Modular Dc-Dc Converter In Input Series Output Parallel Configuration

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Abstract. Series–parallel dc/dc conversion systems have been drawing more attention in recent years and are widely used in various applications. Input Series Output Parallel (ISOP) multiple dc-dc conversion systems can be used in applications where the input voltage is relatively high and the output voltage is relatively low, such as in high-speed train power systems, industrial drives, and undersea observatories[1].The proposed control strategy using equal rating dc-dc converter modules that can be connected in series at the input side for higher input voltages and in parallel at the output side for higher output currents. The proposed control scheme is a closed loop control scheme with common duty ratio for all the converter modules. The common duty ratio pulse is given to all converters in series to achieve Input Voltage Sharing (IVS) and Output Current Sharing (OCS).The thesis presents the design, analysis and hardware implementation of two forward converters in ISOP configuration. The performance of the proposed system is evaluated using Matlab7.9.0 (R2009b)-Simulink environment. The verification of input voltage sharing and output current sharing by changing the converter module parameters using simulink is also presented. The gate pulses for two converter modules are generated using microchip controller PIC16F877A. The hardware has been tested by supplying 30V input with a load of 43Ω, 2.8A in both open loop and closed loop manner.

Keywords: ISOP configuration, dc-dc converters, Input Voltage Sharing (IVS), Output Current Sharing (OCS)

I. INTRODUCTION

Modular approach of dc/dc conversion system leads to a significant improvement in the reliability of the overall system. The manufacturing time and cost of such system can be reduced by the standardization of components. Using this high current power-supply requirement can be met with low-current converters that are easier to design. By suitably interleaving the converter modules, the filter requirements can be reduced leading to a higher power density and possibly higher efficiency of the overall system[6].

In Input Series Output Parallel (ISOP) modular dc-dc converters, input of the converter modules are connected in series and outputs connected in parallel. It should require Input Voltage Sharing (IVS) and Output Current Sharing (OCS). The input-series connection has many other advantages [1].

a) Enables use of Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) with low voltage rating, which are optimized for very low $R_{DSON,}$ leading to higher efficiency [6].

b) MOSFETs can be used instead of Insulated Gate Bipolar Transistors (IGBTs) for high input-voltage applications. Hence, switching frequency, and therefore, power density of such systems can be increased[6].

c) Input-series and output-parallel connection leads to smaller conversion ratios for the individual converters especially for the popular low output voltage applications .This leads to more efficient power conversion[6].

The proposed control scheme is a closed loop control scheme having common duty ratio for the two converters connected with input series and output parallel. In this control technique a single output-voltage loop generates the current reference for the inner current loop of the second converter. A peak or average mode current controller in the second converter generates a suitable duty ratio d which is made common for the two converters, such that the output inductor current equals the reference current. If the interleaving of the converters is not required, then the actual gate switching signal with suitable isolation can be made common to the converters. If interleaving is desired, then the duty-ratio signal can be shared, which will then be compared with suitably phase- shifted ramp signals in the individual converters to generate the individual gate drive.

II. OBJECTIVE

The common duty ratio control scheme for ISOP configuration with two forward converters in open loop and closed loop is verified for both R and RL load. It helps to overcome the drawbacks of conventional control schemes improper sharing of input voltage and output current, complexity in design of conventional converter configuration. Hardware implementation and simulation of the converter configuration with the common duty ratio control scheme is obtained.

2.1 Control Scheme

A simple control method to achieve active sharing of input voltage and load current among modular converters that are connected in series at the input and in parallel at the output. The input-series connection enables a fully modular power-system architecture, where low voltage and low power modules can be connected in any combination at the input and/or at the output, to realize any given specifications. This scheme does not require a input-voltage or output-current share controller. It relies on self-correcting characteristic of the ISOP connection when the duty ratio of all the converters is the same.

The self correcting mechanism of the proposed scheme results in stable operation of the system even in the presence of mismatches in input and output capacitors, output inductor values and turns ratio.

