World Applied Sciences Journal 34 (10): 1281-1287, 2016
ISSN 1818-4952
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DOI: 10.5829/idosi.wasj.2016.1281.1287

Wave Shape of Assorted Filters: In a PV Transformer-Less Inverter Topology

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Abstract: The most widespread mechanism for electrical energy generation today are coal, oil and natural gas; all of which unfortunately are extremely detrimental to the environment as a whole. Apart from the leading contributor to the greenhouse effect, these mechanisms produce toxic chemicals that harm the ecosystem and living organisms alike. In order to mitigate these effects, huge amount resources are being invested into developing renewable and eco-friendly mechanism of electrical energy production; with solar energy being one of the championing technologies being developed. Current photovoltaic (PV) are widely accepted for their enhanced efficiency and nominal costs. The challenges facing the Transformer (TRX) less topology is the issue of isolation. It is a challenging task of producing pure high voltage sine wave. This paper proposes incremental and iterative filters for achieving a more accurate pure high voltage sine wave. After the varying filters are applied, the output is subjected to High Order Low Pass Filter (HOLPF) for higher accuracy.

Key words: Photovoltaic (PV) panel · Transformer-less topology · Filters · Load

INTRODUCTION

Solar Energy is multi-faceted in the sense that it is equally suitable for use in residential as well as industrial application [1]. Among its many advantages are that it is non-polluting, inexhaustible and scalable according to its demand. PV in today's markets has inverters as their core component. More accurately, the inverters are operated via switching combination mechanism and in a transformer less topology. Today, we are a few decades into the development of this and when designing photovoltaic systems, one mainly encounters one of the two topologies, which are with and without including transformer [2-3]. It is also noteworthy that the manufacturing and hence the retail prices of photovoltaic units are also reducing at a drastic rate. And due to the above reason it is being preferred to exclude the use of transformer when designing PV topologies, that are costly, efficiency reducing and very bulky [4]. In general practice, for solar-to-grid connections, single-phase inverters are followed by single-phase transformer. The use of transformer, although helps in providing for galvanic isolation between the PV panel and the grid, leads to increase in loss of power and hence loss in revenue. The proposed topology in this paper compensates considerably for the issues of cost and size, but even then, transformer-less topologies result into increased leakage current due to coupling and parasitic capacitances [5].

The transformer-less topology has some more advantages such as being low cost, highly efficient, lightweight and having good overall reliability [6]; but lacks the property of galvanic isolation provided by the topology using transformer. Hence, the most common and prevailing problem for this topology is the 'common mode leakage current' issue which occurs due to current flow through parasitic capacitor in between PV panel to ground [7]. Moreover, the high values of the capacitor and the leakage current can be extensive which can escalate the electromagnetic interference [8]. In addition, the absence of galvanic isolation causes the leakage current to flow in the resonant loop, self-possessed through the output filter, converter, the ground link, the power lines and the parasitic capacitance itself [5]. The maximum or minimum additional losses, grid current distortion and electromagnetic interferences depend on which switches and topology are used in a system [9]. Hence, we use PWM for switching condition for

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improving the whole system, thus reducing the ripple current byusing unipolar PWM. As a result, the maximum ripple current becomes four times smaller than the bipolar PWM system.

Moreover, the coupling with unipolar PWM is being used all over the world for reducing the issue of leakage current. [10]. The common mode ground current (CMLC) actually flow in between the PV panel and ground when the galvanic isolation is absent. These common mode ground current causes an increase in the current harmonics, leading to higher losses, safety and EMI related concerns about human safety hazards [11-16]. Not only that, the CM current is the reason for distortion occurring in grid current [9], [17-19]. In the recent times, many researches are on-going and some of their successful outcomes are discussed [20]. Current ongoing research are focusing on removing this current from the system for getting lossless power effective system. Moreover, the common mode voltage is addressed in recent papers [9], [21-25] suggesting techniques aimed at removing the issue of leakage current.

Additionally, this paper has shown the use of different filters with load and this overall system is working in a synchronous way. Photovoltaic panel is connected with DC-DC converter for achieving pure DC which is converted to square wave by inverter and after that will be used different filters for getting pure sine wave with high voltage.

BLOCK DIAGRAM

Figure 1, actually shows the overall system of Photovoltaic (PV) panel connected to a transformer less inverter system with grid. This PV panel is energized by the sunlight, which is totally renewable and easily attainable. Hence this is a potentially limitless source of energy. The Inside of the solar cell has doped semiconductors that has p and n channel where it generates electricity from sunlight. After that, it can be controlled and or modified for application specific use; e.g being transferred to the battery or driving the load. The PV panels are used as stand-alone or even connected to smart-grids; in both of the cases, power conditioning and regulation make up the core components.

