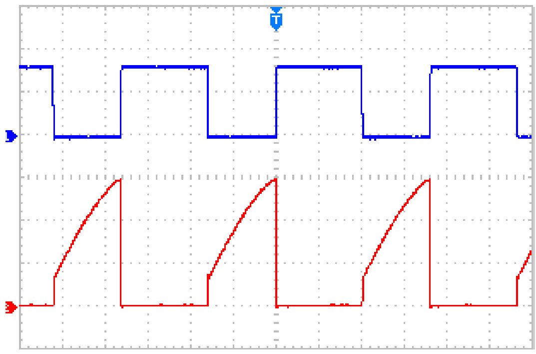


Fig. 15. Experimental waveforms for proposed converter duty cycle [5V/Div, 2msec]; and inductor L_1 current [0.5Amps/Div, 2 msec].

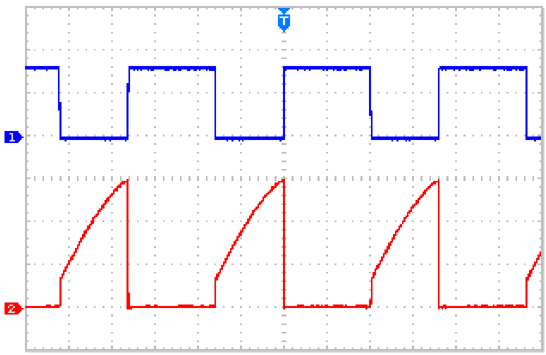


Fig. 16. Experimental waveforms for proposed converter duty cycle [5V/Div, 2msec]; and inductor L_2 current [0.5Amps/Div, 2 msec].

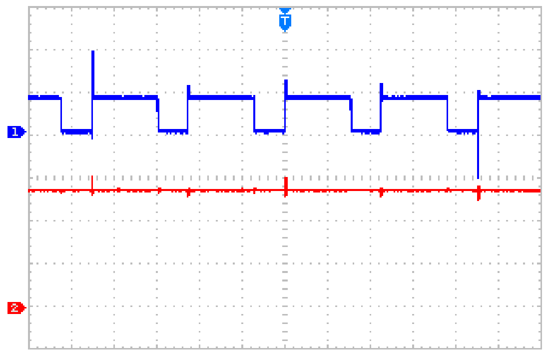


Fig. 17. Experimental waveforms for proposed converter duty cycle [5V/Div, 2msec]; and output voltage [30 Voltage Amps/Div, 2 msec].

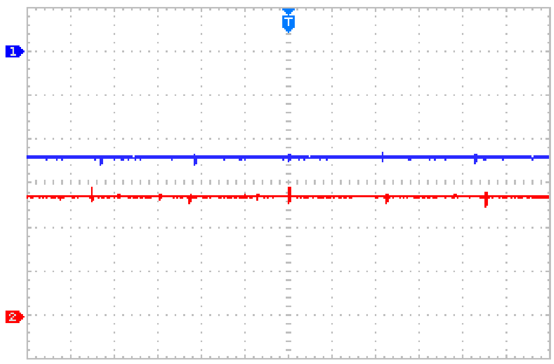


Fig. 18. Experimental waveforms for proposed converter input voltage [100V/Div, 2msec]; and output voltage [30V/Div, 2 msec].

Next, the change control algorithm for route prediction is tested based on the current value of the vehicle battery's SOC. It proposes all the charging stations covering the limit.CSS communicates with other vehicles to determine the road traffic and gives an approximate time and charge remaining until a specific charging station is reached. It also suggests an alternate route to the nearest charging station in case of heavy traffic. The driver chooses the charging type and blocks a slot considering least waiting time. The CSS uses the mobile network to communicate with the vehicle and CSS. It also proposes the current metering scheme at particular CS and compares with other CS price which can be done through a demand based metering system where EVs will be charged according to peak time and peak load.

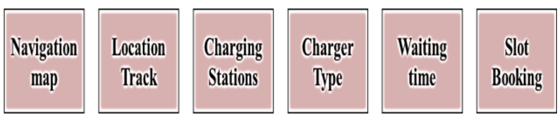


Fig. 19 Route prediction algorithm

Speed, battery pack KW rating, driving conditions, aerodynamics, vehicle weight, hills, temperature, driving styles and several others play a vital role in the distance prediction. Here the battery pack KW rating and the speed is considered for the distance estimation. The equations (7), (8) and (9) are used for the distance estimation.

$$\text{Distance} = \frac{\text{Battery pack size (KW)}}{\text{Watt–hour}/_{\text{mile}}} \quad (7)$$

$$\text{Watt} - \text{hour}/_{\text{mile}} = \text{Volts X } \left(\text{Ampere draw}/_{\text{mile per hour}}\right) \quad (8)$$

$$\text{Battery pack size(KW)} = \text{pack voltage X Amp} - \text{Hour rating} \quad (9)$$

The battery condition is tested based on three case studies as follow;

Case 1: When PV power is less, and EV battery SOC is less than 50%;

In this case, the based on the SOC value the battery charges from the PV and the converter provides the high voltage gain for helping the fast changing to rate in quicker time interval.

