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Study On Battery Integrated Multiple Input DC-DC Boost Converter

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Abstract:

In the context of a sustainable hybrid energy supply, this research provides a battery-integrated multi-input step-up DC-DC as a unified interface for diverse energy sources. The proposed converter has one bidirectional battery port and numerous unidirectional power input ports. While charging/discharging durations are independent of switching duty ratios for input sources, the battery can be charged by input sources, discharged into load, or bypassed. Higher voltage gains with lower duty ratios are accomplished in the given BIMISUC not only by increasing the number of inputs but also by using switched inductor (SI) modules. As a result, BI-MISUC can be utilised for a wide range of applications ranging from low to high voltage/power.In addition, input sources can be run independently or concurrently to supply load energy at the required output voltage. The operation of the converter is explained under three circumstances (no battery, battery charging and discharging). For various cases, a linear quadratic regulator (LQR) control is also utilised to regulate the output voltage and output power of input sources at the appropriate references. Finally, simulation and experimental findings support the BI-MISUC's performance.

Keywords — **DC-DC converter, Interleaved, Multiple input, Renewable energy, Voltage multiplier.**

INTRODUCTION:

Concerns about using sustainable and clean energy sources for power generation stem from environmental degradation and the expected depletion of fossil resources. The search for sustainable energy resources has spilled over into the transportation sector. Electric automobiles are predicted to completely replace petrol or diesel-powered vehicles in the near future in order to reduce pollution. Renewable energy (RE) sources such as fuel cells (FC), wind turbines, and photovoltaic (PV) cells have recently been used in hybrid electric vehicles, microgrids, traffic lights, and telecommunication/satellite systems. [1]

Because the development of societies around the world is closely related to their energy consumption, developing societies indicate an increasing demand for energy. The current environmental concerns and non-sustainability in the use of non-renewable resources make energy generation through the consumption of fossil fuels less and less feasible, and this is how the abolition of dangerous energy generation methods is becoming a contemporary requirement around the world.

Alternatives to fossil fuels include non-polluting renewable energy sources found in nature, such as solar, hydropower, and wind. As a result, they have emerged as the most promising technique of power generation in the globe for meeting current electricity demand.However, despite the numerous benefits that their use represents, there are certain factors to consider, such as the fact that these sources are not continuously available, and they are unstable and discontinuous due to weather conditions; for this reason, hybrid systems are a suitable option, for which the use of power electronics interfaces has become essential, thus developing numerous converter topologies. Hybrid renewable energy systems are often implemented by combining different renewable energy generation sources to create a high-quality energy generation system that is self-sufficient, efficient, and robust.These systems are made up of various input power sources that are integrated via multi-input power electronics converters that can accommodate a variety of input sources and combine their benefits to provide controlled output for a variety of applications (multiple input, single output (MISO) DC-DC converters). Because of their ability to stabilise voltage output during intermittent conditions, converters are the most important component of any hybrid renewable energy system. [2]

Multiple input, single output (MISO) DC-DC converters are classified into two categories:

(a) Isolated Converters

(b) Non-isolated Converters

(a)Isolated converters:

It isolates the low-voltage DC side from the high-voltage side to avoid electric shock, achieves high-voltage conversion, equalises the voltage, and bypasses semiconductor devices with high current/voltage ratings by employing high-frequency transformers. The disadvantage of this system is that it must include a transformer core, which makes it bulky and increases the cost.

(b) Non-isolated converters:

They have a basic design and are utilised when galvanic isolation between the load and the source is not required. Non-isolated converters can match the source's input impedance and the load's output impedance, but they cannot achieve a high voltage conversion ratio. Power quality in renewable energy systems is heavily reliant on the stable operation of the power converter; yet, as previously stated, most conventional converters and control strategies have significant shortcomings that overshadow their usefulness. Thus, improved multiple input, single output (MISO) DC-DC converter design and more effective control approaches are critical in renewable energy generation.

A battery integrated interleaved multiple input DC-DC boost converter is proposed in this paper.The current state of the art demonstrates the necessity to incorporate more RE sources while also achieving higher output voltage. The suggested converter can connect two renewable energy sources and an energy storage device. The converter can lower inductor current while also providing a large step up in input voltage.

