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Research paper

Performance enhancement analysis of an isolated DC-DC converter using fuzzy logic controller

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Abstract

High voltage gain dc-dc converters plays an major role in many modern industrialized applications like PV and fuel cells, electrical vehicles, dc backup systems (UPS, inverter), HID (high intensity discharge) lamps. As usual boost converter experiences a drawback of obtaining a high voltage at maximum duty cycle. Hence in order to increase the voltage gain of boost converter, this paper discusses about the advanced boost converter using solar power application. By using this technique, boost converter attains a high voltage which is ten times greater than the input supply voltage. The output voltage can be further increased to more than ten times the supply voltage by using a parallel capacitor and a coupled inductor. The voltage stress across the switch can be reduced due to high output voltage. The Converter is initially operated in open loop and then it is connected with closed loop. More over the fuzzy logic controller is used for the ripple reduction.

Keywords: *Boost Converter; Parallel Capacitor; High Voltage Gain; Soft Switching.*

1. Introduction

In present years, due the uniform increase in the demand for electrical utility the researchers and developers are working on the various applications of natural resources. Among all the available natural renewable resources the photovoltaic cell and fuel cell had been considered as a best choice. Apart from renewable resources, a high dc step up converter is used for the power conversion for the generation of voltage. [1] Due to its simple design and low conduction loss, a conventional boost converter is widely used in the step-up applications which do not require high voltage gain. Ideally, the voltage gain of boost converter is infinity at unity duty cycle. But practically, the voltage gain is restricted due to the presence of I^2R loss in the inductor. This loss results in high cost drive circuit and also effects the output voltage directly [2]
Hence to attain a high step-up voltage ratio, a coupled inductor based converter and a isolated transformer are the widely used choices. But due to low current stress, low conduction loss, less ripple content and simple design a coupled inductor based converter is considered. For some applications with low input voltage high output voltage requires high turn's ratio. The significant energy in the converter is still trapped by its leakage inductance and results in high voltage stress of the switch and produces significant loss. Therefore to overcome the above problems many methods such as use of resistor capacitor diode, converters operating in discontinuous conduction mode [3-4] a passive lossless clamped circuit and use of additional snubbers had been suggested to reduce the voltage stresses of switches and to retrieve the energy trapped in the leakage inductor. A soft switching method is also used in dc-dc converter for high efficiency and to increase the power conversion density and high efficiency [5].

In static power converters, soft switching techniques have been employed to increase the switching frequency and reduce the weight, size of static components and switching losses in semiconductor. To achieve the characteristic of zero voltage switching at turn on power switch the asymmetrical PWM methods, active clamp techniques have been proposed. In modern low power industrial applications SMPS storage based on fly back converter are widely used. An isolated transformer is used to obtain the energy storage and circuit isolation in the fly back converter [6]. The zeta converters are discussed to minimize the volume of converter, voltage stresses and switching losses [7-8]. It is also used to produce isolated output voltage or for power factor correction. [9-10]
Due to the presence of all above mentioned features, an asymmetrical interleaved high set-up converter is also discussed. In the proposed converter, the turn's ratio of coupled inductors can be arranged to enhance the voltage gain. A voltage lift capacitor is also used to provide an extra voltage conversion ratio [11]
Multi cascaded sources arrangement and this topology linked to a fundamental dc-dc converter is used to supply the power from load. It doesn't results in any power loss as the remaining power is directly given to the output load. Thus, a source cascaded topology results in high efficiency, high voltage gain and reduced volume of the transformer [12]

1.1. Interleaved boost converters

Interleaved boost converters play an important role in recent years due to its enhancement in size, transient response, conducted electromagnetic emission and its efficiency. The use of a coupled inductor as an alternative of multiple distinct inductors is more advantageous since inductor is the largest component used in high-boost inverter. Use of coupled inductor also reduces the winding and core losses, inductor ripple current. The steady-state analysis of the multiphase IBCs with conclusions have been formerly described.

