wjert, 2022, Vol. 8, Issue 6, 118-132. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.924

DESIGN AND IMPLEMENTATION OF ROBUST CONTROLLER FOR DUAL ACTIVE BRIDGE CONVERTER IN EV APPLICATION

B. Vivek*[1] and S. Karthikeyan[2]

[1]Final Year, M.E Power Electronics and Drives AVS Engineering College, Ammapet, Salem 636 003.

[2]PHD Scholar, Sona College of Technology, Salem-636005.

Article Received on 26/03/2022 **Article Revised on 16/04/2022** **Article Accepted on 06/05/2022**

***Corresponding Author**
B. Vivek
Final Year, M.E Power Electronics and Drives AVS Engineering College, Ammapet, Salem 636 003.

ABSTRACT

The primary objective of this work is to making Environmental sustainability and utilizing Power convertors for electrical vehicle's Designing. now days fuel based vehicle's like wise two wheeler ,four wheeler and railway system running condition depending upon fuel petrol, diesel, block body contents etc. in current scenario Environmental resources availability is very poor by chance available means that time cost of resource is high there for we are taking power convertors based scheme with mainly focusing on Hybrid electric vehicle's .The Plug in Hybrid Electric Vehicle has become passion today for its less emission of gasoline and reduced fuel price. PHEVs have battery to be recharged from a standard power vent. It is an unexpected load in residential power system. Uncoordinated charging of many PHEVs at a time creates a sudden change in load demand of grid causes a potential drop in power system and power loss. PHEV consumes more energy from the grid. This report offers a technique to trim power consumption from the power system. A high power, DAB converter is introduced in PHEV to charge the battery when the motor in PHEV acts as a generator. In this work, intelligent fuzzy logic controller is proposed as charging controller of the battery. Performance of the proposed system is simulated using MATLAB and compared to the conventional controls. This work proposes a technique to reduce load demand on distribution grid.

KEYWORDS: Hybrid, Power Convertors, MATLAB, DAB Converter, Fuzzy Logic.

1. INTRODUCTION

Bidirectional DC-DC Converters (BDCs) allows the benefits in either increasing or decreasing the level of voltage between two DC sources along with the bidirectional power flow capability.[1-9] These features of BDC have recently gained increasing focus in the field where an energy storage system is required for future utilization. This type of energy storage will supply an uninterrupted power to the load connected to it. However, to perform transformation of energy between the system and the auxiliary storage device, a DC-DC converter is required. Therefore, a BDC should possess flexible control of bidirectional power flow in all modes of operation.[14-16] Thus, the modeling and the control of BDC becomes an important issue. In order to overcome these problems, solutions are proposed in this research work.

2. MATERIAL AND METHODS

The main focus of this research work is to analyze the performance measures of both NBDC and IBDC with low output ripple voltage/current using suitable control techniques. This has been realized by using three Dual Active Bridge Converter. The bidirectional DC-DC converter transfer power between the two sources by increasing or decreasing the voltage levels depending upon the requirements. In IBDC, isolation is required between the two circuits. For this purpose, transformers are utilized. This IBDC comprises of half bridge and full bridge type converters. By adjusting the transformer ratio, high voltage gain can be achieved. Fundamentally, the NBDC comprises of conventional boost/buck and coupled inductor types. The coupled inductor converter can achieve high voltage gain without control complexity. Generally for the requirement of high voltage gain in boost/buck converters, more switches are implemented. When number of switches gets increased, the design of converter becomes complicated. A conventional bidirectional DC-DC boost/buck converter shown in Figure 1.4 proposed by Camera et al. (2010) which is simple in structure and easy to control. During buck and boost mode of converter operation, the switches operate under hard switching which gives rise to high switching losses. This in turn reduces the efficiency of the system. Hence, to minimize these switching losses, many soft switching approaches such as ZVS (Zero Voltage Switching) and ZCS (Zero Current Switching) have been presented.

2.1 BIDIRECTIONAL DC-DC CONVERTERS

The basic configuration of bidirectional DC-DC converters is shown in Figure 1.1. The BDC can be classified into two types namely boost type and buck type which is based on the auxiliary storage device position. The energy storage device is positioned on the high voltage side in a buck type whereas in boost mode, it is retained on the low voltage side. Basically BDCs are divided into two types, Non-isolated Bidirectional DC-DC Converters (NBDCs) and Isolated Bidirectional DC-DC Converters (IBDCs) meeting the requirements of different applications.

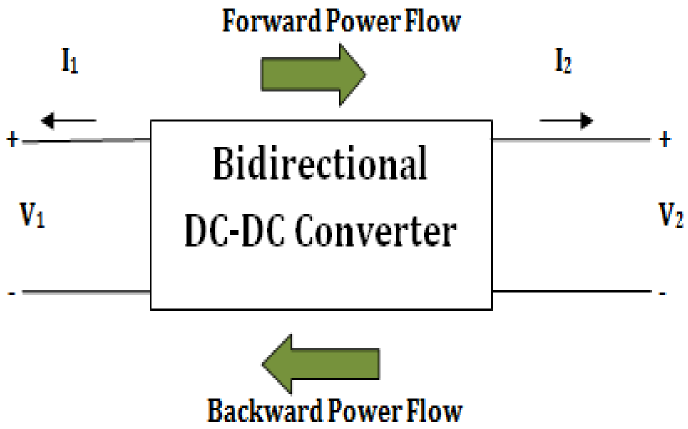


Figure 1.1: Typical Structure of BDC.

