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ANN Based Closed loop control scheme for High Gain DC – DC Converter

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Abstract: —
The paper proposes a high step up boost converter. The proposed converter has used a coupled inductor with switchedcapacitors. The capacitors were made to get charged in parallel and were made to get discharged in series by the configuration to achieve high step up voltage gain. And the voltage across the load is maintained constant by using a closed loop control.Switch voltage stressand the circulating current are reduced by a clamp circuit which is composed of a diode followed by a capacitor. Thus the efficiency ofthe converter is improved. The operating principle and the steady state analysis are discussed in detail. A Fuzzy logic controller is designed such that it eliminates the Voltage Drift problemComputer simulation by MATLAB/ SIMULINK hasbeen used to support the developed concept.

Keywords: Coupled Inductor; FLC; Switched Capacitor circuit; Switched Capacitor; PI Controller; Fuzzy Logic Controller

I. INTRODUCTION

Boost converter is one of the most important and widely used devices of modern powerapplications. These converters are electronicdevices used to change DC electrical powerefficiently from one voltage level to another. They provide smooth acceleration control, high efficiency, and fast dynamic response. There areFOUR main types of converter usually called the buck, boost, buck-boost and Boost converters. The buck converter is used for voltage stepdown/reduction, while the boost converter is used for voltage step-up. The buck-boost and Cukconverters can be used for either step-down or step up.

Basically, the DC-DC converter consists of the power semiconductor devices which are operated as electronic switches and classified as switched mode DC-DC converters. Operation of the switching devices causes the inherently nonlinear characteristic of the DC-DC converters. Due to this unwanted nonlinear characteristics, the converters requires a controller with a high degree of dynamic response. Pulse Width Modulation (PWM) is the most frequently consider method among the various switching control method. In DC-DC voltage regulators, it is important to supply a constant output voltage, regardless of disturbances on the input voltage.

Nowadays, the control systems for many power electronic appliances have been increasing widely. Crucial with these demands, many researchers or designers have been struggling to find the most economic and reliable controller to meet these demands. The idea to have a control system in dc-dc converter is to ensure desired voltage output can be produced efficiently as compared to open loop system. Controller for the PWM switching control is done by Fuzzy Logic Controller.

Many different methods have been proposed to improve the efficiency of the converter and to achieve high voltage gain, which can be done by using a switched capacitor and a coupled inductor is used for high gain by adjusting its turns ratio. Voltage spikes may occur due to the coupled inductor. For which we have used an active clamp circuit with coupled inductor which avoids voltage spikes.

Here voltage stress of the active switch is reduced thereby the conversion efficiency is improved. This converter requires a multi winding transformer which makes the circuit design complex [9].This converter avoids extremely narrow turn off period, ripples and switching losses are eliminated by ZVS technique. It uses two coupled inductors which makes the circuit complex [10]. In this converter no additional magnetic components used, switching losses are minimized by adopting a regenerative snubber circuit. As the circuit uses more switches controlling is complex [11]. In this converter high voltage gain is obtained but the circuit has more passive components [12]. It employees single ended scheme cost is reduced. Galvanic isolation is needed, butsuitable only forlow power and frequency applications [13], [14]. In this converter no need of extreme duty ratio but if conduction losses or switching losses occurs the efficiency is reduced [11]. It is possible to generate the non-isolated dc-dc converters but the major drawback is that switching frequency must be maintained constant and the turn ratio of the auto transformer must be unity [11]. Some converters operate at very high frequency with fast transient response. The main switch is fabricated from an integrated power process, the layouts can be changed to vary the parasitic, however design of switch layout is complex, fixed frequency and constant duty ratio must be maintained [12]. This converter provides high voltage gain and can be employed for high power applications however the duty ratio is limited to 0.85 [8], [9]. In this, the energy of the leakage inductor is recycled to the output load directly, limiting the voltage spike on the main switch. To achieve a high step-up gain, it has been proposed that the secondary side of the coupled inductor can be used as flyback and forward converters [10], [10].In some converters voltage gain is improved through output voltage stacking [12].

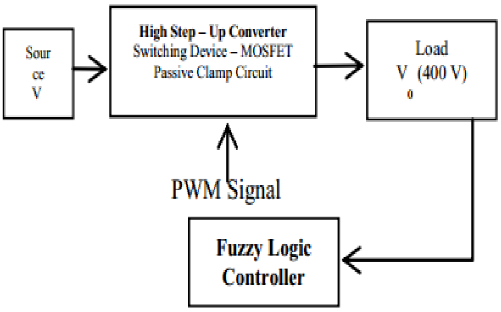

Fig.1. Proposed Block Diagram.