1.2. Coupled inductor

Voluntary core gaps are the one of the major cause of leakage flux in the energy storing inductor. The flux related with leakage takes a smaller path and is uncoupled outside the windings. While the flux related with mutual inductance passes through all the associated windings and the huge allocation of which debris in the core. A flux cancelling inverse coupled arrangement is employed by resolving the windings having opposite polarity. For N turns each, the resultant flux at the core directly is given by,

$$\frac{(1-k)LI_0}{N}$$

Where, I_0 is dc current through the winding.

2. Proposed concept

In this coupled inductor working benefits is achieving a high voltage gain about 10 times of input voltage, so that the coupled inductor is useful of one of the voltage lift technique for the converter. It has two same rating of capacitor value, one capacitor is parallel with source side and another one capacitor is parallel with load side, but both of the capacitors are useful for continuous supply to the load.

2.1. Operation of the proposed converter

A boost converter operates in four different modes and the basic circuit diagram of boost converter is shown in fig.2-5. The operation of boost converter can be explained in four modes.

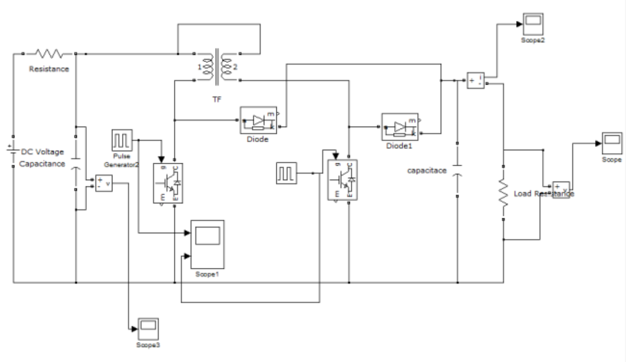

Fig. 1: Basic Circuit Diagram of the Proposed Converter.

MODE I: (t=t_0 to t_1 for S_1 & t=t_2 to t_3 for S_2)
In this transition interval, from the figure 2 the switch S1 is going to turned ON at t=0 but S2 is already maintained conduction is to be extended to reach at t=t3 the L2 is fully energised and C1 also got fully charged but L1 have 1/3 level of energy stored in the Inductor L1 at t=t1. In this mode 1 duration C2 capacitor discharge the energy to the load. Diodes D1 and D2 are turned OFF, so supply voltage is not present on the output load.

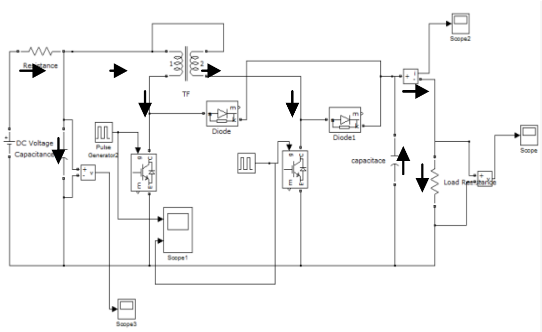

Fig. 2: Mode 1 Circuit Diagram.

MODE II: (t=t_1 to t_2 for S_1 & t=t_3 to t_4 for S_2)
In this transition interval, from the fig.3.3 the switch S2 is going to turned OFF at t=t3 but S1 is already maintained conduction is to be extended to reach at t=t2, the L1 is 2/3 level of energy is energized and the fully charged C1 capacitor is discharge through L2 and D2 to the load and in this duration C2 is getting charge but L1 have 2/3 level of energy stored in the Inductor L1 at t=t2. In this mode 2 duration C1 capacitor and L2 inductor discharge the energy to the load by using Diodes D2 and D1 is turned OFF because of S1 is maintained conduction.

