ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

A Transformerless Multiinput Multioutput DC–DC Boost Converter Using Fuzzy Logic Controller for Electric Vehicle Applications

Jayashankar V V[1], Uma R[2]

PG Student [PE], Dept. of EEE, Sree Narayana Gurukulam College of Engineering, Kadayiruppu, Kerala, India[1]

Assistant Professor, Dept. of EEE, Sree Narayana Gurukulam College of Engineering, Kadayiruppu, Kerala, India[2]

ABSTRACT: A new fuzzy controlled transformerless multiinput multioutput dc–dc boost converter is proposed in this paper. This converter is applicable in hybridizing alternative energy sources in electric vehicles.In fact, by hybridization of energy sources, advantages of different sources are achievable. In this converter, the loads power can be flexibly distributed between input sources. The proposed converter has two outputs with different voltage levels which makes it suitable for interfacing to multilevel inverters and also for electric vehicles. The proposed converter has just one inductor.Depending on charging and discharging states of the energy storage system (ESS), two different power operation modes are defined for the converter.In this paper battery discharging mode is evaluated by using fuzzy logic control which is more efficient than conventional controllers.

KEYWORDS: DC–DC converters, electric vehicle, hybrid power system, multiple-input–multiple-output(MIMO).

I.INTRODUCTION

It has been well recognized that hybrid electric vehicles (HEVs) are much more efficient and cleaner than the vehicles powered by gasoline and diesel engine alone.The EVs can be used for environmentally friendly transportation application with the usage of clean and renewable energy sources such as fuel cell etc.Due to the slow power transfer rate and increased cost of fuel cell,they are used along with batteries and supercapacitors.To provide a specific voltage level for load and to control power flow between input sources,dc-dc converter is needed.In hybrid power systems ,multiinput dc-dc converters have been used.

In this paper, a new multiinput multioutput nonisolated converter based on combination of a multiinput and a multioutput converter using fuzzy logic control is proposed. The proposed converter compared to similar cases has less number of elements. This converter can control power flow between sources with each other and load. Also, proposed converter has several outputs that each one can have different voltage level.The terminal output voltage is controlled by using fuzzy logic controller which performs better than conventional controllers.

II.LITERATURE SURVEY

To address the issues of depletion of fossil fuels, rising gasoline prices, over-dependence on foreign energy, and growing greenhouse gas emissions, vehicle manufacturers have increasingly found electric vehicles as a solution. All-electric vehicles (EVs) run on electricity only. Electricity can be produced from renewable energy sources like fuel cell,etc[1].As the usage of fuel cell alone have certain disadvantages, it is used along with energy storage systems such as batteries or super capacitors.

FC and ESSs such as battery and SC used in converter topologies have different voltage levels[2]. So, to provide a specific voltage level for load and to control power flow between input sources, using of a dc–dc converter for each of the input sources is need. Usage of a dc–dc converter for each of the input sources leads to increase of price, mass, and losses. Consequently, in hybrid power systems, multiinput dc–dc converters have been used. Multiinput converters are of two main types, isolated and nonisolated.

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

In isolated multiinput converters high frequency transformer is used for isolation and impedance matching between two sides of the converter[3].These converters need inverters in the input sides and rectifier in the output side.So several switches are applied which increases the cost and losses[4].Hence non isolated multiinput dc-dc converters are widely used.Several nonisolated multiinput converter topologies were introduced[5].Most of these converters are having single output.In applications such as electric vehicles that several input energy sources like fuel cell and battery are employed, using of multiinput multioutput converters is favourable.Then several multioutput topologies which has just one inductor were proposed. Using of large number of switches is drawback of these converters which caused low efficiency[6]. Impossibility of energy transferring between input sources is another disadvantage of these converters.

In this paper, a new fuzzy controlled multiinput multioutput nonisolated converter based on combination of a multiinput and a multioutput converter is proposed. The proposed converter compared to similar cases has less number of elements. This converter can control power flow between sources with each other and load.Also, proposed converter has two outputs that each one can have different voltage level.The converter control is done by using fuzzy logic which is having better performance characteristics than conventional controllers.

