Current Loss Comparison of PWM Operated Transformer-Based and Transformer-Less Inverter

Zeeshan Shahid[#1], Sheroz Khan[#2], Ahm Zahirul Alam[#3], Musse Mohamud Ahmed[#4]

Abstract— **This paper presents the current and power loss comparison of single-phase 50Hz transformer-less and transformer-based PWM-operated inverters that can be used in applications from small-voltage AC supplies to distributed grid systems or Grid tied systems. The major concern in these inverters is its reliability and power conversion efficiency. The less current loss occur while conversion the more power efficient inverter is. This work obtains 220V 50 Hz AC from a 12V DC input supply voltage (from Solar source or battery). The current loss comparison at each sampling frequency ranging from 1 KHz to 20 KHz for both cases of transformer-based and transformer-less is shown and discussed. Also, are explained circuit configuration and switching pattern for the two configurations of inverters under consideration.**

Index Terms— **Transformer-less inverter, Transformer-based inverter, DC-AC inverter, current loss.**

I. INTRODUCTION

DC-DC and DC-AC inverters are used in applications from complex uninterrupted power supplies to Distributed Generation (DG) for grid-tied systems, making them as the element of whole power conversion structure. The basic principle of inverters is to produce an AC output of power frequency (50/60Hz) by using switching devices operated by a suitable switching frequency in the kHz range. The power frequency is to make sure that the corresponding devices are kept ON or OFF continuously for passing the collections of samples onto a low-pass filter or other conditioner circuits in an effort of making sure better output waveform shapes with minimum harmonics are obtained. Obviously the larger is the sampling frequency, the better close to sinusoidal will be the output. The inverters have become with unparalleled importance when used for harvesting of energy from sources in hard-to-man locations such as desert railway or highway stations, inaccessible location in waters (or oceans) and in out of space satellite stations. In industrial environment the use of the inverters is confined to deriving low voltage power supplies for motors, transmitters or controllers or even for charging of batteries from non-conventional sources such as light or vibrations.

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To make these energy conversion systems more efficient, low cost and easy to transport today's researchers are giving more interest to make these inverters low power loss and transformer-less.

The power supply used in these inverters can be from DC storage device or any renewable energy sources, such as solar panel or wind turbines. After the wind, solar is the source under serious investigation and consideration for harvesting of energy in numerous applications taking from that required for signaling or powering up nodal devices in wireless networks used for monitoring purposes in hard-to-man installation centers such as those in railway track passing through forests or deserts or over long stretches of highways. This interest has increased many folds over the recent past. In residential premises, the main investment option seriously thought about is for powering small loads requirement of residential consumers. In which case, large area panels of solar on roof or shops tops could be used for powering requirement either in standalone fashion or could be tied to grid of the main utility of the area. All such applications necessitates the use of converters and conditioner beside the energy generation technique in use, the former case DC needs be stabilized at a constant level while in the later scenarios, besides being stabilized, it has to be into a stable AC output by utilizing power electronics devices such as MOSFETs and IGBTs [1-6].

Another research demanding aspect is that such sources remain highly volatile over a single day not only depending on the intensity of the sun-light striking on the surface of the solar panel, rather the output remains highly dependent on the time of the day, obviously more output at mid-day when sunlight falls almost perpendicularly on the panel's surface. Hence getting the most of the generated power by solar panel, is another issue being covered under the heading of Maximum Power Point Tracking (MPPT) [7]. There thus lies the need of a controller making sure that the panel's surface stays at orientation for a maximum output, but also through the use of the conventional Pulse width modulation (PWM) for controlling power switches (MOSFETs or IGBTs), which later generate AC pulses at the load side [8, 9].

In all such cases, the inverters are installed in most of the cases for meeting power requirement in the mW range, and even a small amount of power saving will be important factor to be explored [10]. An analytical pursuit supported by simulation results is a good tool for estimating the power loss

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when comparing inverter topologies. In the case of transformer-less topology, an inverter is with low cost, reduced weight, but rare work on power losses has reported, obviously should be large in the absence of transformer acting as galvanized isolator.

