

Investigations on Fuzzy logic Controlled Soft Switched Push -Pull DC to DC Converter (PPDDC) for Storage batteries

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Abstract

The purpose of this paper is to develop the better controller for Push-Pull DC to DC converter for obtaining Improved Dynamic response. The Push-Pull DC to DC converter is modelled dynamically considering the system output voltage. This paper presents an advanced control approach on Fuzzy Logic Control to obtain the steady output voltage and Pi filter is added to minimise the ripple in output voltage. The dynamic characteristics of the closed loop system is analysed. Also a comparative analysis of other controller is insured. The performance of proposed controller is illustrated using MATLAB Simulink. The prototype model is built and verified. The Simulation and Experimental results validate each other, which show that the presented method is both satisfactory and consistent with expectation.

Keywords: DC to DC converter plays a vital role in conversion of power. The proposed Push-Pull DC to DC converter has a simple circuit and reduced voltage drop than forward converter. The Fuzzy Logic Controller generates the control signal to obtain the controlled output voltage and also provides improved dynamic response. Presented results challenge the view that at low-Voltage improved steady state error.

1 INTRODUCTION

The most recent contribution addresses the complication and exclusive power needs of healthcare systems such as imaging equipment, surgical equipment, home healthcare therapeutic devices, and as well as other critical medical applications that require pure and consistent power for the maximum level of performance. The design of medical grade DC to DC converter demanding for large standard range of high isolation DC to DC converters (Li.et.al.,2004) with wide power range and low input and output DC voltage.

The switched mode converters are the power electronics circuits which are most commonly used for changing the voltage level. These converters are used for various applications to vary from no load to full load with high efficiency (Datasheet). The most useful power converter is the buck converter, which step-down the voltage at a lower value (Mude.et.al., 2012).The design, analysis and control of the switching converters are the important factors that have to be considered and also a suitable controller is in demand for the industrial applications. The PWM method is the well known process (Florin.et.al, 2007,Mousumi.,2011,Qiang.,2010).

Fast increase in the development of high switching frequency power electronic devices in the recent years led to the study of power electronic converters. In power electronics the power density is important consideration. To improve it the effectual technique is increasing the switching frequency. On boosting the switching frequency, first the switching losses should be minimized. In systems with low value of input voltage, the conduction loss is the major

thought. The Push-Pull DC to DC converter (Erichson et al., 2001, Ned Mohan et al., 1995, Mousmi et al., 2012) is used for low and medium power systems. In several industrial applications, in case of critical systems, low, steady state output voltage with good transient response is required. Fastest switching speed of the converter will directly lead to introduction of EMI, which interferes in the usual operation, thus the study of soft switching has become more essential.

In number of industries, the dynamic response of the system for power, the uninterruptible power supply is restricted by certain uncertainties like time domain specifications. Further, when fed by PWM converter, suffer from high switching loss, more conduction loss and electromagnetic interference. A Push-Pull resonant topology, working over ZVS condition (Boornamante et al., 2002, Lawler et al., 2001, Subrahmanya et al., 2012) is used, but it is hard to decrease output voltage ripple. Then an LC and LCL (Arun, 2007) resonant push-pull topology (Liu et al., 1990, Zhigan et al., 2003) is designed, where the primary and secondary switches will switch on and switch off under ZVS and ZCS. In these resonant converters, it is easy to control the current flowing through capacitor at the output, but it leads to large voltage and current stress on switches and also higher conduction loss is tough to control. To provide better control on output voltage and superior transient response, the closed loop system is used.

Conventional method of closed loop system uses a PI controller, which is very sensitive to parameter variations. The PID controllers are used in the largest part of industrial application because of its simplicity, clear functionality, feasibility and poor transient and steady state response. Fuzzy Logic controller (Abraham et al., 1994, Ranjani et al., 2014, Stefanos et al., 2014) was suggested as a new and proposed controller than the conventional PI and PID controllers (Veeresh et al., 1993). Fuzzy Logic Controller (Dragan., 2013, Sooraka et al., 1998) is reasoned by human knowledge where the mathematical model is complicated because of non linearities and uncertainties. The Fig: 1 Existing system without pi filter and controller. The work done earlier do not deal with closed loop Fuzzy Logic controlled PushPull DC to DC converter. The improvement in dynamic response with FLC was not reported. The dynamic re-

sponse of hybrid forward converter is presented (Anand.et.al ,2016) .The fuzzy logic controller was designed (Pedrycy.et.al, 1993) to overcome the variations due to environmental and load variations. In this paper, the output voltage regulation for Push-Pull DC to DC converter fed storage battery is controlled using FLC methods.

This paper presents an isolated bidirectional DC-DC converter topology for application as a battery charger. The block diagram of proposed converter is shown in Fig. 2, is a modification of well known topology, namely Push-Pull DC to DC converter.