III.CONVERTER STRUCTURE AND OPERATION MODES

In Fig. 1, the proposed converter with two-input two-output is shown. Four power switches Q_1 , Q_2 , Q_3 , and Q_4 in the converter structure are the main controllable elements that control the power flow and output voltages of the converter. In the proposed converter, source V_1 (fuel cell) can deliver power to source V_2 (battery) but not vice versa. Depending on the utilization state of the battery, two power operation modes are defined for proposed converter,charging mode and discharging mode. In each mode, just three of the four switches are active, while one switch is inactive. In this paper,battery discharging mode is evaluated using fuzzy logic control.

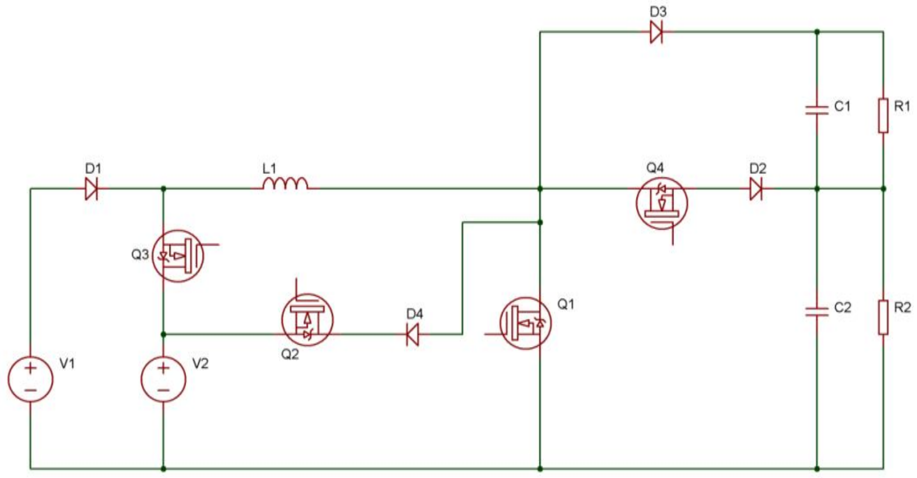

Fig. 1 Proposed converter

3.1 Battery Discharging Mode.

Here, two input power sources V_1 and V_2 are responsible for supplying the loads. In this mode, Q_2 is OFF entirely and Q_1, Q_3 , and Q_4 are active. Q_1 is active to regulate battery current by controlling inductor current and Q_3 regulates total output voltage.Switching signals of switches and also voltage and current waveforms of inductor are shown in Fig. 2.

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

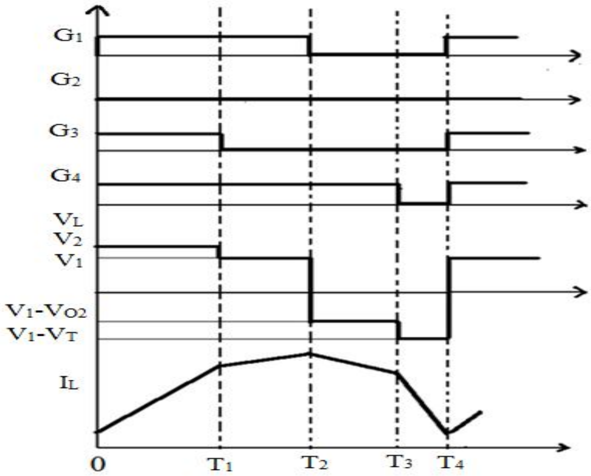

Fig. 2 Switching Waveforms

According to switches states, there are four different operation modes in one switching period as follows:

1) Mode 1 (0 < t < T1):

In this state, switches Q_1 and Q_3 are turned ON. Diodes D_2 ,D_3 and D_1 are reversely biased.Switch Q_4 is turned OFF.In this state, V_2 charges inductor L_1, so inductor current increases. Also, in this mode, capacitors C_1 and C_2 are discharged and deliver their stored energy to load resistances R_1 and R_2 ,respectively.

