RESEARCH ARTICLE

SAMRIDDHI Volume 14, Issue 4, 2022 Print ISSN: 2229-7111 Online ISSN: 2454-5767

Design of Multi Input Converter Topology for Distinct Energy Sources

Chirag Gupta*, Vikas K. Aharwal

Dr. A.P.J. Abdul Kalam University, Indore, Madhya Pradesh, India

Abstract

Two input energy sources are introduced in the suggested Multi input DC-DC converter topologies. The converters may send power to the load from both the input and output energy sources at the same time. The capacity to execute the buck, boost, and buck-boost modes of operation using the same structure, as well as the ability to transmit power to the load even if any one of the input energy sources fails, are the key advantages of the upgraded converter over the basic design. As a result, the MATLAB/Simulink platform was used to do a full software simulation of the enhanced converter. The state topology of the converter is illustrated independently for the buck, boost, and buck boost operations, indicating the integration of two renewable energy sources. In comparison to current converter topologies that have been published in the literature, the suggested converters offer various advantages such as a lower component count, a compact construction, and efficient energy usage.

Keywords: Multi Input Converter (MIC), multiple sources, Buck Boost operation, DC-DC converter.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2022); DOI: 10.18090/samriddhi.v14i04.09

Introduction

The gap between global energy demands and energy harnessed through various technologies has been widening. Compared to Centralized Energy Resources (CER) of the past, Distributed Energy Resources (DER) have grown fairly promising in supplying the world's future energy demands. CERs were crude oil, natural gas, and other non-renewable energy sources contributing significantly to climate change and environmental problems. Furthermore, the expensive cost of establishing transmission lines and increased security concerns have rendered CER technology uneconomical, particularly in underdeveloped nations where grid availability is already patchy.[1] Furthermore, technical advancements in smaller generators, power electronics, and storage systems have paved the road for DER growth to continue. A further benefit of this type of DER development is that the targeted load is closer to the generator, which reduces transmission line loss. It should also be noted that no CER energy resource currently exists that satisfies all economic, social, and environmental criteria. On the other hand, renewable energy sources are environmentally friendly, abundant, and employed for revenue and industrial growth.[2] As a result, the development of renewable energy sources is being emphasized more than ever before. Furthermore, many governments worldwide are promoting using renewable energy to fill the energy gap, stabilize the present grid, and construct micro-grids where grids are absent, among other things. As a result, DER development has received widespread support worldwide.

Corresponding Author: Chirag Gupta, Dr. A.P.J. Abdul Kalam University, Indore, Madhya Pradesh, India, e-mail: cgupta.011@gmail.com

How to cite this article: Gupta, C., Aharwal, V.K. (2022). Design of Multi Input Converter Topology for Distinct Energy Sources. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology,* 14(4), 55-59.

Source of support: Nil

Conflict of interest: None

Proposed System

The development of new strategies for combining two or more diverse energy sources will significantly impact the future of energy technology. Separate dc-dc converters with their outputs linked in series or parallel were used in early versions of hybridization to integrate different sorts of sources.[3] Selection of voltage levels, limitation in operating modes, switching scheme complexity, poor switch selection, and inadequacy in analysis and component counts were some of the shortcomings of such multiple input converter (MIC) topologies. As a result, power electronics has played a significant role in improving power usage via power conditioning. Apart from reminiscences of MIC topologies, inverters must keep the voltage and frequency at the consumer's terminal constant to ensure system stability and adequate transient performance. Inverter control in stand-alone mode has been the subject of several control approaches documented in diverse literature.[4] The repeating control strategy has the disadvantage of being unable to deal

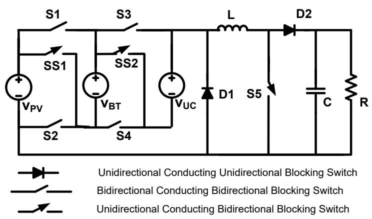

Figure 1: Equivalent Switch configuration of proposed MIC

with periodic disruptions and having a significant memory need.[5,6] Although capable of providing a good balance between system performance and stability margin, two desirable but incompatible features of the system, the robust control (H-infinity control) technique faces the challenge of not being implemented on digital processors, and their design specifications are complex.[7,8] The current project addresses all of the flaws mentioned above in stages, first by implementing the solution through a MIC in which the energy storing units Battery is connected to the PV source, and then by implementing the solution through a MIC in which the PV source is connected to the energy storing units Battery.

