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Fault Diagnosis and Fault Tolerant Operation of A Non-Isolated High Voltage Gain Three Level Boost Converter

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***Abstract*—This topic presents a non-isolated high voltage gain boost converter with fault diagnosis and fault-tolerant operation. The converter is made to work by adding an extra inductor to a conventional 3-level-boost (TLB) converter. The traditional TLB converter is commonly used in power electronics systems due to its simple structure and various advantages. When comparing the traditional boost and TLB converters, the new non-isolated boost converter achieves a higher voltage conversion ratio along with lower voltage and current stresses in the switch. Also, by reducing the current of the switch the new converter can reduce the losses of active devices. The non-isolated boost converter has more efficiency compared with conventional TLB converter. The converter's special feature is to balance output voltages automatically for an unbalanced load without needing any additional control strategy or auxiliary circuit. The converter is more suitable for high-step applications, including photovoltaics, power factor correction, and other renewable power generation systems than the traditional TLB converter. The converter performance study is held out with MATLAB / SIMULINK to examine whether the converter performance is improving. In order to maintain operation for various applications, it is proposed to detect, locate and reconfigure the open-circuit fault methodology that could occur due to power switch failures of the three- level booster converter. The forecasted current and its correlating calculated inductor current are used to diagnose switch fault in the converter, which could radically minimize the need for redundancies**

.Keywords— Boost converter, fault detection, three stage fault tolerant, voltage balancing

I. INTRODUCTION

Due to its simple structure, conventional boost dc-dc converter is widely utilized in power electronics systems. However, due to the passive component's equivalent series resistance its voltage gain is typically limited to 4 to 5 times. Additionally, the voltage and current ratings of the semiconductor devices are determined by the voltage and input current of the converter output, respectively. High voltage and high current level switching systems, which results in higher losses in semiconductor devices and ultimately reduces converter performance, must therefore be used for high-step-up applications. [8] [9].

The high surge voltage caused by the inductance of the leakage requires the use of high voltage rating devices or snubber circuits. A three-level boost (TLB) converter was implemented to overcome the aforesaid drawbacks and has been widely used [2]. Fig. 1.(a) Shows conventional TLB converter. Depending on its application, the converter can be operated as either single output(Vo) or double output(Vo1, Vo2). It has several benefits over the conventional boost converter including high voltage gain and lower transfer volt-age tension compared to the traditional boost converter [5] ; Therefore losses from switching and reversing recovery can be significantly reduced. As a matter of fact, the conventional TLB converter is more appropriate for high-level applications than the traditional boost converter, along with power factor correction, photovoltaic and wind power generation systems [1] .Such implementations and devices mainly use circuit topologies based on the standard TLB converter and multi-level inverters like neutral-point-clamped inverters [6]. A novel non-isolated, high voltage gain boost converter is being introduced in this phase. The voltage gain from the proposed converter is double that of the conventional TLB converter illustrated in Fig. 1. More specifically, the proposed converter has inherent (automatic or self-correcting) balancing of output voltage features [1], which is not recorded in earlier literary works. In addition, the three switche's current stress (S1, S2, and S4) is decreased to one-half of the input current.

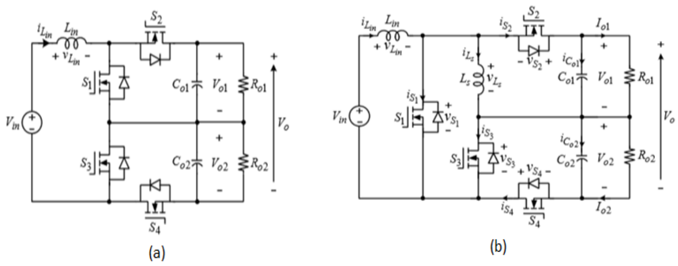

Fig. 1. Circuit diagram (a)Conventional TLB converter(b)Proposed Converter

In the area of fault detection and also the efficiency of power electronic converters, a huge number of research has been done to avoid converter damage loss of supply to end users, and to reduce their high maintenance costs [3]. The second most relevant fault in power converters are the faults of the Semiconductor circuit, the fault of the capacitor being the main of these faults. More effective and faster fault detection is expected in this field as increased use of power converters in industrial service applications such as power supply systems, automotive industry, control interfaces for renewable energy, etc .. The two main faults in switches are the open circuit fault (OCF) and short circuit fault (SCF). The SCF, the most severe switch fault, produces a high current which is more than the rated current induced. Failure to detect this fault and to quickly enough protect the converter poses a