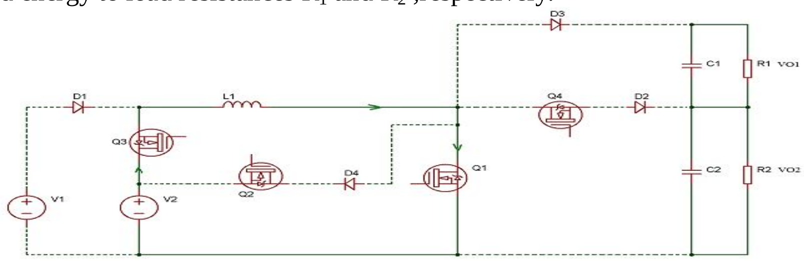

Fig. 3 Mode1 Operation

2) Mode 2 (T1 < t < T2):

Here, switch Q_1 is still ON and Q_3 is turned OFF. Because Q_1 is ON, diodes D_2 and D_3 is reversely biased, so switch Q_4 is still OFF. In this state, V_1 charges inductor L_1, so inductor current increases. In addition, capacitors C_1 and C_2 are discharged and deliver their stored energy to load resistances R_1 and R_2 , respectively.

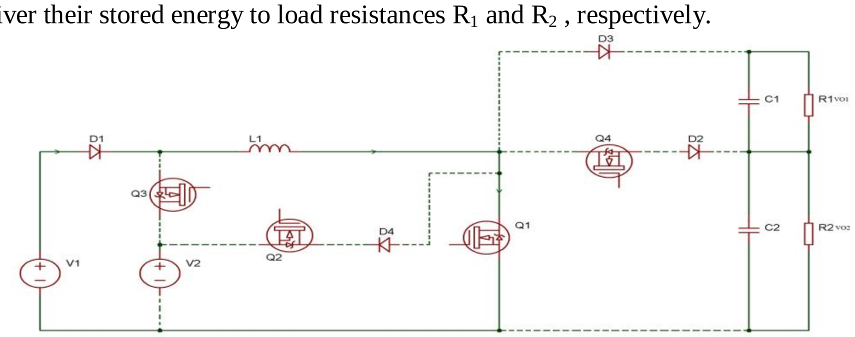

Fig. 4 Mode 2 Operation

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

3) Mode 3 (T2< t<T3):

Here, switch Q_1 is turned OFF and switch Q_3 is still OFF. Also, switch Q_4 is turned ON. Diode D_3 is reversely biased. In this state, inductor L_1 is discharged and delivers its stored energy to C_2 and R_2 , so inductor current is decreased. In this state, C_2 is charged and C_1 is discharged and delivers its stored energy to load resistance R_1.

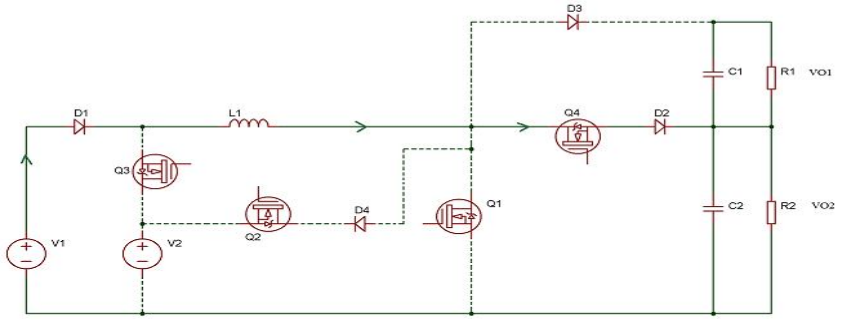

Fig. 5 Mode 3 Operation

4) Mode 4 (T3 < t<T4):

In this mode, all of three switches are OFF. So, diode D_3 is forward biased. Inductor L_1 is discharged and delivers its stored energy to capacitors C_1 , C_2 , and load resistances R_1 and R_2. Also, in this mode, capacitors C_1 and C_2 are charged.

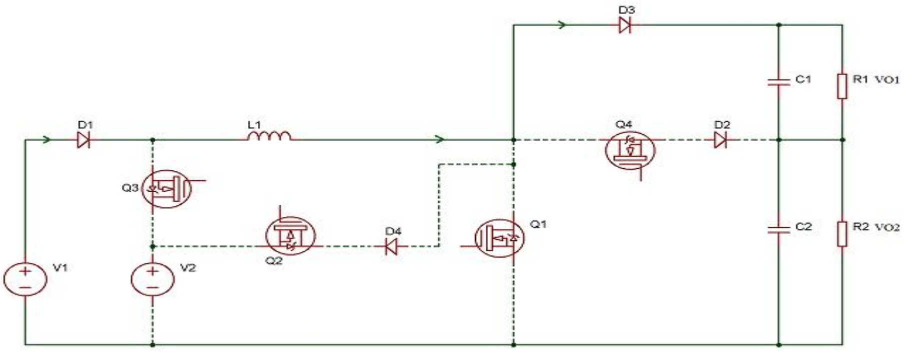

Fig. 6 Mode 4 Operation

IV.FUZZY LOGIC CONTROL

Fuzzy Logic (FL) is a multivalued logic, that allows intermediate values to be defined between conventional evaluations like true/false,yes/no, high/low, etc. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic.Here,Mamdani type Fuzzy Interface System(FIS) is used.