In place of a bidirectional conducting and unidirectional blocking (BCUB) switch, a bidirectional conducting and bidirectional blocking (BCBB) switch is employed in the MIC design. The aforementioned adjustments address a problem with the BCUB switches' unwanted conduction when a reverse bias is placed across them.[9,10] The created MIC is used to link a solar PV system to a storage battery system.[11] By connecting the sources in either mode: series or parallel,[12,13] the converter may transmit power from the sources discretely or continuously. The converter also allows for accurate power flow regulation between the sources and the load. The suggested converter can also power flow in both directions and operation modes such as buck, boost, and buck-boost. The suggested converter also has a compact design, flexibility in power regulation, and the ability to choose a voltage source with the least number of parts. Figure 1 illustrates the proposed MIC's comparable switch arrangement.

Working States

In this section, a detailed description of proposed MIC is illustrated. The proposed converter shown in Figure.1 comprises of three voltage sources, (i) VPV obtained from the solar PV system, (ii) VBT obtained from the storage battery and (i) VUC obtained from UC. The switch network that combines the sources comprises of bidirectional switches (S1-S4), unidirectional switches (SS1, SS2, S5) and diodes (D1, D2). The switch group (S1-S4) is for the parallel operation of the sources. Switch group (SS1-SS2) is for series connection of the sources. Diode, D1 is for freewheeling action. The conduction of switch S5 and diode D2 decides the converter operation in buck mode, boost mode, buck-boost mode and bidirectional mode. For converter operation in bidirectional mode, the Diodes are needed to be replaced by unidirectional controlled switches.

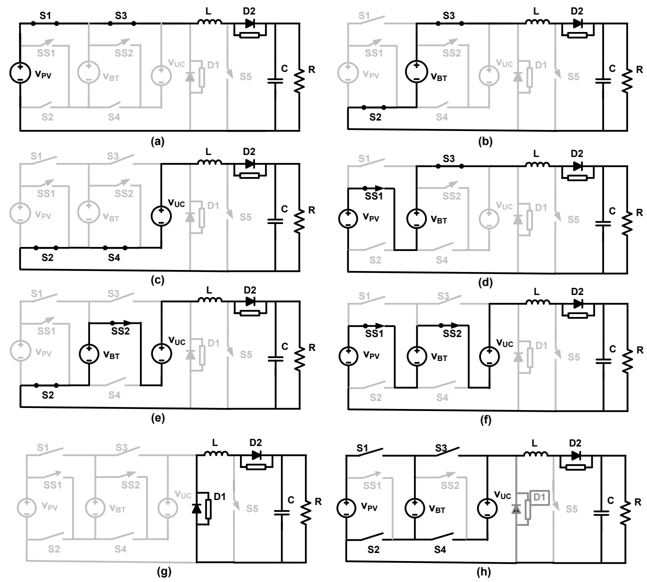

Figure 2: Working states of Multi source converter (a) VPV (b) VBT, (c) VUC (d) VPV and VBT simultaneously (e) VBT and VUC simultaneously (f) VPV, VBT and VUC simultaneously (g) Freewheeling period (h) Parallel operation of all sources

Based on switching strategy of switches S1-S4 and SS1, SS2, with diodes D1 and D2, there are seven working states extracted from the converter proposed in work and the same is presented in Figure. 2 (a-h). The description of operational states is delineated as follows;

State-I: Figure 2(a). Switches S1 and S3 get the driving pulse in this condition, while the remainder of the switches remain off. Switch S1 is turned on, and the source VPV is connected to the inductor's supply end. By using an inductor, the load is linked to the source VPV. The voltage at the input terminal of the inductor is greater than the common terminal of the load due to switch S1 and S3 conduction, resulting in a reverse bias across diode D1. At the same time, the inductor stores energy in its electromagnetic field and charges the capacitor. Source VPV, functioning alone, also supplies power to the load.