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risk or failure to the whole power converter. Even though the OCF is not as severe as the SCF, failure to diagnose it quickly causes stress and failure of other switches and circuit components[7].

Throughout previous literatures to date, several switch fault diagnostic methods have been introduced to identify faults throughout dc-dc power converters, in less than one switching period in non-isolated dc-dc converters the fault is detected and evaluated, mostly by a digital signal processor (DSP), a software module. In this project, the method for detecting and identifying both OCF and SCF in dc-dc converters is proposed to be easy to implement and quickly respond to fault diagnosis. The method is based on the monitoring of the inductor current [3] [4], together with the input and output voltages of the dc- dc converter. The key benefits are faster detection of faults, identification of faults and stability regardless of the dc-dc converter asymmetry.

II. CIRCUIT TOPOLOGY AND MODES OF OPERATION OF CONVERTER

The circuit topology proposed for the converter can be seen in Fig.1(b). The converter has four active switches (S1,S2,S3 and S4), two inductors (Lin and Ls), and two output capacitors (Co1 and Co2). Here downstream converters or loads associated with the suggested converter are defined respectively as Ro1 and Ro2. Operating mode analysis and key waveforms of the proposed converter are shown in Figs. 2 and 3, separately. From the figure 3, it is clear that the proposed converter has the same gate signal generation as that of the conventional TLB converter.

Fig. 3 shows the detailed steady-state analytical waveforms under operation. Duty cycles D represent Switches gating signals. Based on the waveforms, four significant operating types are recognized in the converter at each switching period.

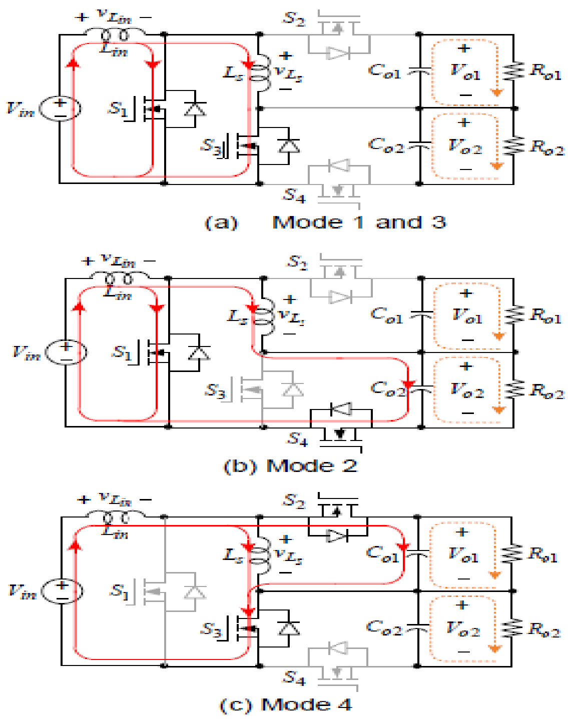

Fig. 2. Operating modes of the proposed converter

2.1 Mode 1

This mode is shown in Fig.2(a) from time interval 0 to DTs/2, the corresponding circuit. In this setting, the switches S1 and S3 are switched on, and S2 and S4 are turned off. Inductor voltage becomes the input voltage Vin, and the voltage across Ls is zero. Switch S1 carries the current and S3 carries iLs.