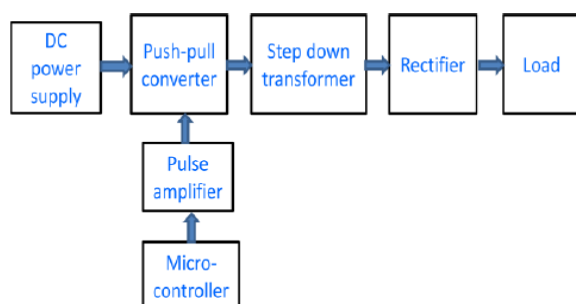


Figure 1: Block diagram of existing system

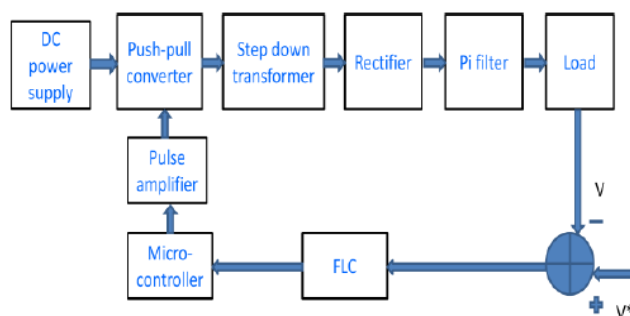


Figure 2: Block diagram of proposed converter system

The proposed converter provides the desired flow of power for battery charging with FLC than the independent isolated power

converters in conventional schemes. Other advantages of the proposed topology include low stresses on the switches because of soft switching, improved galvanic separation, small ripple at the output voltage, rapid transient response and reduced steady state error. The paper also provides detailed steady state analysis for power flow topological modes. A generalized design procedure is given that facilitates design of the power converter. The paper is structured as follows: Section 2 presents the description and operating modes of the converter. Controller design analysis is described in Section 3. The results and discussion is described in section 4. In order to validate and to provide verification for the proposed system the experimental results is given in Section 5. Finally section 6 presents the conclusion.

2 Topology And Operating Mode Of Converter

2.1 Topology and operating modes of the converter

The soft switching of Push-Pull DC to DC converter is used in the current work. Fig: 3 gives the basic circuit diagram of Push-Pull Converter and the timing diagram is shown in Fig.4.

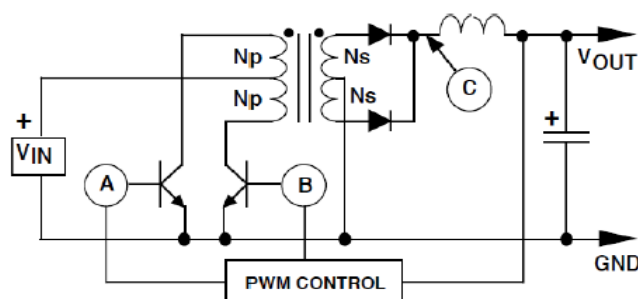


Figure 3: Basic Push-Pull Converter

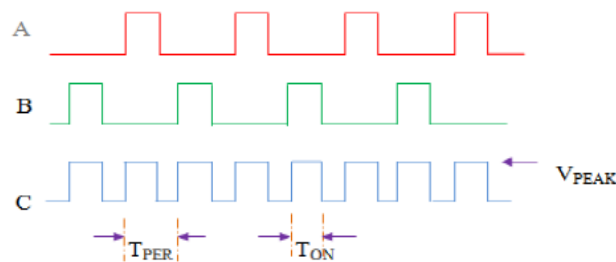


Figure 4: Timing diagram of Push-Pull converter

The Push-Pull converter is operated by alternatively switching on the two transistors. As Current flows in the primary of the transformer at the same time, current flows in secondary also. When transistor A is switched on, the input voltage appear across the upper part of the primary winding with dotted negative terminal. On the secondary side, a negative voltage will emerge across the windings which forward bias the second diode. Thus allows the flow of current through the inductor which in turn supplies both output capacitor and load. If transistor B is switched on, the input voltage appear across the lower part of transformer primary winding with positive dot polarity. Thus the identical voltage will appear across the secondary winding which will forward bias the first diode. This allows the current to flow through output capacitor and load. In proposed topology the transistors are replaced by MOSFET switches because of less conduction and switching loss.

It is well suited for the applications of low input voltage. Thus, it is widely used in converters operating at 12V in battery powered systems. The timing diagram gives the relationship between input and output pulses. The pulse denoted on "A" gives the switching pulse for MOSFET S1 and the pulse denoted on "B" gives the switching pulse for MOSFET S2. The secondary side voltage pulses are double as that of the frequency of operation of PWM controller. The DC output voltage is given by equation 1 and the peak amplitude of secondary pulses are given by equation 2. This characteristic highlights the use of Push-Pull converter for low voltage converters.

The DC output voltage is given by

$$V_{out} = V_{pk} * \left(\frac{T_{on}}{T_{per}} \right) \quad (1)$$

Where V_{pk} = peak amplitude of the secondary pulses

$$V_{pk} = (V_{in} - V_{switch}) * \left(\frac{N_s}{N_p} \right) - V_{rect} \quad (2)$$

3 Controller Design Analysis

3.1 PID Controller Design

Push-Pull DC to DC converter uses the conventional proportional, integral and derivative controller (PID) to reduce the steady state errors. In this controller, the parameters proportional, integral and differential gains K_{pro} , K_{in} and K_{de} are designed by using Ziegler-Nichols method which is given in Table.1. The Circuit model for Push-Pull DC to DC converter with PID controller is shown in Fig:5. Here a step change in input voltage is applied which leads to a step change in output voltage. The output is sensed and compared with the reference signal, which generates the error signal the difference between the measured and output voltages is given by equation (3). The firing angle of the switches is varied by varying the pulse width which is proportional to this error signal. The step change in output voltage is nullified by the use of PID controller. The output voltage of this controller is obtained by equation (4).