The main objective is to improve the Voltage Gain of the Step-up Converter and also to reduce Voltage stress of the circuit. Further the Voltage Drift problem is reduced using closed loop control of the proposed converter with fuzzy logic controller. From Fig.1, The output voltage from the converter is fed as feed back to the FLC; there it compares the feedback voltage signal and the reference voltage signal to produce PWM pulse which triggers the main switch of the converter.

II. PROPOSED TOPOLOGY – STEP-UP DC-DC CONVERTER

A. Basic diagram of the proposed:

Fig. 2 shows the circuit configuration of the proposed converter, which consists of a boost converter, coupled inductor, switched capacitor circuit and a clamp circuit. The equivalent circuit of the coupled inductor has a magnetizing inductor Lm, leakage inductor Lk, and an ideal transformer. Ns and Np is the primary and secondary winding of theideal transformer,Vin DC input voltage, V0 is the DC output voltage, and S main switch.

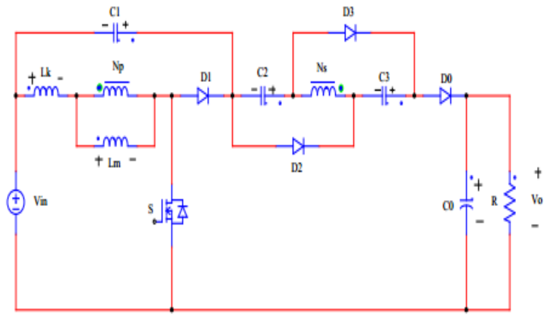

Fig.2.Proposed diagram

The diodes D2, D3 and capacitors C2, C3 forms the switched capacitor circuit. D1, C1 are the clamp diode and clamp capacitor respectively. The operating principle is that when the switch S is ON, the input supply voltage charges the magnetizing inductor Lm which is in the primary side of the coupled inductor Np. This Np induces emf to the secondary side of the coupled inductor which makes the capacitors C1, C2, C3 to discharge in series and delivers to the load resistance. The output capacitor C0 is in charging state. When the switch S is turned OFF, the energy stored in the magnetizing inductor gets discharged and makes the capacitors C2, C3 to charge in parallel. Meanwhile, the D1 is turned ON and charges the clamp capacitor C1, thus reduces the switch voltage stress andthecirculating current. The energy stored in C0 is delivered to the load resistance. Fig. 3 shows the typicalwaveforms

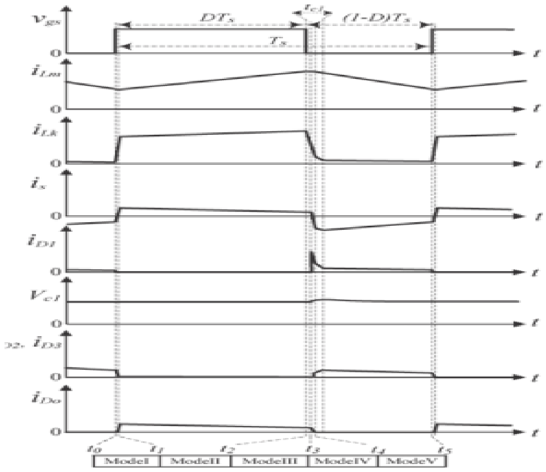

Fig.3. Switching Waveforms of the proposed converter.

Assumptions to simplify the circuit analysis, 1. Capacitors C1, C2, C3 and C0 are large enough. And so, VC1, VC2, VC3 and VC0 are considered as constants in one switching period.

2. The power devices are ideal.

3. The coupling coefficient of the coupled inductor k isequal to Lm/ (Lm+Lk), and the turn ratio of the coupled inductor n is equal to Ns/Np.

B. Modes of operations and design parameters:

There are five operating modes in one switching period. Fig. 4 shows the current-flow path of each mode of the circuit.

1. Mode I [t0, t1]: In this mode, S is turned on. Diodes D1 and D0are turned off, and D2 and D3 are turned on. The current flow path is shown in fig. 4(a).Theleakage inductor LkchargedbyVin. Output capacitor C_0provides its energy to load R
2. When current iD_2becomes zero at t = t1, this operating mode ends.

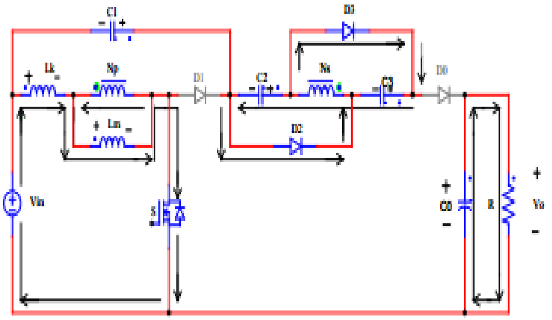

Fig.4(a). Equivalent circuit Mode I [t0, t1].