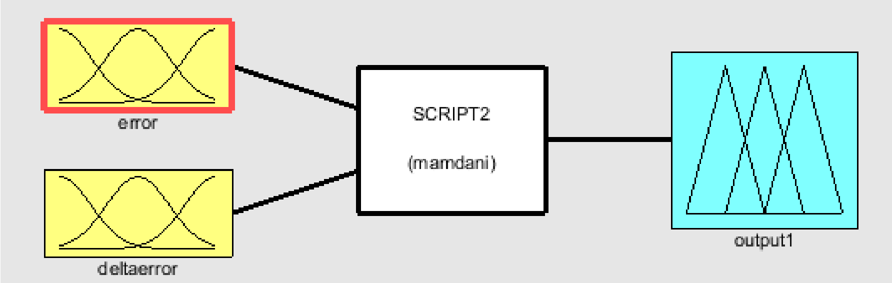

Fig. 7 Fuzzy Interface System

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

The two inputs error and deltaerror are fed to the FIS. Fuzzification, Application of rules, Implication ,Aggregation and Defuzzification are the major process taking place in the fuzzy interface system. After these process a crisp output is obtained.The membership functions used here are negative big (NB), negative medium (NM), negative small (NS), zero (Z), medium (M) ,positive small (PS),positive medium (PM) and positive big (PB).

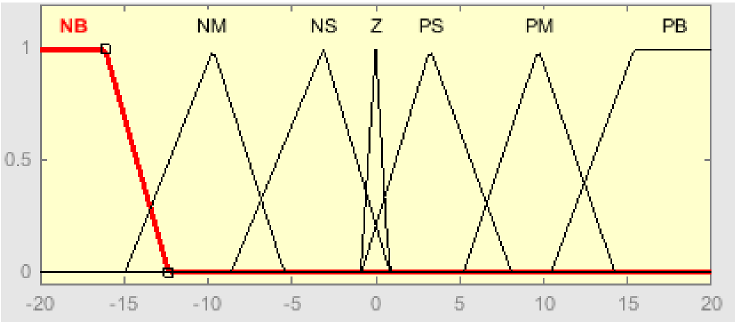

Fig.8 Membership functions of the variable error

Fig. 8 shows the membership functions of input variable error.Here,seven membership functions are used.They are NB,NM,NS,Z,PS,PM and PB.

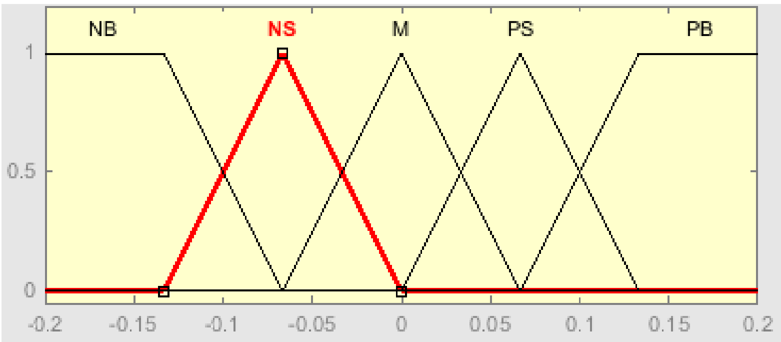

Fig.9 Membership functions of the variable deltaerror

The five membership functions used for the input variable deltaerror are shown in the fig. 9.They are NB,NS,M,PS and PB.