State-II: Figure. 2(b). Switches S2 and S3 get the driving pulse in this mode, while the remainder of the switches remain off. The source VBT is connected to the inductor's supply end by turning on switch S2 with switch S3. By using an inductor, the load is linked to the source VPV. The voltage at the input terminal of the inductor is greater than the common terminal of the load due to switch S2 and S3 conduction, resulting in a reverse bias across diode D1. At the same time, the inductor stores energy in its electromagnetic field and charges the capacitor. Source VBT, functioning alone, also supplies power to the load.

State-III: Figure. 2(c). Switches S2 and S4 get the driving pulse in this mode, while the remainder of the controlled switches remain off. The source VUC is connected to the inductor's supply end when switch S2 and S4 are turned on. By using an inductor, the load is linked to the source VUC. The voltage at the input terminal of the inductor is greater than the common

Table 1: Different Working States of MIC Operation

State	*Conducting switches*	*Active source*	*Inductor voltage*	*Inductor status*
1	S_1, S_3, D_2	V_{PV}	V_{PV}-V_O	Charging
2	S_2, S_3, D_2	V_{BT}	V_{BT}-V_O	Charging
3	S_2, S_4, D_2	V_{UC}	V_{UC}-V_O	Charging
4	SS_1, S_3, D_2	$V_{PV}+V_{BT}$	$V_{PV}+V_{BT}$ -V_O	Charging
5	SS_2, S_2, D_2	V_{BT} +V_{UC}	$V_{BT}+V_{UC}$-V_O	Charging
6	SS_1, SS_2, D_2	$V_{PV}+V_{BT}+V_{UC}$	$V_{PV}+V_{BT}+V_{UC}$-V_O	Charging
7	$D_{1,}$ D_2	None	-V_O	Discharging

terminal of the load due to switch S2 and S4 conduction, resulting in a reverse bias across diode D1. At the same time, the inductor stores energy in its electromagnetic field and charges the capacitor. Source VUC, functioning alone, also supplies power to the load.

State-IV: Figure. 2(d). Switches SS1 and S3 receive driving pulses in this mode, while the remainder of the switches remain off. When switch SS1 is turned on, the source VPV is linked in series with the source VBT, and the supply end of the inductor is fed from both sources. Through an inductor, the load is coupled to the series combination of sources VPV and VBT. The voltage at the input terminal of the inductor is higher than that at the common terminal of the load due to switches SS1 and S3 conduction, resulting in a reverse bias across diode D1. The energy is stored in the inductor's electromagnetic field, the capacitor is charged, and the load is additionally powered by the combined sources VPV and VBT operating in series.

State-V: Fig 2 (e). Switches SS2 and S2 receive driving pulses in this mode, while the remainder of the switches remain off. When switch SS2 is turned on, the source VBT is connected in series with the source VUC, and the supply end of the inductor is fed from both sources. Through the inductor, the load is linked to the series combination of sources VBT and VUC. The voltage at the input terminal of the inductor is higher than that at the common terminal of the load due to switches SS2 and S2 conduction, which causes a reverse bias across diode D1. Through the combined sources VBT and VUC functioning in series, the inductor stores energy in its electromagnetic field, the capacitor is charged, and the load is also supplied with power.

State-VI: Figure. 2(f). Switches SS1 and SS2 receive driving pulses in this mode, while the remainder of the switches remain off. When switches SS1 and SS2 are turned on, all three sources are linked in series, and the inductor's supply end is fed by a combination of all three sources. By using an inductor, the load is linked to a series combination of the sources VPV, VBT, and VUC. The voltage at the input terminal of the inductor is higher than that at the common terminal of the load due to the conduction of switches SS1 and SS2, resulting in a reverse bias across diode D1. The energy is stored in the inductor's electromagnetic field, the capacitor is charged, and the load is additionally powered by the combined sources VPV, VBT, and VUC operating in series.

