# Energy Management System for Hybrid Electrical Vehicle Using Fuzzy Logic Control Based Bidirectional DC/DC Converter

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***ABSTRACT***
This work discuss an application of hybrid electric vehicle frameworks worked with novel planned bidirectional dc-dc converter which interfaces a fundamental energy stockpiling (ES1),an helper energy stockpiling (ES2) and dc transport of various voltage levels. Proposed BDC converter can work both advance up and venture down mode. In which venture up mode addresses low voltage double source - controlling mode and step down mode addresses high voltage dc interface energy – recovering mode, both the modes are worked heavily influenced by bidirectional force stream. This model can autonomously control power stream between low voltage double source buck/support modes. Here in, the circuit arrangement, activity, consistent state examination, and shut circle control of the proposed BDC are talked about as per its three methods of force move. In this task fluffy rationale regulator is utilized and furthermore framework results are approves through MATLAB/SIMULINK programming.

Kew words —Bidirectional dc/dc converter (BDC), double battery stockpiling, half and half electric vehicle, Fuzzy rationale regulator.

## I. Introduction

The adjustment in climate and energy supply is diminishing have invigorating changes in vehicular advancement. For the applications in future vehicles the cutting edge innovations are at present being working. Among such applications, energy component mixture electric vehicles (FCV/HEV) are effective. Previously, Ehsani et al. contemplated the vehicles elements to search for an ideal force speed profile of the electric drive framework and

discussed different vehicles alongside HEV, FCV. To fulfill immense vehicular burden, for cutting edge vehicular force framework Emadi et al. learned about coordinated force hardware. Schaltz et al. partition the heap power among the energy component stack, the battery, and the ultra capacitors as per two proposed energy-the executives methodologies. Thounthong et al. considered the effect of energy unit execution and the advantages of hybridization for control frameworks. Chan et al. explored about electric, half and half, and power device vehicles on designs and demonstrating for energy the executives. Rajashekara examined on stream status and fundamental parts like battery, electric engine and gadgets framework. Lai et al. executed a bidirectional dc/dc converter geography with two-stage and interleaved characteristics.

The Voltage Transformation proportion of the converter has improved in the EV and DC miniature lattice frameworks. Moreover, Lai additionally inspected a bidirectional dc to dc converter (BDC) geography has a high voltage change proportion for EV batteries related a dc-miniature matrix framework. In FCV frameworks, the essential battery stockpiling gadget is ordinarily used to start the FC and to supply to the impetus engine.

The battery stockpiling gadgets improve reaction time for the FC stack through providing top force during quickening the vehicle .Besides, it contains a powerful thickness part for instance, super capacitors (SCs) dispose of pinnacle power drifters during quickening and regenerative slowing down. By and large, SCs can store regenerative energy during deceleration and delivery it during quickening, accordingly providing extra force. The powerful thickness of SCs delays the life expectancy of both FC stack and battery stockpiling gadgets and improves the general productivity of FCV frameworks.

A utilitarian chart for a regular (FCV/HEV) power framework is shown in Fig. 1 [4, 13]. The low-voltage FC stack is utilized as the fundamental force source, and

SCs straightforwardly associated in corresponding with FCs. The dc/dc power converter is utilized to change over the FC stack voltage into an adequate dc-transport voltage in the driving inverter for providing capacity to the impetus engine. Moreover, ES1 with rather higher voltage is utilized as the principle battery stockpiling gadget for providing top force, and ES2 with rather lower voltage could be an assistant battery stockpiling gadget to accomplish the vehicle range extender idea [13]. The capacity of the bidirectional dc/dc converter (BDC) is to interface double battery energy stockpiling with the dc-transport of the driving inverter. By and large, the FC stack and battery stockpiling gadgets have distinctive voltage levels.

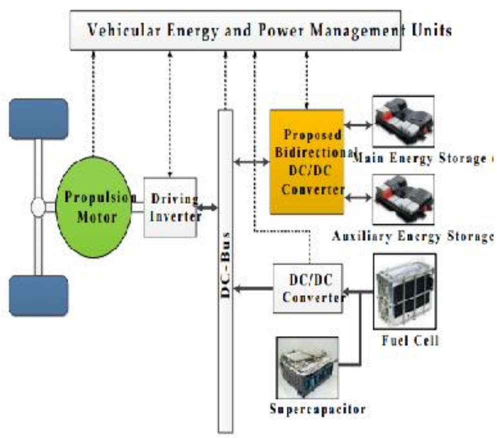



Fig.1.Typical functional diagram for a FCV/HEV power system.

