ANALYSIS ON DYNAMIC RESPONSE OF ELECTRIC VEHICLE BATTERY CHARGER USING GRID CONNECTED PV SYSTEM

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ABSTRACT

This analysis suggests that the current rise in the automotive sector is mostly due to the renewable energy-based electric vehicle battery charging technology. Due to the intermittent nature of renewable energy sources, grid-connected renewable energy systems are used to charge the batteries of electric vehicles. As a result, this article suggests a grid-connected PV system-based electric vehicle battery charger. The suggested system uses bidirectional ac-dc converters and dc-dc converters to continually charge the EV battery regardless of solar radiation. With the aid of the suggested bidirectional design in the charging system, Sepic converter is selected for dc-dc converters and Line commutated converter is employed as a bidirectional ac-dc converter. During sunshine hours,PV array power generated is used to charge the EV battery alone and during peaksunshine hours, apart from charging of EV battery, the excess PV array power is fed to the single phase utility grid. During low and non sunshine hours, the EV battery chargingwas supported by the utility grid throughbidirectional ac-dc converter. The proposed electric vehicle battery charger is simulated in the MATLAB/Simulink environment and the dynamic response of the system was studied and its results are furnished in this paper.

Keywords: Electric Vehicle Battery, Bidirectional ac-dc converter, Line commutated converter, Photovoltaic array,Sepic converter, Utility grid

INTRODUCTION

The development of electric vehicles (EV) as a means of reducing the CO2 emissions from conventional internal combustion (IC) engine cars has fueled the growth of the transportation industry during the past ten years [1]. The development of electric vehicles (EV) in the automotive sector depends heavily on battery charging stations [2]. Recently, battery charging facilities powered by renewable energy have spread quickly around the world [3]. PV array installation is simple compared to other renewable energy sources, and the ongoing decline in PV module costs makes it more alluring. As a result, many EV customers have chosen PV array-based EV battery charging [4-5]. Although the EV battery charging system discussed above has several benefits, including simple installation, minimal maintenance costs, and clean charging system, it has the disadvantage of intermittent nature and non-availability during night [6-7]. To overcome these disadvantages, there is a need for alternate source of energy during non sunshine hours [8-9]. Thus, grid connected PV-EV battery charging system isproposed in this paper. The proposed systemcan charge the EV battery from PV array and grid during sunshine hours and low or non sunshine hours respectively. Also, thissystem has the advantage of reducing theelectricity bills to the users by feeding the excess PV generated power to the grid during peak sunshine hours. To integrate PV array, utility grid and EV battery, there is a need for intermediate dc-dc converter and bidirectional ac-dc converter [10-12]. Among various dc-dc converters, sepic converter is preferred in the proposed system due its advantages like (i) capability of operating in boost and buck mode (ii) providing output voltage with the same polarity as input voltage [13]. Silicon controlled rectifier (SCR) based line commutated converter (LCC) is used as a bidirectional ac-dc converter. In order to operate LCC in bidirectional mode, a bidirectional configuration is proposed in this charging system. It can operate both in rectifier and inverter mode depending on thefiring angle of SCRs, α. Thus, during peak sunshine hours, LCC works in inverter modewith α > 90° in order to feed the excess PV array generated power to the utility grid. During non-sunshine hours, LCC works in rectifier mode with α < 90° to charge the EVbattery from the utility grid. Also, LCC has the added advantage of self-grid synchronizing capability inherently [14-15]. Thus, an uninterruptable grid connected PV system with sepic converter and line commutated converter is proposed to charge the EV battery.

Object

Ever increasing effects of green house gases from the conventional IC engines lead toenvironmental concerns. This paved to the booming of pollution free electric vehicles (EVs) in the automobile industry [1–3]. However, EV battery charging from the utility grid increases the load demand on the grid and eventually increases the electricity bills to the EV owners which necessitate the use of alternate energy sources [4, 5].