$$V_e = V_{ref} - V_{meas} \quad (3)$$

The output voltage of the controller is

$$V_1 = K_{pro}e + K_{in} \int e dt + K_{de} \frac{de}{dt} \quad (4)$$

Table 1: Values of K_{pro} , K_{in} and K_{di}

Parameters	Symbol	Value
Proportional gain	K_{pro}	0.12
Integral gain	K_{in}	0.16
Differential gain	K_{de}	0.092

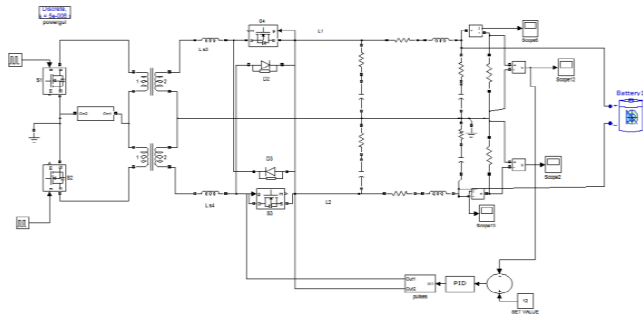


Figure 5: Simulink model of the proposed Push-Pull DC to DC converter with the PID Controller

3.2 Fuzzy Logic Controller Design

Fuzzy Logic Controller can provide improved control for this method, without the knowledge of mathematical model. Though it should undergo the following process. The fuzzification, where the real values are converted to fuzzy set values using IF-THEN rule. Here by using linguistic depiction the fuzzy values are set, which provides good control. Next is the inference mechanism, it helps the experts for decision making in the analysis and use of knowledge to control the system in the most excellent way. Lastly the defuzzification, the output from inference engine which is in fuzzy set state are converted to the actual output. In FLC design it is essential to illustrate the following inputs, the difference between the output voltage V_o of the Push-Pull Converter and reference voltage V_{ref} is the error V_e (q) is the first input given by equation (5) and the difference between the error at q th sampler and $V_e(q-1)$ gives change in error $V_{ce}(q)$ is the second input given by equation (6).

$$V_e(q) = V_{ref} - V_o \quad (5)$$

$$V_{ce}(q) = V_e(q) - V_e(q-1) \quad (6)$$

These inputs are fed on to FLC respectively, the output obtained is due to the change in duty cycle of the switches S3 and S4. The controller input-output gain varies from -1 to 1, as they are normalized, it facilitates the controller fine-tuning. The discrete time integration in FLC is that, the duty cycle is calculated through FLC output in the q^{th} sampling $\Delta d(q)$ and adding it to the preceding sampling $d(k-1)$. The output of FLC is compared with high frequency carrier signal to generate the switching pulse, Out1 switching pulse for S4 is obtained by comparing the FLC output to carrier without phase shift and for Out2 the control signal is obtained by comparing the carrier signal with 180° phase shift. This FLC output increases the type of the system and thus decreases the steady state error. The schematic diagram is shown in Fig: 6.

3.2.1 Fuzzification

The Fuzzy rules require minimum data input and linguistic rules. Here the membership function used to produce the control signal is of triangular shape which is shown in Fig.7. The five variables negative big (NB), negative small (NS), zero (Z), positive big (PB) and positive small (PS) are used for error 'e' and change in error ' Δe '

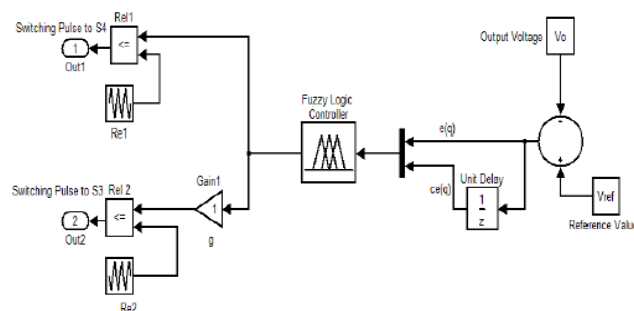


Figure 6: Schematic diagram of FLC

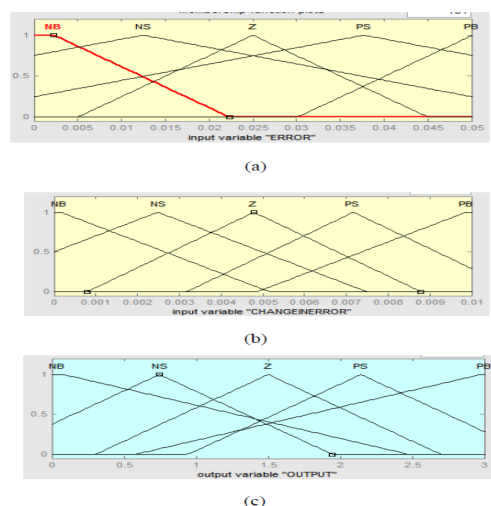


Figure 7: Triangular membership function of fuzzy set rules a) Error b) change in error and c) Output pulse

3.2.2 Rule Base

The rule base is the relationship between input and output values based on IF-THEN rule. In the proposed system the controller is designed with 5 fuzzy sets for each linguistic variables, where 25 rules are generated which may be defined as a mamdani linguistic model given by equation (7)

$$\text{If } V_{e(q)} \text{ is } C_{i1} \text{ and } V_{ce(q)} \text{ is } C_{i2} \text{ then } \Delta a_i \text{ is } D_i \quad (7)$$

where $V_{e(q)}$ and $V_{ce(q)}$ are the linguistic inputs and Δa_i is the output variables. The C_{i1} and C_{i2} are the values of input variables for which the output is D_i in the universe of discourse.