## II. PROPOSED TOPOLOGY

The proposed BDC geography with double battery energy stockpiling is shown in Fig.1, where VH, VES1, and VES2 address the high-voltage dc-transport voltage, the primary energy stockpiling (ES1), and the assistant energy stockpiling (ES2) of the framework, separately. Two bidirectional force switches (SES1 and SES2) in the converter structure, are utilized to turn on or switch off the current circles of ES1 and ES2, individually. A charge-siphon capacitor (CB) is incorporated as a voltage divider with four dynamic switches (Q1, Q2, Q3, Q4) and two stage inductors (L1, L2) to improve the static voltage acquire between the two low-voltage double sources (VES1, VES2) and the high-voltage dc transport (VH) in the proposed converter. Besides, the extra CB lessens the switch voltage stress of dynamic switches and takes out the need to work at an outrageous obligation proportion. Moreover, the three bidirectional force switches (S, SES1, SES2) showed in Fig. 2 show four-quadrant activity and are embraced to control the force stream between two low-voltage double sources (VES1, VES2) and to hinder either certain or negative voltage.

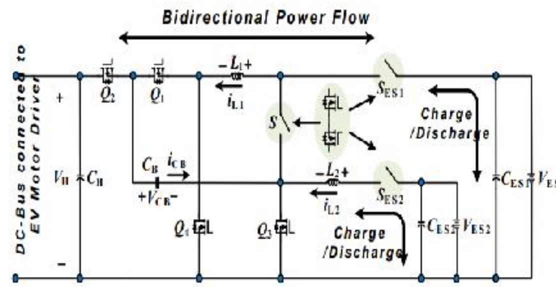



Fig.2.1. Proposed BDC topology with dual-battery energy storage.

This bidirectional force switch is executed through two metal-oxide-semiconductor field-impact semiconductors (MOSFETs), pointing in inverse bearings, in arrangement association. To clarify the idea for the proposed converter, all the conduction situations with the force gadgets engaged with every activity mode are shown in Table 2.1. Likewise, the four working modes are represented as follows to improve understanding.

