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A Comparative Study on Multiport DC-DC Converter for Satellite Application

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***Abstract*— High power density and high voltage step up ratio is most desirable characteristics for any converters when the application is satellite we require alternate energy source for continuity of power transfer, but for this purpose two converters are required. Instead of that by making modification in the conventional converters a single compact unit can be made available to achieve the objective. In this paper we are discussing multiport DC-DC converter which are derived from the conventional converters and by providing the comparative analysis the conclusion provided to be achieved on the basis of requirement.**

***Keywords*— satellite, DC-DC converter, high voltage step up ratio, pulse width modulator, full bridge DC-DC converter**

I. Introduction

In past few decades more and more researches are diverted towards satellite application in view of better communication for entertainment, ecology, environmental study, defense etc.

The satellite is now having so many application and auxiliary which run through electric power while in space the only source which is available can be solar. But for better reliability we have to depend upon alternate energy sources such as battery bank, super capacitors etc.

Nowadays battery bank can be considered as the best alternative for solar application. When we are dealing with solar and battery work so, two conventional converters are required one of them can be unidirectional and the other may be bidirectional to have bidirectional power transfer with load and battery.

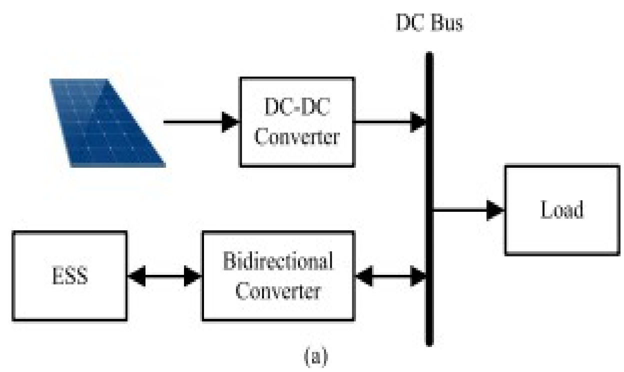

Figure-1: conventional PV and Load connection with Battery

If the convectional way is used then it requires two converters with different control scheme for each that make the system more bulky and large. Nowadays more research are taken place to achieve less space consuming, compact, highly efficient with high step up ratio and should have high power handling capability. So, the researchers are trying to develop different topology which is derived from the conventional topology by keeping the characteristics remains constant.

II. Literature Survey

In this paper the control strategy and power management for an integrated three-port converter, which interfaces one solar input port, one bidirectional battery port, and an isolated output port. Multimode operations and multi-loop designs are vital for such multiport converters [1].

Figure-2 shows the Half bridge topology of the DC-DC converter which is modified to accommodate the battery and PV module to ensure the power transfer from PV to Load, Battery to Load and PV to Battery.

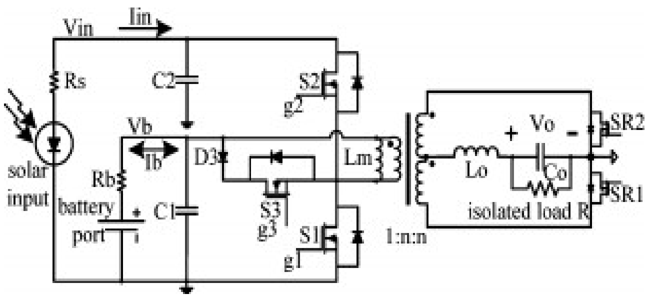

Figure-2: Three Port Half Bridge modified DC-DC Converter

Fig. shows the modified Half Bridge three port converter which consists of three main switches S1, S2 and S3 working in the synchronous rectification mode to achieve ZVS operation [8]. There are only to control variables d1 and d2 for switches S1& S2 respectively and the third port is employed to have power balance. In this converter the C1 and C2 provided for the Battery and PV module are sufficiently large enough to ensure that at steady state the voltage of battery should be constant. A three winding high frequency transformer is employed to connect the source and the load. The magnetizing inductance of the transformer is lumped at the primary side of the converter.

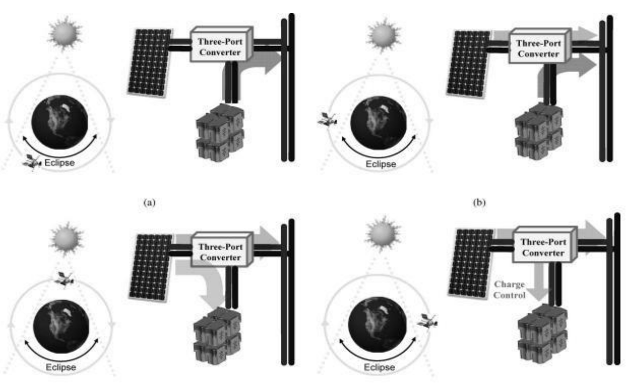

Figure-3: Operational working of the converter

In stage I there is no isolation received hence the battery behaves as the primary source and during this period the battery state of charge is reduced.

