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# A Stable Control Strategy for Input-Series Output-Series Connected Boost half Bridge DC-DC Converter

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***Abstract***

*Boost half bridge DC-DC converters in the combination of an input-series and output-series (ISOS) connected configuration with a stable control strategy has been investigated in this paper. A stable control strategy comprises of two loops that are current loop and voltage loop. The reference to the current loop has been chosen from the input side of the DC-DC converter. The reference to the voltage loop has been selected from the output side of the DC-DC converter. Such a reference makes the circuit configuration simple, easy and eventually results in reduced cost. The control strategy for input-series output-series (ISOS) configuration of DC-DC converters is proposed to achieve equal input voltage sharing (IVS) as well output voltage sharing (OVS). Furthermore, in this paper, the performance of the stable control strategy for input-series output-series (ISOS) boost half bridge DC-DC converter has been observed not only for the fixed but also for the varying and continuously varying load. The proposed Stable control scheme has been developed by modeling it on MATLAB using Simulink and Simpower toolboxes. The operation of the proposed stable control strategy has been found to be satisfactory.*

***Keywords**: Boost half bridge (BHB) DC-DC Converter, Input current sharing (ICS), Input-series Output-series (ISOS), Input voltage sharing (IVS), Output current sharing (OCS), Output voltage sharing (OVS).*



## 1. Introduction

To realize any input-output specifications of boost half bridge DC-DC converters in power system architecture either in series or parallelcan be connected in any combination both at the input as well as at the outputsides [1]. Input-output combinations can possibly be connected in four different form [2], [3]. Presently one of them is quite well known due to its many applications, the input-parallel, output-series (IPOS) connection; requiring high output voltages [3]. The applications requiring low-voltage and high current outputs uses input parallel, output-parallel (IPOP) combination. Input series output series (ISOS) converters allow appropriate control techniques so as to connect in series for dynamic voltage sharing capability at the input. It has several merits for example utilization of lower voltage MOSFETs [4], [5] and improved transient performance.

This paper introduces a stable control strategy consisting of two loops for ISOS configuration, related to that of ISOP configuration [6], [7], to make sure that input-voltage and output-voltage distribution amongst the converters is shared equally. The ISOS configuration is compatible in applications where high input voltage and output voltage is required mutually. [2], [8].

Multilevel converters have an advantage of using low-voltage rating switches for high voltage applications. Nevertheless, for a large number of diodes or capacitors, system reliability cannot be assured [9]. Both the input and output of the ISOS configuration contains several DC-DC converters connected in series combination. This enables a utilization of low voltage rating MOSFETs with high switching frequency, which leads toward high conversion efficiency [7]. However, control must be taken to make sure equal input voltage distribution among all of the modules for the ISOS DC-DC converters. A small number of control schemes to achieve this purposehave been proposed [10]. One of them was proposed with input voltage and output voltage loop and the other was proposed with an additional current loop with input and output voltage loops [1], [6]. However, both input voltages and input currents have been sensed.

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Three-loop control strategy [11] was applied by means of sensing both input voltages and output currents [12]. The disadvantages of the former control strategy are poor dynamic response and lacks of resistance to load short circuiting. Although using the latter control strategy these disadvantages can be overcome by using inner current tracking loops. It is more complex [10] and not cost effective. Therefore, this paper proposes a very simple IVS and OVS control for ISOS boost half bridge DC-DC converter systems, which does not require changing the voltage references for each converter. Perfect voltage sharing can be achieved by forcing the input voltage between the converters equally, no matter what the total input voltage is. The proposed individual converters consist of boost half bridge DC-DC converters, which have the advantages of no risks of shooting through, automatic voltage spike clamping and demagnetizing through diodes [7].

This paper is structured as follows. The Input series output series mechanism is discussed in section II along with the mathematical representation. The proposed stable control strategy is presented in Section III. Simulation and results are illustrated in Section IV. Representation of results in block diagram has been demonstrated in section V. Conclusions are given in Section VI.