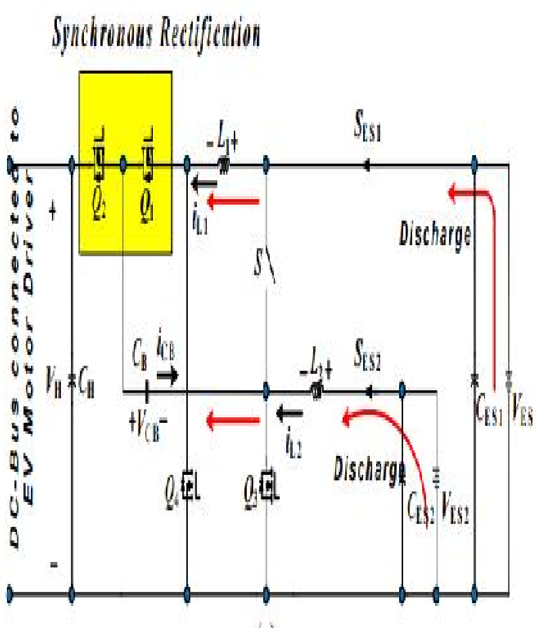
**TABLE 2.1.**
**CONDUCTION STATUS OF DEVICES FOR DIFFERENT OPERATING MODES**

| Operating Modes | ON | OFF | Control Switch | Synchronous Rectifier (SR) |
|---|---|---|---|---|
| Low-voltage dual-source-powering mode (Accelerating, $x_1$=1, $x_2$=1) | $S_{ES1}, S_{ES2}$ | $S$ | $Q_3, Q_4$ | $Q_1, Q_2$ |
| High-voltage dc-bus energy-regenerating mode (Braking, $x_1$=1, $x_2$=1) | $S_{ES1}, S_{ES2}$ | $S$ | $Q_1, Q_2$ | $Q_3, Q_4$ |
| Low-voltage dual-source buck mode (ES1 to ES2, $x_1$=0, $x_2$=0) | $S_{ES1}, S_{ES2}$ | $Q_1, Q_2, Q_4$ | $S$ | $Q_3$ |
| Low-voltage dual-source boost mode (ES2 to ES1, $x_1$=0, $x_2$=0) | $S_{ES1}, S_{ES2}$ | $Q_1, Q_2, Q_4$ | $Q_3$ | $S$ |
| System shutdown | – | $S_{ES1}, S_{ES2}$ $Q_1, Q_2, Q_3, Q_4$ | – | – |

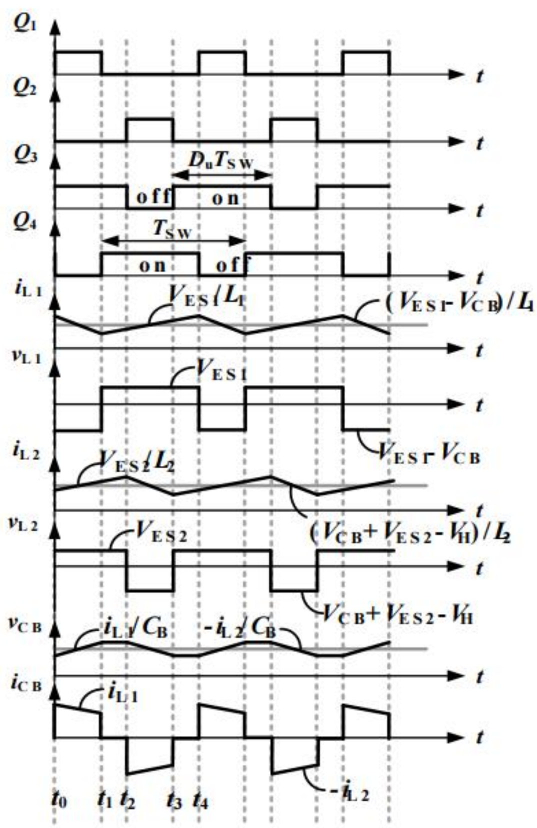
### 2.1. Low-Voltage Dual-Source-Powering Mode

Fig. 2.2(a) portrays the circuit schematic and consistent state wave structures for the converter under the low-voltage double source-driving mode. In that, the switch S is killed, and the switches (SES1, SES2) are turned on, and the two low-voltage double sources (VES1, VES2) are providing the energy to the dc-transport and loads. In this mode, the low-side switches Q3 andQ4 are effectively exchanging at a stage move point of 180°, and the high-side switches Q1 and Q2 work as the simultaneous rectifier (SR). In light of the run of the mill waveforms appeared in Fig. 2.2(b), when the obligation proportion is bigger than half, four circuit states are conceivable (Fig. 2.2). In the light of the on/off status of the dynamic switches and the working guideline of the BDC in low-voltage double source-driving mode, the activity can be clarified momentarily as follows.

State 1 [t0 < t < t1]: During this express, the time period (1-Du)Tsw, switches Q1, Q3 are turned on, and switches Q2, Q4 are killed. The voltage across L1 is the distinction between the low-side voltage VES1 and the charge-siphon voltage (VCB), and henceforth iL1 diminishes straightly from the underlying worth. Furthermore, inductor L2 is charged by the fuel source VES2,




(a)



(b)

Fig. 2.2. Low-voltage dual-source-powering mode of the proposed BDC: (a)
circuit schematic and (b) steady-state waveforms.
thereby generating a linear increase in the inductor current. The voltages across inductors L1 and L2 can be denoted as

$$L_1 \frac{di_{L1}}{dt} = V_{ES2} - V_{CB} \quad (1)$$

$$L_2 \frac{di_{L2}}{dt} = V_{ES2} \quad (2)$$

State 2 [t1 < t < t2]: During this state, the interval time is (Du-0.5)Tsw; switches Q3 and Q4 are turned on; and switches Q1 and Q2 are turned

