Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 14, Issue 1, January 2023: 90-98

Modeling and Control of Bidirectional Buck-Boost Converter for Electric Vehicles Applications

B. Revanth Goud[1], Dr. P. Nagashekar Reddy[2]

[1]PG Student, Dept of EEE, Mahatma Gandhi Institute of Technology, Hyderabad, TS, India

brevanthgoud_pg20eee5402@mgit.ac.in

[2]Associate Professor, Dept of EEE, Mahatma Gandhi Institute of Technology, Hyderabad, TS, India

pnsreddy_eee@mgit.ac.in

ABSTRACT

The modelling, design consideration, and control studies of the bidirectional DC/DC buck-boost converter for usage in hybrid and electric vehicles are presented in the current work. The recommended concept includes the electric motor, the vehicle's dynamics, and their controllers. This study examines the viability of grid-connected constant current EV charging utilising a DC-DC converter with fuzzy logic control (FLC). FLC does not require intricate mathematical modelling and is simple to apply. In MATLAB/Simulink, the whole model of the system under examination was built. The resulting simulation results show the suggested architecture's strength and capacity. The results collected demonstrate that the suggested technique is suitable for a range of electric vehicle-related applications.

Keywords— Modeling, Control, Electric and hybrid vehicles, Bidirectional DC/DC converters

I. INTRODUCTION

Recently in contemporary society, electric cars (EVs) are being used more frequently. Because it can function as both a motor and a generator when the car is accelerating and braking, the electric motor enables an improved control over the vehicle's energy conversion. To realise the possibility of total control over the energy in both directions, the onboard DC/DC converter must be able to accept both of its ports as potential energy sources. These converters are known as bi-directional DC/DC converters, and it is essential to maintain and research them in order to get the most out of full electric propulsion. These converters may work in a variety of operational modes, including step-down function (buck), step-both, and boost function thanks to their fixed switching frequencies and variable duty cycles (buck-boost). These characteristics enable the development of an energy storage technology. Almost 64% of the oil consumed globally, according to the International Energy Agency, is used in the transportation sector. Due to the increased demand for non-renewable energy sources and the speeding up of environmental change, restrictions on CO2 and NOx emissions have been put in place [1].

Eventually, there will be a greater need for renewable energy sources. The adoption of electric vehicles (EV) can lessen the risk posed by climate change [2]. There will be a lot of study done in the future on electric vehicles (EV) [3] as well as the feasibility of building the charging interface using power matrix association [4]. In any event, EV charging configurations need to be greatly improved. The reduction of charging time is a crucial factor in the development of Using EV is Simple [5]. Thus it makes sense to use fast DC and constant current (CC) charging methods. [6]. The author of [7] discusses the two levels of DC quick charging in accordance with international standard IEC 61851-1. The DC-DC bus connection is preferred because it necessitates less switching and allows for greater efficiency [8]. Moreover, using the method described in [9], the charging power requirement can also be determined using the battery capacity, departure and arrival times, and battery charge level. [10] examines the speedy charging process in great detail, along with the necessary charging voltage and current. Despite this, [9] has created the specialised architecture for EV charging that is connected to the photovoltaic grid. Not even a bare minimum of the EV charging procedure is shown. A proportional integral (PI) controller is used in [11] to enable fast DC charging for electric vehicles, while PI controllers are frequently modified in general. In [2], an energy management system that combines a PI controller with voltage sensing smart charging takes care of the buck converter charging for the EV. The battery is shown in [12] as a basic resistor with an eye-catching fuzzy logic regulator for EV charging. The PV board is made using a DC voltage supply. These studies, in contrast to previous efforts, focuses on buck DC-DC converter charging of electric vehicles connected to lattices using a constant flow fluffy rationale regulator (FLC).

This study examined the entire EV charging system using MATLAB/Simulink and real models of the lattice association and battery. Many domestic and mechanical applications are possible with FLC [13]. In comparison to the outdated relative required (PI) regulator, FLC is easier to implement and better equipped to respond to changes in working conditions [14]. It is typically registered using etymological criteria rather than numerical ones. Membership functions are used to describe fuzzy sets (MF). In fuzzy logic, MF, which stands for degree of accuracy, is mapped from 0 to 1. In fuzzy logic, an MF value of 0.2 represents an accuracy level of 20%. Without the requirement for substantial numerical modelling, operators for difficult and non-linear systems can use the fuzzy set control technique using fuzzy rules. Moreover, it has a high degree of dependability and resistance to transient events and changes in circuit parameters [15]. This essay is organised as follows: In Section 2 of this paper, the buck converter's design and the grid connection are covered. Part 3 goes into great detail regarding the constant current fuzzy logic controller for EV charging. Section 4 presents the simulation findings. Section 4 is the fifth and last part of this essay.