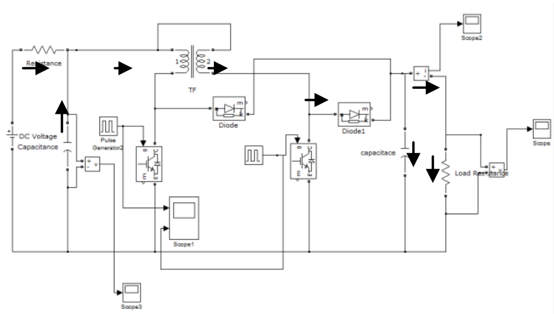

Fig. 3: Mode 2 Circuit Diagram.

MODE III: (t=t_2 to t_3 for S_1 & t=t_0 to t_1 for S_2)
In this transition interval, from the fig.3.4 the switch S_2 is going to turned ON at t=0 but S_1 is already maintained conduction is to be extended to reach at t=t3 the L1 is fully energized and C_1 also got fully charged but L_2 have 1/3 level of energy stored in the Inductor L2 at t=t1. In this mode 1 duration C_2 capacitor discharge the energy to the load. Diodes D_1 and D_2 are turned OFF, so supply voltage is not present on the output load.

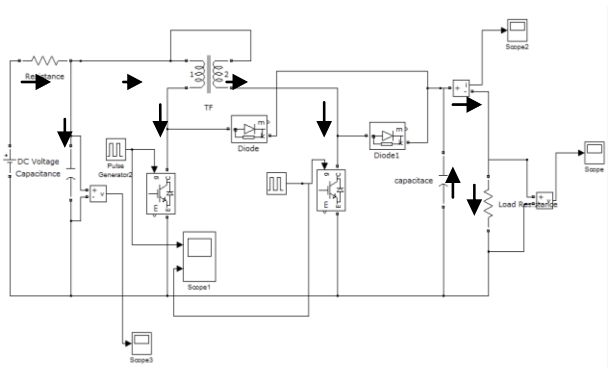

Fig. 4: Mode 3 Circuit Diagram.

MODE IV: (t=t_3 to t_4 for S_1 & t=t_1 to t_2 for S_2)
In this transition interval, from the fig.3.5 the switch S2 is going to turned ON at t=0 but S_1 is already maintained conduction is to be extended to reach at t=t3 the L1 is fully energised and C_1 also got fully charged but L_2 have 1/3 level of energy stored in the Inductor L_2 at t=t_1. In this mode 1 duration C_2 capacitor discharge the energy to the load. Diodes D_1 and D_2 are turned OFF, so supply voltage is not present on the output load.

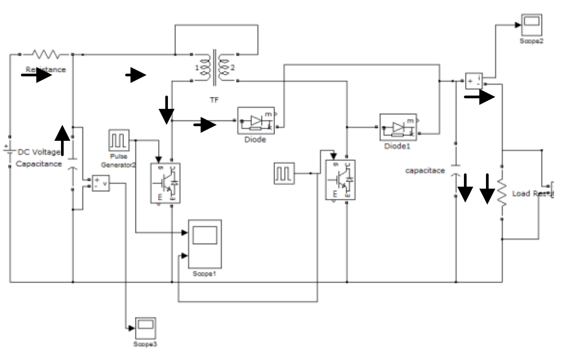

Fig. 5: Mode 4 Circuit Diagram.

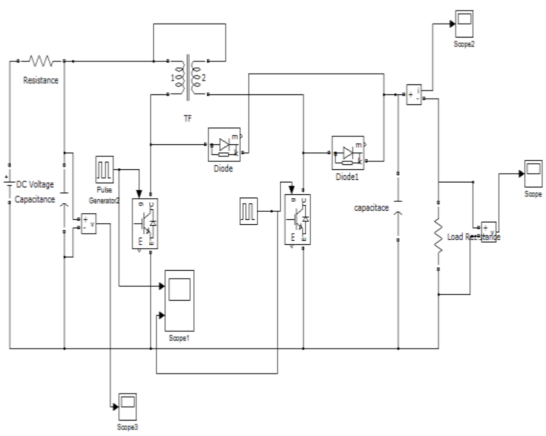

Fig. 6: Simulation Circuit Configuration.

