Pakistan Journal of Engineering and Technology, PakJET
Multidisciplinary & Peer Reviewed
Volume: 4, Number: 2, Pages: 1- 4, Year: 2021

Simulation Analysis of Single-Phase Transformerless H6 Inverter based Dual Input buck-boost Converter

Waqar Ahmed[1], Rizwan Ali[2], Ahmed Muddassir Khan[3], Shafquat Hussain[4], Faisal Hussain[5]

[1,3,4]Electrical Engineering Department, Indus University, Karachi, Pakistan
[2,5]Electronic Engineering Department, NED University of Engineering and Technology, Karachi, Pakistan

Corresponding author: Waqar Ahmed (https://orcid.org/0000-0002-7347-2450).

Abstract- **To use the multiple renewable energy sources for single-phase AC applications with an H6 converter topology. Dual input DC-DC buck-boost converters that integrate the solar panel and a battery will regulate the required output DC voltage. Furthermore, for the AC applications of having small power and High power, the H6 topology of single-phase transformerless inverter is preferred because of less leakage current. To validate the proposed technique's feasibility, the MATLAB simulation is performed for the whole process that validates the converter's results and performance.**

Index Terms-- **Dual input Buck-Boost Converter, H6 Topology, Solar Panel, Transformerless inverter**

I. INTRODUCTION

The use of renewable energies is increasing day by day as fossil fuels become depleted. Different topologies of the converter have been proposed for renewable energies. With these topologies' advent and these topologies, renewable energies can be accessed easily from low power to high power applications. In this way, renewable fuels can compensate for conventional sources. The main problem with renewable energy sources like solar and wind are that they are suitable in standalone applications because of their dependencies on weather conditions. The integration of these sources will work applicable to overcome their dynamic nature. The distributed generation and microgrids are two main applications [1-2]. Using renewable energy sources like PV or wind, the system's stability and reliability can be boosted.

To reduce weight, size, cost, and efficiency, the transformerless inverter is preferred over the conventional isolating transformers and can easily interface with the grid [3]. Moreover, these both operate in parallel with the PV grid, and If power is more than the grid, it supplies it. This feature attracts researchers to go for in-depth research for PV-inverters [4]. The H5 and H6 are widely used topologies for the transformerless inverter. The DC decoupling is possible in the H5 topology, while the HERIC topology can achieve AC decoupling. In the H6 topology of the transformerless inverter, both DC decoupling and AC decoupling can be reached [5].

II. DUAL INPUT DC-DC BUCK-BOOST CONVERTER

The working of the Dual input DC-DC buck-boost converter can understand from the below waveforms.

The switches T_1 and T_2 act as bidirectional conduction and bidirectional blocking. The L and C values help to set current and voltage ripples. T_1 and T_2 switching will change the operating of the converter while T_3 performs buck and boost operations. The T_4 helps in making current bidirectional.

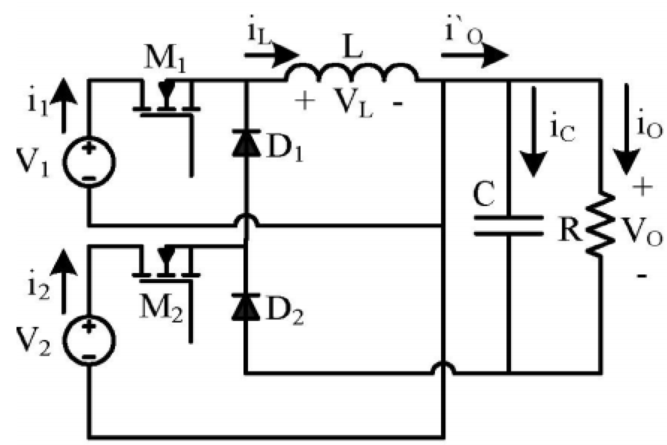

FIGURE 1. Dual input DC-DC Buck-Boost Converter [6, 7].