CONVERTER TOPOLOGY:

The proposed converter topology, as well as the operation modes and circuit analysis, are presented. Figure 1 depicts the proposed structure. The converter is divided into three separate components. The input section, the interleaving section, and the virtual machine section. The input section has three inputsources, $V1$, $V2$and $Vb$$V1$and $V2$are unidirectional ports. $Vb$is a bidirectional port hence it is ideal forconnection to a storage element. The converter has $n + 3$ power switches. A pulsating voltage source cell(PVSC)isformed by V1,switch S1and diodeD1.Two additionalPVSCsareformed byV_2, S_2, $D_2$and V_b, S_3,D_3respectively.ControloftheunidirectionalportsV_1 andV_2canbedonebymanipulatingthedutyratios,d_1 and $d2$, of switches $S1$and $S2$. Switches $S3$and $S4$facilitates the bidirectional capability of Vb. Batterydischarging can be done by controlling the duty ratio $d_2$of S_3while the duty ratio $d_4$of switch S_4controlledthechargingofthebattery.Intheinterleavingsection,inductors,L_1andL_2,areconnectedinaninterleaved manner with switches $S5$ and $S6$. The VM section has a combined single stage of VM cell with capacitors $C1$, $C2$ and diodes $D4$−$D6$. $Cout$ and $Dout$ are the respective output capacitor and diode. RL is the load served by output voltage, Vo.[3]

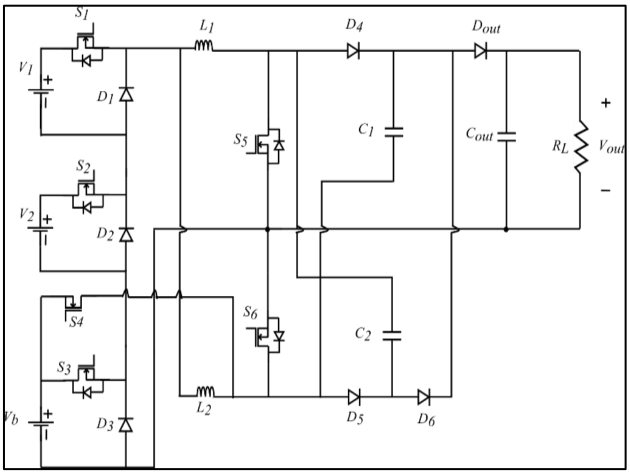

Figure 1: Proposed battery integrated multiple input boost converter

Operation mode one:

In this mode, the battery state of charge is optimal and the power of input sources $V1$ and $V2$ can sufficiently serve the load. During this operation mode, the battery neither charges nor discharges. This is the default operation mode. In this mode $S3$ and $S4$ are permanently turned off.

Operation mode two:

This mode of operation occurs when the RE sources are unable to service the load optimally. In this case, the associated battery storage device, Vb comes into play to supplement power transmission from the RE sources to the load. Switch S3 controls whether or not the battery can give electricity to the load. During this mode of operation, S4 remains turned off.

Operation mode three:

The battery state of charge is drained during this operation mode, and the RE sources can service the load in addition to charging the battery. Switch $S4$ allows charging current to go to the battery. During this mode of operation, $S3$remains turned off.

Three Input Buck-Boost DC-DC Convertor:

The general circuit topology for a multiple-input buck-boost converter (MIBB) is shown in Figure 2. There are three input voltages VS1, VS2, and VS3.The inputs are connected through forward-Conducting switches. The switches can be realized as a Power MOSFET. The input inductance is L, and the output capacitance is C. As illustrated in Figure 2, this design only allows unidirectional power flow. basic voltage sources include basic batteries, solar cells, and fuel cells.

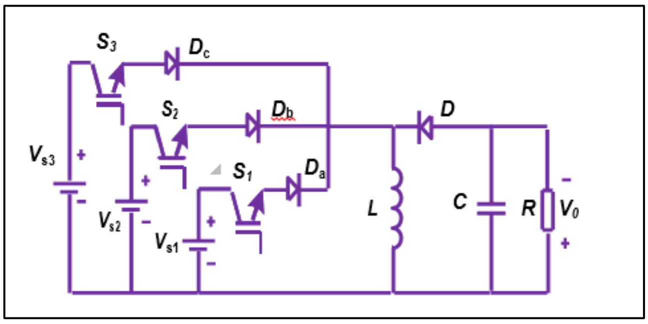

Figure 2: Non isolated high gain DC-DC Converter

If the inductor current, I_L, is greater than zero in the steady state, continuous conductionmode results. This guarantees that at least one FCBB switch or the diode is conducting at alltimes