## 2. Input Series and Output-Series Configuration (ISOS)

### 2.1. Circuit Description

Two modules comprising of boost half bridge DC-DC converter are connected in series at the input and output side as shown in figure 1 which is represented as the general block diagram of ISOS configuration.

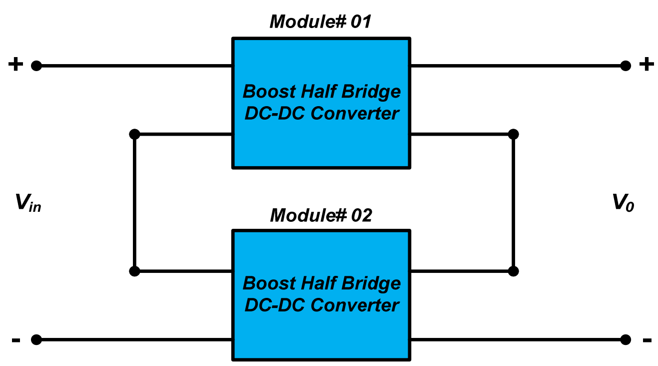


Figure 1. Block diagram of ISOS BHB DC-DC Converter

As shown in figure 2, the ISOS BHB DC-DC converter configuration considered here consists of a DC voltage source $V_{in}$, feeding two boost half bridge DC-DC converters. Each BHB DC-DC converter consists of input inductance and half bridge at the input side of the high frequency transformer whereas voltage doubler rectifier is connected at output of the high frequency transformer. Figure 2 also describes the feasibility of the proposed ISOS system, under steady state using the idea of power balancein presence of varying and continuously varying load. Under steady state condition two converters can have equal average input currents caused by the series combination at the input. In the same way, under steady state condition two converters can have the equal average output currents caused by the series combination at the output. Furthermore if the two converters maintain their input voltages equally by control strategy, subsequently input powers, and as a result, by means of power balance, the output powers of the two converters will be the same. Hence this describes that two converters automatically share the output voltage equivalently.

The isolated high frequency transformers having the turns ratio of 1: N, where the N is equal to 2. Equal duty ratios can be generated for the two converters with the help of control strategy because the converters are identical. The configuration of ISOS boost half bridge DC-DC converter is not only made for the fixed but also for varying and continuously varying load, inspite of which the input and output of the converters share equal voltages. This applies to converters working under current mode control plus voltage mode control, besides it can furthermore be expanded to several number of converters connected in series.