The rules are framed based on the knowledge of Push-Pull DC to DC converter. If output voltage is higher than the reference the duty cycle has to be increased and if it is less than the reference the duty cycle has to be decreased. The rule is showed in Table: 1.

3.2.3 Inference Mechanism

The inference mechanism is based on the intersection of membership grades using Mamdani mini fuzzy implication as given in equation (8).

$$X_k = \min \{ve(k), vce(l)\} * C_k \quad (8)$$

Where $ve(k)$ and $vce(l)$ are membership grades obtained from the intersection function and the results are taken as x_k and c_k

Table 2: Fuzzy set rules

$e / \Delta e$	NB	NS	Z	PS	PB
NB	NB	PB	NS	PB	PS
NS	PS	NB	PB	Z	NS
Z	PS	PB	Z	NB	PB
PS	Z	NS	PS	PB	NS
PB	PS	NB	NS	NB	Z

The controlling rules for this system are given in table: 1. Proposed systems have been designed using five membership function; the system transient response had been improved.

3.2.4 Defuzzification

In defuzzification the value from inference engine is converted to actual value for processing the system. Here Centre of gravity by Mamdani type shown in equation (6) is used.

$$\Delta ai = \frac{\sum b_k \int v(k)}{\sum \int v(k)} \quad (9)$$

$$\int v(k) = p \left(h - \left(\frac{h^2}{2} \right) \right) \quad (10)$$

The centre of gravity Δai can be determined using the equation (9) where b_k is the centre of the membership function and $v(k)$ is the area beneath the membership function $v(k)$. It is determined by using the equation (10) where p is the base and h is the height of the membership function.

4 Results And Discussion

4.1 Closed Loop Fuzzy Logic Control Simulation Results

The designed FLC control is implemented in Push-Pull DC to DC converter for low voltage battery charger. The PIC16F84 microcontroller is used to obtain the control signals for the switches. The Push-Pull converter is designed using IRF840 MOSFETs, IN4007 diodes, an inductor with 1mH, a capacitor of 4700 μ F and load resistance of 500 Ω . The input voltage of 48 V and Output voltage of 12V. The converter is modelled using MATLAB Simulink and also designed. The FLC is included using Fuzzy logic toolbox. Fig:8 gives the circuit diagram of Push-Pull DC to DC converter with FLC in closed loop. The step change in input voltage from 48V to 58V at 4ms is shown in Fig:9, the switching pulses for S_1 and S_2 are shown in Fig:10, the switching pulses for S_3 and S_4 is shown in Fig:11, the transformer primary voltage is shown in Fig:12, the transformer secondary voltage is shown in Fig:13 and the controlled output voltage is shown in Fig:14.

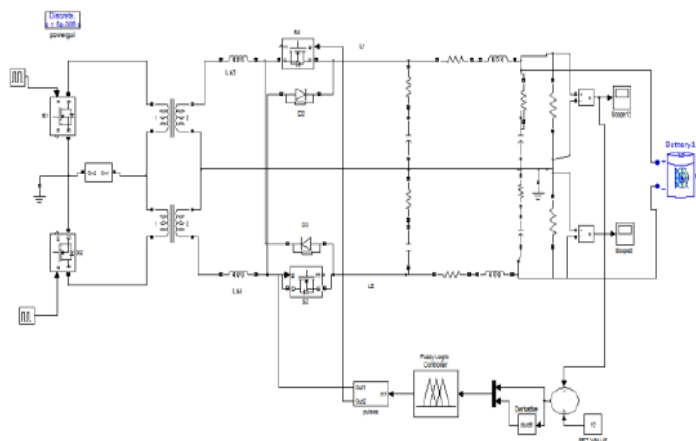


Figure 8: Simulink Model Of Push-Pull DC to DC Converter with Fuzzy Logic Controller