II. BUCK CONVERTER AND GRID CONNECTION DESIGN

MATLAB/Simulink is used to produce the overall reproduction graph of the EV charging framework, as depicted in Fig. 1. The voltage source in this concept is a single-stage source made of super capacitors, DC/DC converters, and Li-ion battery DC/DC converters. To convert AC to DC, a two-level extension inverter is employed. Fig. 1 illustrates how the control system, DC controller, and integrated ac/dc converter alter the structure's DC transport voltage and receptive current. This involves both a current control and a DC voltage control. The DC voltage controller's yield is represented by the current reference, or Idref. [16] claims that the current controller regulates the converter using the voltage and strength it produces. DC-DC buck converter framework with yield Vo. The converter allows for a desired reduction in the voltage magnitude for charging the EV.

$$D = \frac{V_o}{V_s} \text{--------} (1)$$

Where
D stands for duty cycle,
Vs for source voltage,
Vo for output voltage.
The on/off stages of the converter are determined by the duty cycle. The buck converter must be configured with the appropriate switching frequency and inductor size in order to run continuously. The smallest permissible inductor size, Lmin, can be calculated by:

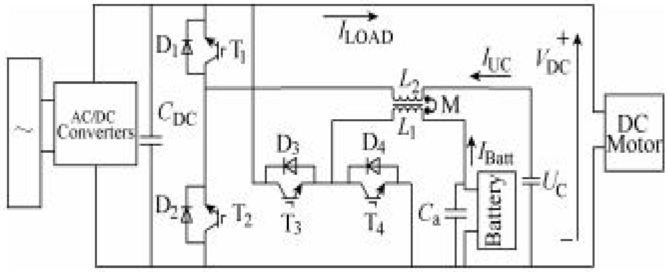


Fig. 1 a hybrid energy storage system's topology

Super capacitors, a DC/DC converter, and a lithium-ion battery make up this device. A DC/DC converter is composed of four IGBT switches (T1–T4) and four diode tubes (adding battery) (D1–D4). Moreover, self- and mutual-inductors share a core with an integrated magnetic structure. The powerful DC motor is powered by the battery pack. The current peak power supply issue is handled by the super capacitor. Electric vehicle power management systems regulate the flow of electrical energy based on the requirements of the load. The converter functions generally in five different modes (mode due to the additional battery pack modification) (mode due to the additional battery pack change). Table 1 reveals the particulars. DC-DC converter operating mode as well as the energy flows that go along with it for the hybrid energy storage system.

III. DESIGN OF THE DC/DC CONVERTER WITH INTEGRATED MAGNETIC STRUCTURE

The essential building blocks of energy transformation, sifting, electrical disengagement, and energy stockpiling are attractive components like inductors. The size of the attractive component is a significant factor in deciding the size and weight of the converter. In this study, an E-type attractive centre is used to combine the appealing aspects. L1 and L2 are the coupling inductances employed here. According to Fig. 2, Ca is an extra capacitance, L1 is the external inductance, and L2 is the output filter inductor. Table 1 shows how the hybrid energy storage system functions. Without taking into consideration the voltage of Ca is steady state and identical to the output voltages of L2 and L1, eliminating the capacitor's voltage ripple.

Table 1

The way a hybrid energy storage system operates

Working mode	Power source	Power flow	Operation mode
Parking charging mode	AC power	Battery and super capacitor	Buck
Constant speed mode	Battery	DC	Boost
Acceleration mode	Super capacitor	DC motor	Boost
Braking mode	Braking energy	Battery and super capacitor	Buck
Super-capacitor charging mode	Battery	Super capacitors and DC motors	Boost or buck

Figure 1's DC/DC converter is made up of four diodes (D1-D4) and four IGBT switches (T1-T4). A buck converter has three additional operating modes in addition to the two for a lift converter (L1, T4, D4 or L2, T2, D1) (comprising of L1, T3, D4 or L2, T1, D2). Table 2's examination of two DC/DC converter designs illustrates that the DC/DC converter with an integrated, visually beautiful architecture is typically lighter and smaller in size. Reduce system size and weight in an electric car by using a DC/DC converter with an integrated magnetic structure. Moreover, a magnetic component of the device aids in reducing output current ripple. The combined magnetic structure's viability is demonstrated in Section 5 through modelling and testing.