Basically BDCs are divided into two types, Non-isolated Bidirectional DC-DC Converters (NBDCs) and Isolated Bidirectional DC-DC Converters (IBDCs) meeting the requirements of different applications.

2.1 NON-ISOLATED BIDIRECTIONAL DC-DC CONVERTERS

A non-isolated bidirectional DC-DC converter shown in Figure 1.2 is obtained from the unidirectional DC-DC converters. Here, the bidirectional switches are implemented instead of a unidirectional switch. Generally, the diodes present in the conventional converters, do not have the capability of controlling power flow in either direction. In order to overcome this constraint in the conventional converter, Power MOSFET or an IGBT with anti-parallel diode across them is introduced. These semiconductor devices allow the conduction of current in both forward and reverse direction and thereby act as a bidirectional switch with the controlled switching operation.

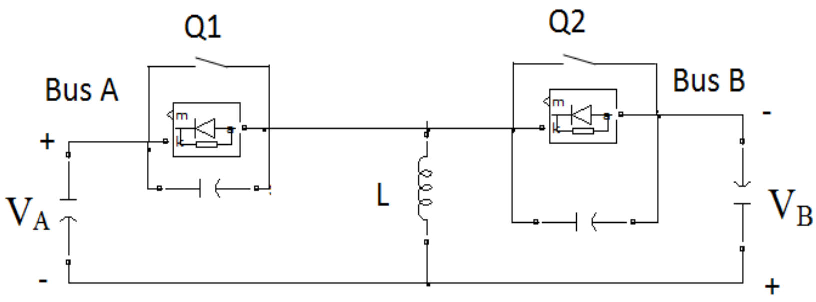


Figure 1.2: Typical structure of NBDC.

The operation of the NBDC is as follows. In the above figure, the inductor functions as energy transfer component. For every switching cycle, the component is charged via the source side active switch. The inductor is charged for the duration of $T_{on} = \delta T$, where T is the switching period and δ is duty cycle. Then the inductor releases the energy stored in it to the load during the period, $T_{off} = (1- \delta)$ T. Synchronous rectification technique can be adopted so as to increase the efficiency of the converter by adding more features to the configuration.

2.3 ISOLATED BIDIRECTIONAL DC-DC CONVERTERS

The structure of an IBDC is shown in Figure 1.3. It consists of two DC-AC converters namely, Converter A and Converter B with high-frequency switching and a high-frequency transformer of ratio 1: n. This transformer provides a galvanic isolation between the two converters and also helps in voltage matching between them. Thus both DC-AC converters should possess bidirectional energy transfer capability because power flow transfer is required in either direction from Mode A-B or Mode B-A.

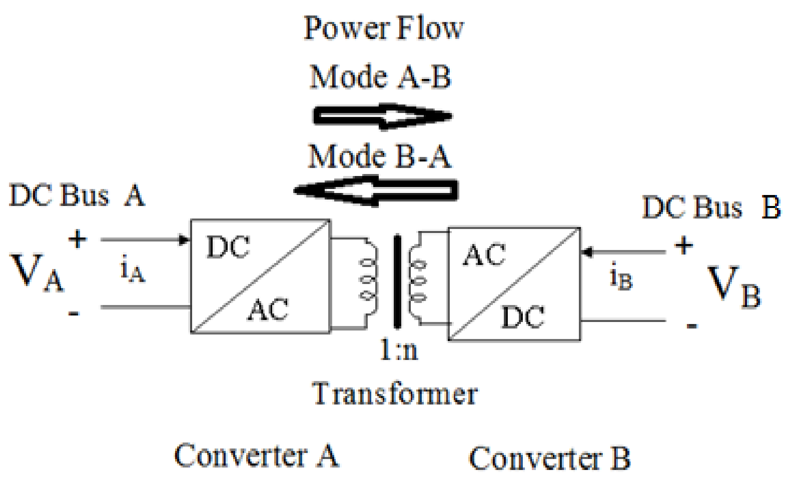


Figure 1.3: Typical structure of an IBDC.

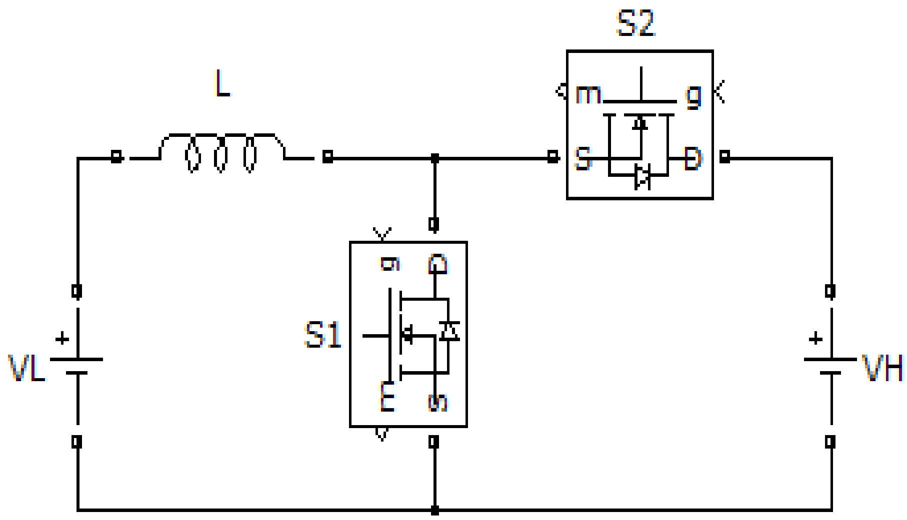


Figure 1.4: Conventional DC-DC boost/buck converter.