2.2 Mode 2

From time interval DTs/2 to Ts/2 this mode of operation is. S3 is turned off in this mode and S4 is turned on while S1 remains on. The VLin is same as Vin and the VLs is-Vo2. Switch S1 bears (iLin-iLs) and S4 is equal to iLs. Fig. 2(b) displays the above mode's current flow path.

2.3 Mode 3

From time interval Ts/2 to (1+D)Ts/2 this mode of operation is. S3 is switched on again while S1 is still on. Thus, this mode operation is identical to mode 1.

2.3 Mode 4

From time interval (1+D)Ts/2 to Ts this mode of operation is. S1 is switched off, and S2 is switched on while S3 is still on. The VLin is the same as (Vin-Vo1) and the VLs is Vo1. The current (iLin-iLs) runs via the S2 switch (or body diode) and S3 flows through iLin. Fig. 2(c) displays that mode's current flow path.

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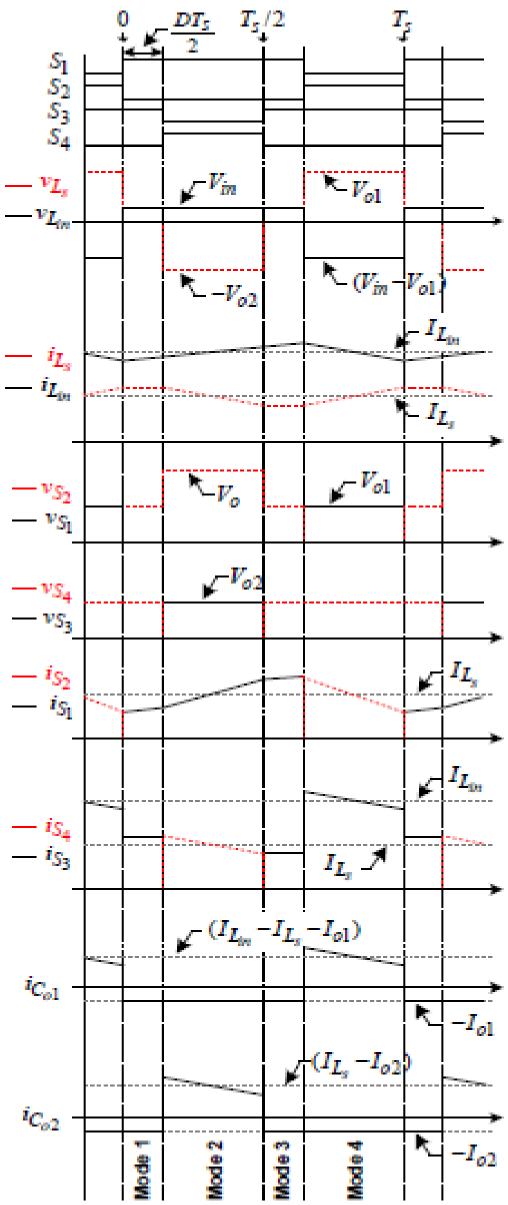

Fig. 3. Operating modes of the proposed converter [1]

III. SIMULATION OF CONVERTER

The simulation of proposed system is carried out by MATLAB/SIMULINK. Fig. 4 shows that the simulation of proposed high gain dc - dc converter. The simulation diagram was constructed with four active switches (S1, S2, S3 and S4), two inductors (Lin and Ls), and two output capacitors (Co1 and Co2). The downstream converters or load linked to the suggested converter are defined equivalently as Ro1 and Ro2. Close loop simulation is completed with the parameters listed in the table 1 and the waveforms of output voltage and output current is shown in figures 5(a) and 5(b).