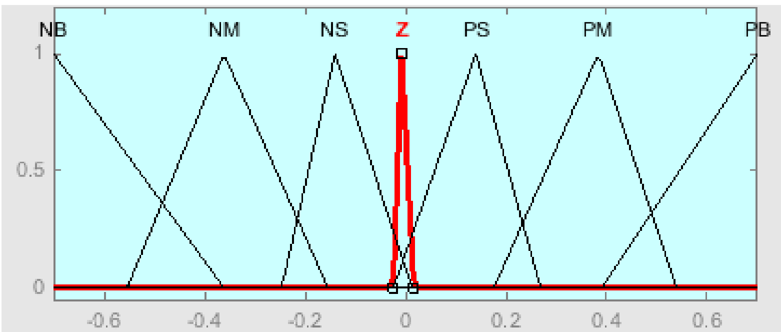

Fig.10 Membership functions of the output variable

For the output variable seven membership functions,NB,NM,NS,Z,PS,PM,PB, are used.They are shown in the fig 10.In this paper, eleven rules are used to control the output variable. The weightage for all the rules are set to one.

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

Rule 1: If error is (Z) then output1 is (Z).
Rule 2: If error is (PB) then output1 is (PB).
Rule 3: If error is (NB) then output1 is (NB).
Rule 4: If error is (NS) then output1 is (NS).
Rule 5: If error is (PS) then output1 is (PS).
Rule 6: If error is (NM) then output1 is (NM).
Rule 7: If error is (PM) then output1 is (PM).
Rule 8: If error is (PS) and deltaerror is (PS) then output1 is (PS).
Rule 9: If error is (PS) and deltaerror is (PB) then output1 is (PM).
Rule 10: If error is (NS) and deltaerror is (NS) then output1 is (NS).
Rule 11: If error is (NS) and deltaerror is (NB) then output1 is (NM).

V.SIMULINK MODEL

In order to verify the performance of the multi input multi output dc-dc boost converter, simulations have been done using Matlab/Simulink software in battery discharging mode. There are two input sources and three outputs,voltage across the resistors R_1 and R_2 and the sum of the voltages across R_1 and R_2.In simulations,battery mode is used as input source 2.As mentioned in previous sections, in this mode switches Q_1 , Q_3 , and Q_4 are active.The simulation parameters used are V_1=35V,V_2=48V,L_1=2.5mH,T=100µs,C_1=C_2=1000µF ,R_1=35 Ω and R_2=45 Ω.