3. PROPOSED SCHEME FLOW

The block diagram shown in Figure 1.5 illustrates the methodology of the proposed work. The high performance DC-DC converter output is connected to filter unit. This filter unit reduces the ripples present in the output of the converter. However, these converters are subjected to several interferences either from input or output side. Hence in order to maintain the output voltage constant, controllers are implemented. Thus the controller controls the switching pulses of the converter.

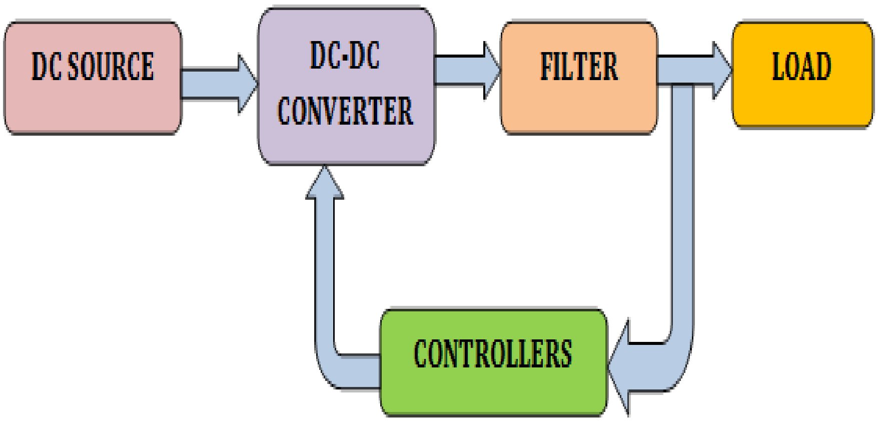


Figure 1.5: Typical Block Diagram Of Robust Controller For A Dual Active Bridge Converter For Electric vehicle Design.

3.1 DESIGN OF FUZZY CONTROLLER

Fuzzy logic controllers (FLCs) are intelligent control systems characterized by a set of linguistic statements based on expert knowledge or experience. Processing of uncertain information, modeling of physical systems using common sense rules and linguistic statements are the basis for fuzzy logic control.

3.2.1 CONFIGURATION OF FLC

The basic configuration of Fuzzy Logic controller is shown in Figure 2.10. The function of each blocks and its realization are explained below.

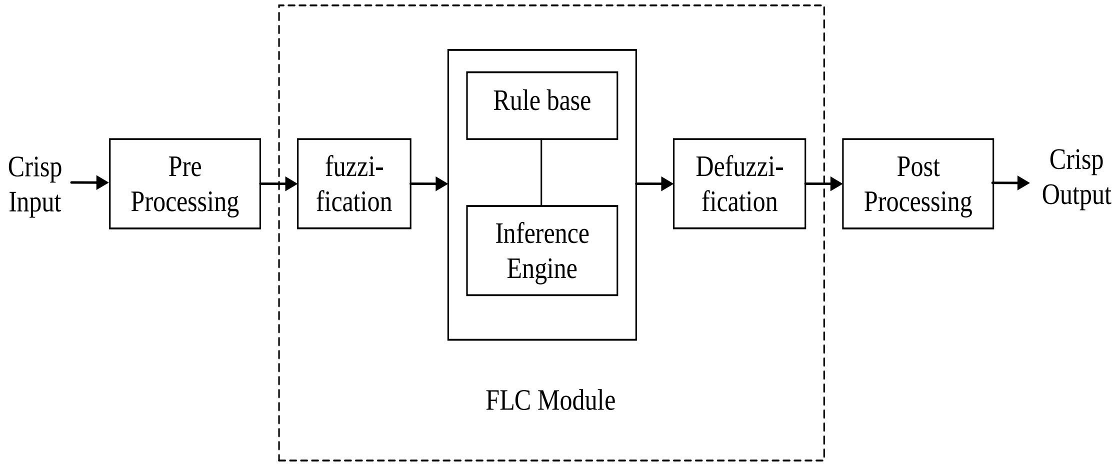


Figure 3.1: Basic configuration of fuzzy logic controller.