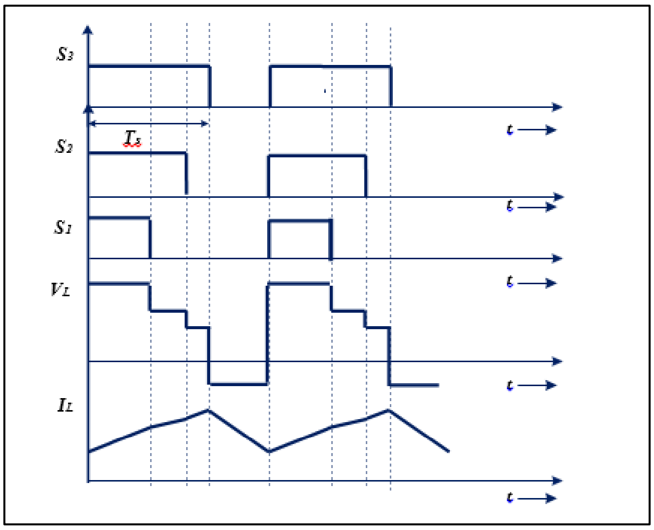

Figure 3: Analytical waveforms

In the steady state, the average inductor voltage is zero and the output capacitor is largeas to make the output voltage almost constant. When all the switches connected in series withthe sources are OFF, the inductor voltage is equal to the output voltage $V_L = V_O$. If severalactive switches are on, then the inductor voltage is equal to the highest of the voltages forwhichthe respectiveswitch is on.

OBJECTIVES:

1. To analyses isolated, non-isolated high gain DC-DC Converter, Analytical waveforms.
2. To study of dc-dc converter with topology converter.
3. A detailed analysis along with input voltage and battery SOC levels operation mode two and three.

RESEARCH METHODOLOGY:

To serve the scientific community, research must concentrate on reaching accurate conclusions. This entails being cautious not to change the outcome to meet the author's demands or desires. The selection of research methodology and method is critical for achieving the desired outcome. The research reported in this thesis is quantitative rather than qualitative because it is based on measuring variables and analysing data rather than observing behaviours, views, or meanings. The applied research method is used with a deductive approach to solve the problem by understanding the theory and limitations of different DC-DC converter architectures and identify the ones that meet the specifications.

REVIEW OF LITERATURE:

Kwansinski investigated the feasibility of converting a number of classic single-input converters to multiple-input converters. This was accomplished by developing four rules that could aid the designer in the creation of the desired converter. Only buck and buck-boost converters can be changed if these restrictions are strictly followed. When the rules are changed, other converter types can be extended. Time-multiplexing control, for example, was used to realise the Cuk and single-ended primary inductance converter (SEPIC). [4]

To add an extra pulsating voltage or current source to the pulse width modulation (PWM) converter, Liu and Chen used a strategy based on appropriate connections.Based on the breakdown of the primary converter pulsating current source cells (PCSC), Li et al. devised a set of rules. These restrictions result in two MIC families. The low voltage gains of the proposed converters suggest poor performance in high voltage applications. [5][6]

The cascade structure was utilised by Huber and Jovanovic et al. to reduce ripples and boost voltage gain. Because the input voltage is lower, it is discovered that the original cascaded structure must have reduced voltage stress that can operate with increased switching frequency. Furthermore, the second portion operated at a lower switching frequency, reducing switching losses. The main drawback of the cascaded structure was the circuit with the greater number of components, less efficiency and the noise affected by Electromagnetic interference.[7]

RESULT AND DISCUSSION:

Simulation results:

In a bid to confirm the compliance of the proposed converter with the discussed operation and characteristics, it has been simulated on the MATLAB/Simulink environment. The component sizes and other parameters are presented in Table 1. The values of the input voltages are 24 V, 12, and 12 V for $V1$, $V2$ and Vb respectively. The inductor value of 360 μH for each inductor are obtained using (19) with the desired current ripple. The switching frequency is 50 kHz. The duty ratio of the interleaving switches, $S5$ and $S6$ is 0.5 while 0.75 is used for the individual power switches, S1 and S2. In the first operating mode, the maximum input voltage delivered by $V1$ and $V2$ is 33 V.[8]