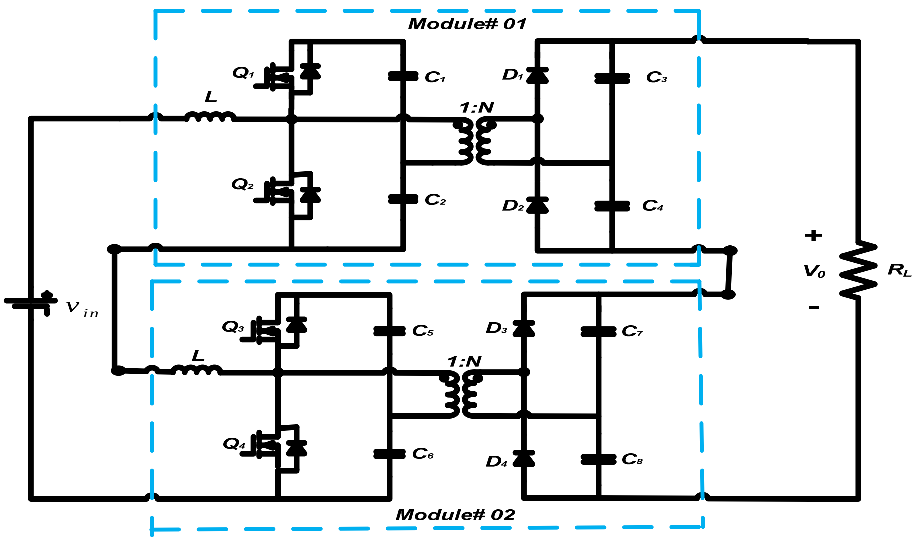


Figure 2. Schematic diagram of ISOS BHB DC-DC Converter

### 2.2. Mathematical Representation

Figure 2 shows schematic of ISOS converter made up of two boost half bridge DC-DC converters. The total input voltage $V_{in}$ is divided into $V_{in_1}$ and $V_{in_2}$ across each converter module respectively. Thus we get the voltages for each converter module working as individual input. Hence total input voltage $V_{in}$, described as Input voltage sharing (IVS) for two boost half bridge DC-DC converters for ISOS configuration and can be describe as:

$$V_{in} = V_{in_1} + V_{in_2} \tag{1}$$

The two converter modules are considered to be identical, therefore it is obvious that the input voltage sharing (IVS) for two boost half bridge DC-DC converters can be represented as:

$$V_{in_1} = V_{in_2} \tag{2}$$

However, satisfying (2) is our basic control objective. This objective has not only been considered for the fixed but also for varying and continuously varying load. Once the voltage across the input side is equal consequently the voltage across the output will be equal. Hence the voltage sharing between the input and output can be obtained.

## 3. Proposed Stable Control Strategy

The control strategy of conventional DC-DC converter is designed in a sophisticated way. The proposed stable control strategy for ISOS BHB DC-DC converter is illustrated in Figure 3.

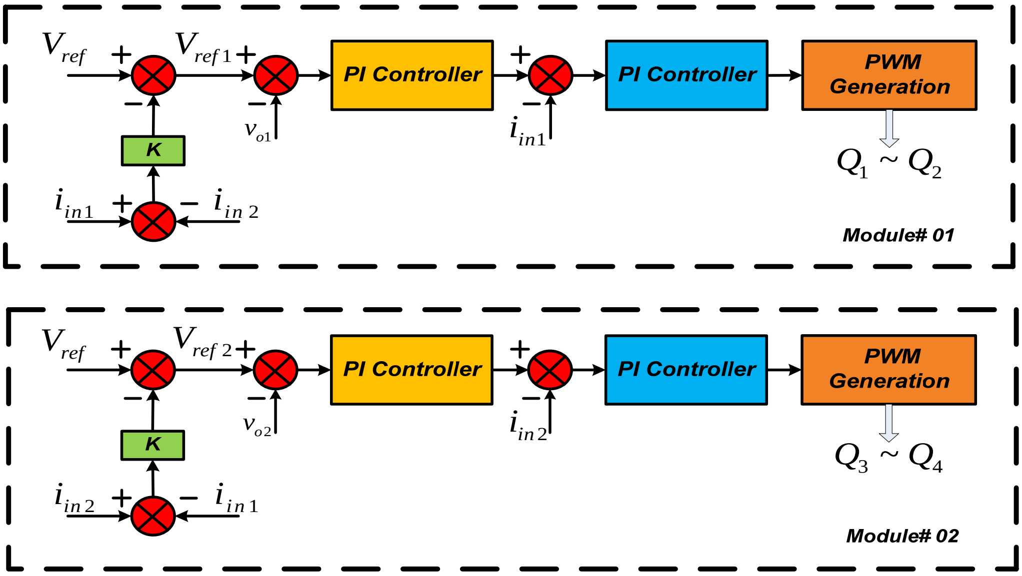


Figure 3. Proposed Stable Control Strategy

Proposed stable control strategy contains two loops that are voltage loop and current loop. Consequently with the help of above said loops the controlblock can achieve equal IVS and equal OVS simultaneously

## 4. Simulations and Results

The two boost half bridge DC-DC converters with ISOS configuration was simulated along with proposed stable control strategy. The specifications for the simulated model are represented in Table 1. In order to show efficient performance of proposed stable control strategy for ISOS configuration of the two converters was not only simulated for fixed but also for varying and continuously varying load. Therefore the simulation results are classified into three different sections.