The inputs are the measurements from some measuring equipment, rather than linguistic. A preprocessor, conditions the measurements before they are fed into the controller. The preprocessor then passes the data on to the controller. Fuzzification is the process where the crisp quantities are converted to fuzzy values. The conversion of fuzzy values is represented by the membership functions. There are various methods to assign the membership values or the membership functions to fuzzy variables. Rules form the basis for the fuzzy logic to obtain the fuzzy output. The rule-based form uses linguistic variables as its antecedents and consequents. The antecedents and the consequents express an inference and the output. For any linguistic variable, there are three general forms in which the canonical rules can be formed. They are: Assignment statements, Conditional statements, Unconditional statements The linguistic connections like “and,” “or,” “else” connects the conditional, unconditional and restriction statements. For each rule, the inference engine looks up the membership values in the condition of the rule and then evaluates. De-fuzzification means the fuzzy to crisp conversions. The fuzzy results generated cannot be used as such to the applications, hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing. This can be done by using defuzzification process. Defuzzification can also be called as "rounding off" method. Defuzzification reduces the collection of membership function values in to a single sealer quantity. Various methods used for defuzzifying the fuzzy output functions are given Max-membership principle, Centroid method, Weighted average method, Mean–max membership, Centre of sums, Centre of largest area and First of maxima or last of maxima. In all of these methods centroid method is widely used because of its accuracy. The most important types of fuzzy inference systems are Mamdani's fuzzy inference method and Sugeno or Takagi–Sugeno–Kang method The main difference between the two methods lies in the consequent of fuzzy rules. Mamdani fuzzy systems use fuzzy sets as rule consequent whereas TS fuzzy systems employ linear functions of input variables as rule consequent. So all the fuzzy systems deal with Mamdani fuzzy systems. FLC has the following advantages over the conventional controllers: they are cheaper to develop, they cover a wider range of operating conditions and they are more readily customizable in natural language terms. Hence, the application of PI-type fuzzy controller increases the quality factor.

4. RESULTS AND DISCUSSION

The DAB converter topology has been chosen as it features high power density, high efficiency, bidirectional power flow capability, inherent soft switching, galvanic isolation and low number of passive components. Hence, the converter is a candidate for high-power-density aerospace applications. This chapter makes a contribution to the steady-state analysis of the DAB converter by producing equations for the RMS and average device currents and the RMS and peak inductor/transformer currents. These equations are useful in predicting the losses that occur in the devices and passive components and for the design of the converter prototype. The SABER simulations verified the theoretical results of the analysis. Future aircraft will employ high power transient loads such as electrically powered actuators for adjusting flight control surfaces. Ultracapacitors are one possible form of energy storage device that may be used to meet these high transient power demands and smooth the load on the generators. Ultracapacitors could conceivably be beneficial in aircraft energy storage applications due to their fast response time and high current/power handling capability over a wide range of operating temperatures. A Maxwell Technologies 125V ultracapacitor module specification has been used in SABER simulations to evaluate the converters performance.

The input supply voltage for the converter was chosen as 540V. These two voltage levels are likely to be used in future aerospace systems. As the switching frequency is increased, the transformer and inductor size decreases. But, if the switching frequency is high, the switching losses increase. Therefore, based on the current handling capability and power dissipation capability of available devices for the specified voltage levels on the HV and the LV sides of the DAB converter, the device switching frequency was chosen as 20 kHz. The analysis of the DAB converter was performed for both charging and discharging modes of operation, and the conditions to achieve ZVS have been derived. The effect of the snubber capacitor during device turn-off has been analysed, from which the turn-off equivalent circuit has been obtained. The minimum load current requirement to achieve ZVS has been determined by analysing the action of turn-off snubbers.

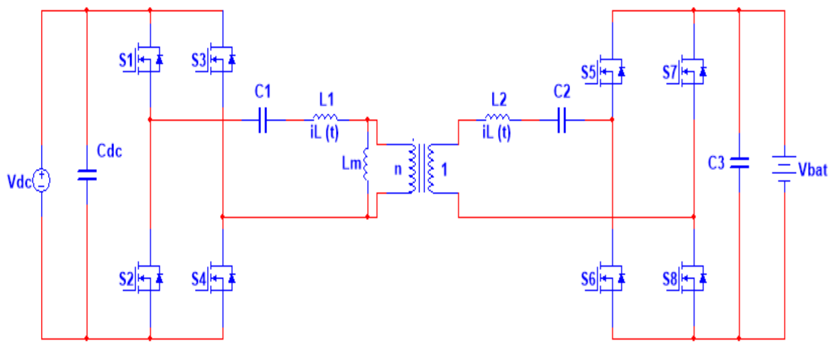


Figure 4.1: Circuit topology of IBDC.

Figure 4.2 depicts the simulink model of the proposed IBDC in open loop control for a boost mode is performed successfully with quad-filter.

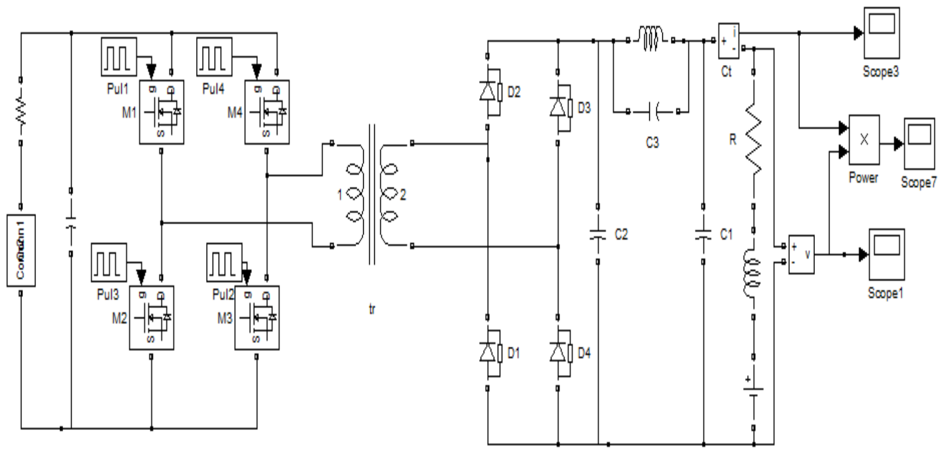


Figure 4.2: Simulink model of the proposed IBDC in open loop control for boost mode.