III. STEADY STATE OPERATION OF THE BUCK-BOOST CONVERTER.

Over a one switching period, switches will perform their duty cycle mathematically.

$$t_1 = (d_1 - d_2)Ts \quad (1)$$

$$t_2 = d_{12}Ts \quad (2)$$

$$t_3 = (d_2 - d_{12})Ts \quad (3)$$

$$t_4 = (1 - d_1 - d_2 + d_{12})Ts \quad (4)$$

d_1 indicates the duty cycle of T_1 and d_2 for the duty cycle of T_2

The inductor voltage can be calculated by knowing t_1, mathematically:

$$e_L = e_1 * t_1 \quad (5)$$

During the time t2, the voltage across an inductor is:

$$e_L = (E_1 + E_2) * T_2 \quad (6)$$

Similarly, for t_3 it will be:

$$e_L = e_2 * t_3 \quad (7)$$

For t4/Toff

$$e_L = (-E_0)T_{off} \quad (8)$$

After applying volt-sec balance, average values of inductor voltage should be zero, therefore:

$$e_L = (E_1 * t_1) + \left((E_1 + E_2) * t_2\right) + (E_2 + t_3) + (-E_0)T_{off} = 0 \quad (11)$$

The relationship between the input and output voltages can be obtained after solving the above equations,

$$E_0 = \frac{E_1 d_1 + E_2 d_2}{(1 - d_1 - d_2 + d_{12})} \quad (12)$$

The ripple voltage (Δv) of the capacitor and ripple current (Δi) of the inductor can be obtained from the following equations, respectively.

$$\Delta i = \frac{E_0(1 - d_1 - d_2 + d_{12})}{L * f_s} \quad (13)$$

$$\Delta v = \frac{E_0(d_1 + d_2 - d_{12})}{R * C * f_s} \quad (14)$$

IV. THE H6 TYPE SINGLE PHASE TRANSFORMERLESS INVERTER

After regulating the required output voltage, the buck-boost converter feeds it to the single-phase transformerless inverter, converting this DC voltage into AC for AC power applications. The working and description of this topology are given in [8]. It consists of six switches S1, S2, S3, S4, S5, and S6. The unipolar PWM techniques are used. The third-order filter LCL is used to mitigate harmonics. It has a 60dB/dec slope as compared to L and LC filter.

This H6 topology-based single-phase transformerless inverter, as shown in figure No: 02, possess the least leakage current as compared to the conventional topologies of the inverter [9, 17]

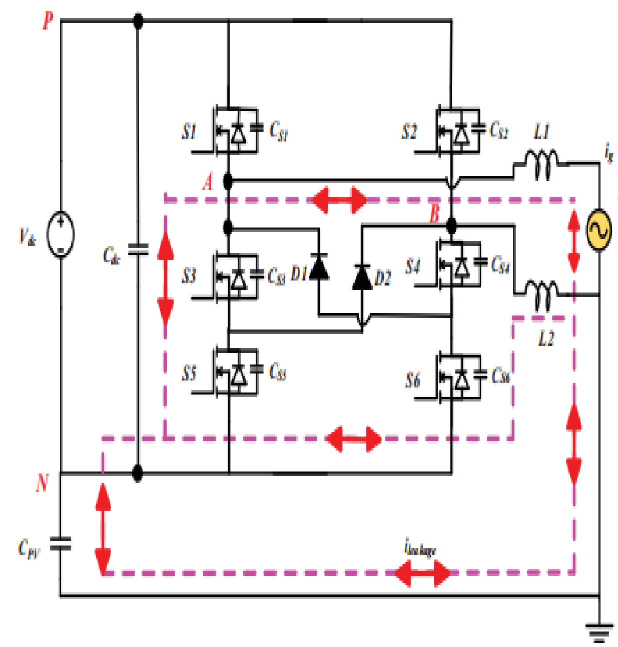

FIGURE 2. The H-6 type transformerless Inverter [10].

There are four modes of operation of the H6 topology. The two of them are active modes, and the two remaining are freewheeling modes. Figure No. shows the unipolar PWM technique for a single-phase H6 transformerless inverter. In this modulation technique, S2 is a complement to S1 and S3 is also complementary to S4. To get a positive half cycle S1 and S4 should be turned on, and in this output will be equal to input voltage [11, 12].