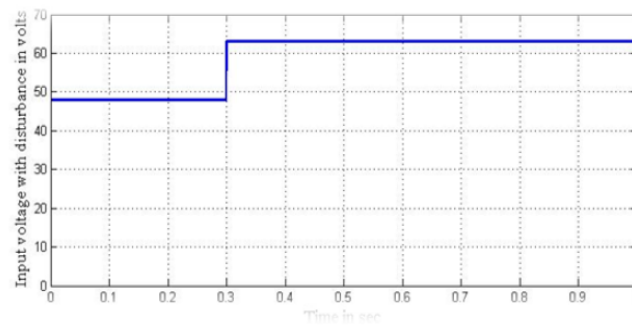
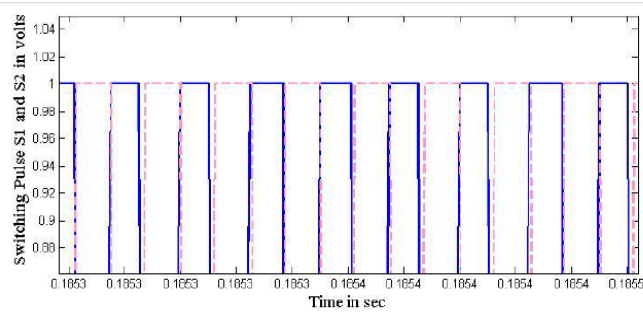
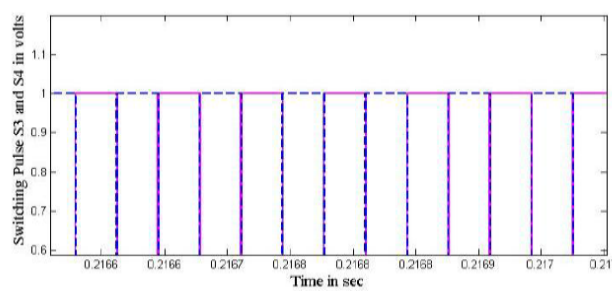


Figure 9: Step change in input voltage

Figure 10: Switching Pulse S_1 and S_2 Figure 11: Switching Pulse S_3 and S_4

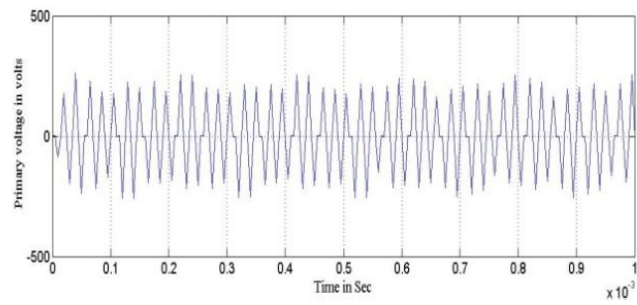


Figure 12: Transformer primary voltage

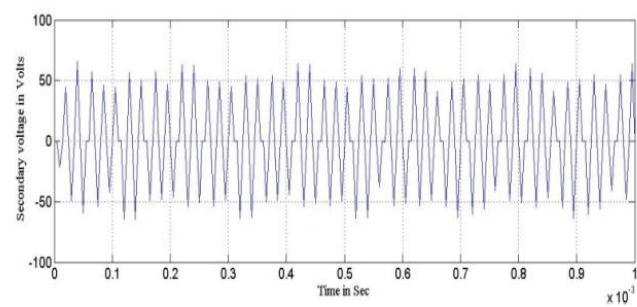


Figure 13: Transformer secondary voltage

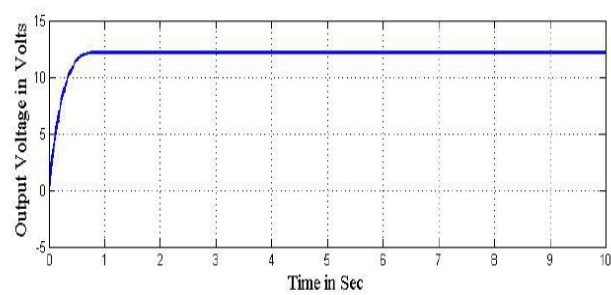


Figure 14: Output Voltage

4.2 Simulation Results Of Comparative Analysis Of PI ,PID and FLC

The closed loop control of Push-Pull DC to DC converter with PI controller, PID controller was done. Here the comparative analysis of time domain specifications in its output voltage waveform is shown in Fig: 15. Also the steady state output voltage waveform is shown in Fig: 16. The analysis shows that the time domain specifications of FLC yields better steady state error. Fig:14 shows that the ripple content is more using PI and PID controller than FLC. Hence FLC proves to have better steady state value than other controllers.