TABLE I : Simulation Parameters

PARAMETERS	SPECIFICATION
Input voltage	120V
Output voltage	600V
Inductors	Lin=280µH Ls=960µH
Capacitor	188µF
Resistor	180Ω
Switching frequency	50KHz

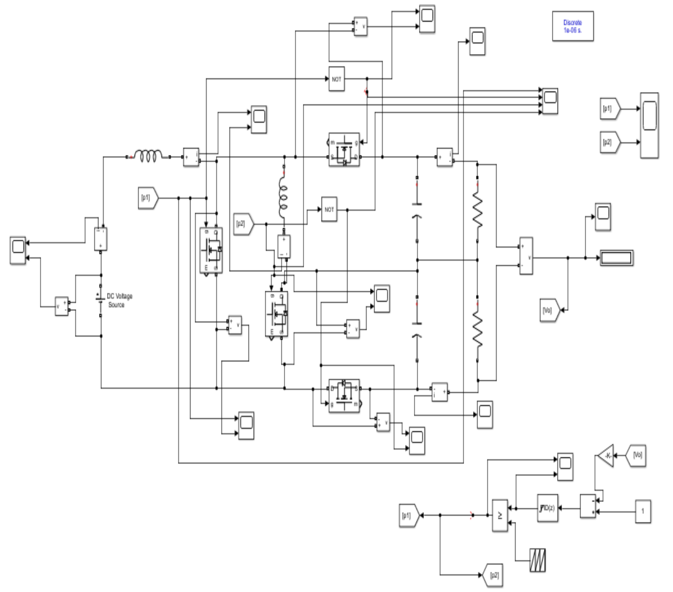

Fig. 4. Close Loop Simulation of Converter

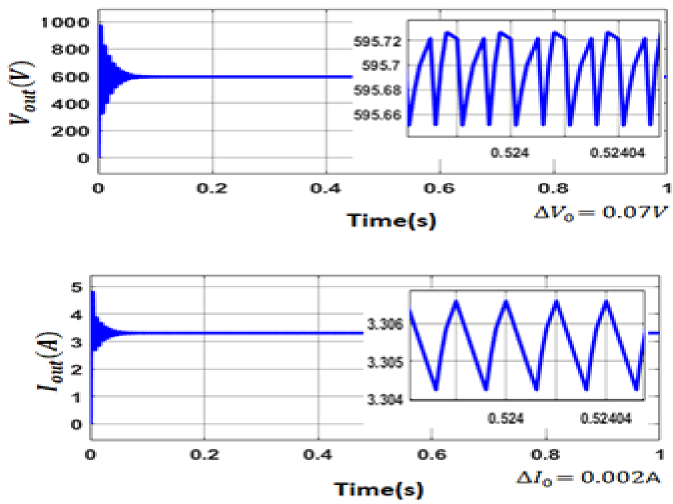

Fig. 5. Graph Showing (a)Output voltage (b)Output Current

IV. COMPARISON TO THE CONVENTIONAL CONVERTER

When using the conventional TLB converter as the front-end step up dc-dc converter for the downstream converters / inverters that take both the outputs of the TLB converter as inputs, there may be a voltage unbalance issue in the TLB converter outputs. This is caused by many factors including incompatible gate drive signals, finite time delays in switching devices and others in practical applications. For this reason, balancing methods are sometimes required in the conventional TLB converter to resolve voltage unbalance issues. To figure out the question of voltage unbalance, several different control mechanisms and systems have been implemented to date, focused on either controlling the modulation process or incorporating passive or active components. Despite that, these methods restrict the converter's reliability and work and raise the unpredictability of the structure. The table 2 shows the comparison of the conventional and proposed system with respect to number of components, Efficiency, Losses, Voltage gain and stress, and Duty ratio.