Table 1. Specifications

| Parameters | Value | Parameters | Value |
|---|---|---|---|
| Input voltage | 50V | Output voltage | 100V |
| Input Inductance | 200μH | Output capacitance | 8μF |
| Input Capacitance | 10μF | Fixed load | 50 Ohms |
| Switching frequency | 20KHz | Varying load | 25-50 Ohms |

### 4.1 Simulation Results for Fixed Load

Figure 4, in general, is representing the equal output voltage sharing (OVS), input current sharing and output current sharing, and the load voltage. Figure 4 is classified from 4.1 to 4.4. Figure 4.1 is representing the input current, figure 4.2 shows the output current, figure 4.3 indicates output voltage sharing (OVS) on each module respectively and figure 4.4 illustrates the load voltage.

### 4.2 Simulation Results for Varying Load

The simulation results for varying load are shown in Figure 5. When load is varying the input current values change from 4A to 8A and consequently the values of output currents also change but the voltages remain constant. Figure 5 is classified from 5.1 to 5.4. Figure 5.1 is representing the input current, Figure 5.2 shows the output current, Figure 5.3 indicates output voltage sharing (OVS) on each module respectively and Figure 5.4 illustrates the load voltage.

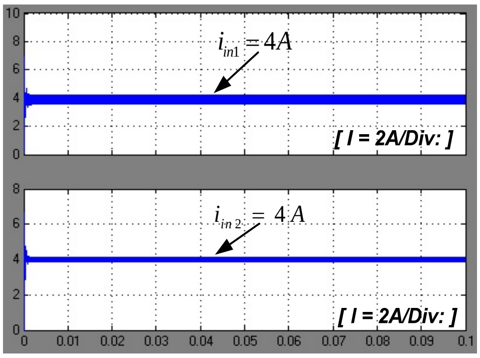


Fig. 4.1 Input Current

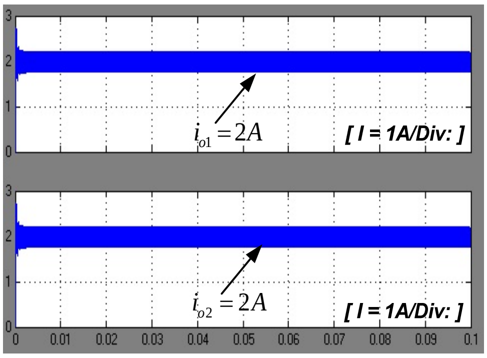


Fig. 4.2 Output Current

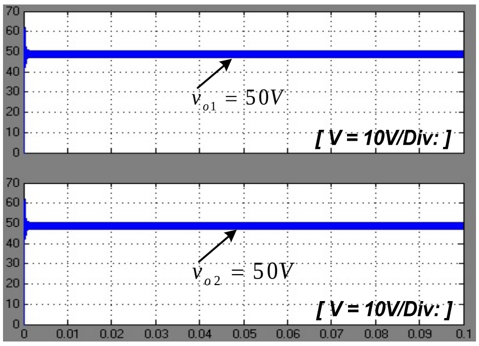


Fig. 4.3 Output Voltage

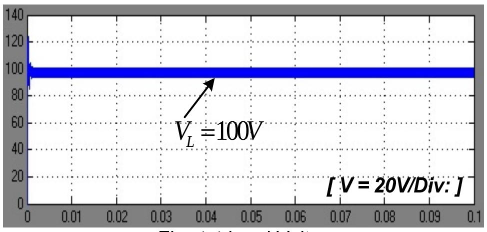


Fig. 4.4 Load Voltage

Figure 4. Representing the equal output voltage sharing (OVS), input current sharing and output current sharing, and the load voltage