In stage II which shows the initial isolation period, the power generation by PV module is not sufficient to supply the load, hence during this period the PV and Battery fulfil the load requirement. During this period the battery state of charge also gets reduced.

In stage III the full isolation received by the PV module. Power generation by the PV module is sufficient to supply the load and charge the battery. During this period the battery state of charge is increased.

is equivalent to stage II in which the battery and PV module cater the load. In this mode of operation battery charge control is provided to prevent the overcharging the battery which in turn increases the battery life.

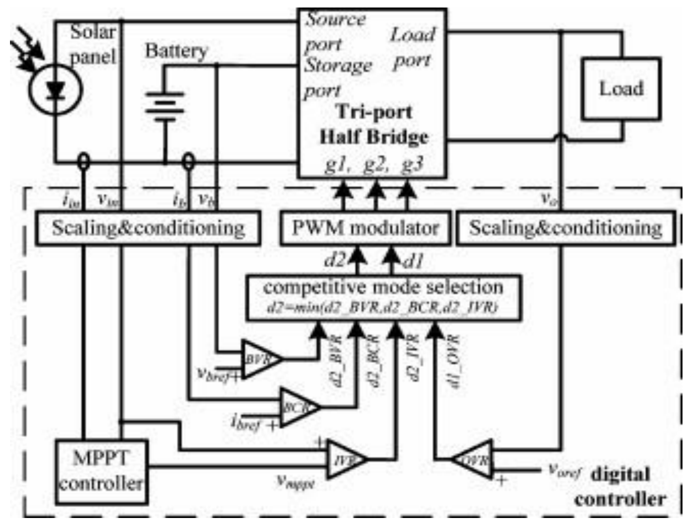

Figure-4: Control Scheme of the Converter

The figure shows the simplified view of the control scheme of the given DC-DC converter. In which all the parameters are measured and scaled as to match with the reference value to generate required output. The output of the comparator of the control scheme will behave as the gate pulse generator while following the required PWM.

The duty cycle of the switches which are employed in the converter will be decided with the help of competitive mode selection. This block is employed to ensure the modes of operation such as day time operation, night time operation and no load operation.

The output of the particular block can be the key element to decide the duty cycle of the converter.

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In this figure the modified and derived topology from the Boost converter is employed to achieve the required objective while keeping the operational principle of the Boost converter as its conventional way.

In this paper DC -DC converters of single input and multiple outputs (SIMO), without a transformer, with a single power switch, and therefore a single control circuit, which results in a smaller size, lower weight and simplicity compared to other known SIMO DC–DC configurations. In a novel form, it comprises at least two converters which share the DC source, an inductor and the power switch. This is obtained by the combination of basic converters: step-down (buck), step-up (boost) and step-down/step-up (buck–boost).

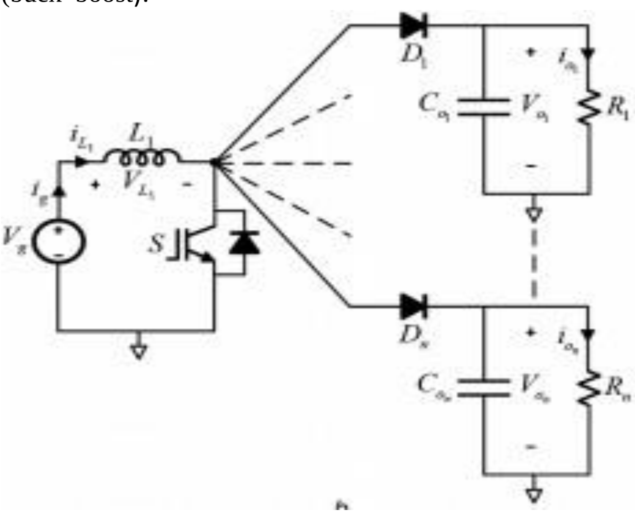

Figure-5: A modified Boost converter (n-Type)

Fig. 6 shows an SIMO converter, step-up and n outputs, which is obtained from a basic configuration of a boost converter. In this case, the common input to each output is composed of an inductor (L1) and a power switch (S) connected to the reference node. The common connection node is located between the inductor and the switch. The diode of each output (D1… Dn) is connected to this node.