There are few decoupling topologies that mitigate the common mode current are H5 topology [13], H6 DC side topology [14, 15], H6 DC side_1 topology [16], H6 DC side_2 topology [16]

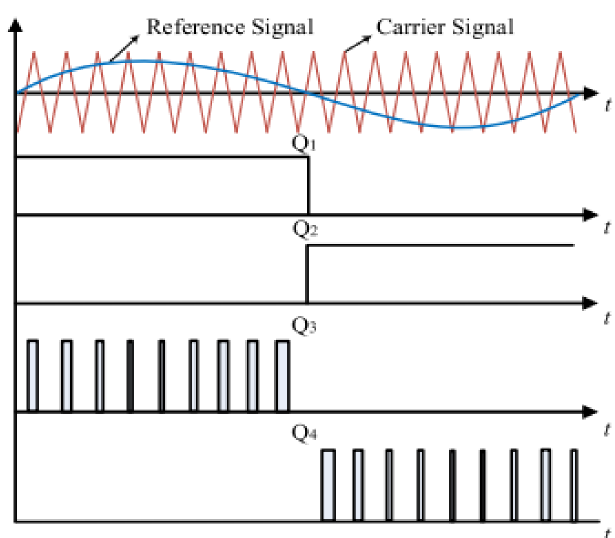

FIGURE 3. Unipolar PWM technique for single H6 transformerless inverter

V. SIMULATION RESULTS

The Dual input DC-DC converter feeds two energy sources. One is a solar panel, and the other is a battery. The Dual input DC-DC converter regulates the desired voltage and provides it to the single-phase transformerless inverter to convert it into AC voltage. The main advantage of using a single-phase transformerless inverter is that it ranges from low power to grid powers' high capacity. The above whole process is simulated, tested, and verified in MATLAB Simulink, shown in figure 04(a) and 4(b).

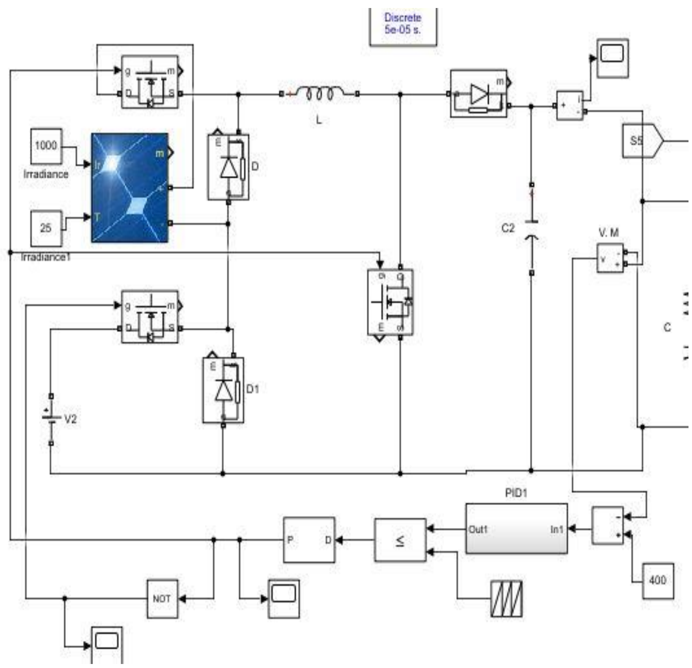

FIGURE 4(a). The integration of solar panel and battery through dual input converter and with Single phase Transformerless Inverter