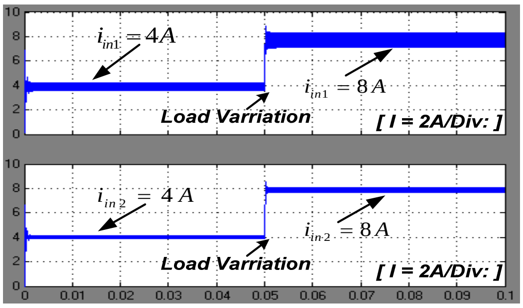


Fig. 5.1 Input Current

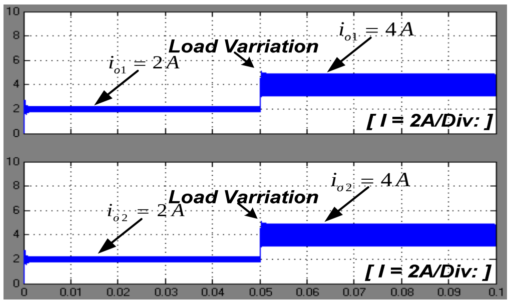


Fig. 5.2 Output Current

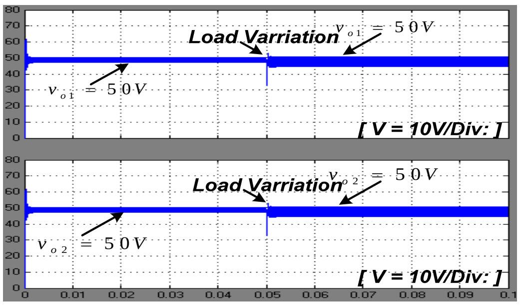


Fig. 5.3 Output Voltage

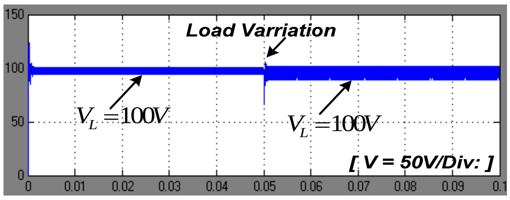


Fig. 5.4 Load Voltage

Figure 5. The simulation results for varying load are shown

### 4.3. Simulation Results for Continuously Varying Load

The simulation results described in Figure 6 illustrate the continuous load variation due to which the input current varies from 8A (half of the full load) to 4A (full load) and again goes to

8A, as the result the output current changes accordingly, but the voltages remain constant. Figure 6 is classified from 6.1 to 6.4. Figure 6.1 is representing the input current, Figure 6.2 shows the output current, Figure 6.3 indicates outputvoltage sharing (OVS) on each module respectively and Figure 6.4 illustrates the load voltage.