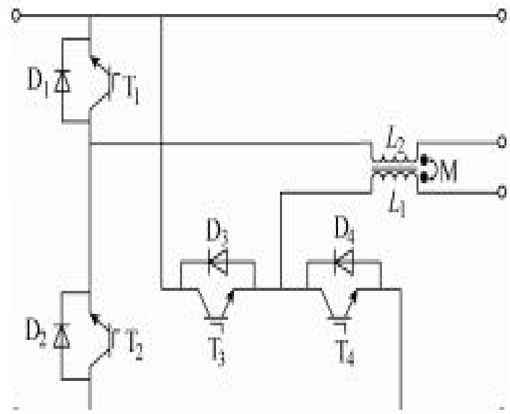


Fig. 2 DC/DC converter topology of the magnetic components

IV CONTROL STRATEGY OF HYBRID ENERGY STORAGE SYSTEM

A. Super Capacitor

To supply a steady load voltage, a straight-line voltage and current regulator is selected. Super-capacitors are able to respond more quickly and recycle the energy when the DC side voltage considerably rises during slowing down. The super capacitor regulators control In Fig. 3, a block diagram is displayed. Where Vdc and Vdc-sen represent the actual and estimated voltages of the DC engine, the supercapacitor, and *UC I and *UC sen I, respectively, and fs is the exchanging recurrence. G1 and G2 are the exchanging signs of T1 and T2, respectively. The inductor current exchange capacity obligation pattern can be sent as follows in the help mode:

$$\frac{I_{l2}(s)}{D(s)} = \frac{V_{dc}\,R_{Load}C_{dc}s+2V_{dc}}{R_{Load}L_2C_{dc}s^2+L_2s+R_{Load}(1-D)^2} \quad (1)$$

L2's reference current is IL2(s), the DC motor's voltage is Vdc, its capacitor is Cdc, and its duty cycle is D. Relationship between frequency range and

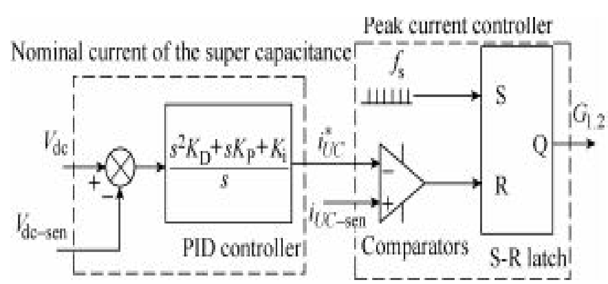


Fig.3 A super-capacitor voltage and current controller's block diagram

The following equation illustrates the connection between the inductor current and the DC-side voltage;

$$\frac{V_{dc}(s)}{I_{L2}(s)} = \frac{-L_2s+R_{load}\,(1-D)^2}{R_{L2}(s)C_{dc}(1-D)s+2(1-D)} \text{ -----(2)}$$

B. Fuzzy Logic Controller

The primary objective of using controllers is to reduce the difference between the output parameter that is being measured and the reference value. This work uses a fuzzy logic controller that basing its design on the bang-bang control theory [15],[12]. The automatic on/off switching of the bang-bang control mechanism keeps measured output close to the reference value. The term "two-step controller" is used to describe it. The configuration of the control system, which uses a fuzzy controller to regulate current, is shown in Figure 4. The difference between the measurements of the reference voltage and the actual voltage serves as the input to the fuzzy controller.

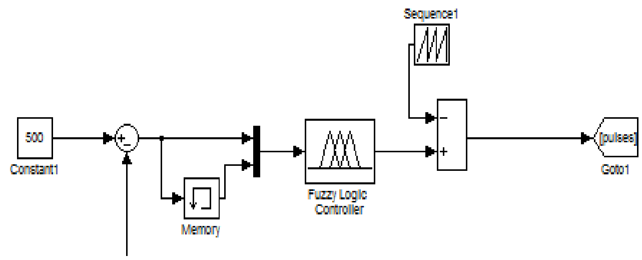


Fig. 4 DC-DC converters using fuzzy logic controllers

By doing so, The defined reference current is used to charge the EV battery. The matching inductor, capacitor, and resistor are denoted in Fig. 4 by the letters L,, and R, respectively. The starting point of Figure 4 represents the grid link that was described earlier. The pulse width modulation (PWM) block in Fig. 4 produces the MOSFET's switching frequency. The input, output membership functions as well as the crisp output function is shown in Figures 6 and 8, respectively HESS simulation for use with electric vehicles.

