High Gain Transformer-less DC/AC Inverter for PV System

I A Zunnurain1, M F Hariz2, S M Ilham2, N Kimpol2, M N K Anuar2 and K M Yumi3

1Kulliyyah of Engineering (Electrical), Universiti Islam Antarabangsa (UIA), Malaysia.
2Faculty of Electrical Engineering, University Malaysia Perlis (UniMAP), Malaysia.
3School of Electrical Engineering, Universiti Teknologi Malaysia (UTM), Malaysia.
Email: iman.alyzza@gmail.com

Abstract. Investigation interests on many scientific aspects of photovoltaic (PV) trans-former-less inverter system has improved over the past decade. Using step-up transformer or high frequency transformer in electrical system has made the entire system expensive and voluminous. There is alternative topology to replace the transformer by implementing DC/DC quadratic boost converter to expand the voltage from $12V_{DC}$ to $325V_{DC}$ from the photovoltaic (PV) solar and convert it to AC applying H-bridge inverter circuit. This method will replace the conventional method of bulky transformer into a lighter converter with the same performance. The circuit is simulated using Power Sim (PSIM) software to initiate the design and study the circuit capability. The experimental result will project the exact voltage in the range of $230V_{ACrms}$. The harmonic profile of the inverter is studies and compared with the normal inverter configuration.

1. Introduction
The demand for electricity is growing and to reduce the emission of carbon dioxide gases during the power conversion leads the power electronic engineers to choose the power sources that are non-conventional. Amongst all the clean energy sources, Solar photovoltaic (PV) are attracting greater interest because of their cleanliness [1-4]. As well as infinite availability of nature. In the power grid, the operation of PV acquires with the significant advances in the technology of power electronics, more emphasis is granted [5-9]. Since it needs low maintenance cost, it plays an important role in the electric power generation. The voltage harvested from the PV system is direct voltage (DC) [1-4]. The conversion of availed $D_{DC}$ voltage to $A_{AC}$ voltage before connected to the load performed by two different configurations, namely the quadratic boost conversion system and $D_{DC}$ to $A_{AC}$ voltage conversion using H-bridge inverter [8,10-12].

The conventional inverter configuration usually using the standard bridge inverter and connected to the center tap transformer for the conversion of AC voltage to a higher level [13-14,16]. The different approach in this system where the input voltage from the solar PV will be injected into a quadratic boost converter where it will boost up the small voltage into a higher voltage and it can be adjusted up to $500V_{ACrms}$ voltage. By having this option, the conventional transformer can be avoided and straightforward using inverter for conversion purposes. This quadratic boost converter and inverter are designed using PSIM Software. The inverter, which is commonly used in uninterruptible power supplies (UPS), solar panels and AC engine drives, takes on substantial jobs to provide each operation of the AC source. This kind of high-gain inverter-less transformer is not quite the same as another one that is usually
practical on the market. A high gain boost converter, which is a quadratic boost and h-bridge inverter, is used for the proposed ideas of high gain transformer-less inverter. With the grouping of this circuit, the output produced can be used in the electrical system in the secondary customer.

2. High Gain Transformer-less Inverter Topology

The characteristics of a transformer-less inverter can be described as lightweight, compact and relatively inexpensive [14,16]. It is because electronic exchange instead of mechanical exchange is used for transformer-less inverters, the calculation of warmth and stickiness shaped by regular inverters is greatly reduced. The one-of-a-kind functionality of transformer-less inverters is to use two power direct trackers to handle facilities as discrete solar PV frameworks. At the end of the day, on a similar housetop with transformer-less inverters, solar PV panels can be implemented in two different directions, such as north and west, and generate Dc yield with perfect impacts at isolated high point hours [7-9]. Conventional inverters run from a single power point, which ensures that the Dc yield of the whole framework can be decreased by boards running at lower frequencies.

Dc to Dc converter topology is at work on a high number of applications. In this interest Dc - Dc converter topology, the framework with low yield highlights to illustrate signs of change is typically associated in a sustainable power source framework. In the PV monitor and in the energy modules, the transformer should be used to build up the output voltage. In any event, in the middle of the exchange task, the voltage tension will be increased. Figure 1 revealed the quadratic boost converter with a single switch, where \( V_{in} \) is the incoming supply voltage, \( V_c \) is the output voltage at the \( C \) capacitor, and \( S \) is the independent Switch 1 at MOS. While for Figure 2 using the basic H-bridge inverter circuits. This model usually allows active and passive switches to appear in pairs and to form a three-terminal network. This system can, however, be stretched with a single switch to evaluate the quadratic boost converter, which requires an active switch and three passive switches. The diode \( D \) and the transistor switch 1 are replaced by the corresponding current source and the diodes \( D \) are replaced by voltage sources [15].

![Figure 1. Quadratic Boost Converter configuration](image1)

![Figure 2. Full Bridge Inverter configuration.](image2)
3. Parameter and circuits setting
The design of the complete system will be depending on the load for the system. The perspective might be different for the different operations of load and demands for current for each category. In this research, a standard single-phase load will be used and the demand for the load is around a 115-Watt system. Table 1 shows the parameter settings and specifications for the developed prototype.

| Parameter                  | Value                  |
|----------------------------|------------------------|
| Duty                       | 0.73                   |
| Load                       | 115 W (230Vrms, 460 ohms) |
| Capacitor, \(C_1\)         | 2.5 mF                 |
| Capacitor, \(C_2\)         | 45 uF                  |
| Inductor, \(L_1\)          | 150 uH                 |
| Inductor, \(L_2\)          | 300 uH                 |
| Switching Frequency, \(f\) | 20 kHZ                 |
| Quadratic                  |                        |
| Fundamental                | 50 Hz                  |

4. Simulation and Experimental Setup and Results
Simulation is the technique used to analyse the circuit functionality before proceeding to the actual hardware. The Power Sim (PSIM) software is used in this article to simulate the main circuit and testify all the component parameters and hardware setup is the best practice and implementation of proving the research.