In this paper a comparison of current loss is analyzed in between transformers-less and transformer based inverter. The effect of PWM sequences used for sampling reasons applied to power switches (MOSFETs) is another parameter being explored to investigate the frequency dependence of such power losses. The simulations results obtained are in the process of being verified experimentally in an associated work by the same authors.

II. TRANSFOMER-BASED CIRCUIT CONFIGURATION

The inverter circuit (Figure 1) is consisting of four power MOSFET transistors connected in H-bridge configuration to be used as switches. For generating both positive half and negative half cycles of a sinusoidal 50Hz AC output, these four switches are operated in pairs (Q1, Q3) and (Q2, Q4) by switching frequency of 50/60Hz frequency. The switching of MOSFETs generates a Square wave signal which is converted to positive and negative half cycles by transformer. These generated AC pulses are then pass through a Low pass filter to filter and reshaping purposes (Figure 2). These switches can also be operated by PWM having modulation frequency of 50 Hz frequency and sampling frequency ranging from 1 kHz to 20 kHz For generation of pure sinusoidal wave.

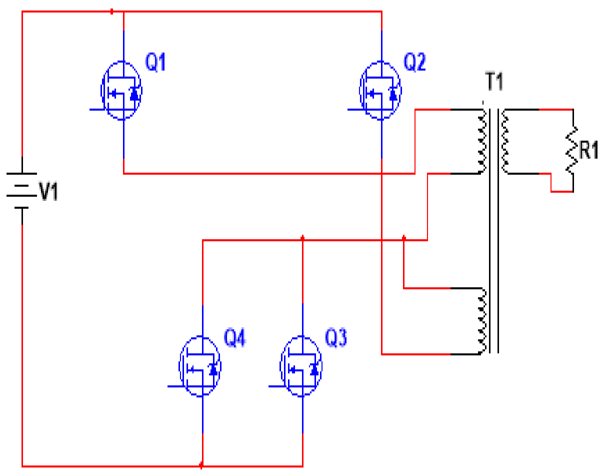

Figure 1: Transformer based inverter

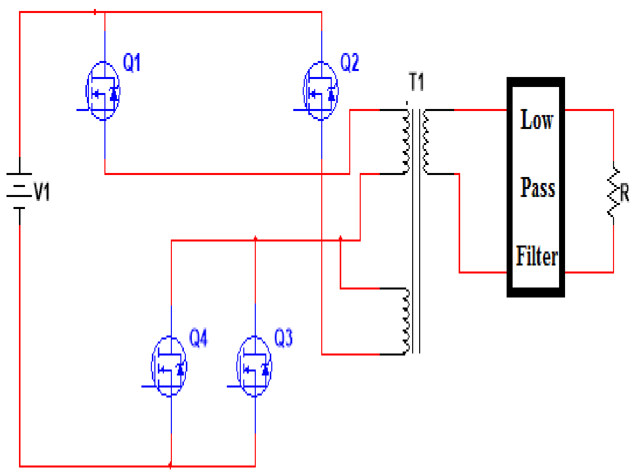

Figure 2: Transformer based inverter with low pass filter connected in series

III. TRANSFOMER-LESS CIRCUIT CONFIGURATION

The inverter circuit (Figure 3) is consisting of four power MOSFET transistors connected in H-bridge configuration to be used as switches. For generating both positive half and negative half cycles of a sinusoidal 50 Hz AC output, these four switches are operated in pairs (Q1, Q3) and (Q2, Q4) by PWM having modulation frequency of 50 Hz frequency and sampling frequency ranging from 1 kHz to 20 kHz. For positive half cycle (as shown in Figure 3) during which switches Q1 and Q3 conduct allowing the current to flow through the load in series with L1 and L3 inductor coils. For the negative half cycle (as shown in Figure 4) switches Q2 and Q4 are turn ON by same PWM control signal making the current to flow in opposite direction through the load in series with L2 and L3. During both of these cycles the low pass filter section is tuning the sample to as close to sinusoidal as possible (Figure 4).