3. Mode II [t1, t2]: In this mode, S remains turned on. Diode D1, D2, and D3 are turned off and D0 is turned on. The current-flow path is shown in fig. 4(b).Magnetizing inductor Lm charges by Vin. The induced voltage VL2 on the secondary side of the coupled inductor makes Vin, VC1, VC2and VC3, which are connected in series, discharge to high voltage output capacitor C0 and load R. when switch S is turned off this mode ends.

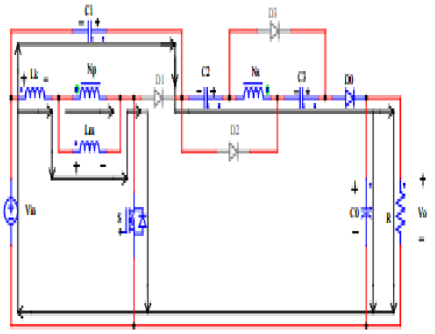

Fig.4 (b).Equivalent circuit Mode II [t1, t2].

4. Mode III [t2, t3]: In this mode, S is turned off. Diodes D1, D2, and D3 are turned off and D0 is turned on. The current-flow path is shown in fig. 4(c). The energies of Lk and Lm charge the parasitic capacitor Cdsof main switch S. Output capacitor C0 provides its energy to load R. At t = t3, diode D1 conducts, and this mode ends.

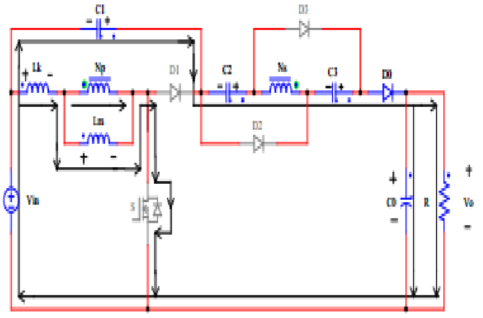

Fig.4 (c).Equivalent circuit Mode III [t2, t3].

5. Mode IV [t3, t4]: In this mode, S is turned off. Diodes D1 and D0 are turned on, and D2 and D3 are turned off. The current flow path is shown in fig. 4(d). The energies of Lk and Lm charge C1. The energy of Lk is recycled. Secondary-side voltage VL2 of the coupled inductor continues charging high-voltage output capacitor C0 and load R in series until the secondary current of the coupled inductor is equal to zero. At t = t4, this mode ends.

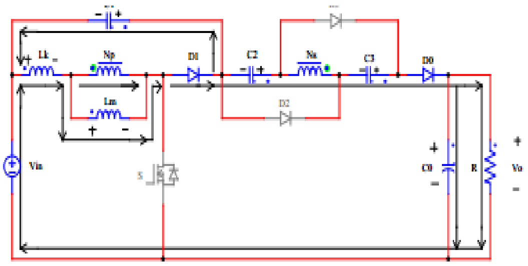

Fig.4 (d).Equivalent circuit Mode IV.[t3, t4].

6. Mode V [t4, t5]: In this mode, S is turned off. Diode D1, D2, and D3 are turned on and D0 is turned off. The current-flow path is shown in fig. 4(e). C0 is discharged to load R. The energies of Lk and Lm charge the C1. Lm is released via the secondary side of the coupled inductor and charges capacitors C2 and C3. Thus, C2 and C3 are charged in parallel and Lk charges capacitor C1.
   This mode ends at t = t6.

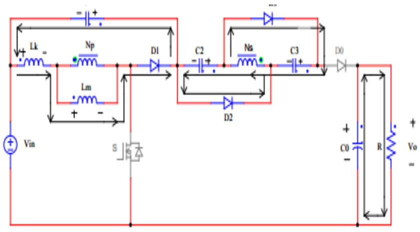

Fig.4 (e).Equivalent circuit Mode V.[t4, t5].

III. ANALYSIS OF PROPOSED CONVERTER OPERATION WITH FUZZY LOGIC CONTROLLER

The energy stored in the leakage inductor Lk of the coupled inductor is released to capacitor C1. The energy-released duty cycle DC1 can be expressed as

$$D_{C1} = \frac{t_{c1}}{T_s} = \frac{2(1-D)}{n+1}$$

The equivalent circuit and state definition of the newly designed converter is depicted in fig.2, where the transformer is modeled as an ideal transformer.