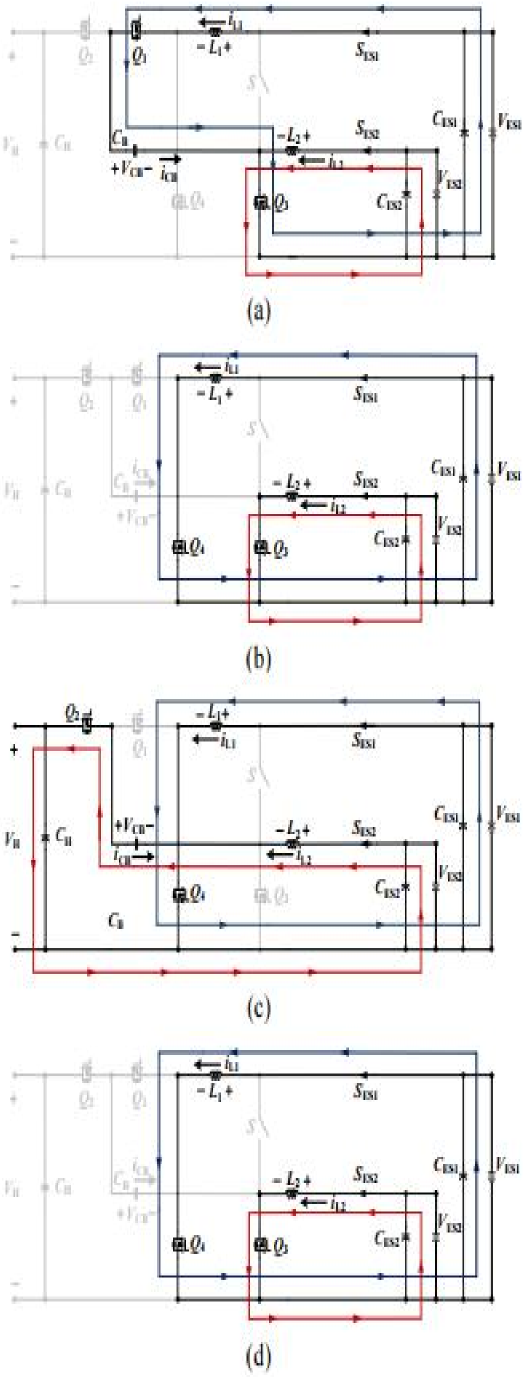


Fig. 2.3 Circuit states of the proposed BDC for the low-voltage dual-source-powering mode. (a) State 1. (b) State 2. (c) State 3. (d) State 4.

a) off. The low-side voltages VES1 and VES2 are located between inductbors L1 and L2, respectively, thereby linearly increasing the inductor currents, and initiating energy to storage. The voltages across inductors L1 and L2 under state 2 can be denoted as

$$L_1 \frac{di_{L1}}{dt} = V_{ES1} \quad (3)$$

$$L_2 \frac{di_{L2}}{dt} = V_{ES2} \quad (4)$$

b) State 3 [t2 < t < t3]: During this state, the interval time is (1-Du)Tsw; switches Q1 and Q3 are turned on, whereas switches Q2 and Q4 are turned off. The voltages across inductors L1 and L2 can be denoted as

**2.2. High-Voltage DC-Bus Energy-Regenerating Mode :**

In this mode, the kinetic energy stored in the motor drive is fed back to the source during regenerative braking operation. The regenerative power can be much higher than what the battery can absorb. Consequently, the excess energy is used to charge the energy storage device. The circuit schematic and the steady-state waveforms of the BDC under the high-voltage dc bus energy-regenerating mode are illustrated in Fig.2.4.

Therein, the current in the inductors is controlled by the active switches Q1 and Q2, which have a phase-shift angle of 180° and thereby direct the flow away from the dc-bus and toward the dual energy storage devices; the switches Q3 and Q4 function as the SR to improve the conversion efficiency.