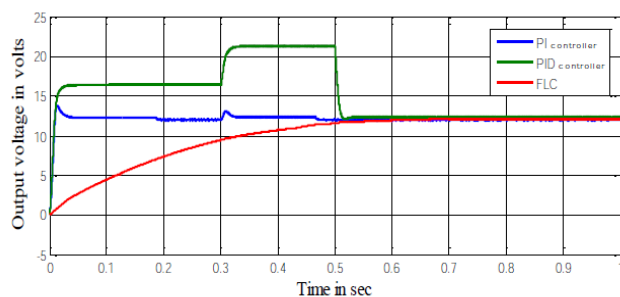


Figure 15: Output voltage of PI, PID and FLC

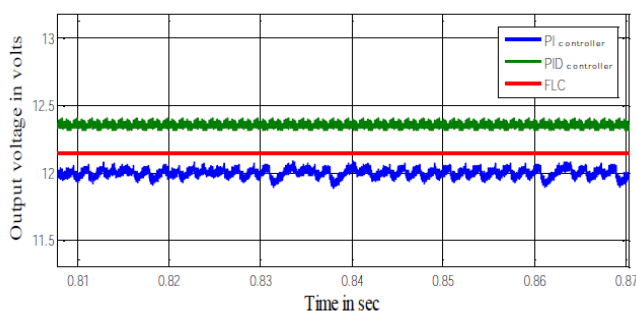


Figure 16: Steady state output voltage of FLC

5 Experimental Results

In order to verify the simulation results, the experimental setup is developed as shown in Fig: 15. The block diagram of the proposed converter system consists of the power supply, user interface, driver circuit, power circuit, switching pattern generation unit, FPGA Controller Section and the output unit. The control signal for switches is generated and controlled by using FPGA, the field programmable Gate Array. The FPGA is configured using a hardware description language (HDL). The elements used are MOSFET IRF840, 8A, DIODE-DYQ48, Inductor 1mH, 2A, Capacitor of 4700 μ F, resistors of 500 Ω , 5W, ADC-DCF8591, 4 Channel, 8bit and snubber capacitor of 1nF, 2KV, 1nF. The experimental results are validated as shown Fig:17. The step change in input voltage is shown in Fig: 18, the switching pulses for S 1 and S 2 with 20m/div, 5V/div are shown in Fig:19, the switching pulses for S 3 and S 4 with 20ms/div, 5V/div is shown in Fig:20, the transformer primary voltage with 50ms/div, 10V/div is shown in Fig:21, the transformer secondary voltage with 100ms/div, 10V/div is shown in Fig:22 and the controlled output voltage transient is shown in Fig: 23.

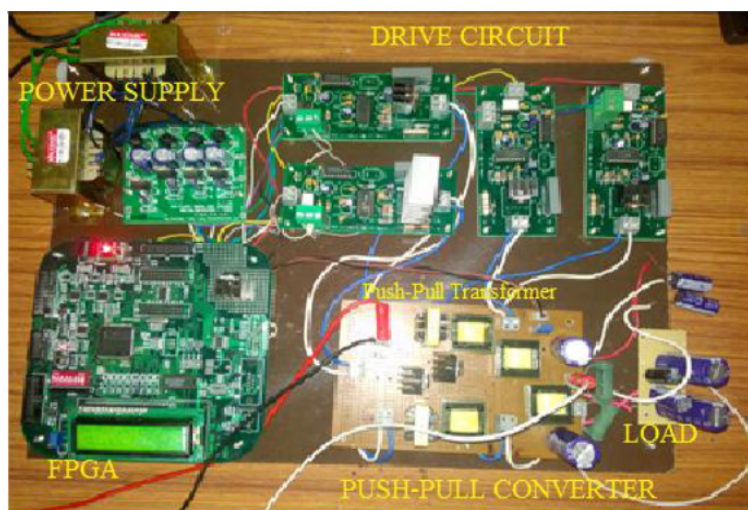


Figure 17: Prototype model of FLC based Push-Pull DC to DC converter

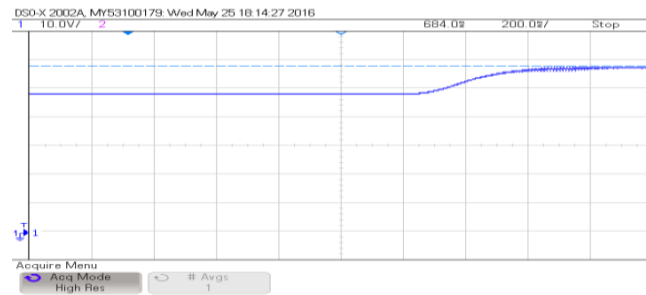


Figure 18: Step change in Input Voltage (200ms/div, 10V/div)

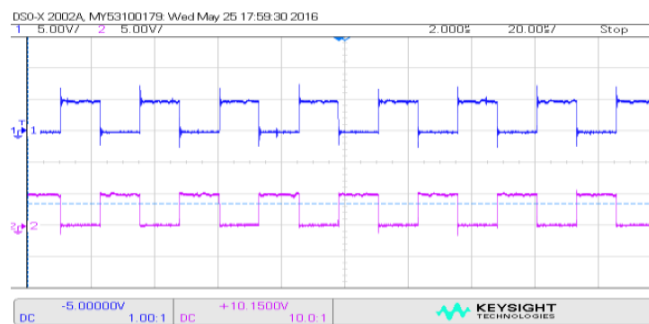


Figure 19: Switching pulses of S_1 and S_2 (20ms/div,5V/div)

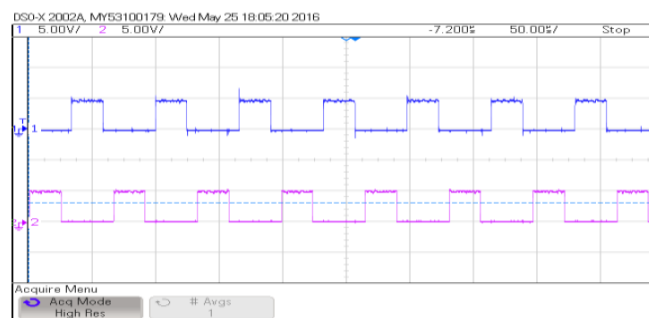


Figure 20: Switching pulses of S_3 and S_4 (50ms/div,5V/div)