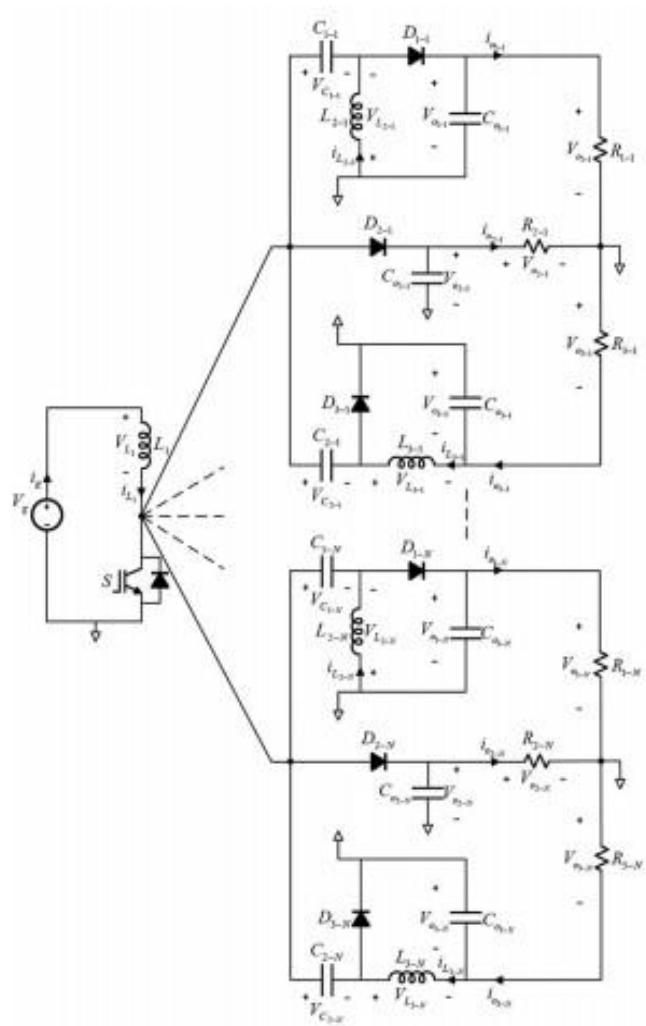

Figure-6: n-Type SEPIC converter for Bidirectional Operation

The Figure shows the SEPIC derived n-Type DC-DC converter to achieve the bidirectional power flow form PV to Load, from PV to Battery, and from Battery to Load depending upon the atmospheric condition.

So, in this paper at the end SEPIC-Boost-Cuk combination converter with six loads is done from which the proposed converters are characterised by having a single power switch andnot requiring a transformer. So, it results in a smaller size, lower weight and simplicity compared to other known SIMO DC–DC configurations.

In this paper the design and implementation of a power system for artificial satellites based on photovoltaic power conversion. Batteries are used as auxiliary power supply during eventual eclipses. The Shunt Switched Sequential Regulator (S3R) processes, conditions and regulates the generated electric power based on Direct Energy Transfer (DET) architecture in order to adapt it to the necessities of the payload and batteries.

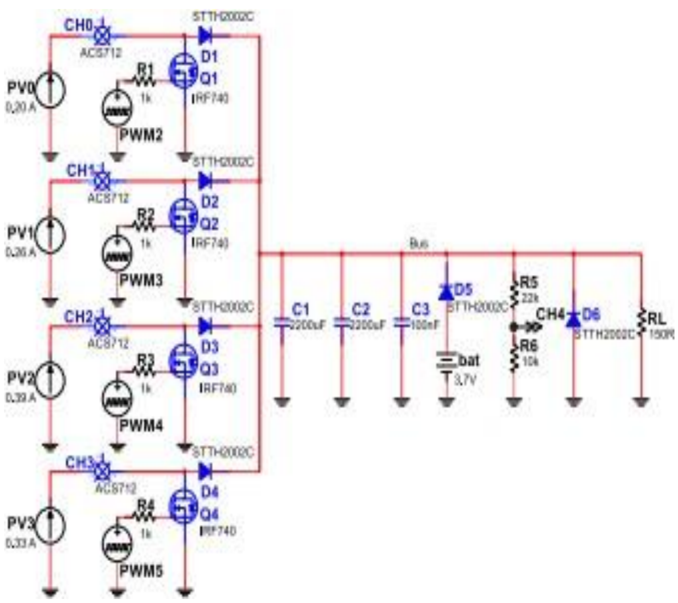

Figure-6: Cuk derived DC-DC converter for bidirectional power Transfer

The Figure shows the Cuk derived DC-DC converter for bidirectional power flow, the following converter can be considered as the alternate option for the SEPIC derived converter. The operating principle, control scheme and working remain same

Fig. consists of two input inductors, L1 and L2, an ac inductor Lac, four power MOSFETsM1 ~ M4, and a high frequency transformer with a turn ratio of 1: n. The ac inductor, whichis the sum of the leakage inductance and the auxiliary inductance, is the power interface element between primary and secondary sides of the transformer.