The simualted voltage waveforms of input and output and also the corresponding power obtained during forward power flow direction is depicted in Figure 4.3 The proposed converter response is studied by varying the input voltage from 15V to 18V at time, t=1.0secs and the corresponding results are presented. For the step input change of 4V, the corresponding output voltage changes by 8V and the load current increases by 0.01A is noted. The power also gets increased due to step change in the input voltage.

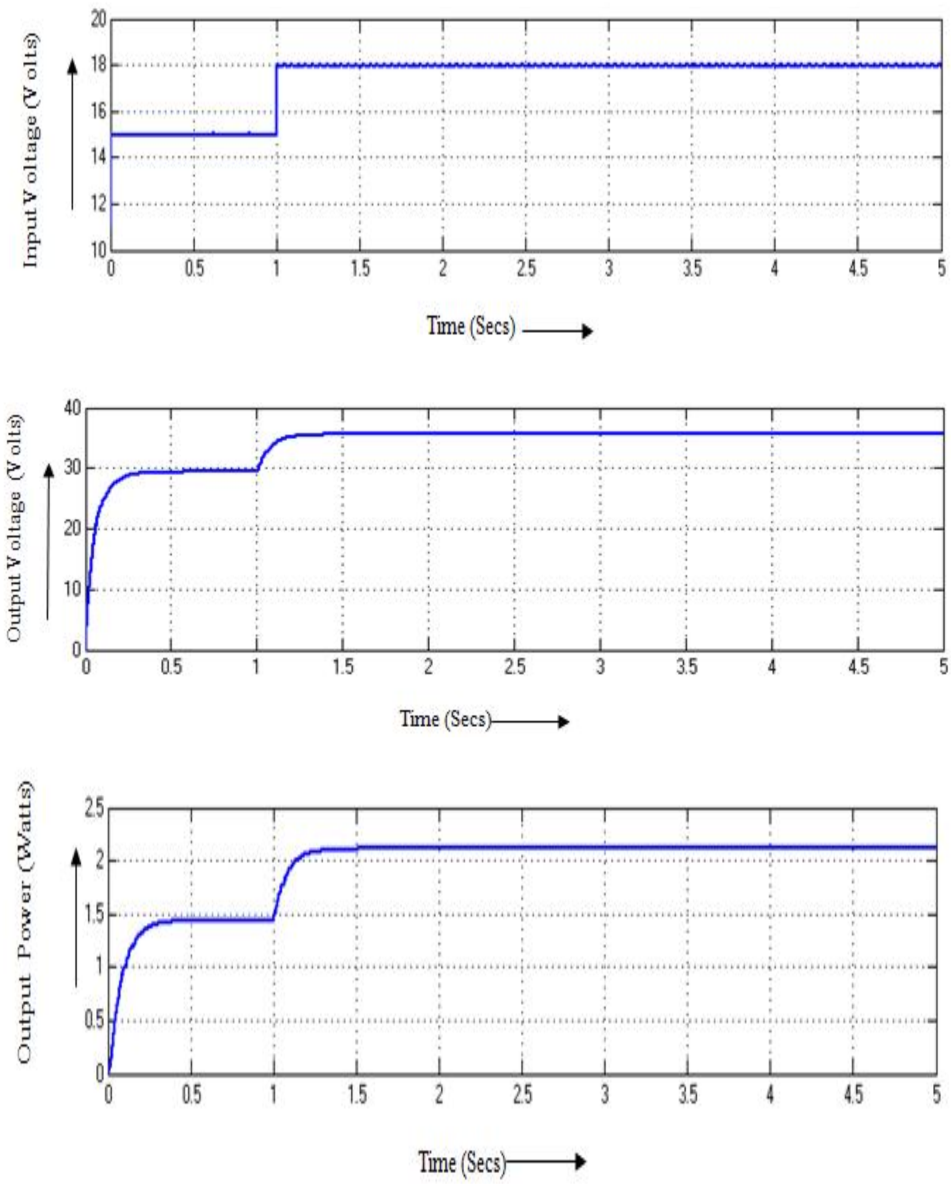


Figure 4.3.: Analysis of proposed IBDC in open loop control for boost mode.

4.1 STUDY OF PROPOSED IBDC IN BOOST MODE UNDER CLOSED LOOP CONTROL

The performance of the converter can be further improved by implementing the conventional controllers such as PI fuzzy and fuzzy and a comparative study is carried out to analyse their performance. The performnces are analysed for an input voltage of 15V during boost mode and similarly, for buck mode it is about 30V.

4.1.1 IBDC with PI Controller

The simulink diagram of closed loop system with PI controller is shown in Figure 4.4The following parameter settings are considered for PI controller: K_p= 2.5, K_i =3 and t_s=50 μsecs.