Case 2: When PV power is less, and EV battery SOC is greater than 50%;

In this case, based on the SOC value, the battery charges from the PV and the converter provides the normal voltage gain for helping the nominal changing

Case 3: When PV power is less;

In this case, the based on the SOC value is near to 100 %, the PV directed their power to the local battery.

4. Conclusion

The main aim is to develop power converter and battery changing controller for electric vehicle users. The proposed DC-DC converter and EV power management is verified though hardware with different PV and battery SOC conditions. It mainly concentrates on measuring the battery state of charge. After measuring the SOC it must be communicated to the android application via the Bluetooth module (HC – 05). An algorithm must be developed in order to predict whether through the available power the converter must do fast or regular charging method. For future implementation, the bidding process can be used in the allocation of the parking lot to the electrical users.

References

[1]. M.A.Hannan, F.A.Azidin, A.Mohamed, "*Hybrid Electric vehicles and Their Challenges*", Renewable and Sustainable Energy Reviews 29(2014)135–150

[2]. Yunyan Wang, Jingxin Li, Jiuchun Jiang, LiyongNiu, "*Management Information System of Charging Station for Electric Vehicle (EV)*," National High Technology Research and Development Program of China.

[3]. P. Simonik, A. Havel, M. Hromjak, and P. Chlebis , "*Active Charging Stations for ElectricVehicles Charging*", Electromagnetics Research Symposium Proceedings, KL, MALAYSIA, March 27, 2012

[4]. Charles Botsford, Adam Szczepanek," *Fast Charging vs. Slow Charging: Pros and cons for the New Age of Electric Vehicles*," EVS24 Stavanger, Norway, May 13-16, 2009.

[5]. Sahu, B., Rincon-Mora, G.A.: 'A low voltage, dynamic, non-inverting, synchronous buck–boost converter for portable applications', IEEE Trans. Power Electron., 2004, 19, (2), pp. 443–451

[6]. Ren, X., Tang, Z., Xuan, R., Wei, J., Hua, G.: 'Four switch buck–boostconverter for telecom DC–DC power supply applications'. IEEEApplied Power Electronics Conf. and Exposition, 2008, pp. 1527–1530.

[7]. Boora, A.A., Zare, F., Ghosh, A.: 'Multi-output buck-boost converterwith enhanced dynamic response to load and input voltage changes',IET Power Electron., 2009, 4, (2), pp. 194–208

[8]. Liu, W.S., Chen, J.F., Liang, T.J., Lin, R.L.: 'Analysis, design, and control of bidirectional cascaded configuration for a fuel cell hybrid power system', IEEE Trans. Power Electron., 2010, 25, (6),pp. 1565–1575

[9]. Praveen Kumar and Kalyan Dash, "*Potential Need for Electric Vehicles, Charging Station Infrastructure and its Challenges for the Indian Market*", Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 3, Number 4 (2013), pp. 471-476

[10]. Wenbo Shi, Eun-Kyu Lee, Daoyuan Yao, Rui Huang, Chi- Cheng Chu, and RajitGadh, "*Evaluating Microgrid Management and Control with an Implementable Energy Management System*" Smart Grid Energy Research Center University of California, IEEE International Conference on Smart Grid Communication 3-6 November-2014.

[11]. Hwu, K.I., Yau, Y.T.: 'A novel voltage-bucking/boosting converter: KYbuck-boost converter'. IEEE Int. Conf. Industrial Technology, 2008,pp. 1–4

[12]. Hwu, K.I., Yau, Y.T.: 'Two types of KY buck–boost converters', IEEE Trans. Ind. Electron., 2009, 56, (8), pp. 2970–2980

[13]. Hwu, K.I., Chen, Y.H., Lin, Z.-F.: 'Negative-output KY buck-boost converter'. Fourth IEEE Conf. Industrial Electronics and Applications(ICIEA), 2009, pp. 3347–3350

[14]. Hwu, K.I., Lin, Z.F., Chen, Y.H.: 'A novel negative-output KY buck-boost converter'. Int. Conf. Power Electronics and Drive Systems (PEDS), 2009, pp. 1158–1162

[15]. M. Verbrugge, D. Frisch, and B. Koch, "*Adaptive Energy Management of Electric and Hybrid Electric Vehicles*," Journal of Power Sources, 2005.

[16]. Minghao AI, LinhaiQI,"*Orderly Charging Based Electric Vehicle Charging Stations' On-Line Monitoring System*", CIRED Workshop - Rome, 11-12 June 2014

[17]. Mukesh Singh, Praveen Kumar, and IndraniKar," *Implementation of Vehicle to Grid Infrastructure Using Fuzzy Logic Controller*," IEEE transactions on smart grid, vol. 3, no. 1, march 2012.

[18]. Ricardo Faria, Pedro Moura, Joaquim Delgado, and Aníbal T. de Almeida, "*Managing the Charging of Electrical Vehicles: Impacts on the Electrical Grid and on the Environment*", IEEE Intelligent transportation systems magazine.