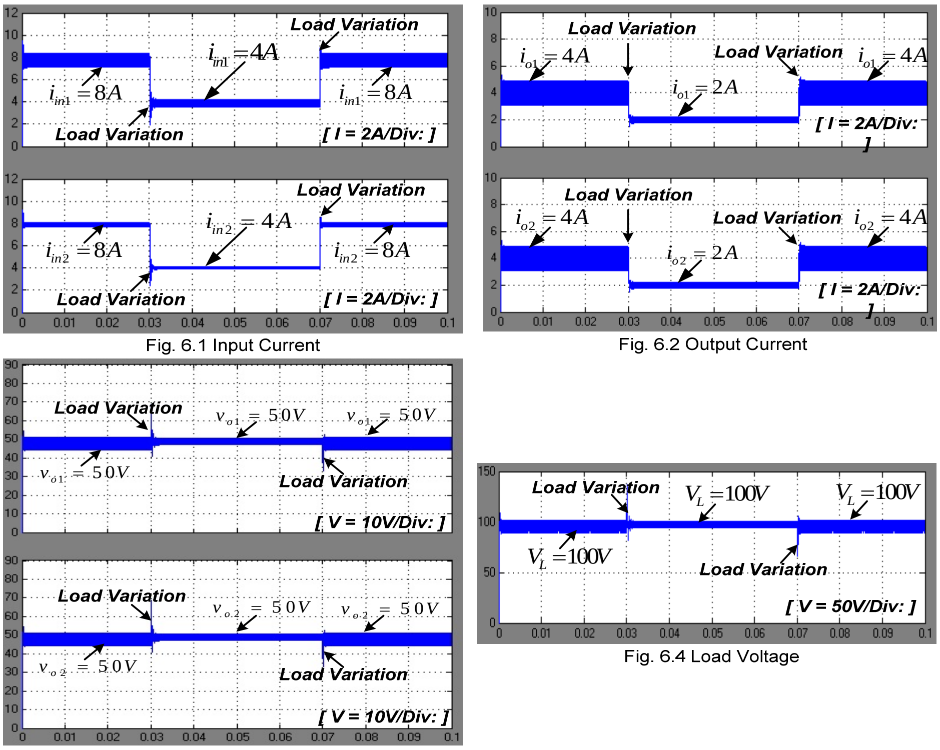


Fig. 6.1 Input Current

Fig. 6.2 Output Current

Fig. 6.3 Output Voltage

Fig. 6.4 Load Voltage

Figure 6. Ilustrating of the continuous load variation

## 5. Representation of Results

The results of ISOS BHB DC-DC converter configuration obtained above can be demonstrated below by considering the block diagram of Figure 1. As described in Table. 1 the load can be varied by 25Ω (half of the full load) to 50Ω (full load), therefore Figure 7 shows the block of ISOS configuration with results at full load ($R_L$=50Ω) and Figure 8 indicates the block diagram of ISOS configuration with results at half load ($R_L$=25Ω).

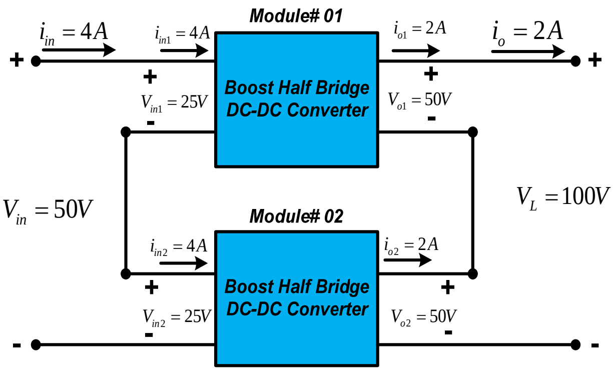


Figure 7. Block diagram of ISOS configuration with results at full load ($R_L$=50Ω)

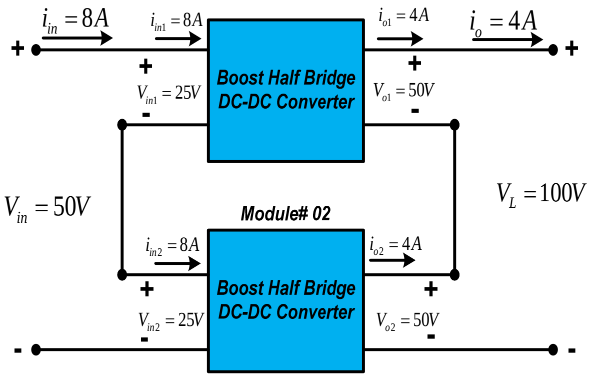


Figure 8. Block diagram of ISOS configuration with results at half load ($R_L$=25Ω)

## 6. Conclusion

A stable control strategy along with the configuration of ISOS connection of boost half bridge DC-DC converters proposed here described that under steady state conditionequal IVS and OVS can be obtained. The proposed Stable controlscheme is verified for fixed load, varying load and continuously varying load for the ISOS connected boost half bridge DC-DC converters. Proportional Integral controller with PWM is enough for the current loop and voltage loop to maintain the IVS and OVS equally. The stable control strategy has been confirmed through simulation and results are presented. Although two converters system has been concentrated in this paper, the design and analysis techniques are applicable for any number of series connected converters

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