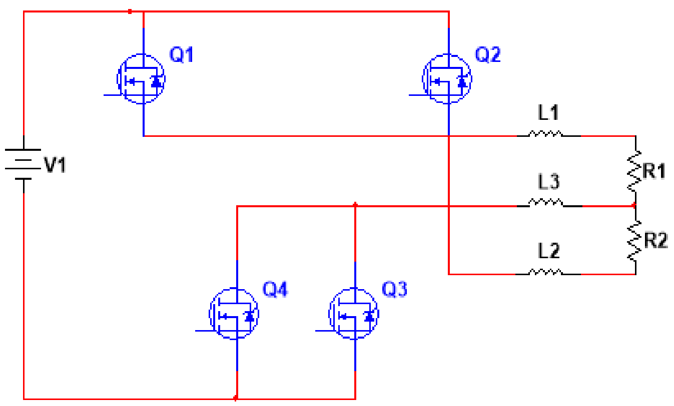

Figure 3: Transformer-less inverter

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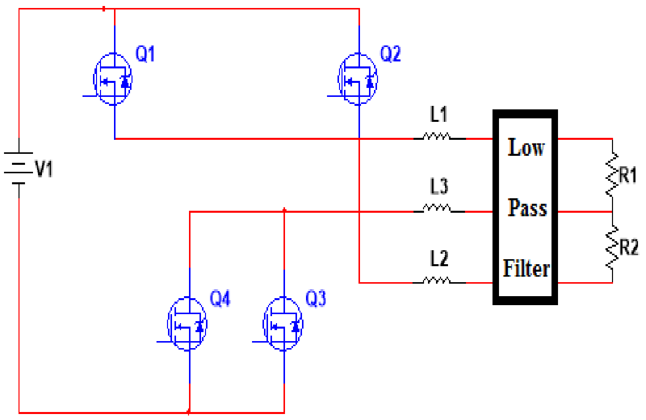

Figure 4: Transformer-less inverter with low pass filter connected in series

IV. RESULTS AND DISCUSSION

Figure 5, shows AC output generated by circuit in discussed in Figure 1, while Figure 6, shows PWM pulses generated at primary side of the transformer which later filter to sinusoidal wave by using Low pass filter as shown in Figure 7.

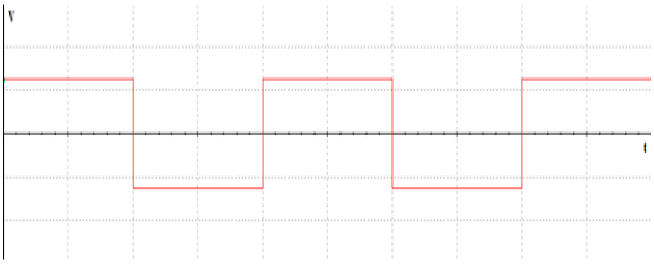

Figure 5: Square wave output of Transformer based inverter at primary side of transformer