[19]. Bharatiraja, C., Jeevananthan, S., Munda, J.L., Latha, R., "*Improved SVPWM vector selection approaches in OVM region to reduce common-mode voltage for three-level neutral point clamped inverter,*" International Journal of Electrical Power and Energy Systems, vol. 79, august 2016

[20]. Moreno-Muñoz, V. Pallarés-López, J. J. G. de la Rosa, R. Real-Calvo, M. González-Redondo, and I. M. Moreno-García, "*Embedding synchronized measurement technology for smart grid development*," IEEE Trans.Ind. In format., vol. 9, no. 1, pp. 52–61, Feb. 2013.

[21]. V. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella, C. Cecati, and G. Hancke, "*Smart grid technologies: Communications technologies and standards*,"IEEETrans.Ind.Informat., vol. 7,no.4,pp.529–539,Nov.2011.

[22]. G. A. Shah, V. C. Gungor, and O. B. Akan, "*A cross-layer QoS-aware communication framework in cognitive radio sensor networks for smart grid applications*," IEEE Trans. Ind. Informat., vol. 9, no. 3, pp. 1477–1485, Aug. 2013.

[23]. V. C. Gungor, B. Lu, and G. P. Hancke, "*Opportunities and challenges of wireless sensor networks in smart grid*," IEEE Trans. Ind. Informat., vol. 57, no. 10, pp. 3557–3564, Oct. 2010.

[24]. P. P. Parikh, T. S. Sidhu, and A. Shami, "*A comprehensive investigation of wireless LAN for IEC 61850-based smart distribution substation applications*,"IEEE Trans. Ind. Informat., vol. 9, no. 3, pp. 1466–1476,Aug. 2013.

[25]. Sabbah, A. El-Mougy, and M. Ibnkahla, "*A survey of networking challenges and routing protocols in*

smart grids," IEEE Trans. Ind. Informat.,vol. 9, no. 1, pp. 1551–3203, Feb. 2013.

[26]. J. C. Ferreira, V. Monteiro, J. L. Afonso, and A. Silva, "*Smart electric vehicle charging system*," in Proc. IEEE IVS Intell. Veh. Symp., Baden-Baden, Germany, Jun. 2011, pp. 758–763.

[27]. P. Simonik, A. Havel, M. Hromjak, and P. Chlebis, "*Active Charging Stations for Electric Vehicles Charging*, "Progress In Electromagnetics Research Symposium Proceedings, KL, MALAYSIA, March 27-30, 2012, pp. 995-998

[28]. Haiying Wang, Yang Liu, Hang Fu and Gechen Li, "*Estimation of State of Charge of Batteries for Electric Vehicles*," International Journal of Control and Automation, V ol. 6, No. 2, April 2013.

[29]. J. C. Ferreira, A. Silva, and J. L. Afonso, "*EV-cockpit—Mobile personal travel assistance for electric vehicles*," Microsystems for Automotive Applications. Smart Systems for Electric, Safe and Networked Mobility, Berlin, Germany: Springer, 2011, pp. 247–257.

[30]. Ganta Naveen, Tony Ho-Tung Yip, YuyuXie, "*Modeling and Protection of Electric Vehicle Charging Station*".

[31]. Fabian Kennel, Daniel Görges, and Steven Liu, "*Energy Management for Smart Grids with Electric Vehicles Based on Hierarchical MPC*," IEEE transactions on industrial informatics, vol. 9, no. 3, august 2013.

[32]. MadhuriUnde, Bharat Borkar, "*Remote Vehicle Tracking & Driver Health Monitoring System Using GSM Modem & Google Maps*", International Journal of Computer Science and Information Technologies, Vol. 5 (3), 2014, 2828-2832

[33]. C.Bharatiraja, P. Sanjeevikumar, PierluigiSiano, K.Ramesh ,S.Raghu, "Real Time Forecasting of EV Charging Station Scheduling for Smart Energy System", *Energies* vol.10, no.3, 377-395,2017

[34]. MelikeErol-Kantarci, Hussein T. Mouftah, "*Wireless Sensor Networks for Cost-Efficient Residential Energy Management in the Smart Grid*", IEEE Transactions on Smart Grid, vol. 2, no. 2, June 2011

[35]. SeokJu Lee, GirmaTewolde, Jaerock Kwon, "*Design and Implementation of Vehicle Tracking System Using GPS/GSM/GPRS Technology and Smartphone Application*", IEEE World Forum on Internet of Things (WF-IoT) 2014

[36]. PankajVerma, J.S Bhatia ," *Design And Development Of GPS-GSM Based Tracking System With Google map Based Monitoring*", International Journal of Computer Science, Engineering and Applications (IJCSEA) Vol.3, No.3, June 2013

[37]. Lin Ch T, Wang J P and Chen Q S, *Methods for state of charge estimation of EV batteries and their application*, Battery Bimonthly, 2004, vol.34, no.5, pp. 376-378