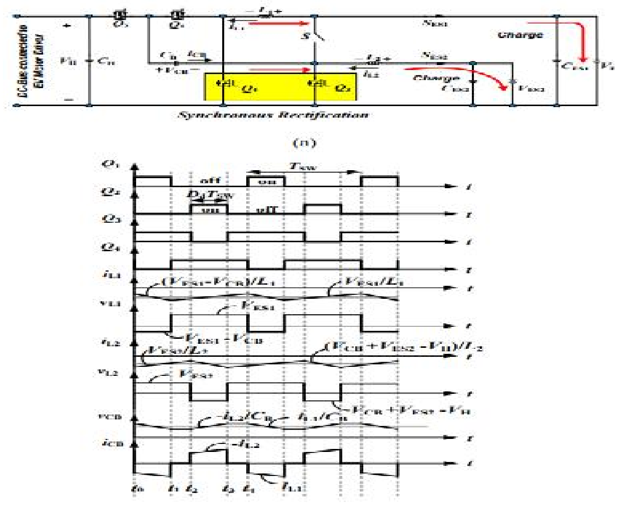


Fig.2.4. High-voltage dc-bus energy-regenerating mode of the proposed BDC: (a) circuit schematic and (b) steady-state waveforms.

On the basis of the steady-state waveforms shown in Fig. 2.4(b), when the duty ratio is below 50%, four different circuit states are possible, as shown in Fig. 2.5. In the light of the on-off status of the active switches and the operating principle of the BDC in high-voltage dc-bus energy-regenerating mode, the operation can be depicted briefly as follows.

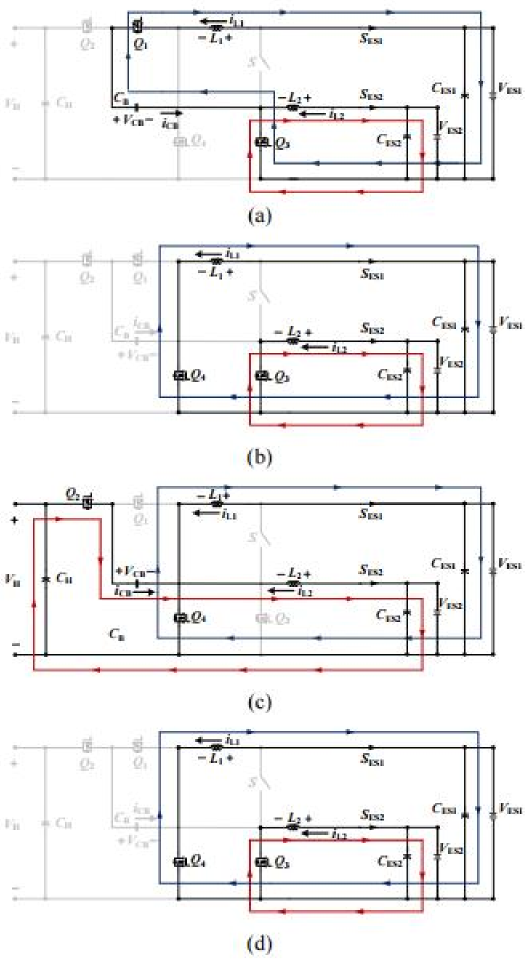



Fig. 2.5. Circuit states of the proposed BDC for the high-voltage dc-bus energy-regenerating mode. (a) State 1. (b) State 2. (c) State 3. (d) State 4.

a) State 1 [t0 < t < t1]: During this state, the interval time is Dd Tsw; switches Q1 and Q3 are turned on, and switches Q2 and Q4 are turned off. The voltage across L1 is the difference between the low-side voltage VES1 and the charge-pump voltage VCB; hence, the inductor current iL1 decreases linearly from the initial value. In addition, inductor L2 is charged by the energy source VES2, which also contributes to the linear increase in the inductor current. The voltages across inductors L1 and L2 can be denoted as

$$L_1 \frac{di_{L1}}{dt} = V_{ES1} - V_{CB} \qquad (9)$$

$$L_2 \frac{di_{L2}}{dt} = V_{ES2} \qquad (10)$$

State 2 [t1 < t < t2]: During this state, the interval time is (0.5-Dd)Tsw; switches Q3 and Q4 are turned on, and switches Q1and Q2 are turned off. The voltages across inductors L1 and L2 are the positive the low-side voltages VES1 and VES2, respectively; hence, inductor currents iL1 and iL2 increase linearly. These voltages can be denoted as