V. SIMULATION

In order to evaluate the system's dynamic performance, With Matlab/Simulink, a simulation model of the proposed HESS is created and used to a typical car driving cycle. Table 5 lists the parameters of the simulation system. To simulate how cars function in the acceleration, constant speed, braking, and parked charging modes, Matlab/Simulink is employed. It's important to pay attention to the voltage stability of the load side and load side as well as the current ripple that the battery and super capacitor cause.

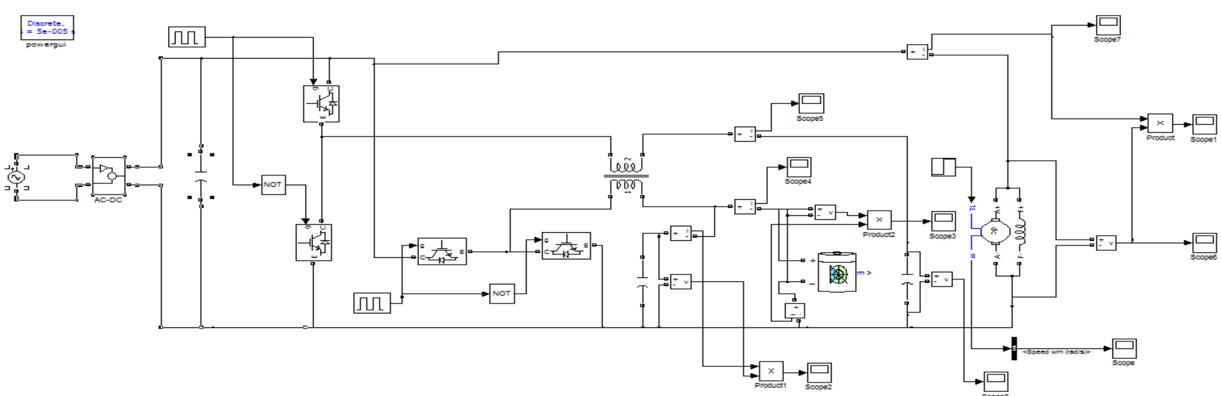
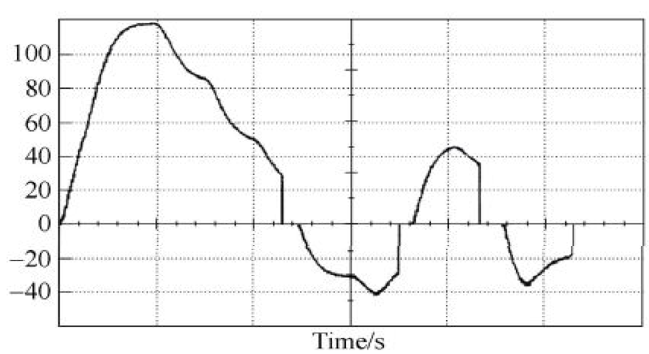
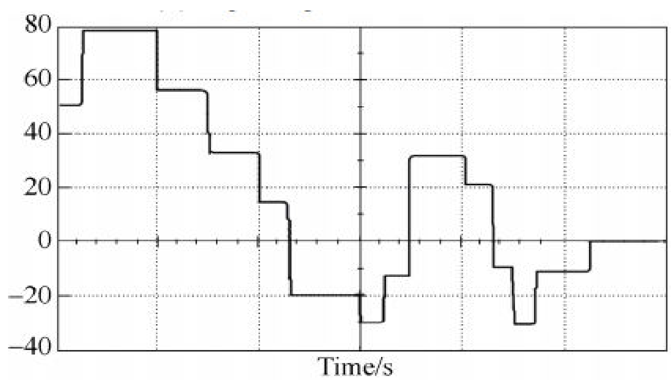