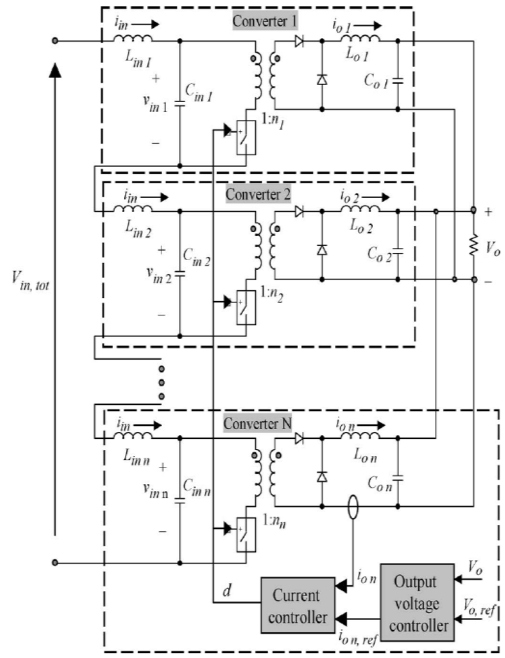

Fig 1. Proposed ISOP configuration with common-duty-ratio scheme with N converters

III. SIMULATION RESULTS

Simulation is the initial step for proving any concept in a modeled system, avoiding practical risk included in the real hardware implementation. MATLAB from math works Inc. is one of the mostly used simulation packages. This has become widely used software package in academic and industries for modeling and simulating dynamic systems. It includes block sets specific for power systems, control systems, mechanical systems and mathematical systems. Simpower system is the toolbox used for simulation of power systems. It includes vast library of all the elements, machines, voltage sources, measurement and power electronic components used in any power system. It also includes a large collection of demos on the state-of-the-art technique used in power systems.

3.1 Design Parameters of Closed Loop (200-48) V Multiple Forward Converter in ISOP Configuration with R Load

Input Voltage :200V
Output Voltage:48V
Switching frequency:200KHz
Duty ratio:31.4%
Inductance:0.0495mH
Capacitance:6.496µF
Load:5Ω

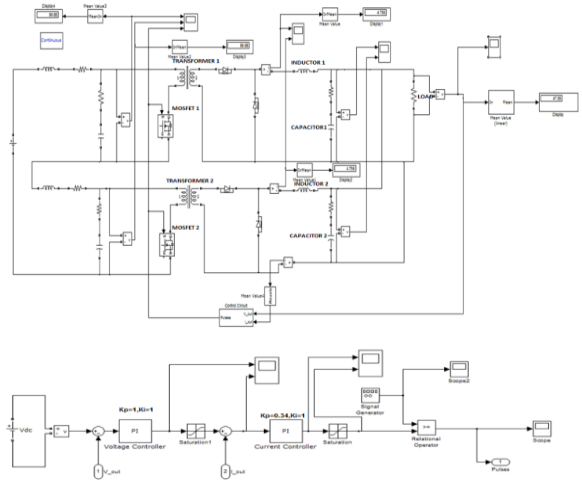

Fig 2. Simulation circuit of closed loop multiple forward converter in ISOP configuration with R load

Likewise design of multiple forward converter in ISOP configuration with different output capacitor values, inductor values and turn ratios were done with R load. The consolidated results for R load are given in a table.

Table 1. Consolidated Results-R Load

Sl no	Input Voltage (V)	Input Capacitor value (µF)		Turns ratio		Output Capacitor value (µF)		Output Inductor value(mH)		Input Voltage Sharing (V)		Output Current sharing (A)		Output Voltage (V)
		Cin1	Cin2	TR1	TR2	Cout1	Cout2	L1	L2	Vin1	Vin2	Io1	Io2	Vout
1	200	66	66	153/100	153/100	6.496	6.496	.0495	.0495	99.88	99.88	4.76	4.76	47.62
2	200	66	132	153/100	153/100	6.496	6.496	.0495	.0495	100.3	99.41	4.78	4.78	47.81
3	200	66	66	153/100	153/100	6.496	12.992	.0495	.0495	100.3	99.41	4.78	4.78	47.81
4	200	66	66	153/100	153/100	6.496	6.496	.0495	.099	100.3	99.41	4.78	4.79	47.81
5	200	66	66	153/100	200/100	6.496	6.496	.0495	.0495	115.4	84.44	4.59	3.35	39.71