$$L_1 \frac{di_{L1}}{dt} = V_{ES1} \qquad (11)$$

$$L_2 \frac{di_{L2}}{dt} = V_{ES2} \qquad (12)$$

c) State 3 [t2 < t < t3]: During this state, the interval time is DdTsw; switches Q1 and Q3 are turned off, and switches Q2 and Q4 are turned on. The voltage across L1 is the positive low-side voltage VES1 and hence iL1 increases linearly from the initial value. Moreover, the voltage across L2 is the difference of the high-side voltage VH, the charge-pump voltage VCB, and the low-side voltage VES2, and its level is negative. The voltages across inductors L1 and L2 can be denoted as

$$L_1 \frac{di_{L1}}{dt} = V_{ES1} \qquad (13)$$

$$L_2 \frac{di_{L2}}{dt} = V_{ES2} + V_{CB} - V_H \qquad (14)$$

d) State 4 [t3 < t < t4]: During this state, the interval time is (0.5-Dd)Tsw; switches Q3 and Q4 are turned on, and switches Q1 and Q2 are turned off. The voltages across inductors L1 and L2 can be denoted as

$$L_1 \frac{di_{L1}}{dt} = V_{ES1} \qquad (15)$$

$$L_2 \frac{di_{L2}}{dt} = V_{ES2} \qquad (16)$$

Remaining modes of operation were explained in [1].

## 3. FUZZY CONTROLLER:

The word Fuzzy methods unclearness. At the point when the limit of snippet of data isn't obvious, at that point the fluffiness happened. The fluffy set hypothesis is propounded Lotfi A. Zahed in 1965. For successful addressing of the vulnerability in the issue, the fluffy set hypothesis shows enormous potential. To deal with the vulnerability emerging because of unclearness, the Fuzzy set hypothesis is an astounding numerical instrument. Fluffiness shows, the understanding human discourse and perceiving written by hand characters are a portion of the normal cases.

Fluffy set hypothesis is an augmentation of old style set hypothesis. Fluffy set hypothesis components have shifting levels of enrollment. To depict human thinking, thefuzzy rationale uses the entire stretch somewhere in the range of 0 and 1. In FLC the information factors are planned by sets of participation capacities and these are known as "Fluffy SETS".

Fluffy set includes from a participation work which could be characterizes by framework boundaries. The incentive in the scope of 0 and 1 reveals a level of enrollment to the fluffy set. "Fuzzificaton" is the way toward changing over the fresh contribution to a fluffy worth. The yield of the Fuzzier module is interfaced with the rules. The fundamental activity of FLC is created from fluffy control rules utilizing the estimations of fluffy sets overall for the mistake and the distinction of blunder and control action. Key fluffy module is showed up in fig.6.3. The outcomes are solidified to give a new yield controlling the yield variable and this strategy is known as "DEFUZZIFICATION."