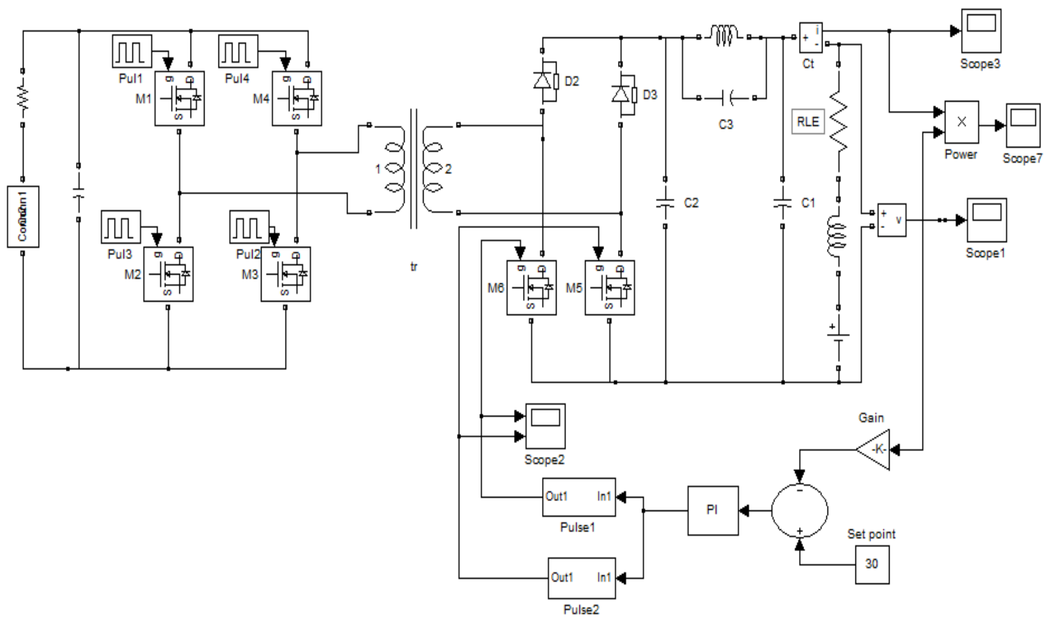
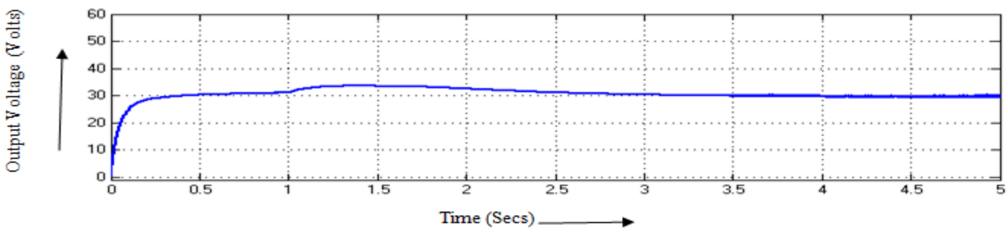


Figure 4.4: Simulink model of the proposed IBDC with PI controller in boost mode.

Figure 4.5 shows the output voltage and their corresponding output power obtained for an input voltage of 15V DC. It demonstrates the converter output voltage for the nominal case of set value 30V and the PI controller response has reached its set value at t=3.0secs.



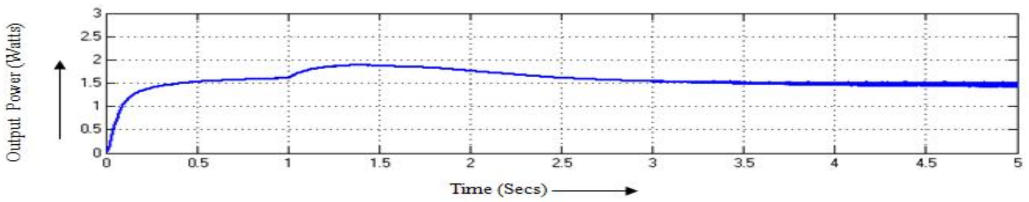


Figure 4.5: Analysis of proposed IBDC with PI controller in boost mode.

4.1.2 IBDC with Fuzzy Controller

The simulink model of the proposed IBDC with fuzzy controller in boost mode is depicted in Figure 4.6 The triangular membership function are chosen to estimate the input values. The switching pulses of the converter is controlled by the fuzzy controller output.

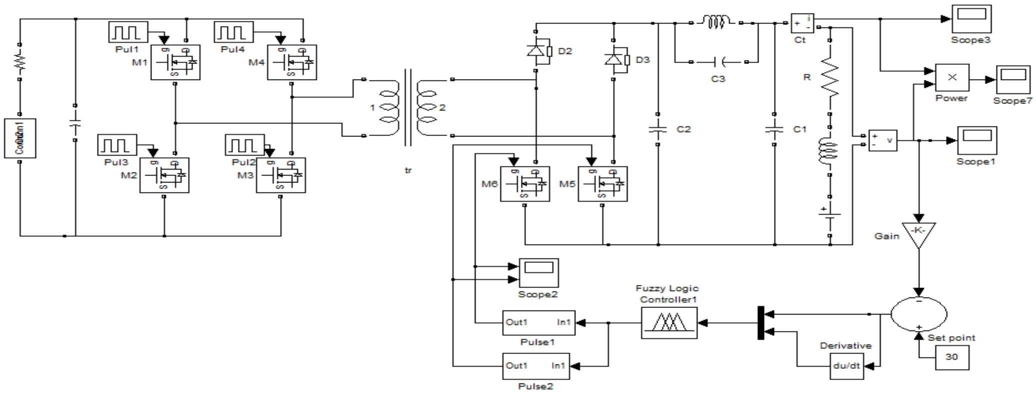


Figure 4.6: Simulink model of the proposed IBDC with Fuzzy controller in boost mode.