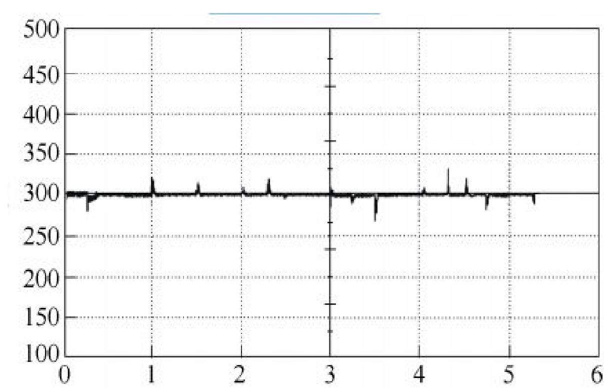
Fig. 5 In order to construct an EV charging system, MATLAB/Simulink was employed



(a) Battery current



(b) Load current



(c) Load voltage

Fig.6 The EV with PI simulation's findings

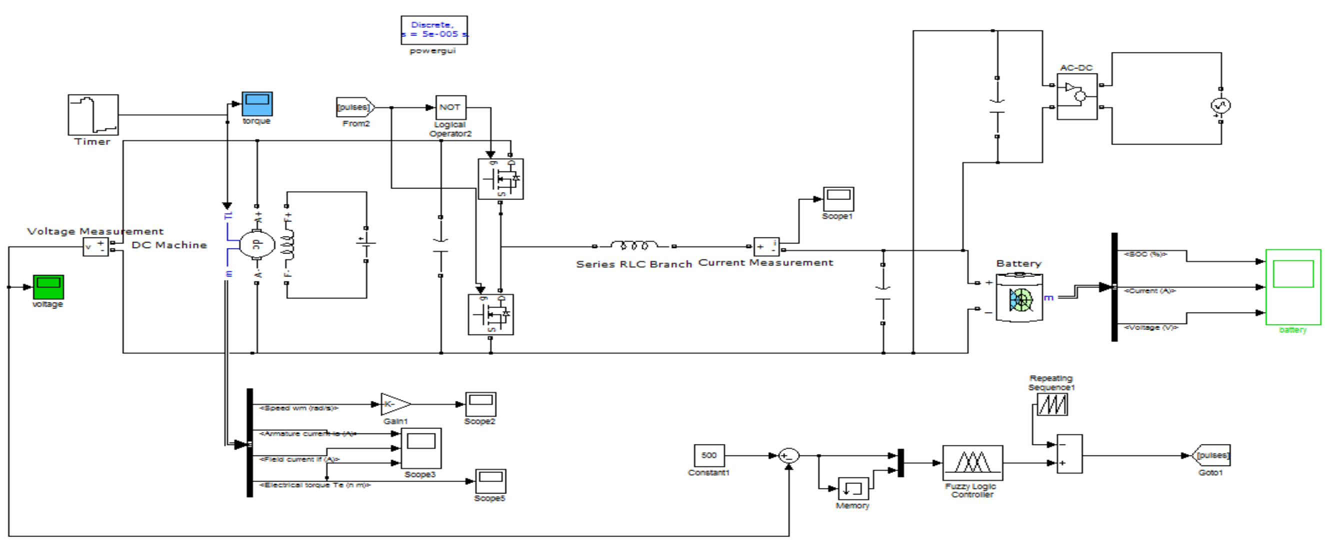
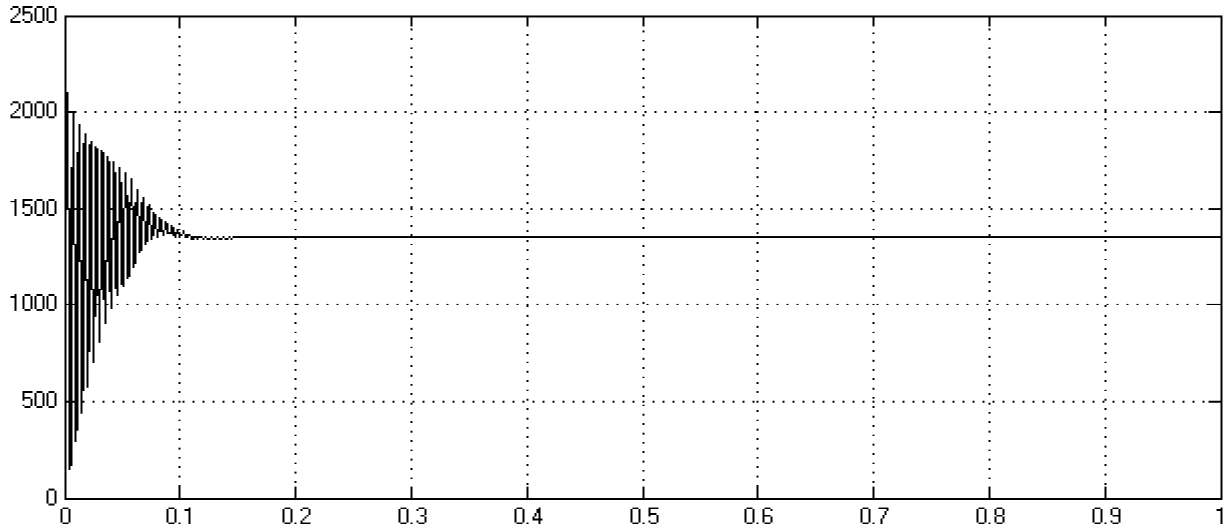
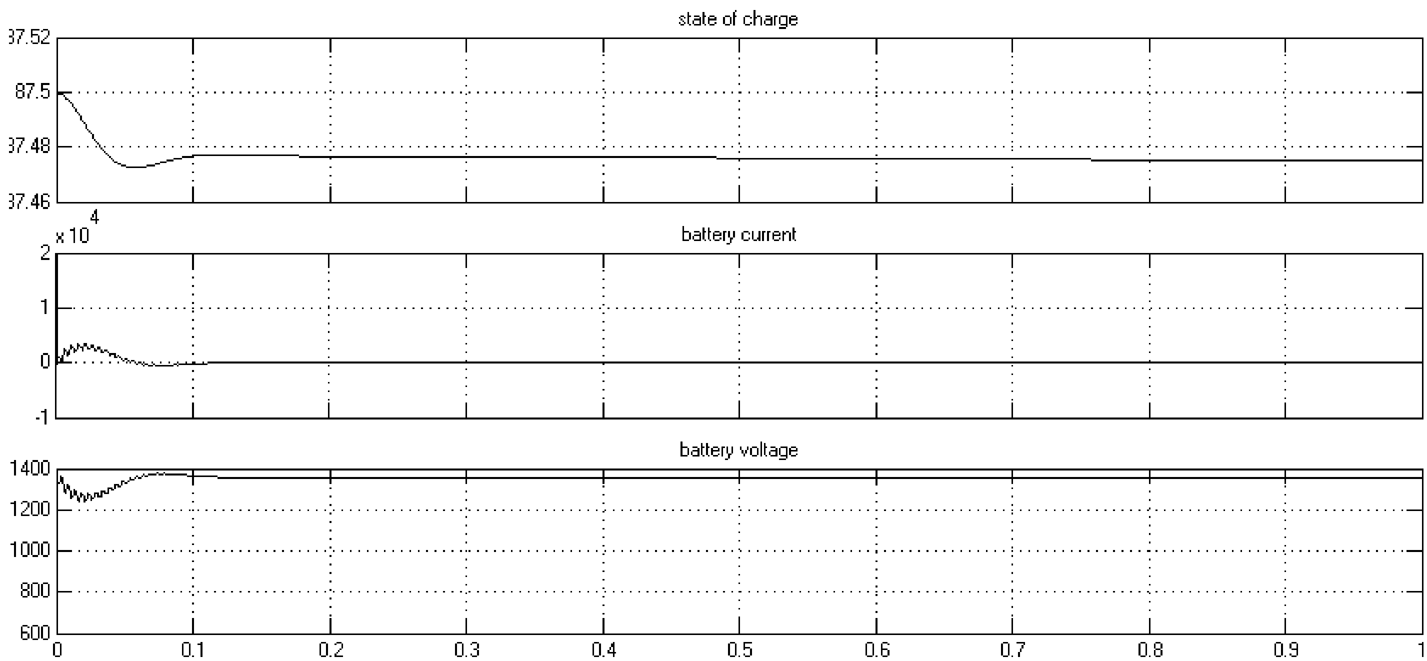


Fig. 7 MATLAB/Simulink-based EV charging system developed using FLC



(a) Load Voltage



(b) Battery waveforms

Fig. 8 Results of the EV with FLC simulation

VI. CONCLUSION

This paper provides a comprehensive model of an EV charging station using a fuzzy logic controller. In MATLAB/Simulink, the entire simulation model was created. The results of the simulation demonstrate how straightforward it is to use FLC for EV charging without the need for further fine-tuning as with PI controller. In light of this work, it is possible to carry out an experimental validation of the suggested system.