3.2 Design Parameters Of Closed Loop (200-48) V Multiple Forward Converter In ISOP Configuration With RL Load

Input Voltage :200V
Output Voltage:48V

Switching frequency:200KHz
Duty ratio:31.4%
Inductance:0.0495mH
Capacitance:6.496µF
Load:R=5Ω,L=200mH

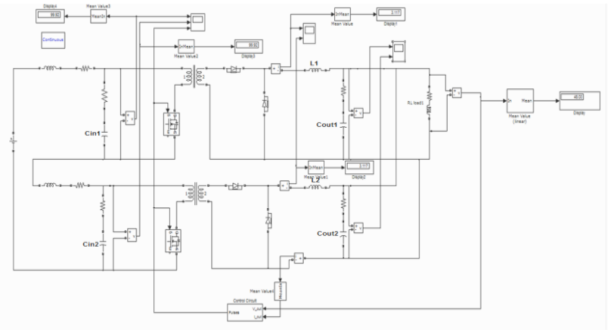

Fig 3. Simulation circuit of closed loop multiple forward converter in ISOP configuration with RL load

Likewise design of multiple forward converter in ISOP configuration with different output capacitor values, inductor values and turn ratios were done with RL load. The consolidated results for RL load are given in a table.

Table 2. Consolidated Results-RL Load

Sl no	Input Voltage (V)	Input Capacitor value (µF)		Turns ratio		Output Capacitor value (µF)		Output Inductor value (mH)		Input Voltage Sharing (V)		Output Current sharing (A)		Output Voltage (V)
		Cin1	Cin2	TR1	TR2	Cout1	Cout2	L1	L2	Vin1	Vin2	Io1	Io2	Vout
1	200	66	66	153/100	153/100	6.496	6.496	.0495	.0495	99.91	99.91	3.49	3.49	47.93
2	200	66	132	153/100	153/100	6.496	6.496	.0495	.0495	99.91	99.91	3.49	3.49	47.93
3	200	66	66	153/100	153/100	6.496	12.992	.0495	.0495	99.92	99.92	3.12	3.12	48.04
4	200	66	66	153/100	153/100	6.496	6.496	.0495	.099	99.91	99.92	3.06	3.07	48.04
5	200	66	66	153/100	200/100	6.496	6.496	.0495	.0495	112.9	86.88	4.05	3.03	54.30

IV. HARDWARE IMPLEMENTATION

Input Series Output Parallel (ISOP) multiple dc-dc Conversion systems can be used in applications where the input voltage is relatively high and the output voltage is relatively low. ISOP converter consisting of two converter modules is explained in this paper. Hardware implementation is done for the open loop and closed loop. The converter is implemented for the proposed control scheme. The switching frequency of the converter is 200 kHz and the switching device is MOSFET IRF640.

4.1 Multiple DC-DC Converter In ISOP Configuration with Open Loop

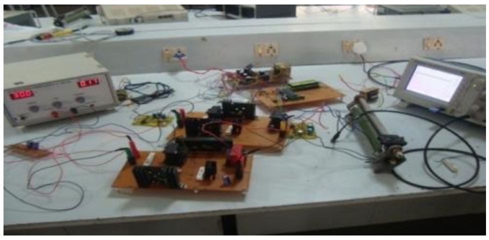

Fig 4. Hardware setup of multiple dc-dc converter in ISOP configuration with open loop