The proposed fuzzy system consists of five Membership Functions for error (E), change in error (CE), and output control signal (u). The implication from the system is obtained by means of Mamdani fuzzy reasoning method. The MAX-MIN composition is used as fuzzy reasoning approach. The Membersip Functions plots corresponding to the variables E (voltage error), CE (change in error) and fuzzy output control variable are illustrated in the Figures 4.7, 4.8 and 4.9 respectively. Table 4.1 summaries the rule table of the proposed controller.

Table 4.1: Rule base for IBDC.

e(n)/ce(n)	**NB**	**NS**	**ZE**	**PS**	**PB**
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB
PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PB	PB	PB

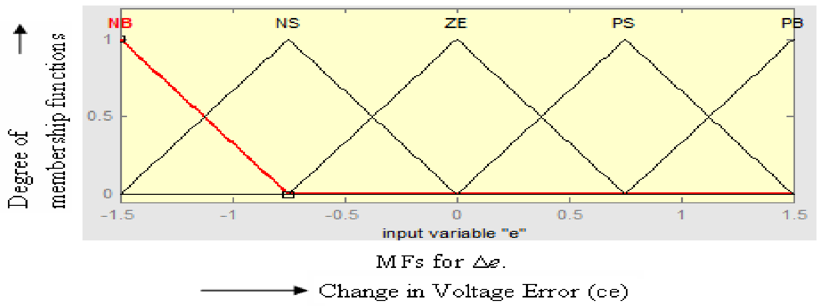


Figure 4.7: Membership functions for e(n).

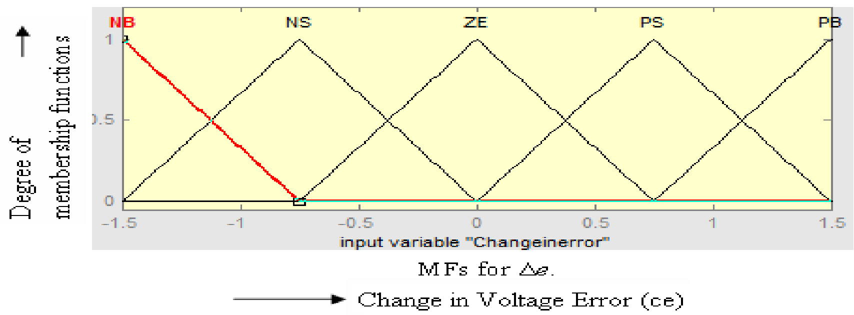


Figure 4.8: Membership functions for ce(n).

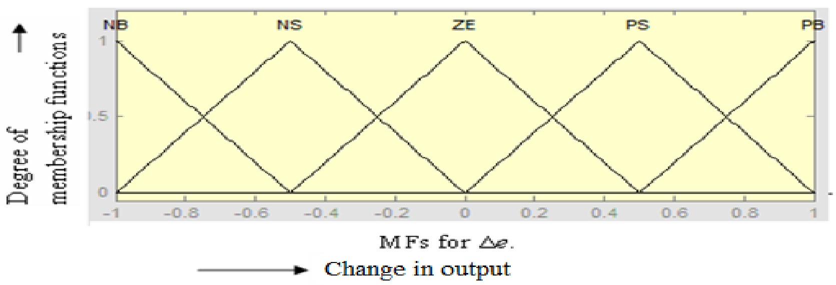
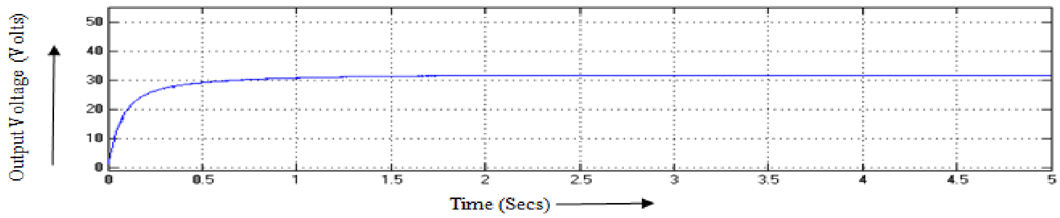


Figure 4.9: Membership functions for cu(n).

Figure 4.10 illustrates the performances of the proposed converter with fuzzy controller for the input voltage 15V. From the results, it is clearly stated that at any change in input voltage changes does not affect the performance of the converter and the output voltage attains its desired value very quickly without any overshoot.



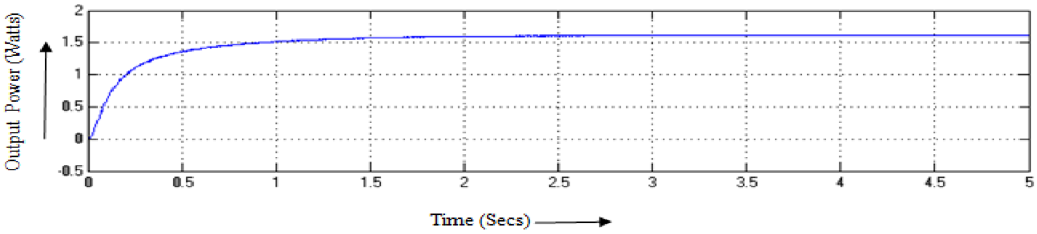


Figure 4.10: Analysis of proposed IBDC with Fuzzy controller in boost mode.