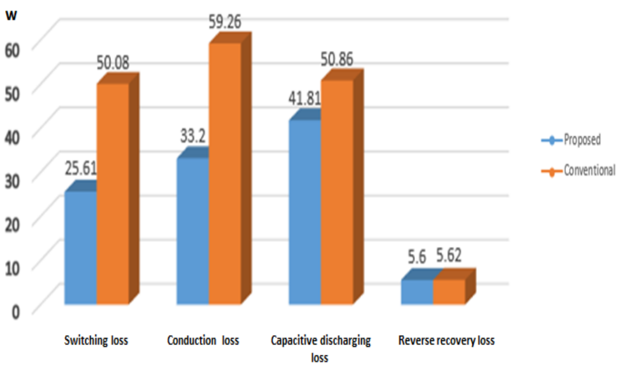

Fig. 6 Graph Showing Loss Analysis of the converter

A novel un-isolated, higher voltage gain boost converter is being suggested in this scheme. The voltage gain from the suggested converter is multiple times that of the conventional TLB converter displayed in Fig. 1(a).More specifically, the suggested converter has inherent (automatic or self-correcting) balancing functions for output voltage, which are not taken into account in previous works of literature. The analysis of losses and the efficiency plot is given in the paper, it can be surmised that the decreased losses of switching and the current stress in the suggested converter switches lead to higher efficiency and have less over all losses

V. FAULT DETECTION OPERATION

When studying the closed loop control of the new three-level boost converter, an outer voltage and an internal current controller are used for the fault detection operation. The current controller controls the PWM's duty cycle command,

and the voltage controller serves as a point of reference for the current controller. By changing the service cycle the output voltage must obey the reference voltage. The inductor current is to be estimated for unusual conditions and is used for error detection. When a fault happens with the converter, the current of the inductor can vary from the normal state and this variation in the current of the inductor can be measured and contrasted to the value expected to determine the fault. When the error is higher than the maximum under any fault scenario, the fault detection method can identify the fault is significantly very little than one switching period.

When an open circuit fault occurs the discharges of the inductor and therefore the current decreases, a negative error is found during the comparison and this is used to detect and analyze OCFs.

When a short circuit fault is happened in the circuit or connected load the inductor current increases continuously and so a positive error is observed. That state causes a short circuit path and no current flows through the device, so the output voltage equals zero in that second.

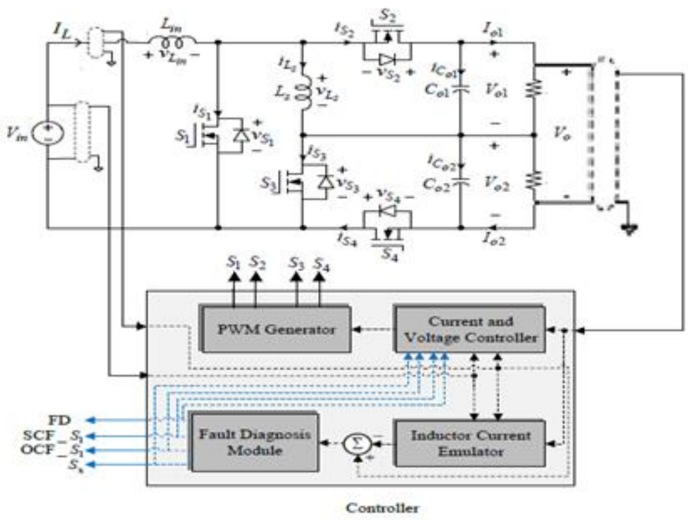

Fig. 9 Proposed Topology

VI. CONCLUSION

It proposes a novel, non-isolated high voltage gain boost converter. The new converter has the following unique features, with the inclusion of an additional inductor (Ls) to the traditional TLB converter. For decreased voltage and current stresses in the circuits, it can achieve higher voltage conversion ratio and performance than the traditional TLB converter.

The switch faults in dc-dc converters are among the most common faults. Being able to identify these faults quickly enough, enables components of circuits to be shielded, resulting in a highly enhanced reliability of converters. This paper presented a novel technique for the diagnosis and identification of faults in open and short circuit switches. The approach utilizes readily available sensor measurements to design the current emulator for the inductor. Specifically the sensor signals used are measurements of inductor current, input and output voltage, because they already exist. In the dc-dc converter, and therefore there is no extra cost to produce them. This form of actual-time fault diagnosis is introduced in a DSP, so no extra hardware is needed. It also offers fault- tolerant activity that enables the converter to be operational after the fault condition. This approach is resilient to typical circuit asymmetry such as differences in load and perturbations in data. It provides an alarm for quick and accurate detection of faults.

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