According to the description of operating modes, voltage stresses on active switch S and diodes D1, D2, D3, and D0are given as

$$V_{ds} = \frac{1}{1-D} V_{in} = \frac{V_O + nV_{in}}{2n+1}$$

$$V_{D1} = \frac{1}{1-D} V_{in} = \frac{V_O + nV_{in}}{2n+1}$$

$$V_{D2} = V_{D3} = V_{D0} = \frac{n}{1-D} V_{in}$$

$$= \frac{n(V_O + nV_{in})}{2n+1}$$

Table.I. shows the simulation parameters for the proposed system.

The block diagram of fuzzy logic controller (FLC) is shown in fig.5. It consists of three main blocks: fuzzification, inference engine and defuzzification. The two FLC input variables are the error E and change in error E*. Depending on membership functions and the rules FLC operates.

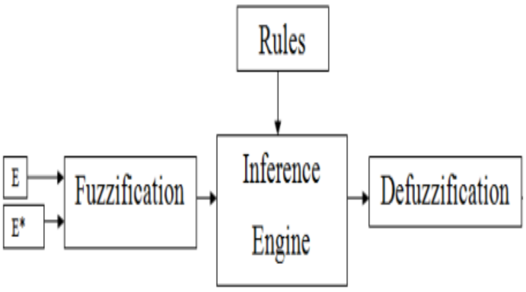

Fig.5 Block Diagram of FLC

Table.II.shows the representation of the typical Rule Surface of fuzzy logic controller.

RULE TABLE FOR FLC

E \ E*	N	Z	P
N8	N7	N8	N6
N7	N6	N7	N8
N6	N5	N6	N7
N5	N4	N5	N6
N4	N3	N4	N5
N3	N2	N3	N4
N2	N8	N2	N3
N1	N8	Z	P2
Z	P1	Z	N1
P1	P2	P1	Z
P2	P3	P2	P1
P3	P4	P3	P1
P4	P3	P4	P3
P5	P6	P5	P5
P6	P7	P6	P5
P7	P8	P7	P6
P8	P8	P8	P7

Table.II. Rule Surface of fuzzy logic controller

IV. MATLAB BASED SIMULATION &RESULTS

To verify the feasibility of the proposed system a simulink model is developed. Fig.6&Fig.7.shows the sub system in the simulink model.

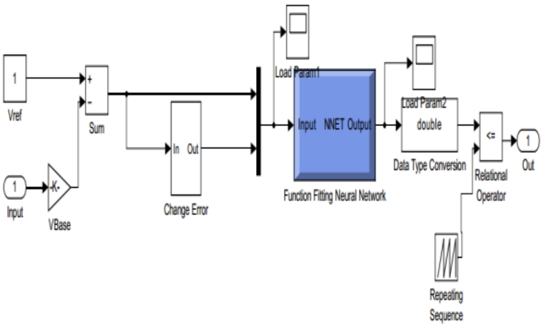

Fig.6.MATLAB based simulation diagram of proposed system with masked diagrams

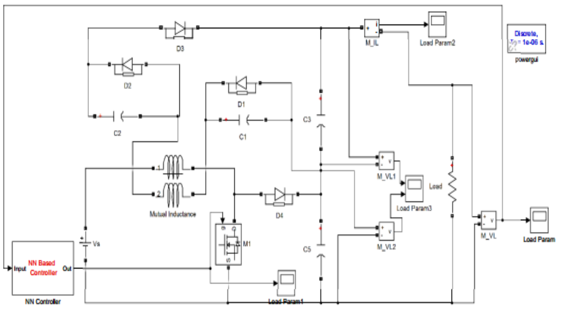

Fig.7.MATLAB based simulation diagram of proposed system with masked blocks for output responses