4.2 Waveforms Obtained

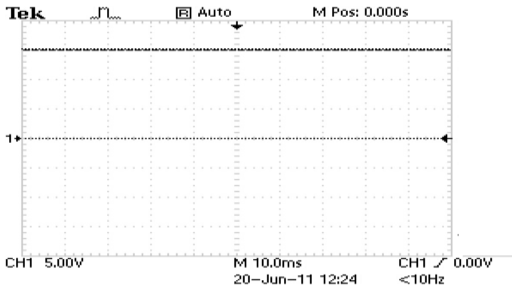

Fig 5. Input voltage of first converter

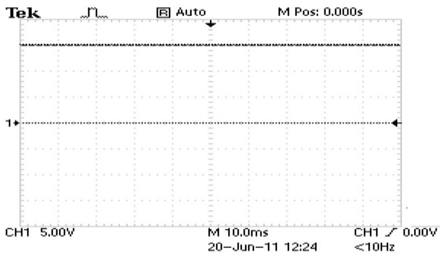

Fig 6. Input voltage of second converter

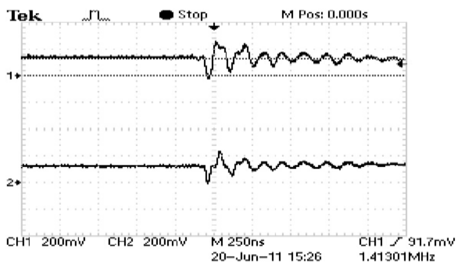

Fig 7. Output current of first and second converters

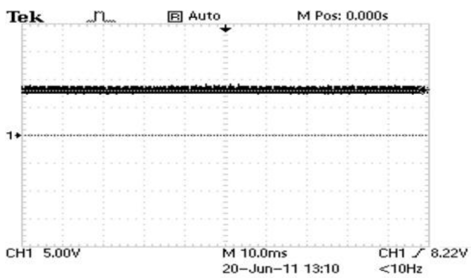

Fig 8 Output voltage

4.3 Output Obtained From Multiple DC-DC Converter in ISOP Configuration with Open Loop

Input voltage	30V
Input voltage of first converter	15.2V
Input voltage of second converter	14.8V
Output current of first converter	122mA
Ouput current of second converter	128mA
Output voltage	7.56V

4.4 Multiple Dc-Dc Converter In Isop Configuration With Closed Loop

Fig 8. Hardware setup of multiple dc-dc converter in ISOP configuration with closed loop

4.5 Waveforms Obtained

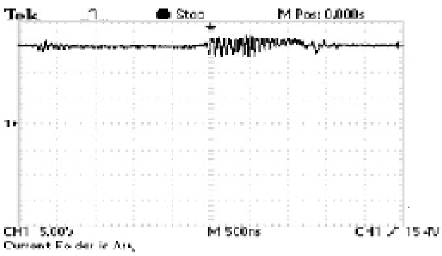

Fig 9. Input voltage of first converter

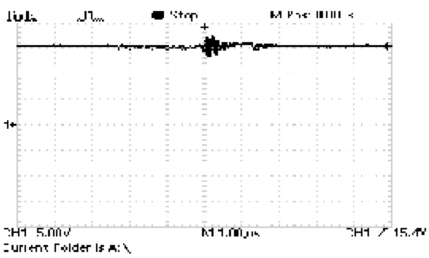

Fig 10. Input voltage of second converter

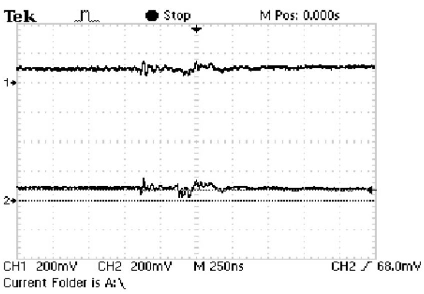

Fig 11. Output current of first and second converters

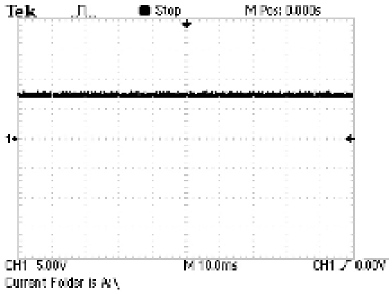

Fig 12. Output voltage

4.6 Output Obtained from Multiple DC-DC Converter in ISOP Configuration with Closed Loop

Input voltage	30V
Input voltage of first converter	14.48V
Input voltage of second converter	14.95V
Output current of first converter	81.2mA
Output current of second converter	90.4mA
Output voltage	7.13V

V. CONCLUSIONS

A complete study of modular dc-dc converters was done through literature survey. Different control techniques were studied and the study revealed that Common duty ratio is the best among them. Simulation for open loop dc-dc single forward converter and dc-dc modular forward converter with ISOP configuration was done. Completed the simulation for closed loop dc-dc modular forward converter with ISOP configuration by R and RL load and checked whether any variation for input voltage and output current sharing for various input and output parameters. Hardware implementation of forward converter in ISOP configuration was done with open loop and closed loop and the output verified. The output shows equal sharing of input voltage and output current when multiple forward converter connected its input series and output parallel.

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