State-VII: Figure. 2(g). The stored energies in the energy-storing materials are freewheeling in this condition. The inductor current flows through diodes D1 and D2, but the capacitor, which is directly linked to the load, directs its energy to it. All other switches are in the rest mode, with no switching signals being sent to them. TOFF period is another name for this time frame.

State- VIII: Figure. 2(h). The driving pulses are supplied to switches S1, S2, S3, and S4 simultaneously to put all of the sources into parallel operation, while the remainder of the switches remain off. When the switches are turned on, all of the sources are linked in parallel, and the inductor's supply end is fed by the combination of all of the sources. Using an inductor, the load is connected to the parallel combination of sources. The voltage at the input terminal of the inductor is greater than the common terminal of the load as a result of switches S1, S2, S3, and S4 conduction, resulting in a reverse bias across diode D1.The energy is stored in the inductor's electromagnetic field, and the capacitor is charged at the same time as the load is powered by the combined sources functioning in parallel. When a higher current is required by the load, the sources are connected in parallel, increasing the source's current supplying capability. When it comes to voltage, the higher voltage among the three sources takes precedence, and the state resembles the operation of either state I, state II, or state III, depending on the magnitude of the voltage.If the magnitudes of the voltage sources are assumed to be equal, all of the voltage sources will release the same amount of energy.

The above-mentioned functioning states of the converter are summarised in Table 1. Working condition, number of conducting switches, active source, voltage across inductor, and inductor status are all listed in the table.

Result And Discussion

The output voltage and the switching method used to meet the load voltage determine the pulse length or pulse width and the repetitiveness of the pulses and their off-duty. Figures 2 and 3 depict the voltage across the inductor, current through the inductor, voltage across the load, and current through the load, respectively, for buck mode converter operation.

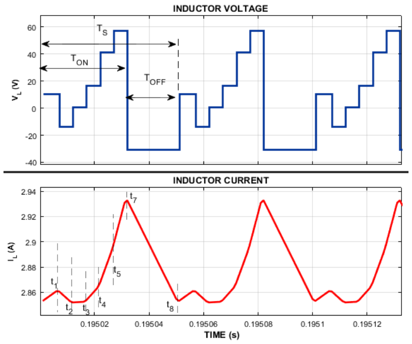

Figure 2: Voltage across inductor and current through inductor for converter operation in Buck mode

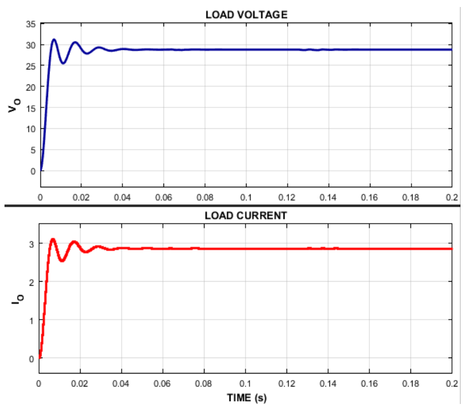

Figure 3: Voltage across load and current through load for converter operation in Buck mode

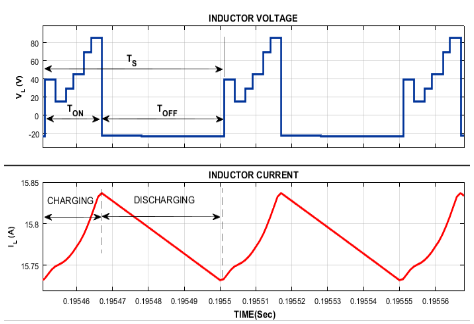

Figure 4: Voltage across Inductor and current through inductor for converter operation in boost mode

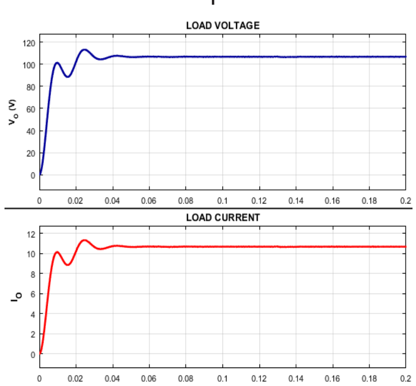

Figure 5: Voltage across load and current through load for converter operation in boost mode