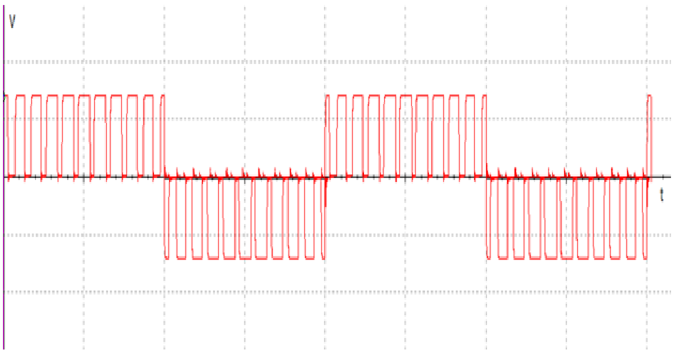

Figure 6: PWM output of inverter at primary side of transformer

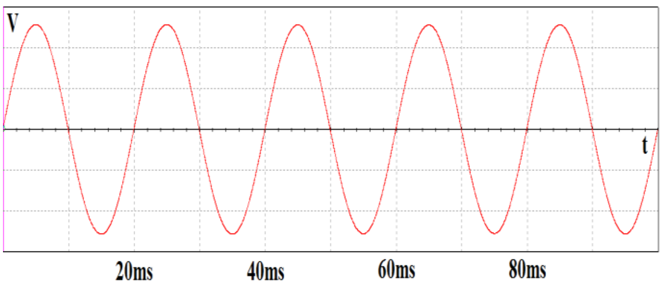

Figure 7: Sine wave 50 Hz AC output of inverter

As the sampling frequency increases the loss in switching of MOSFETs also increases which creates a concern in the efficiency of inverter furthermore the transformer based inverters have many advantages such as galvanic protection, isolation and amplitude stepping up but on the other side the current and power losses of transformer based inverter are also more in compare of transformer-less inverter as in Figure 8 and 9 respectively.

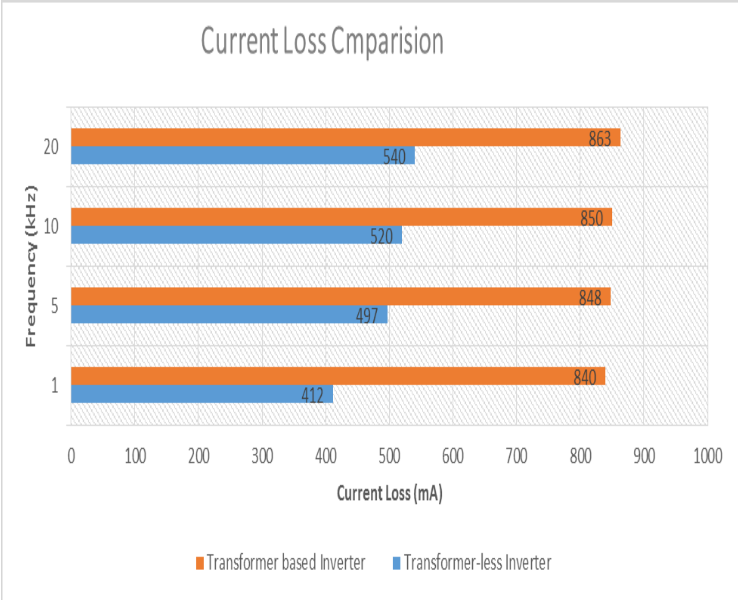

Figure 8: Current loss comparison of transformer-less and transformer based inverter

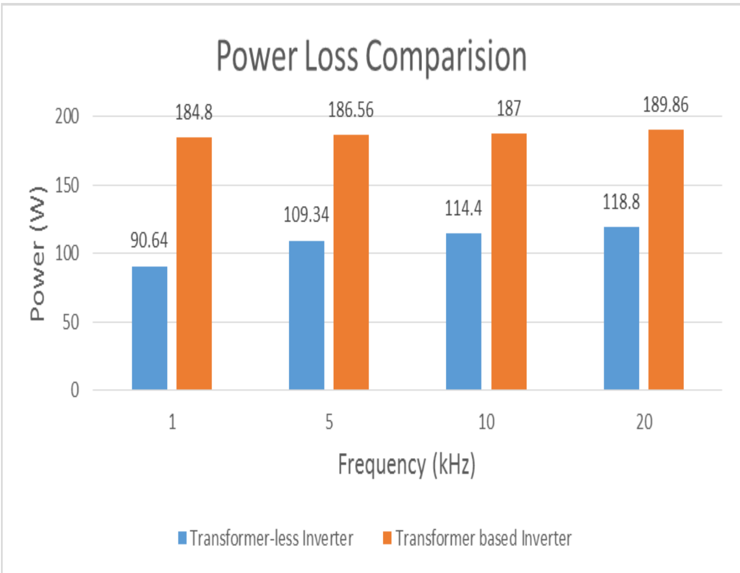

Figure 9: Power loss comparison of transformer-less and transformer based inverter

V. CONCLUSION

The results shown in Figure 8 and 9 indicates the comparison of current and power loss for transformer-less and transformer based inverter. At 50 Hz, 220 V output with different switching frequencies from 1 KHz to 20 KHz the

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power and current losses for transformer based inverters are higher than transformer-less inverter which makes them lower efficient for DC-AC conversion in the applications where high reliability and efficiency is needed.

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