**4.1 MATLAB CIRCUITS:**

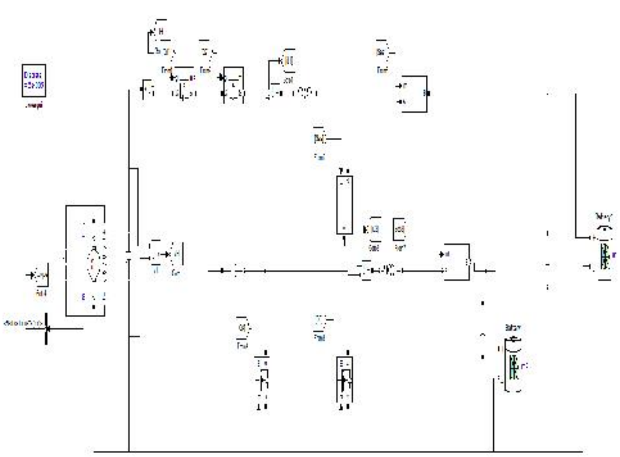


Fig4.1 Simulation Block Diagram

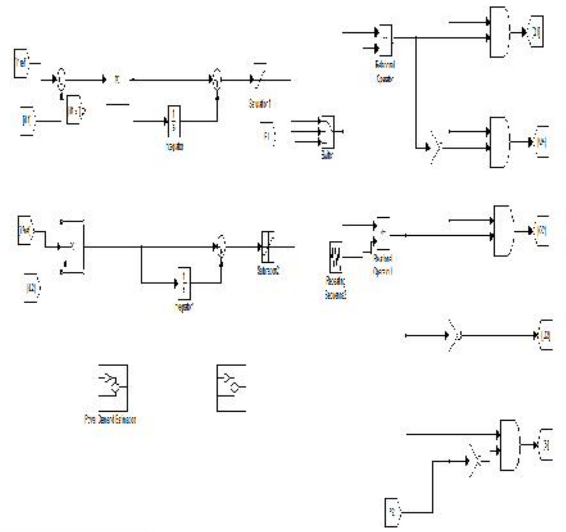


Fig4.2 Simulation Control  Diagram

**4.2 WAVE FORMS:**

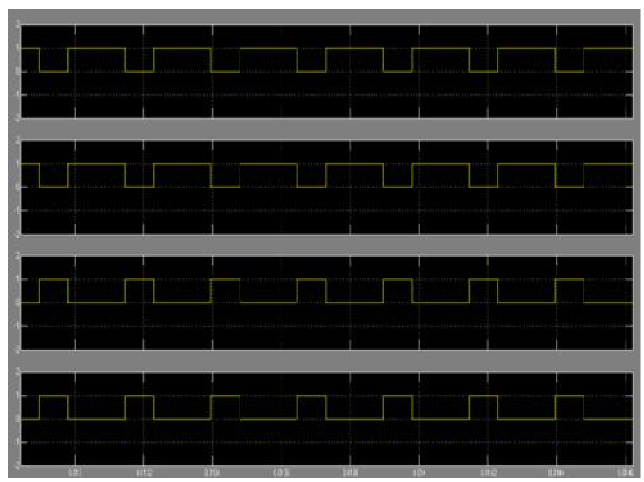
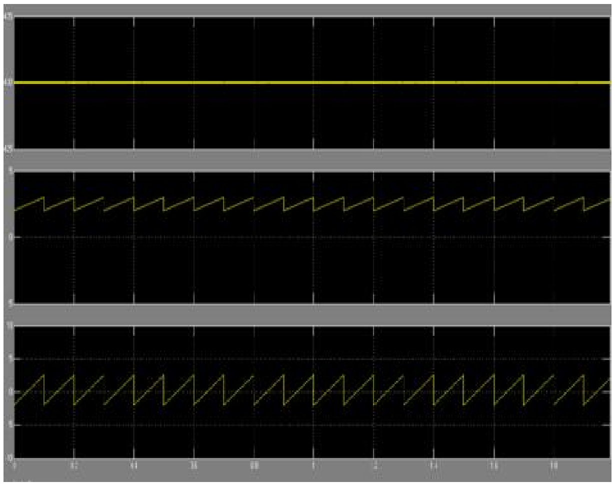


Fig. 4.3. Measured waveforms for low-voltage dual-source-powering mode:(a) gate signals



(b) output voltage and inductor currents.

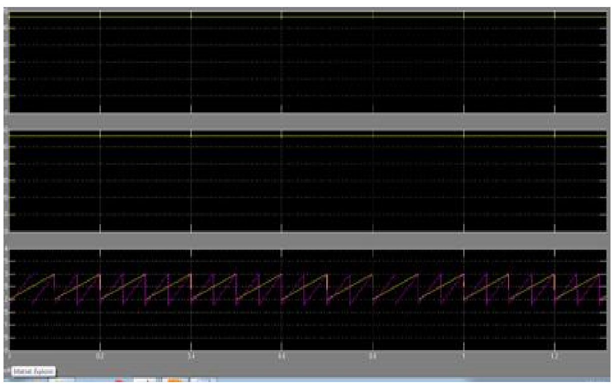


Fig. 4.4. Measured waveforms for high-voltage dc-bus energy-regenerating mode:.