PROBLEM STATEMENT

Due to inexhaustible andpollution free nature of renewableenergy sources (RESs), it can beused to charge the EV battery. Thus,RES driven EV can be termed as‘green transportation’ [6]. Solar is one of the promising RESs which can be easily tapped to utilize its energy to charge EV battery [7, 8]. Hence, PV array power is used tocharge the EV battery in theproposed system with the help ofpower converter topologies

EXISTING SYSTEM

Due to the intermittent nature ofthe PV array, there is a need for power converters to charge the EV battery. Among different converters,multiport converters (MPCs) are preferred in the onboard chargers ofhybrid EVs due to its capability of interfacing power sources and energy storage elements like PV array, ultra capacitors, super capacitors,fuel cells and batteries with the loads in EV like motor, lights,power windows and doors, radios, amplifiers and mobile phone charger. The MPCs have the drawback of increase in weight, cost and maintenance of the EV as all the sources are placed in the EV itself. Also, the complexity of controller implementation increases in theseconverter-based EV batteries charging system [11–13]. Hence, an off-board charger is proposed in this paper inwhich the EV battery is locatedinside the vehicle unit and PV arrayand backup battery bank are located in the charging station or parking station. Various convertertopologies for off-board chargingsystem are presented in the literature [14–16]. Among different converter topology, the sepic converter is preferred due to its capability of working in both boost and buck modes. It also has the advantage of the same input and output voltage polarity, low input current ripple and low EMI [17, 18].However, during low solar irradiation and non-sunshine hours, there is a need for an additional storage battery bank to charge theEV battery. This backup battery bankhas to be charged in the forward direction and discharged in a reverse direction depending on the solar irradiation. Hence, abidirectional converter with power flow in either direction is required[19]. The bidirectional converters are classified into non-isolated andisolated converters. Transformer in the isolated converters provides isolation which increases the price, weight and size of the converter.

PROPOSED SYSTEM

Among various non-isolated bidirectional converter topologies, bidirectional interleaved DC–DC converter (BIDC) is preferred due to its advantages like improved efficiency in discontinuous conduction mode and minimal inductance value, reduced ripple current due to multiphase interleaving technique. Snubber capacitor across the switches reduces the turnoff losses and the inductor current parasitic ringing effect is also reduced by employing zero voltage resonant soft switching technique. These are the added advantages of this bidirectional converter [23–25]. The system in [25] is an off-board EV batterycharging system which charges the EVbattery from PV array power through bidirectional DC–DC converter in stand-still condition and EV batterygets discharged to drive the dc loadin the EV during the running condition. It has the drawback of charging EV battery only during sunshine hours. To overcome this disadvantage and to charge the EV battery without any interruption, the proposed charger is developed using PV array integrated with sepic converter, bidirectional DC–DC converter and backup battery bankfor charging the battery of an EV.

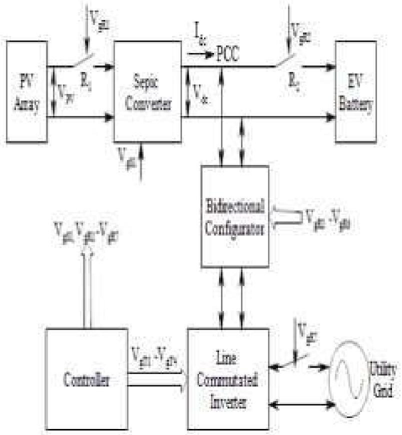

Fig. 1. Block diagram of the EV battery charger

Working of the Proposed EV Battery Charger Working of the proposed system is explained in 4 different modes of operation depending on the solar irradiation conditionsand SOC of EV battery viz (i) mode 1 (P-V),
(ii) mode 2 (P-VG), (iii) mode 3 (G-V) and
(iv) mode 4 (P-G).