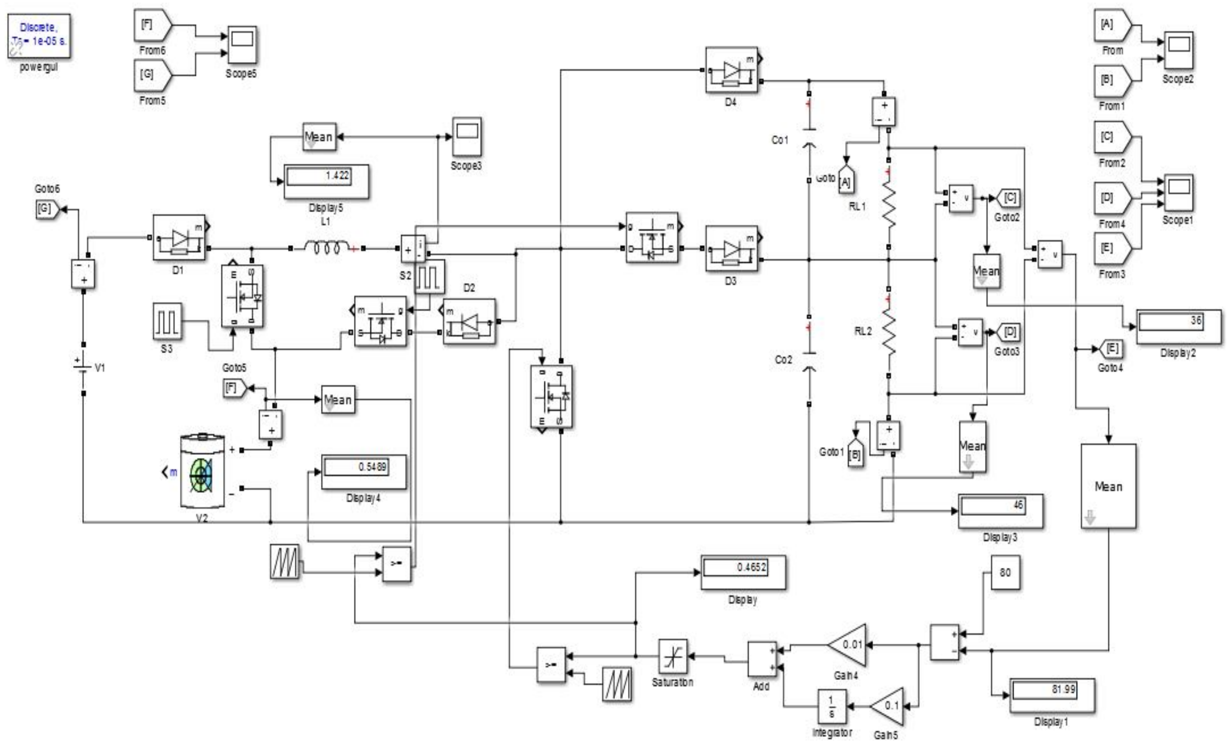

Fig.11 Simulink Model Of Converter Using PI Controller

The simulink block diagram of the converter in closed loop is shown in fig. 11.Here,proportional-integral (PI) control is used.

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

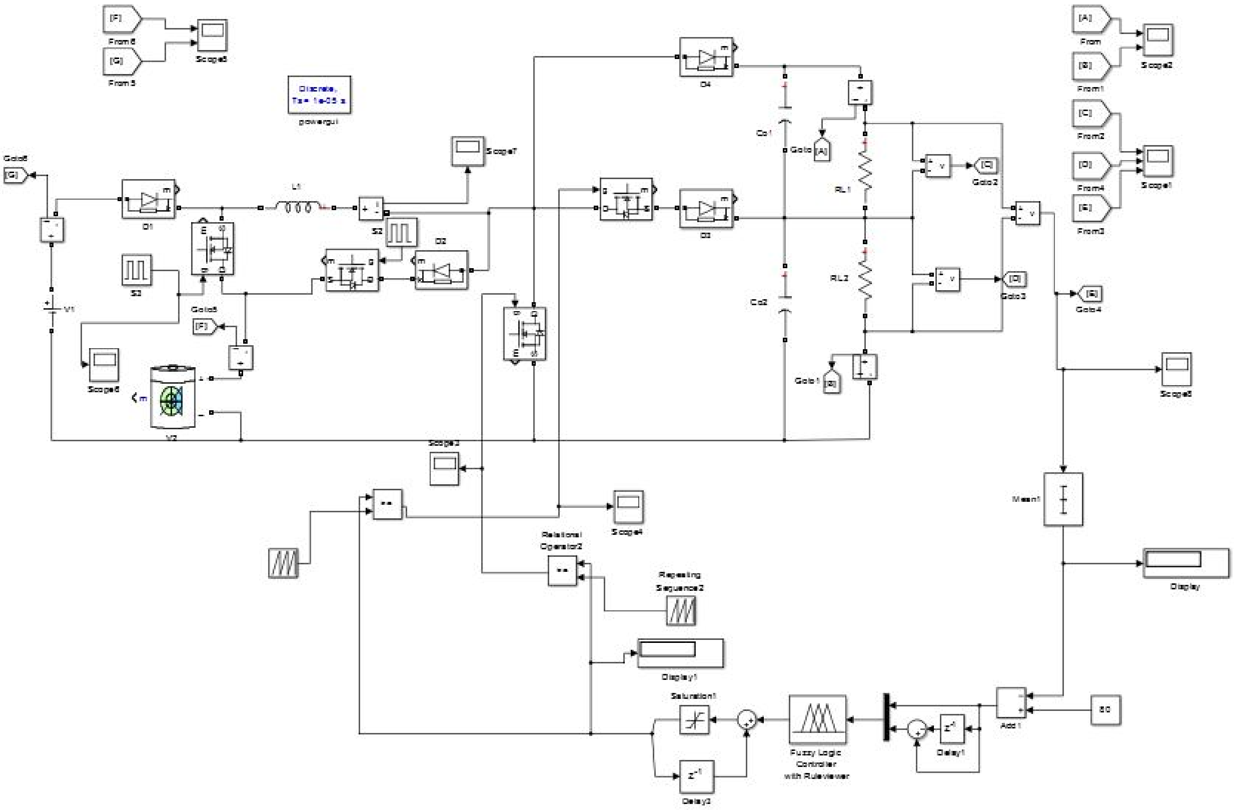

Fig.12 Simulink Model Of Converter Using Fuzzy Logic Controller

The simulink block diagram of the converter in closed loop is shown above.Here,fuzzy logic control is used. The terminal voltage of the converter is compared with the reference voltage ,here,80V.This error voltage along with the change in error serves as the two inputs of the fuzzy logic controller.The output of the fuzzy logic controller is compared with a repeating sequence having frequency 10 kHz to obtain the pulses. These pulses switch the multiinput multioutput dc-dc boost converter.So the converter switching frequency is 10 kHz.