Analysis of the Proposed Converter
Basic formula for boost converter is given as,

$$\frac{V_{OUT}}{V_{IN}} = \frac{1}{1-D} \quad (1)$$

The mutual inductance is M and the self-inductances are consider to be equivalent value of L and the coupling factor (k) is defined as M/L. Coupled inductor acts as a Transformer for the circuit diagram and each winding voltage and current relationship is given below.

$$V_1 = L\frac{di_1}{dt} - M\frac{di_2}{dt} \quad (2)$$

$$V_2 = L\frac{di_2}{dt} - M\frac{di_1}{dt} \quad (3)$$

We have derive the terms of flux in the above equation

$$V_1 = N\frac{d\phi_1}{dt}; N = \frac{LI}{\phi} \quad (4)$$

$$V_1 = (L-M)\frac{di_1}{dt} - M\frac{di_1 - di_2}{dt} \quad (5)$$

$$V_2 = (L-M)\frac{di_2}{dt} - M\frac{di_1 - di_2}{dt} \quad (6)$$

Each winding has a DC current so that find the steady state current by using below equation,

$$I_{DC} = \frac{V}{R} \quad (7)$$

3. Fuzzy logic controller

Unlike conventional controllers A fuzzy logic controller does not require any mathematical representing model for the system being controlled. But it is essential to know the basic mathematical model of system control and process. It is necessary for the designer to know the information about the data flow in the system, data processed and also about solution output variables. In this paper, among all the conventional controllers a fuzzy logic controller is selected for the controlling the voltage of proposed dc-dc converter due to its simple design, easy implementation and robustness to the system parameter variations during operation. The suggested fuzzy logic control scheme attains the simplicity of the mamdani type fuzzy systems that are used for the design of the controller and its variation mechanism.

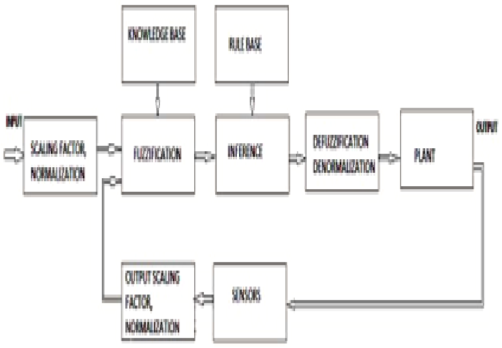

Fig. 7: Fuzzy Logic Controller.

As shown in fig.8 a fuzzy logic controller consists of four main functional blocks- knowledge base, defuzzification, fuzzification and inference mechanism. The knowledge base consists of a rule base and a database.. The rule base is composed of all the set of linguistic rules related to the control actions. While, a data base consists of all the input and output functions and give the information related to fuzzification and defuzzification operations. Fuzzification is used for the conversion of all the crisp input voltage signals, change in error voltage signal and the obtained error voltage signal. Mechanism of inference is used to collect all the linguistic rules and converts the input conditions of fuzzified outputs to the crisp conditions of member function in which the system acts as a rate of change in control input.

Table 1: Rule Base for Fuzzy Logic Controller

'ce' \ 'e'	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

4. Matlab/Simulink results

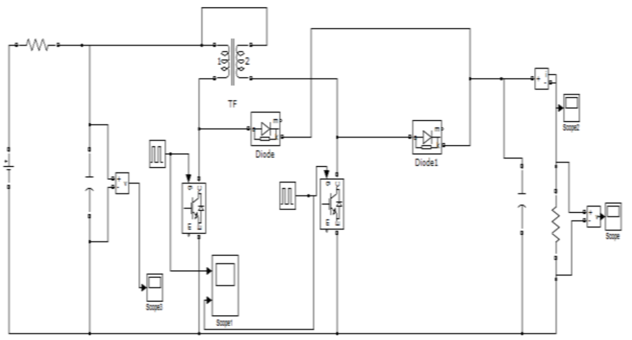

Fig. 8: Matlab/Simulink Model of Proposed Dc-Dc Converter in Open-Loop Method.