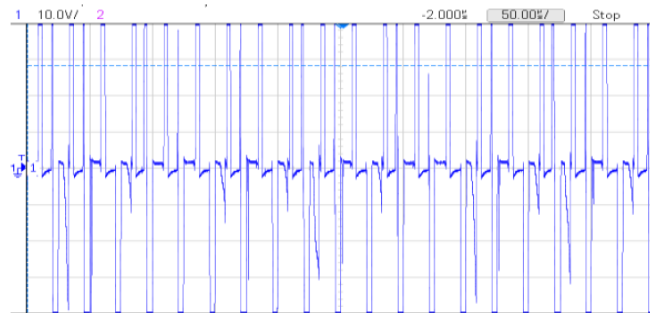


Figure 21: Transformer primary voltage (50ms/div ,10V/div)

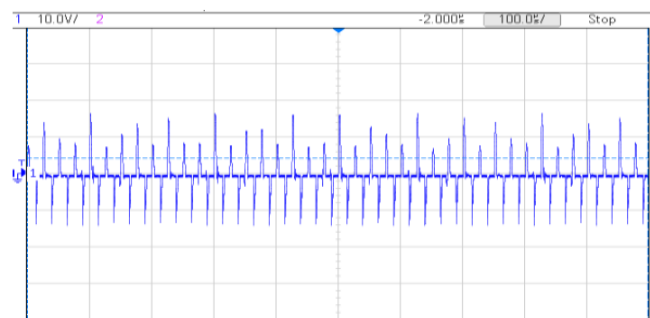


Figure 22: Transformer secondary voltage (100ms/div 10V/div)

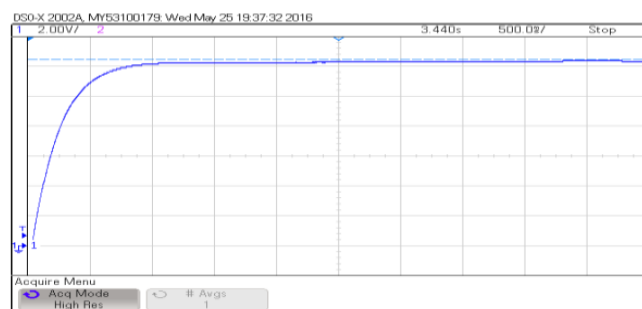


Figure 23: Controlled output DC voltage (500ms/div, 2V/div)

Table 3: Comparison table for PI controller, PID controller and FLC based systems

Controller	Rise time (s)	Peak time (s)	Settling time (s)	Peak Voltage (v)	Steady State error (v)
PI Controller	0.03	0.5	0.54	1.42	0.27
PID Controller	0.015	0.46	0.30	9.41	0.08
FLC	0.02	0.03	0.02	0.01	0.5

The transient specifications of Push-Pull DC to DC converter with PI controller, PID controller and FLC are tabulated in Table: 2. The results validate that the transient response using FLC gives the improved values such as the peak voltage of 0.01V and the steady state error of 0.5 V. The Simulation and experimental results using FLC for Push-Pull DC to DC converter are compared.

6 Conclusion

The paper presents the Soft switching of Push-Pull DC to DC converter using Fuzzy Logic Controller for low voltage applications. The Fuzzy logic controller was designed with less number of membership functions and minimum number of fuzzy sets. The FPGA was used to program and implement the Fuzzy Logic Controller. Also the comparative analysis of time domain specifications shows that the FLC plays the vital role than other conventional controllers. The transient response gives that the settling time is 0.03 and the steady state error is 0.5V. It was noticed that the ripple was minimum in FLC compared to conventional controllers. The results proved that the output voltage is well controlled using FLC. An experimental prototype model designed and implemented and it validates the simulation results.

References

- [1] Abraham Kandel, Gideon Langholz (1994), *Fuzzy Control Systems*, CRC Press.
- [2] Anand1.R, Melba Mary.P (2016), *Improved Dynamic Response of DC to DC Converter Using Hybrid PSO Tuned Fuzzy Sliding Mode Control*. J of Circuits and Systems, 07(6), 946-955. doi:10.4236/cs.2016.76080
- [3] Arun.S, RamaReddy.S (2007), *ZVS LCL Push-Pull DC-DC Converter With Closed Loop Controlled PI Controller*. IET-UK International Conference on Information and Communication Technology in Electrical Sciences vol:1, PP: 175-179. INSPEC Accession Number: 10215104
- [4] Boonyaroonate. I & Mori. S (2002), *A New ZVCS Resonant Push-pull DC/DC Converter Topology*, Applied Power Electronics Conference and Exposition, Seventeenth Annual IEEE, Vol (2):1097-1100. DOI:10.1109/APEC.2002.989380 Datasheet of core from Sections/ProductCatalog/Ferrites
- [5] Deepak Kumar Nayak and S. Rama Reddy (2013), *Comparison of the Synchronous-Rectified PushPull Converter with LLC DC to DC Converter* Arabian Journal for Science and Engineering, 38 (4), pp 913-926. DOI: 10.1007/s13369-012-0365-4
- [6] Devikala .S and Nirmalkumar.P (2012), *Experimental verification of soft switching push-pull DC to DC Converter*, 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), 1 PP: 1-5. doi <http://dx.doi.org/10.1109/PEDES.2012.6484470>
- [7] Drag.C.A, Precup.R.E, Tomescu.M.L, Preitl.S, Petriu.E.M, Rda .M.B (2013), *An Approach to Fuzzy Modeling of Electromagnetic Actuated Clutch Systems*. INT J COMPUT COMMUN, 8(3), PP :395-406.
- [8] Du.Z, Lin.T.C, Balas.V.E (2012), *A New Approach to Nonlinear Tracking Control Based on Fuzzy Approximation*. Int.J. of Computers, Communications & Control, 7(1) :PP: 61-72.