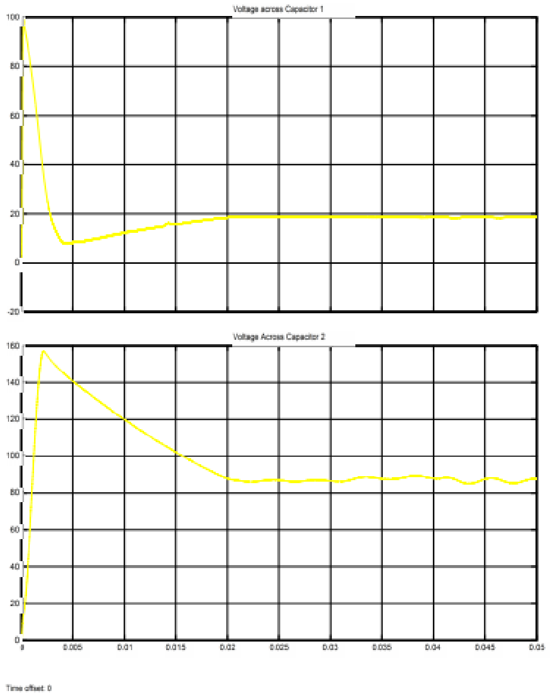

Fig.8.MATLAB based simulation diagram of proposed system –capacitors voltages

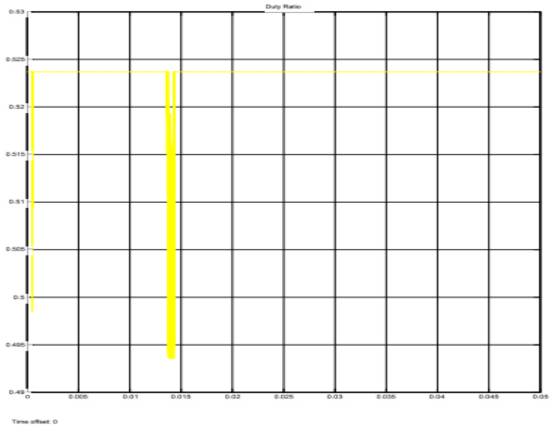

Fig.9.MATLAB based simulation diagram of proposed system –duty ratio value

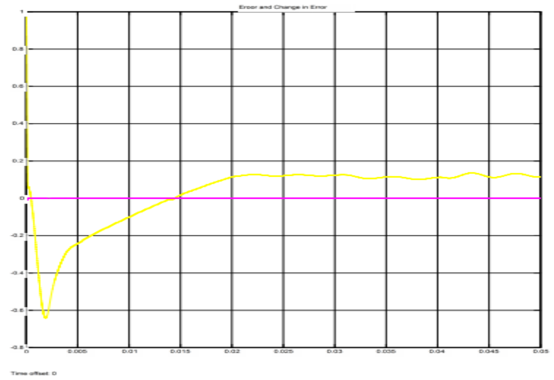

Fig.10. MATLAB based simulation diagram of proposed system with Fuzzy Logic Controller – Error and Change in Error

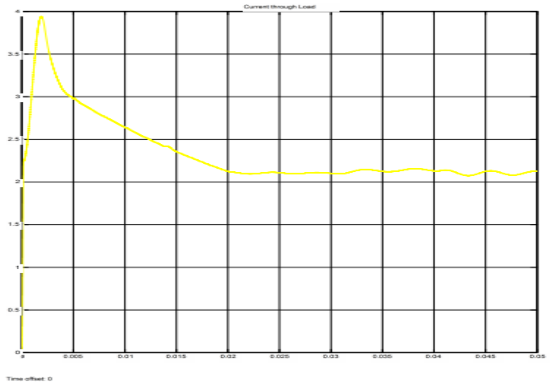

Fig.11.MATLAB based simulation diagram of proposed system –load current

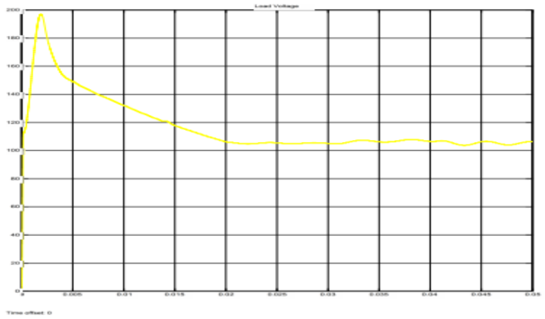

Fig.12.MATLAB based simulation diagram of proposed system –load voltage

TABLE.I.SIMULATION SPECIFICATIONS

Parameter	*Rating*
Input dc voltage	24 V
Output dc voltage	400 V
Maximum output power	200 W
Switching frequency	50 kHz
Capacitors	C1 = 56 µF

	C2/C3 = 22 µF C0 = 180 µF
Coupled inductors	Np:Ns= 1: 4 Lm&Lk = 48 µH&0.25 µH

CONCLUSION

Here a high step-up boost converter using coupled inductor with proportional integral control is simulated. By the capacitor charged in parallel and discharged in series by the coupled inductor, high step-up voltage gain is achieved. As the output voltage of the converter with FLC has minimum overshoot and produces a constant output current shows the better performance compared to the converter with PI controller. These studies could solve many types of problems regardless on stability because as we know that fuzzy logic controller is an intelligent controller to their appliances. Additionally, the switch voltage stress is reduced, thus a switch with low voltage ratings can be selected.

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