Table 4.2.: IBDC - Comparison of responses with various controllers in Boost mode.

Controllers for IBDC in Boost mode	Rise time T_r (secs)	Settling time T_s (secs)	Peak time T_p (secs)	Steady state error E_{ss} (V)
PI	0.25	3.5	1.35	0.6
Fuzzy	0.12	-	-	0.005

From the above table, it is observed that proposed converter with neural controller provides better settling time. Also the steady state error gets reduced considerably from PI controller to neural controller. Thus, the choice of optimal control for the proposed converter operating in boost mode is chosen with neural controller which provides faster response with virtually no overshoots when compared to other controllers.

5. CONCLUSION

The isolated bi-directional converters DAB have preferred. This full bridge converter has a high switching frequency transformer which is placed in between the high and low voltage side of the circuit. This approach has analyzed with different controllers with RLE load, as per the results fuzzy based controller shows better efficiency than the other controllers and also minimised the harmonics and switching loss occurred in the systems.

REFERENCES

1. Biao Zhao, Qiang Song, Wenhua Liu, Guowei Liu & Yuming Zhao, ‘Universal High-Frequency-Link Characterization and Practical Fundamental-Optimal Strategy for Dual-Active-Bridge DC-DC Converter Under PWM Plus Phase-Shift Control,’ IEEE Transactions on Power Electronics, 2015; 30(12): 6488-6494.
2. Hosseini, S, H, Sabahi, M, Sedaghati, F & Gharehpetian, G, B, ‘A new extended topology for dual active bridge DC-DC converter,’ IEEE Electrical Power and Energy Conference (EPEC), 2015; 391-396.

3. Jin-san Kim, Feel-soon Kang, Sun-phil Kim & Sung-Jun Park, 'Bidirectional DC-to-DC converter for motor control unit of electric vehicle,' 41st Annual Conference of the IEEE Industrial Electronics Society, 2015; 927-931.
4. Lingxiao Xue, Zhiyu Shen, Dushan Boroyevich, Paolo Mattavelli & Daniel Diaz, 'Dual Active Bridge-Based Battery Charger for Plug-in Hybrid Electric Vehicle With Charging Current Containing Low Frequency Ripple,' IEEE Transactions on Power Electronics, 2015; 30(12): 7299-7307.
5. Mehnaz Akhter Khan, Adeeb Ahmed, Iqbal Husain, Yilmaz Sozer & Mohamed Badawy, 'Performance Analysis of Bidirectional DC–DC Converters for Electric Vehicles,' IEEE Transactions on Industry Applications, 2015; 51(4): 3442-3452.
6. Kafeel Ahmed Kalwar, Muhammad Aamir & Saad Mekhilef, 'Inductively coupled power transfer (ICPT) for electric vehicle charging,' Renewable and Sustainable Energy Reviews, 2015; 47: 462-475.
7. Punitha, N & Saranya, T, 'High efficiency fly-back converter using resistance compression network,' International Conference on Innovations in Information, Embedded and Communication Systems, 2015; 1-6.
8. Saranya Sasi & Veena Wilson. "Single-phase high gain DC/DC converter with multiplier cell for lighting applications using fuzzy controller", IEEE Conference on Green Engineering and Technologies, India, 2015; 1-6.
9. Sivaprasad, A, Jijo Joseph, Kumaravel, S & Ashok, S, 'Design and analysis of a dual input DC-DC converter for hybrid electric vehicle,' IEEE International Conference on Signal Processing, Informatics, Communication and Energy Systems, 2015; 1-5.
10. Aylapogu Pramod Kumar, V, V, Subrahmanya Kumar Bhajana & Pavel Drabek, 'A novel ZCS interleaved bidirectional buck-boost DC-DC converter for energy storage applications,' International Conference on Applied Electronics (AE), 2016; 180-185.
11. Hossein Ardi, Ali Ajami, Faezeh Kardan & Shahla Nikpour Avilagh, 'Analysis and Implementation of a Nonisolated Bidirectional DC–DC Converter with High Voltage Gain,' IEEE Transactions on Industrial Electronics, 2016; 63(8): 4878-4888.
12. Anupam Kumar, A, H, Bhat & Pramod Agarwal, 'Comparative analysis of dual active bridge isolated DC to DC converter with flyback converters for bidirectional energy transfer, Recent Developments in Control, Automation & Power Engineering, 2017; 382-387.
13. Bhimisetty Manoj Kumar, Anupam Kumar, A, H, Bhat & Pramod Agarwal, 'Comparative study of dual active bridge isolated DC to DC converter with single phase

shift and dual phase shift control techniques,' Recent Developments in Control, Automation & Power Engineering, 2017; 453-458.

14. Hyeonju Jeong, Minho Kwon & Sewan Choi, 'A high gain non-isolated soft-switching bidirectional DC-DC converter with PPS control,' IEEE Energy Conversion Congress and Exposition, 2017; 1723-1727.
15. Krishnan, K, Gokul, Babu, P, Emmanuel, S, Ashok, S, Kumaravel, 'Design and control of non-isolated bidirectional DC-DC converter for energy storage application, IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology, 2017; 289-293.
16. Wu Chen, Guangjiang Wang & Xu Zhu, 'A family of bidirectional DC/DC converters suitable for asymmetrical power flow requirement,' IEEE Journal of Solid-State Circuits, 2018; 53(11): 3314-3326.
17.