- [9] Erickson.F.W & Maksimovic.D (2001) ,*Fundamentals of power electronics 2 nd edition, USA. Khuwar Academic Publishers* ,PP: 93-94.
- [10] Florin Dragan & Daniel Curiac, Daniel Iercan and Ioan Filip (2007), *Sliding Mode Control for a Buck Converter* , International Conference on Automatic Control, Modeling & Simulation, PP: 162-165.
- [11] Lawler.J.S (2001), *A natural ZVS high-power bi-directional DC-DC converter with minimum number of devices*,Conference on IEEE Industry Applications Conference 36th IAS Annual Meeting Vol:3,1874 - 1881 2001.
DOI:10.1109/IAS.2001.955786
- [12] Liu. K. H., Lee. F. C. F.C. Lee.(2002), *Zero- voltage switching technique in DC/DC converters* , IEEE Trans. Power Electron, 5 (3): 293-304, DOI:10.1109/63.56520
- [13] Li.H and Peng.F.Z (2004), *Modeling of a new ZVS Bi-directional dc/dc converter* , IEEE Trans. Aerosp.Electron.Syst.,40(1):272-283,
DOI:10.1109/TAES.2004.1292159
- [14] Mikkili, Suresh, and Anup Panda.*Performance Analysis of SHAF Control Strategies Using Type 1 FLC with Different Fuzzy MFs*, Power Quality Issues, 2015,CRC Press.Chapter:3,PP:61-98.
- [15] Mousumi Biswal, Sidharth Sabyasachi, *A Study on Recent DC-DC Converters* . International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 ,Vol. 2, Issue 6, November- December 2012, pp.657-663.
- [16] Mud .N.R and As is Sa u (2 6). *Adaptive Control Schemes for DC- DC Buck Converter* , Int.J of Eng.Research and Applications 1:463-467, DOI:10.1.1.416.8704
- [17] Ned Mohan et.al. (1995), *Power electronic converters, Application and Design* , John Wiley and Sons
- [18] Pedrycz.W, *Fuzzy Control and Fuzzy Systems* second ed.,Wiley, New York, NY, 1993

- [19] Qiang He , Yixin Zhao (2010), *The Design of Controller of Converter*, Int. Conference on Computer Application and System Modeling (ICCA SM), 15 : 251-255, DOI:10.1109/ICCA SM.2010.5622609
- [20] Rama Reddy et al, *A step down frequency modulated Zero current switching QRC fed DC drive* , ETEP Journal, Ref.No.ET1088, 1995
- [21] Ranjani.M, Murugesan.P (2014), *Modeling and Simulation of Genetic Fuzzy Controller for L-type ZCS Quasi-Resonant Converter*. INT J COMPUT COMMUN, 9(1):48-55, <http://dx.doi.org/10.15837/ijccc.2014.1.59>
- [22] Reznik. L, *Evolution of Fuzzy Controller Design* , IEEE Transactions on Fuzzy Systems, 503-508, 1997
- [23] Sooraksa.P, Chen.G (99), *Mathematical modeling and fuzzy control for flexible link robots* ,J of Mathematical and Computer Modeling, 27 (6): 73-93, doi:10.1016/S0895-7177(98)00030-2
- [24] Stefanos Theodoropoulos, Dionisis Kandris, Maria Samarakou, and Grigorios Koulouras (2014), *Fuzzy Regulator Design for Wind Turbine Yaw Control* . Hindawi Publishing Corporation, Scientific World Journal, Volume 2014, 9 pages, <http://dx.doi.org/10.1155/2014/516394>
- [25] Subrahmanya Kumar Bhajana.V.V. *ZVS/ZCS bidirectional DC-DC Converter for DC Uninterruptable Power Suppl* . International Journal of Computer Applications (0975 8887) International Conference on Communication, Circuits and Systems iC3S-2012, pp: 29-32
- [26] Veeresh H , Dr. Ashok Kusagur, *Design and Development of Push Pull DC-DC Converter by ZCS/ZVS to Electrical Vehicle (EVs) Applications* , International Journal of Modern Trends in Engineering and Research, 2-4 July, 2015
- [27] Zhigan Wu. *A Zero-Voltage-Switching (ZVS) push-pull DC/DC converter for UPS* , The Fifth International Conference on Power Electronics and Drive Systems 2003 PEDS 2003 PEDS-03, 2003, DOI:10.1109/PEDS.2003.1283206

- [28] Zhu.Z.Q and Jiabing Hu (2013), *Electrical machines and power-electronic systems for high-power wind energy generation applications*, The Inte. J for Computation and Mathematics in Electrical and Electronic Engineering,32(1):34-71, DOI <http://dx.doi.org/10.1108/03321641311293740>