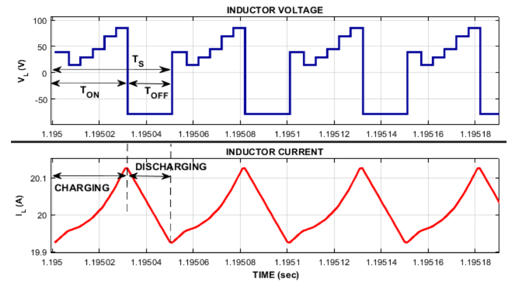

Figure 6: Voltage across Inductor and Current through Inductor for converter operation in buck-boost mode (T_{ON}>0.5T_S)

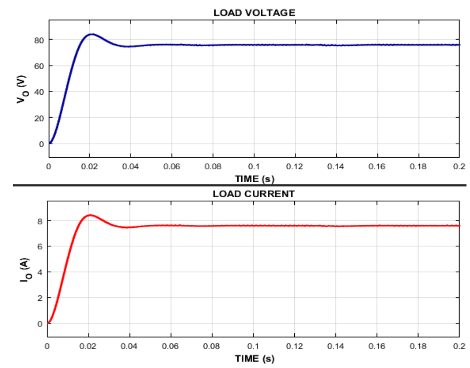

Figure 7: Voltage across Load and Current through Load for converter operation in buck-boost mode (TON>0.5TS)

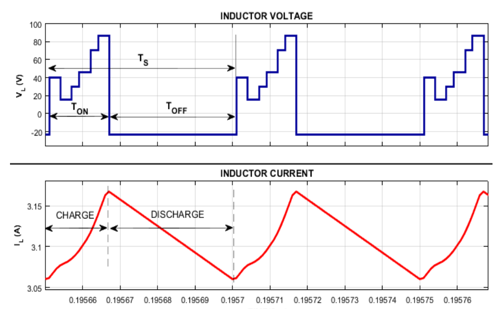

Figure 8: Voltage across Inductor and Current through Inductor for converter operation buck-boost mode (T_{ON}<0.5T_S)

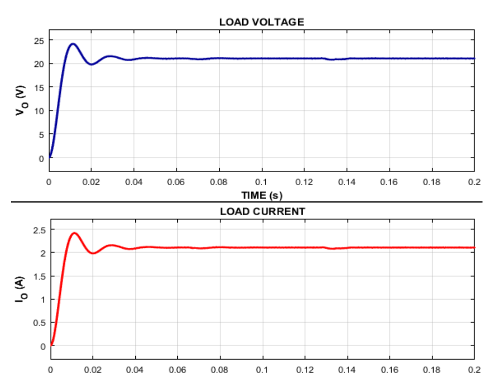

Figure 9: Voltage across Load and Current through Load for converter operation in buck-boost mode (TON<0.5TS)

Simulation Results of Proposed MIC in Boost Mode

The output voltage and the switching technique used to match the load voltage determine the duration of the pulses and the frequency of the pulses with their duty. Figures 4 and 5 depict the voltage across the inductor and current through the inductor and the voltage across the load and current through the load, for boost mode converter operation.

Simulation Results of Proposed MIC in Buck-Boost Mode

The output voltage and the switching method used to meet the load voltage determine the pulse or pulse width's duration and the repetitiveness of the pulses and their off duty. Figures 6 and 7 illustrate the voltage across the inductor and the current flowing through it, as well as the voltage across the load and the current flowing through it, during buck-boost converter operation.

$T_{ON}<T_S$ is used to demonstrate converter operation in buck-boost mode. The output voltage and the switching method used to meet the load voltage determine the pulse or pulse width's duration and the repetitiveness of the pulses and their off duty. Figures 8 and 9 depict the voltage across the inductor and current through the inductor, as well as the voltage across the load and current through the load, for buck-boost converter operation.