4.1 Simulation Results
In the simulation, the component parameters will be set properly set according to the real hardware component as to abstract the good simulation results. Figure 3 below shows the results of the main circuit.

Figure 3. Simulation results for Input voltage of Boost and Output voltage of transformer-less Inverter.

Figure 3 shows the results of main circuit of high gain transformer-less inverter. In can be see that the system is powered up by 12VDC and managed to be boosted up to 325VDC and entering the inverter circuit. The 325VDC is next inverter into sinusoidal AC voltage with the rated
There is some ripple and disturbance at the beginning due to the switching stress of the full bridge to convert the direct voltage into the alternating voltage.

For the hardware configurations for the high gain transformer-less inverter combine the two major circuits of quadratic boost and the inverter circuits as shown in Figure 4. The circuit is injected with a DC voltage supply from solar PV panels of 12\(V_{dc}\). The small 12\(V_{dc}\) will boost up to 325\(V_{dc}\) with the rated current of 0.5\(A_{dc}\). This value is specifically selected due to the conversion from DC into AC Volts RMS condition as standard single-phase voltage is a 325\(V_{peak}\) = 230\(V_{rms}\). The boosted voltage will be injected into the inverter circuit to form an AC voltage system.

**Figure 4.** Experimental Setup of High Gain transformer-less Inverter

### 4.2 Hardware Results

The hardware setup is connected to the Tektronix TPS2014 Digital Oscilloscope for measurement purposes and the probe used for the measurement is the standard differential probe to measure both DC and AC voltage waveforms.

**Figure 5.** Duty Ratio Boost  
**Figure 6.** Unipolar SPWM

Figures 5 and 6 show the pulsation from the controller to controller the quadratic boost converter and the inverter. A uniform pattern duty cycle of 0.73 driving the MOSFET 1 in the quadratic boost converter and the standard unipolar PWM strategy to inverter the DC voltage. Unipolar SPWM does promise a smooth output pulsation [13,17]. While in Figure 7 below shows the small DC voltage from solar PV boosted up into and injected into the inverter forming a sinusoidal AC voltage as in Figure 8. In Figure 8, the readings show the RMS value, and it is approximately which is exactly a standard voltage rating for the single-phase system. There is some voltage spike seen at output voltage due to the extreme ramp up the voltage from the solar PV panels. A new approach by replacing the Solar PV with new cell such as Supercapacitor can be considered as Supercapacitor can supply a better stable current and very fast charging [18-20].
5. Conclusion
The research has successfully achieved its target to convert the small DC voltage into a higher AC voltage without using a transformer. However, this research only explores small load applications. Further research can be extended into a larger scale of output voltage and connect to the grid-connected system.

References
[1] Fahmi M I, Rajkumar R, Chong L W, Isa D and Adnan Khan M D S 2018 IET Conference Publications pp. 70.
[2] Aihsan M Z, Baharudin N H, Mansur T M N T, Ali R B, Sing L S and Rahman N A 2014 Appl. Mech. Mater. 679 14-19.
[3] Ahmad N I 2018 Int. Conf. Comput. Approach Smart Syst. Des. Appl. ICASSDA pp. 1-5.
[4] Aihsan M Z 2020 IOP Conf. Ser. Mater. Sci. Eng 932 p 012075.
[5] Romli M I F, Kumar Rajkumar R, Wan W Y, Lee Wai C, Arelhi R and Isa D 2016 Int. J. Renew. Energy Dev. 3 249.
[6] Liew H F 2020 IOP Conf. Ser. Mater. Sci. Eng. 932.
[7] Fahmi M I, Rajkumar R K, Arelhi R and Isa D 2015 Proceedings of the Universities Power Engineering Conference 2015.
[8] Aihsan M Z 2016 Wind Turbine Constant Voltage Controller Using Modified SHEPWM Technique (Universiti Malaysia Perlis, Malaysia).
[9] Shahmi Bin Bimazlim M A 2020 International Conference on Power and Energy (PECon) pp. 95-100.
[10] Fahmi M I, Rajkumar R, Arelhi R, Rajkumar R and Isa D 2014 IET Seminar Digest 2014 CP659.
[11] Aihsan M Z, Ali R B and Leong J H 2015 IEEE Conf. Energy Conversion pp. 337–342.
[12] Fahmi M I, Rajkumar R, Arelhi R and Isa D 2014 IEEE Student Conference on Research and Development, SCOReD pp. 1–5.
[13] Walter M S M A 2020 J. Adv. Res. Dyn. Control Syst. 12 1196-1207.
[14] Aihsan M Z 2020 IOP Conf. Ser. Mater. Sci. Eng. 932 012074.
[15] Rothe J P 2014 Transformerless High Step-Up Dc-Dc Converter pp 68–71.
[16] Aihsan M Z, Ahmad N I, Mustafa W A, Rahman N A and J Soo A 2019 Int. J. Power Electron. Drive Syst. 10 636.
[17] Sri Revathi B and Prabhakar M 2016 IET Power Electron. 9 1170–1179.
[18] Aihsan M Z 2018 IOP Conf. Ser. Mater. Sci. Eng. 318 1.
[19] Rashed M A, Fahmi M I, Azizan M M, Wai C L, Zhe L W and Rosle N F 2020 Journal of Physics: Conference Series, 1432 012010.
[20] Hanif M H M 2020 J. Phys. Conf. Ser. 1432 012015.
[21] Aihsan M Z, Ali R B, Othman M, Rahman N A, Sing L S 2015 Applied Mechanics and Materials 793 172-176.