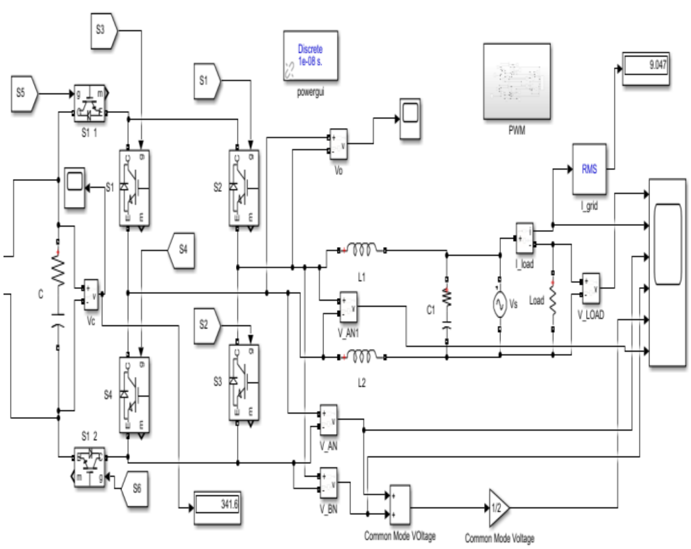

FIGURE 4(b). The integration of solar panel and battery through dual input converter and with Single phase Transformerless Inverter

To see the voltage of phase voltage between leg A and ground, the waveform of phase voltage across leg A and ground is shown in figure 05. This waveform of the voltage has 500V maximum which phase voltage of the inverter.

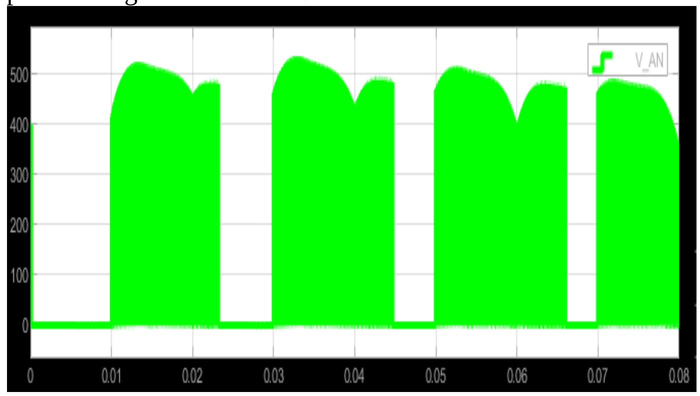

Figure 5. The voltage between Phase A and ground.

To see the voltage of phase voltage between leg B and ground, the waveform of Phase voltage across leg B and ground is shown in figure 06. This waveform of the voltage is 500V peak and its phase voltage of phase B.

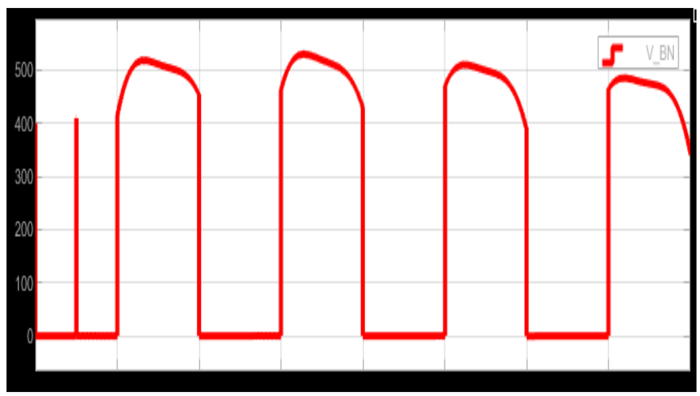

FIGURE 6. The voltage between phase B and ground

To see the voltage of line voltage between leg A and leg B, the waveform of line voltage cross leg A and leg B is shown in figure 07. This waveform is the line voltage across phase A and phase B. which is 500V peak.

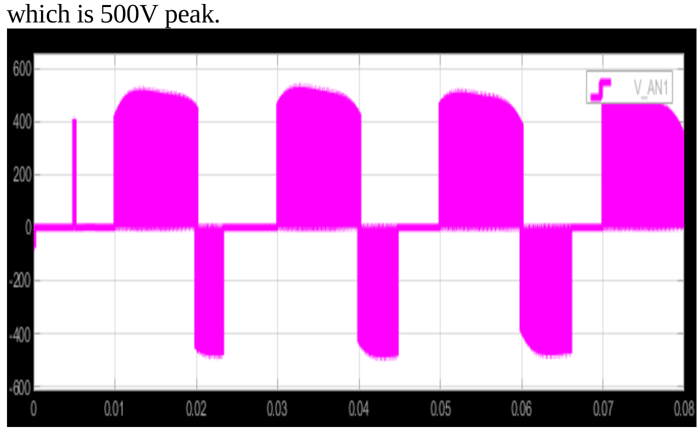

FIGURE 7. The voltage across phase A phase B.