Mode 1: Forward PV-EV battery charging mode (P-V) During normal sun-shine hours, solar power generated is sufficient to charge only EV battery in this mode. During this mode, the relays R1 and R2 are closed in order to transfer power from PV array to charge EV battery. Other relays in bidirectional configurator R3 - R6 and relay R7 are open isolating the LCC and utility grid from the system

Mode 2: Forward PV- EV battery & Grid mode (P-VG) During peak sunshine hours, excess power generated from the PV array isfed to the utility grid apart from chargingEV battery in this mode. In order to transfer the PV array power to EV battery and to the grid, relays R1, R2 and R7 are closed in addition to closing of bidirectionalconfigurator relays R3 & R4 to configure the LCC as line commutated inverter (LCI) as shown in Fig. 3 in this mode

Mode 3: Reverse grid- EV battery charging mode (G-V) During low sunshine hours and night time, solar power generated is insufficient to charge EV battery. Hence, grid power is used to charge EV battery in this mode with relays R2 and R7 closed. In order to transfer power from utility grid to the EV battery, R5 & R6 relays in the bidirectional configurator are closed to configure LCC as rectifier in this mode. Relay R1 was opened to isolate PV array from the proposed charging system in this mode

Mode 4: PV- grid mode (P-G) When EV battery is fully charged, EV battery has to bedisconnected from the charging system and thus the solar power generated is fed to the grid alone in mode 4. In this mode, operations of relays are same as in mode 2 other than opening of relay R2 to isolate EV battery from the proposed system.

RESULTS

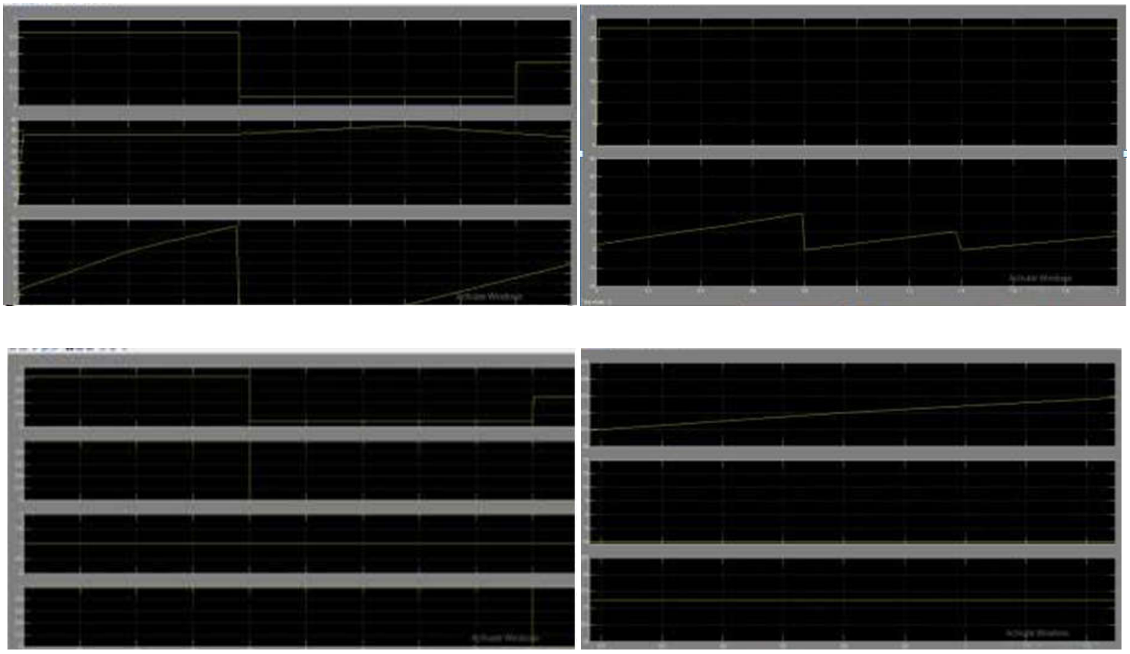

Fig. 7 Waveforms of PV array irradiation and gate pulses to the auxiliary switches