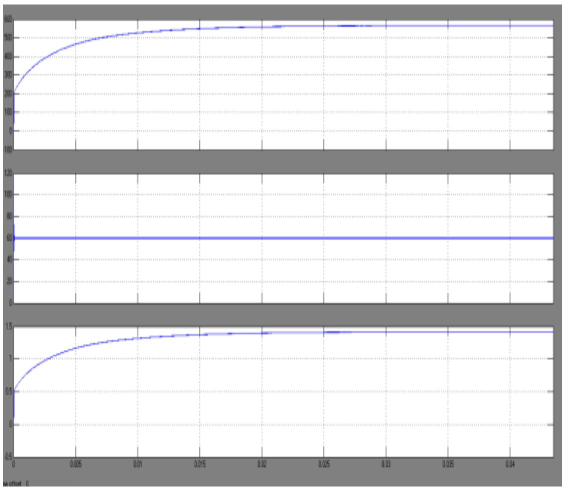

Fig. 9: Waveforms of Output Voltage, Input Voltage and Output Current of Dc-Dc Converter in Open-Loop Method.

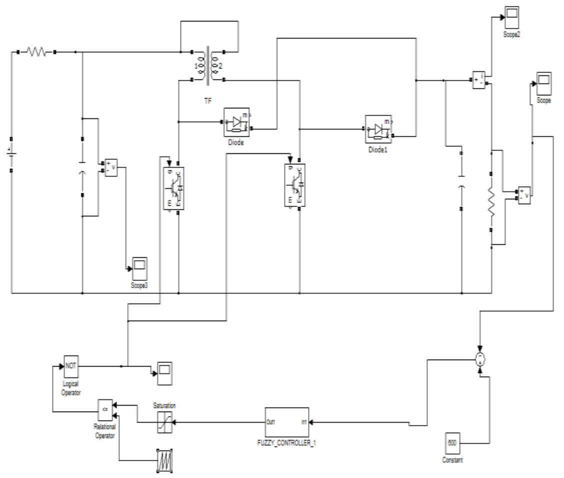

Fig. 10: Matlab/Simulink Model of Proposed Dc-Dc Converter in Closed-Loop Method with Fuzzy Logic Controller.

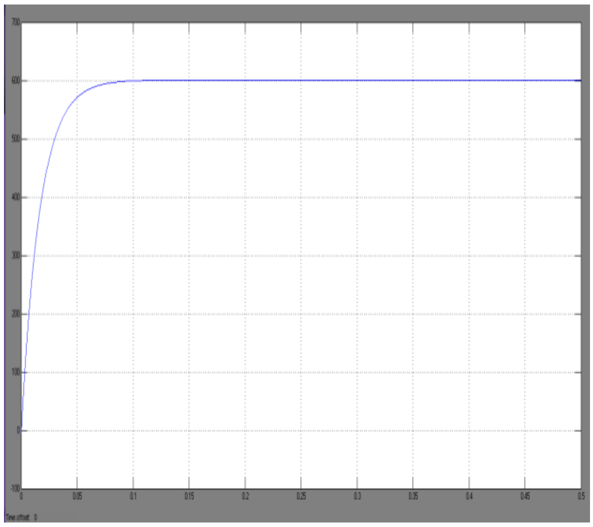

Fig. 11: Shows the Output Voltage of Proposed Dc-Dc Converter in Closed-Loop Method with Fuzzy Controller.

5. Conclusion

The proposed DC–DC boost converter with coupled inductor for the solar power applications has to attain high step-up voltage gain by adjusting the turn's ratio of the coupled inductor and varying the capacitor with proper rating of all the parameters. The energy stored in the leakage inductor of proposed converter is recycled and results in high efficiency of the system. Furthermore, the voltage across the switch is clamped at lower voltage rating resulting the new converter for low rating switch to get better efficiency. The proposed concept operated in open and closed-loop methods. The performance of the converter is better while using fuzzy logic controller compared to conventional converter in open loop.

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