The grid-connected in parallel with the load possess the voltage shown in figure 08. The grid connected at the load side has maximum of 300V and can be connected with main converter.

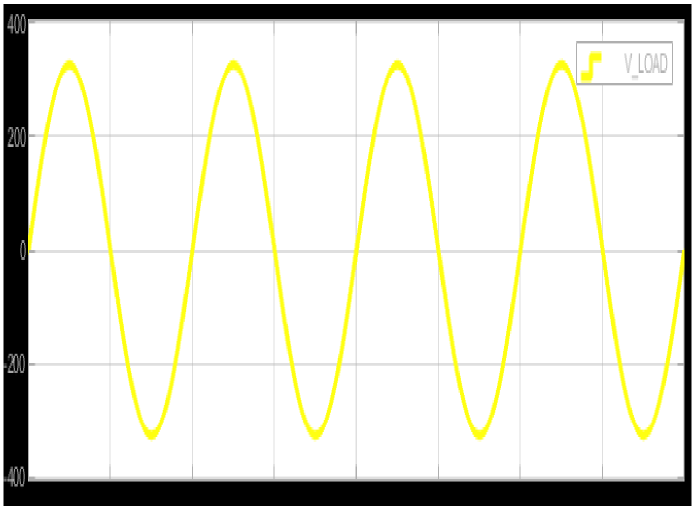

FIGURE 8. Grid voltage waveform

The waveform of the grid current is shown in figure 09. The grid connected at the load side has maximum of 12A and can be connected with main converter .

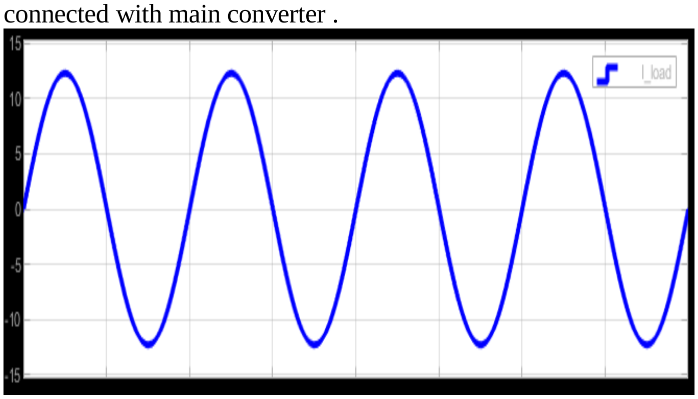

FIGURE 9. Grid Current at the load side

VI. CONCLUSION

In this paper, the two energy sources are feed to the dual input DC-DC converter. After regulating the DC voltage, it's given to the single-phase transformerless H6 inverter. The main advantage of this is that due to its non-isolating topology, the size, weight, and cost have been minimized without affecting the system's performance and efficiency. The integration of two renewable energy sources is very challenging nowadays, and it has been integrated into two sources: Battery and PV. The PV panel provides 350V DC, and the battery is 300V, while these two sources are feeding dual input give a regulated DC voltage of 400V DC at its output. Due to the small size's advantage, the high efficiency of the H6 inverter converting it into AC voltage and supply it to the grid when needed.

VII. FUTURE WORK

By designing an efficient, fast dynamic response of the controller, we can improve the power converters' performance. For this purpose, digital controllers can implement FPGAs to get high performance of the power converters like Single-phase transformerless inverter.

REFERENCES

[1] C. Schuss, et al., "Impacts on the Output Power of Photovoltaics on Top of Electric and Hybrid Electric Vehicles," in IEEE Transactions on Instrumentation and Measurement, vol. 69, no. 5, pp. 2449-2458, May 2020, DOI: 10.1109/TIM.2019.2962850.