VI.RESULT AND DISCUSSION

The simulation results of the proposed fuzzy controlled multiinput multioutput dc-dc boost converter are discussed in this section.

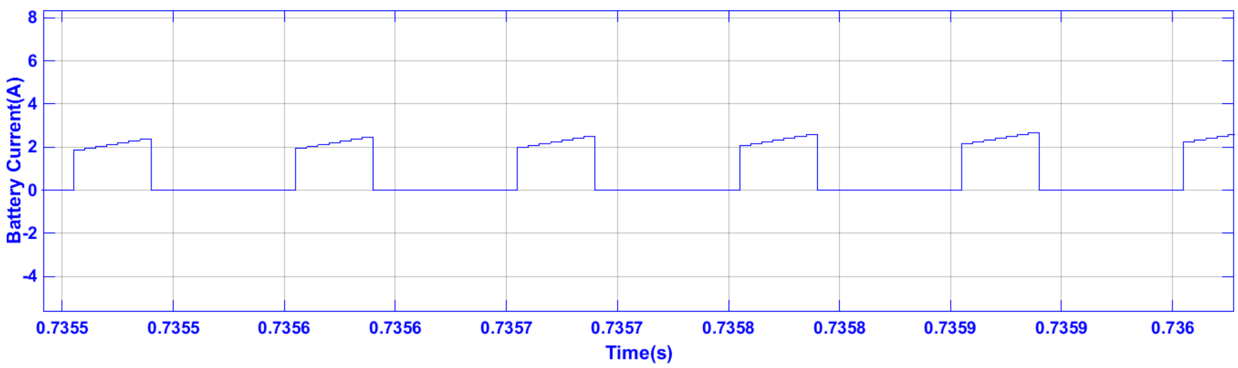

Fig.13 Battery Current Waveform

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

The waveform of the battery current of the proposed converter in closed loop with fuzzy logic control is shown above. It is notable that the battery current in this mode has positive value which means the battery has been discharged.

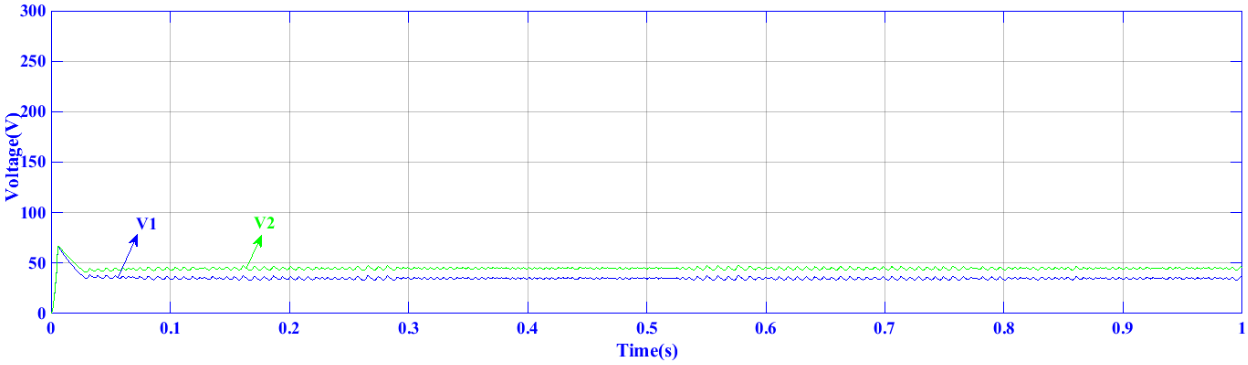

Fig.14 Output Voltages V_1 and V_2

The waveforms of the voltage across the resistors R_1 and R_2 ,ie, V_1 and V_2 respectively is shown in fig 14.The voltage across R_1 is obtained as 34.74V and that across R_2 is obtained as 44.67V.The sum of the voltages across R_1 and R_2 ,ie the terminal voltage is 79.41 V. It is clear that the terminal voltage tracked the reference value well.