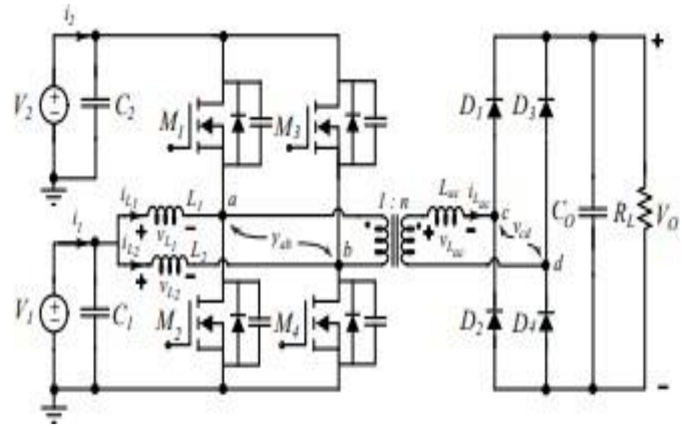

Figure-7 : Flyback-Forward topology derived DC-DC converter for Satelite Application

Switches M1, M2 and M3, M4 are driven with complementary gate signals with a dead band. V1 and V2 represent the input voltages; iL1 and iL2 are defined as the input inductor currents; vab is the voltage between the midpoints of the bidirectional interleaved boost switching legs, and iLac is the current of the secondary side winding.

In order to decouple the two inputs, V1 and V2, and regulate the output voltage accurately, both the duty cycle and the phase-shift angle are adopted as the control variables simultaneously. The duty cycle of the power switches is used to adjust the power among the two independent sources, and the phase-shift angle between the midpoints of the full bridge is employed to regulate the power flow to the output port.

The completely demagnetized operation mode, the partially and fully magnetized operation modes can be analysed by describing the converter operation intervals. By solving the equation relating the average of the rectified inductor current and the load current (VO/RL), the output voltage of the converter operating in partially magnetized operation mode can be obtained.

So, In order to control the power flow between the different ports, a duty cycle and phase- shift control scheme is adopted. The duty cycle is used to control the power flow between the two independent sources, whereas the phase-shift angle is employed to regulate the output voltage. The state-space modeling and control of the proposed TPC operating in completely demagnetized and fully magnetized mode is presented.

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To ensure the integrity of all the converters they are simulated in the MATLAB environment. The voltage input of the converter is made compatible to the battery ratings and resistive load is connected at the output port and based on the results a table formed to show the comparative analysis.

The performance of all the converters with different topologies is operated in same environmental condition and same operating point. The watt ratings of all the converters kept same so that the comparison can be made easier.

A 200 watt converter is designed in MATLAB/simulink platform with proper calculation of all the parameters. And same way the Day time operation, Night time operation and No-load Operation is operated with same operating condition and therefore various parameters we will have for the comparative Analysis.

III. Comparative Analysis

Sr No.	**Parameters**	**Topology -1**	**Topology -2**	**Topology -3**	**Topology -4**
1	Efficiency	Low	High	High	High
2	Step Up Ratio	Low	Low	High	High
3	Galvanic Isolation	Yes	Yes	Yes	Yes
4	Component Count	High	Low	Moderate	Low
5	Overall Mass	High	High	High	Low
6	Conversion Stages	One	Two	One	Two
7	Control Scheme	Complex	Complex	Moderate	Simple
8	Control Variable	High	High	High	High

IV. Conclusion

In this paper a comparative analysis of DC-DC converters which are derived from the conventional DC-DC Converters is discussed on various parameters such as galvanic isolation, High step up ratio, Efficiency, cost effectiveness, compactness etc. for making the comparative analysis, we have simulated all the converters on the MATLAB/simulink platform at same operating points and with same capacity of converter. and thus we found the results that the topology-4 can be found as the best suitable DC-DC converter for the satellite application as it is comprising of all the properties which are desired for the same application.

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