[2] Z. Q. Zhu and S. Cai, "Hybrid excited permanent magnet machines for electric and hybrid electric vehicles," in CES Transactions on Electrical Machines and Systems, vol. 3, no. 3, pp. 233-247, Sept. 2019, DOI: 10.30941/CESTEMS.2019.00032.

[3] E. Kabir, et al., "Solar energy: Potential and future prospects," Renewable and Sustainable Energy Reviews, 2018, 82, pp.894-900

[4] S. Kouro, J.I. Leon, D. Vinnikov, and L.G. Franquelo, "Grid-connected photovoltaic systems: An overview of recent research and emerging PV converter technology," IEEE Trans. Ind. Magazine, 2015, 1, pp. 47-61.

[5] Z. Özkan and A.M. Hava, "Classification of Grid Connected Transformerless PV Inverters with a Focus on the Leakage Current Characteristics and Extension of Topology Families," Journal of Power Electron., 2015, 15, (1), pp. 256-267.

[6] S. Hussain et al., "Simulative Analysis of Power Conversion System for Hybrid Electric Vehicles Based on Dual Input Sources Including Charging From Solar Panel," Pakistan J Engg & Tech, vol. 3, no. 03, pp. 14-19, Dec. 2020.

[7] Muhammad Nasir Khan, Syed K. Hasnain, Mohsin Jamil, Sameeh Ullah, "Electronic Signals and Systems Analysis, Design and Applications International Edition," in Electronic Signals and Systems Analysis, Design and Applications: International Edition , River Publishers, 2020.

[8] Li Zhang, Kai Sun, Yan Xing, Mu Xing, "H6 Transformer-less Fun Bridge PV Grid-Tied Inverters" IEEE Transactions on Power Electronics, Vol-29, Number 3, March 2014.

[9] A. Das and Sheeja G, "Implementation of transformerless step-up converter and H6 inverter for single-phase AC applications," 2016 Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTSE), Bengaluru, India, 2016, pp. 1-5, DOI: 10.1109/PESTSE.2016.7516510.

[10] Khan, Muhammad Nasir, Syed K. Hasnain, and Mohsin Jamil. Digital Signal Processing: A Breadth-first Approach. Stylus Publishing, LLC, 2016.

[11] B. Yang, W. Li, Y. Gu, W. Cui, and X. He, "Improved transformerless inverter with common-mode leakage current elimination for a photovoltaic grid-connected power system," IEEE Trans. Power Electron., vol. 27, no. 2, pp. 752–762, Feb. 2012.

[12] M. N. H. Khan, et al., "Transformerless Inverter Topologies for Single-Phase Photovoltaic Systems: A Comparative Review," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 8, no. 1, pp. 805-835, March 2020, DOI: 10.1109/JESTPE.2019.2908672.

[13] Z. Ahmad and S. N. Singh, "Comparative analysis of single-phase transformerless inverter topologies for grid-connected PV system," Solar Energy, vol. 149, pp. 245–271, Jun. 2017

[14] W. Chen, X. Yang, W. Zhang, and X. Song, "Leakage current calculation for PV inverter system based on a parasitic capacitor model," IEEE Trans. Power Electron., vol. 31, no. 12, pp. 8205–8217, Dec. 2016.

[15] R. S. Figueredo, K. C. M. de Carvalho, N. R. N. Ama, and L. Matakas, "Leakage current minimization techniques for single-phase transformerless grid-connected PV inverters—An overview," in Proc. Brazilian Power Electron. Conf. (COBEP), Oct. 2013, pp. 517–524.

[16] L. Zhang, K. Sun, Y. Xing, and M. Xing, "H6 transformerless full-bridge PV grid-tied inverters," IEEE Trans. Power Electron., vol. 29, no. 3, pp. 1229–1238, Mar. 2014.

[17] Jamil, Mohsin, Muhammad Nasir Khan, Saqib Jamshed Rind, Qasim Awais, and Muhammad Uzair. "Neural network predictive control of vibrations in tall structure: An experimental controlled vision." Computers & Electrical Engineering, vol. 89, pp. 106940, 2021.