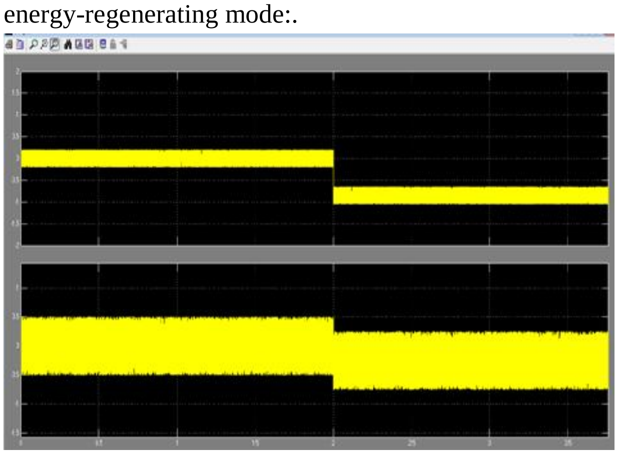


Fig.4.5. Waveforms of controlled current step change in the low-voltage dual-source-powering mode by simulation

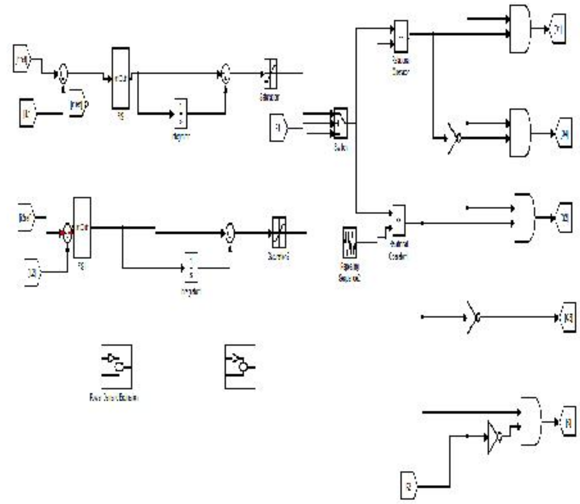


Fig4.6 Simulation of fuzzy logic Control Diagram

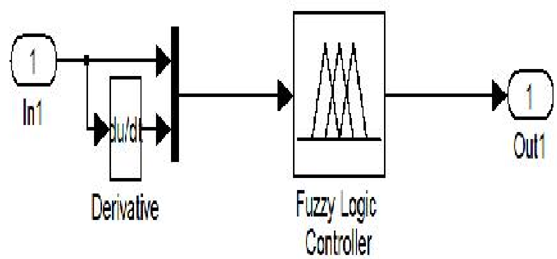



Fig4.7 fuzzy logic Controller

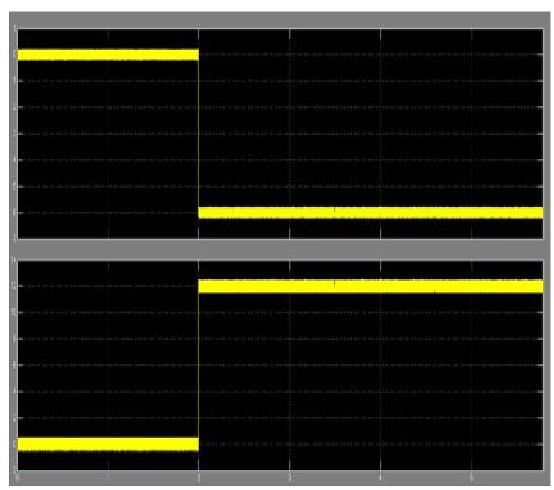


Fig. 4.8 Waveforms of controlled current step change in the low-voltage dual-source boost mode: by simulation;

Fig. 4.9 Waveforms of controlled current step change in the low-voltage dual- source buck mode: by simulation

**CONCLUSION**

Another BDC geography was acquainted with interface double battery fuel sources and high-voltage dc transport of different voltage levels. The circuit plan, activity standards, examinations, and static voltage gains of the proposed BDC were discussed dependent on different techniques for power move. Reenactment waveforms for a 1 kW model framework included the introduction and probability of this proposed BDC geography. The most elevated transformation efficiencies were 97.25%, 95.32%, 95.76%, and 92.67% for the high-voltage dc-transport energy-regenerative buck mode, low-voltage double source-driving mode, low-voltage double source help mode (ES2 to ES1), and low-voltage double source buck mode (ES1 to ES2), independently. In this paper fluffy rationale regulator is utilized to improve the proposed geography. The outcomes show that the proposed BDC can be effectively applied in FC/HEV frameworks to create half and half force engineering.

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