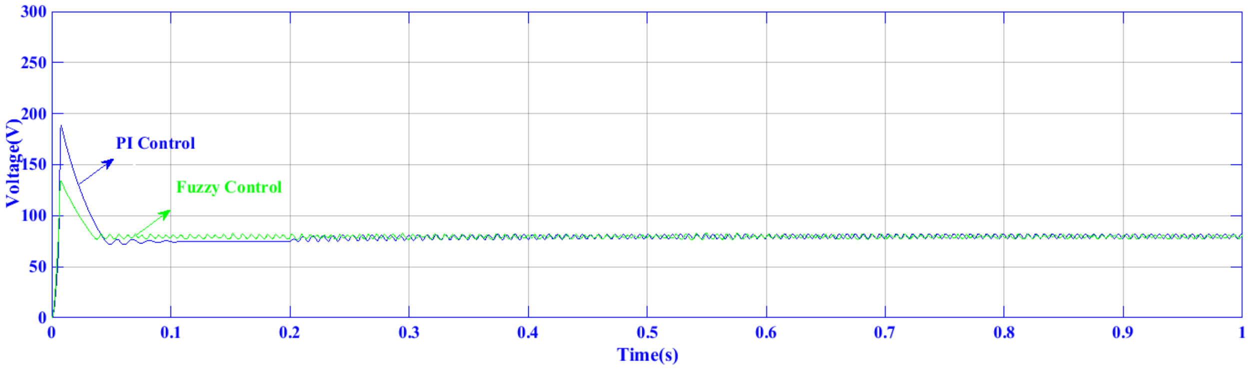

Fig.15 Terminal Voltage Waveform Using PI and Fuzzy Logic Controller

Fig 15 shows the waveform of the terminal voltage using PI and FLC.The waveform with FLC have lesser oscillations. The peak overshoot and the settling time of the converter is much reduced when closed loop control is done using fuzzy logic controller than PI controller. Also the response time is much better when FLC is used.

VII.CONCLUSION

A fuzzy controlled transformerless multiinput multioutput dc-dc converter in battery discharging mode is implemented in this paper.The converter has two inputs and two outputs .The different dc voltage levels at the output can be fed to the input of a multilevel inverter and can also be used for electric vehicle applications.The fuzzy logic controller provides fast response , better settling time and reduced overshoot than conventional controllers.

REFERENCES

1. Majid Zandi, Alireza Payman, Jean-Philippe Martin, Serge Pierfederici,Bernard Davat, and Farid Meibody-Tabar," Energy Management of a Fuel cell/Supercapacitor/Battery Power Source for Electric Vehicular Applications", IEEE Transactions On Vehicular Technology, Vol. 60, No. 2, February 2011.
2. Alireza Payman, Serge Pierfederici, Farid Meibody-Tabar, and Bernard Davat," An Adapted Control Strategy to Minimize DC-Bus Capacitors of a Parallel Fuel Cell/Ultracapacitor Hybrid System", IEEE Transactions On Power Electronics, Vol. 26, No. 12, December 2011.

ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

3. Jorge L. Duarte, Marcel Hendrix, and Marcelo Godoy Simões," Three-Port Bidirectional Converter for Hybrid Fuel Cell Systems", IEEE Transactions On Power Electronics, Vol. 22, No. 2, March 2007.
4. Haimin Tao, Andrew Kotsopoulos, Jorge L. Duarte, and Marcel A. M. Hendrix," Transformer-Coupled Multiport ZVS Bidirectional DC–DC Converter With Wide Input Range", IEEE Transactions On Power Electronics, Vol. 23, No. 2, March 2008.
5. O. C. Onar, Member, IEEE, and A. Khaligh," A Novel Integrated Magnetic Structure Based DC/DC Converter for Hybrid Battery/Ultracapacitor Energy Storage Systems", IEEE Transactions On Smart Grid, Vol. 3, No. 1, March 2012.
6. Hamid Behjati and Ali Davoudi," A MIMO Topology with Series Outputs:An Interface between Diversified Energy Sources and Diode-Clamped Multilevel Inverter", ©2012 IEEE.
7. Ali Nahavandi, Mehrdad Tarafdar Hagh, Mohammad Bagher Bannae Sharifian, and Saeed Danyali," A Nonisolated Multiinput Multioutput DC–DC Boost Converter for Electric Vehicle Applications", IEEE Transactions On Power Electronics, Vol. 30, No. 4, April 2015