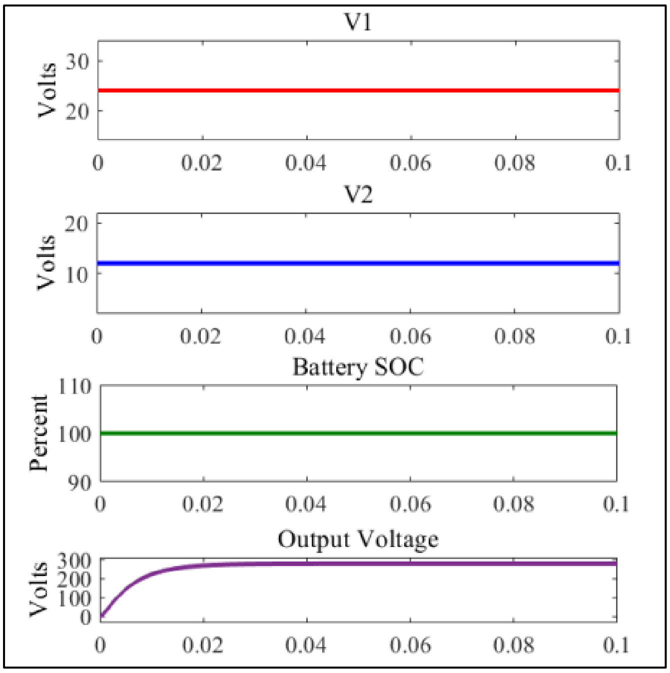

Figure 4: Input voltage and battery SOC levels during operation mode one

Figure 4 shows the state-of-charge (SOC) of the battery and the voltage levels of $V1$ and $V2$ during this operation mode. The battery SOC is 100% and does not deplete while $V1$ and $V2$are 24 V and 12 V. The output voltage is 278 V with a load resistance of 500 Ω. The average values of the inductor currents, $iL1$ and $iL2$ are 5.1 A and 3.5 A respectively. The inductor current ripple, ΔiL is set at 1 A

The inductor currents are illustrated in Figure 5. It can be observed that $iL2$ is higher than $iL1$..

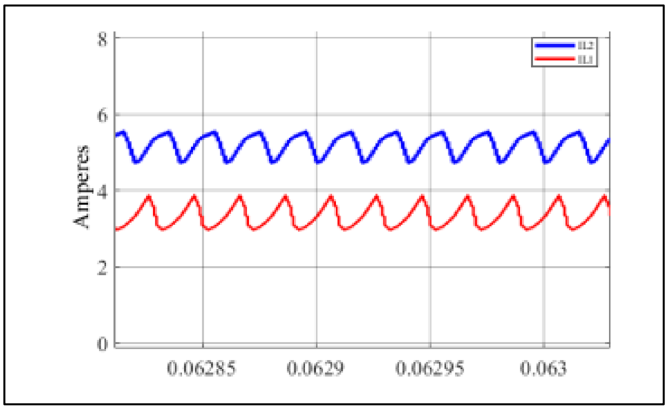

Figure 5: Inductor currents

This is because the number of VM is even and more current is drawn during the charging and discharging stages in $L2$. Also, the waveforms of $iL2$ and $iL1$ appears inverted to relative to one another because there exists a phase delay between the switching signals. [9]

The switch configuration for the respective modes is presented in Table 1. The voltage gain of the converter is given by:

Table 1:Operation modes of new three input boost converter with high voltage gain

State	S_1	S_2	S_3	S_4	L_1	L_1	C	C_o
Mode 1: Battery bypassed, V1, V2 supply load								
1	1	0	0	1	C	D	C	D
2	1	1	0	1	D	C	D	D
3	1	0	0	1	C	D	C	D
4	0	0	0	0	D	D	C	C
Mode 2: V1, V2 and battery supplying load								
State	**S_1**	**S_2**	**S_3**	**S_4**	**L_1**	**L_1**	**C**	**C_o**
1	1	1	1	1	C	C	D	D
2	1	1	0	1	D	C	D	D
3	1	0	0	1	C	D	C	D
4	0	0	0	0	D	D	C	C
Mode 3: V1 and V2 supply battery and load								
State	**S_1**	**S_2**	**S_3**	**S_4**	**L_1**	**L_1**	**C**	**C_o**
1	1	1	1	0	C	C	D	D
2	1	1	0	1	D	D	D	D
3	1	0	0	1	D	D	C	D
4	0	0	0	0	D	D	C	C
Key- C: Charging D: Discharging								

For the fuel cell, it utilised a boost arrangement, and for the PV cell and battery, it used a buck/boost setup. Using four separate switch duty ratios in three different operation modes, arbitrary battery charging and discharge is eliminated. [10]

CONCLUSION:

Using two VM cells positioned after the interleaving stage, the multi-input converter obtained high output voltage in an interleaved inductor architecture. The converter can supply energy from three different sources. Two unidirectional input ports and one bidirectional input port are available for battery storage. Individual energy sources are regulated by their own power switches. The battery storage port is a significant benefit of the proposed converter.

Excess energy from renewable energy sources can be stored in a battery. When there is insufficient electricity, this stored energy can be channelled to meet the power requirements. The charge and discharge rate of the bidirectional port is determined by the power switch's duty ratio. Thus, the proposed converter is appropriate for use in RE applications.

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