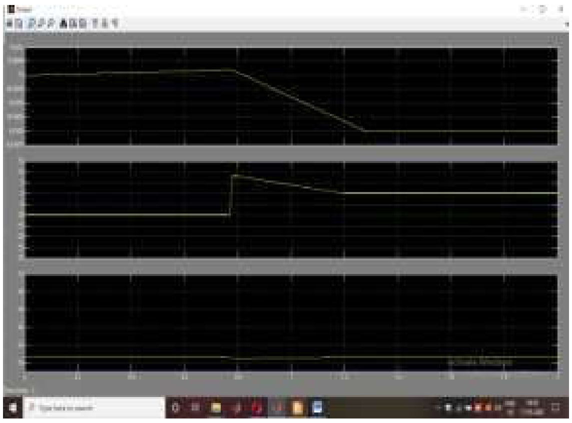

Fig.8 Waveforms of **(a)** PV array voltage, VPV & PV array current, IPV, **(b)** DC link voltage, Vdc, & current, Idc, **(c)** EV battery SOC, EV batterycurrent, IBatt& EV battery voltage, VBatt, **(d)**Backup battery SOC, backup battery current, Backup Batt & backup battery voltage, VBackup Batt

CONCLUSION

This study proposes an off-board EV battery charger powered by a grid-connected PV system. In spite of irradiation circumstances, this study analyses the adaptability of the system for uninterrupted charging of electric vehicle batteries. With the use of a bidirectional configuration, the suggested system may charge EV batteries during peak sunlight hours, give electricity to the grid, and also allow EV batteries to receive charging from the grid during low and non-sunny hours. The suggested charging system is created and then simulated using the MATLAB software's simulink environment. The dynamic results are then shown for the four modes of operation. The simulation results presented in this paper emphasize the effectiveness of the proposed charger

REFERENCES

[1] A. Harrouz, M. Abbes, I. Colak and K. Kayisli, "Smart grid and renewable energy in Algeria," IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA), San Diego, CA, pp. 1166- 1171, 5-8 November 2017.

[2] Ratil H. Ashique, Zainal Salam, MohdJunaidi Bin Abdul Aziz, Abdul Rauf Bhatti, "Integrated photovoltaic-grid dc fast charging system for electric vehicle: Areview of the architecture and control", Renewable and Sustainable EnergyReviews, vol. 69, pp. 1243–1257, 2017.

[3] T. Sakagami, Y. Shimizu and H. Kitano, "Exchangeable batteries for micro EVs and renewable energy," IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA), San Diego, CA, pp. 701- 705, 5-8 November 2017.

[4] Ankita Paul, Krithiga S., Sujitha N., "PV-based off-board electric vehicle battery charger using BIDC", Turkish Journal of Electrical Engineering & Computer Sciences, vol. 27 (4), pp.2850-2865, 2019.

[5] Y. Kobayashi, M. Hamanaka, K. Niimi, K. Yukita, T. Matsumura and Y. Goto, "Power Quality Improvement Method Using EV for PV Output Fluctuation," 2018 International Conference on Smart Grid(icSmartGrid), Nagasaki, Japan, pp. 272- 275, 4-6 December 2018.

[6] Arindam Mukherji,ParthaSarathiSubudhi, Krithiga S.,"Investigation of a PV Fed Improved Smart Home EV Battery Charging System using Multi Output Hybrid Converter",International Journal of Renewable Energy Research, vol. 9(2), pp. 692-703, 2019.

[6] Hassan H. Eldeeb, SamyFaddel, Osama A. Mohammed, "Multi-Objective Optimization Technique for the Operation of Grid tied PV Powered EV Charging Station", Electric Power Systems Research, vol. 164, pp.201-211, 2018.

[7] Md Shariful Islam, Nadarajah M, Duong Quoc Hung, "Coordinated EV charging for correlated EV and grid loads and PV output using a novel, correlated, probabilistic model", Electrical Power and Energy Systems, vol. 104, pp. 335-348, 2019.

[8] S. Kirthiga, N.M. Jothi Swaroopan, "Highly reliable inverter topology with a novel soft computing technique to eliminate leakage current in grid-connected transformerless photovoltaic systems", Computers & Electrical Engineering, vol. 68, pp.192-203, 2018.

[9] Abdelhakim BELKAID, Ilhami COLAK, Korhan KAYISLI, Ramazan BAYINDIR, "Design and Implementation of a Cuk Converter Controlled by a Direct Duty Cycle INC-MPPT in PV Battery System", Internatıonal Journal of SmartGrıd, vol.3(1), pp.19-25, 2019