REFERENCES

[1] M. Tesanovic and S. Vadgama, "Short paper: Vehicle emanation control in Smart Cities," in 2014 IEEE World Forum on Internet of Things (WF-IoT), 2014, pp. 163-164.

[2] P. Goli and W. Shireen, "PV Integrated Smart Charging of PHEVs Based on DC Link Voltage Sensing," IEEE Transactions on Smart Grid, vol. 5, pp. 1421-1428, 2014.

[3] Z. S. R. Bhatti, M. Abdul Aziz, K. Pui Yee "A Comprehensive Overview of Electric Vehicle Charging utilizing Renewable Energy," International Journal of Power Electronics and Drive System (IJPEDS)" vol. Vol. 7, No. 1, p. pp. 114~123, 2016.

[4] V. Tikka, H. Makkonen, J. Lassila, and J. Partanen, "Contextual investigation: Smart charging module crossover vehicle test climate with vehicle-to-lattice capacity," in 2014 sixteenth European Conference on Power Electronics and Applications, 2014, pp. 1-10.

[5] L. Dickerman and J. Harrison, "A New Car, a New Grid," IEEE Power and Energy Magazine, vol. 8, pp. 55-61, 2010.

[6] R. Shi, S. Semsar, and P. W. Lehn, "Consistent Current Fast Charging of Electric Vehicles through a DC Grid Using a Dual-Inverter Drive," IEEE Transactions on Industrial Electronics, vol. 64, pp. 6940-6949, 2017.

[7] D. Sbordone, I. Bertini, B. Di Pietra, M. C. Falvo, A. Genovese, and L. Martirano, "EV quick charging stations and energy stockpiling innovations: A genuine execution in the shrewd miniature lattice worldview," Electric Power Systems Research, vol. 120, pp. 96-108, 2015/03/01/2015.

[8] L. Tan, B. Wu, S. Rivera, and V. Yaramasu, "Far reaching DC Power Balance Management in High-Power Three-Level DC–DC Converter for Electric Vehicle Fast Charging," IEEE Transactions on Power Electronics, vol. 31, pp. 89-100, 2016.

[9] A. Mohamed, V. Salehi, T. Mama, and O. Mohammed, "Continuous Energy Management Algorithm for Plug-In Hybrid Electric Vehicle Charging Parks Involving Sustainable Energy," IEEE Transactions on Sustainable Energy, vol. 5, pp. 577-586, 2014.

[10] A. Meintz, J. Zhang, R. Vijayagopal, C. Kreutzer, S. Ahmed, I. Sprout, et al., "Empowering quick charging – Vehicle contemplations," Journal of Power Sources, vol. 367, pp. 216-227, 2017/11/01/2017.

[11] A. Arancibia and K. Strunz, "Displaying of an electric vehicle charging station for quick DC charging," in 2012 IEEE International Electric Vehicle Conference, 2012, pp. 1-6.

[12] J. Bakalarczyk, "Charging of PV battery at steady current mode by utilizing fluffy rationale control," in 2017 twelfth International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), 2017, pp. 397-400.

[13] B. V. O. Erdinc, M. Uzunoglu,, "A wavelet-fluffy rationale based energy the executives technique for an energy unit/battery/ultra-capacitor crossover vehicular force framework," Journal of Power Sources, vol. 194, pp. 369-380, 2009/10/20/2009.

[14] K. Basaran and N. S. Cetin, "Planning of a fluffy regulator for framework associated photovoltaic framework's converter and contrasting and PI regulator," in 2016 IEEE

International Conference on Renewable Energy Research and Applications (ICRERA), 2016, pp. 102-106.

[15] H. Kim, J. Kim, M. Shim, J. Jung, S. Park, and C. Kim, "A carefully controlled DC-DC buck converter with bang-bang control," in 2014 International Conference on Electronics, Information and Communications (ICEIC), 2014, pp. 1-2.

[16] G. T. R. Gagnon, C. Larose, J. Brochu, G. Sybille, M. Fecteau, "LargeScale Real-Time Simulation of Wind Power Plants into Hydro-Québec Power System," ninth International Workshop on Large-Scale incorporated Wind Power Systems just as on Transmission Networks for Offshore Wind Power Plants, 2010.