Conclusion

The Multi Input Converter (MIC) may be used as a buck converter, a boost converter, or a buck-boost converter, and it can connect the load in series (or parallel) depending on the load's requirements. For both the converters with source side and load side voltages and currents operating in steady state, continuous conduction mode, mathematical equations are formulated independently, followed by theoretical analysis. The modern MIC's effective performance is owing to intensive modelling and mathematical analysis of the converter's behavior as a buck converter, boost converter, and buck-boost converter. Based on the simulation findings, it can be inferred that the suggested converters are capable of collecting energy from a variety of sources (each with its own set of characteristics) and providing a better source electability and flexibility, and availability. Among the converter's other features are the ease with which renewable energy sources may be integrated and the potential to increase the hybrid energy system's power sharing capabilities.

References

[1] Ahmadi, R., Ferdowsi, M. 2012. Double-input converters based on H-bridge cells: derivation, small-signal modeling, and power sharing analysis. IEEE Trans. Circuits Syst. I, Reg. Paper, 59, (4), pp. 875–888.

[2] Liu, Y.C., Chen, Y. M., 2009. A systematic approach to synthesizing multi input DC–DC converters. IEEE Trans. Power Electron., vol. 24, no. 1, pp. 116–127.

[3] Marchesoni, M., Vacca, C. 2007. New DC–DC converter for energy storage system interfacing in fuel cell hybrid electric vehicles. IEEE Trans. Power Electron., vol. 22, no. 1, pp. 301–308.

[4] Hintz, A., Prasanna, U. R., and Rajashekara, K. 2015. Novel modular multiple input bidirectional DC–DC power converter (MIPC) for HEV/FCV application. IEEE Trans. Ind. Electron., vol. 62, no. 5, pp. 3163–3172.

[5] Nejabatkhah, F., Danyali, S., Hosseini, S. H., Sabahi, M., Niapour, S. M. 2012. Modeling and Control of a New Three-Input DC–DC Boost Converter for Hybrid PV/FC/Battery Power System. IEEE Transactions on Power Electronics, Vol. 27, No. 5.

[6] Patra, P., Patra, A., Misra, N. 2012. A single-inductor multiple-output switcher with simultaneous buck, boost, and inverted outputs. IEEE Trans. Power Electron. 27, (4), pp. 1936–1951.

[7] Zhao, H. S., Round, D., Kolar, J. W. 2008. An isolated three-port bidirectional DC-DC converter with decoupled power flow management. IEEE Trans. Power Electron., 23, (5), pp. 2443–2453.

[8] Patra, P., Patra, A., Misra, N. 2012. A single-inductor multiple-output switcher with simultaneous buck, boost, and inverted outputs. IEEE Trans. Power Electron. 27, (4), pp. 1936–1951.

[9] Rosli, M. A., Yahaya, N. Z., Baharudin, Z. 2014. Multi-input DC–DC converter for hybrid renewable energy generation system. IEEE Conf. Energy Convers., Malaysia, Oct. 2014, pp. 283–286.

[10] Tao, H., Kotsopoulos, A., Duarte, J. L., Hendrix, M.A.M. 2006. Family of multiport bidirectional DC–DC converters. IEE Proc. Electric Power Appl., 2006, 153, (3), pp. 451–458.

[11] Dwivedi, A., Pahariya, Y. Design and Analysis of Hybrid Multilevel Inverter for Asymmetrical Input Voltages. J. Electr. Eng. Technol. 16, 3025–3036 (2021).

[12] Dwivedi, Arpan, and YogeshPahariya. "Design and Analysis of 1.4 MW Hybrid Saps System for Rural Electrification in Off-Grid Applications." International Journal of Energy and Power Engineering 11.11 (2017): 1143-1147.

[13] Chattoraj, Juhi, ArpanDwivedi, and DrYogeshPahariya. "Enhancement of power quality in SAPS system with multilevel inverter." Int. J. Eng. Sci. Res. Technol. 6.5 (2017): 779-788.