CIRCUIT SCHEMATIC

Figure 2 shows DC to AC converter schematic where the input is 12V direct current. This input is converted to square wave through timed pulse using MOSFETS switches with a given resistive load and this circuit diagram uses four MOSFET switches. In positive half cycle M1 and M4 are working whereas M2 and M3 are working in negative half cycle.

Low Pass Filter is used primarily for achieving output sine wave. Due to that, High Order Low Pass Filters (HOLPF) is applied that is shown in Fig. 3. Before that, a

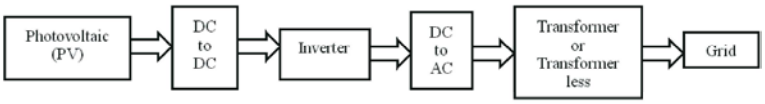

Fig. 1: Block Diagram of overall system.

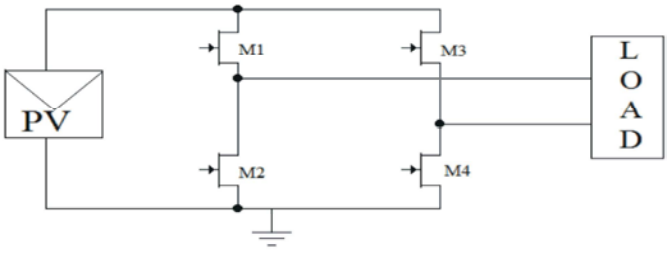

Fig. 2: DC to AC converter with load.

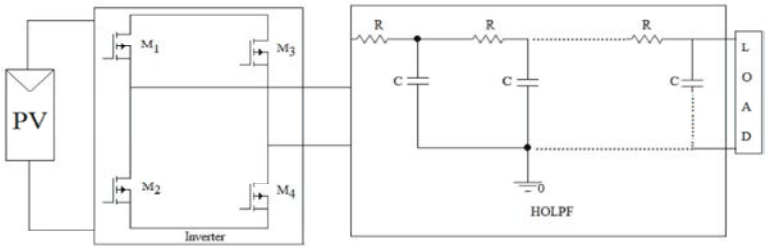

Fig. 3: Applying HOLPF with load.

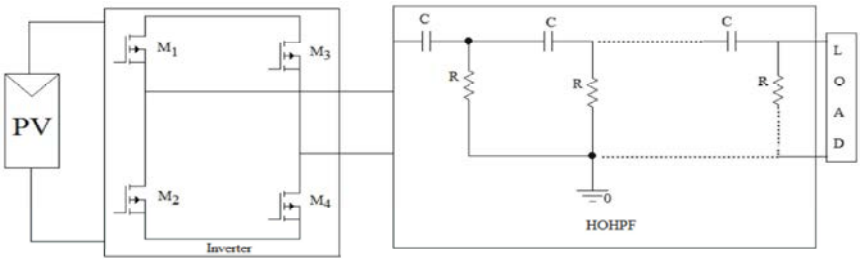

Fig. 4: Applying HOHPF with load.

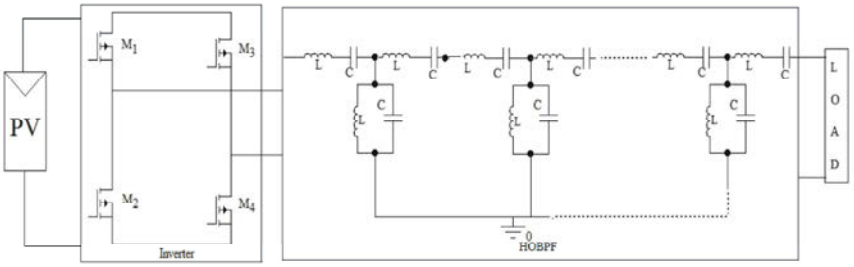

Fig. 5: Applying HOBPF with load.

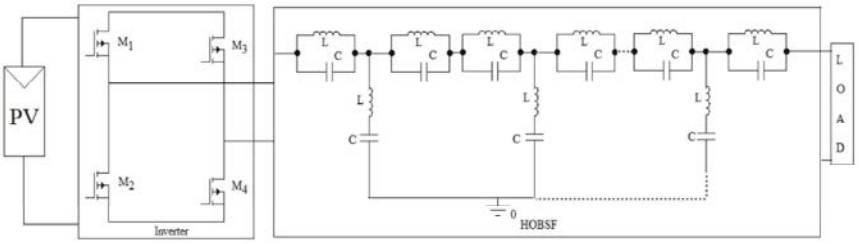

Fig. 6: Applying HOBSF with load.

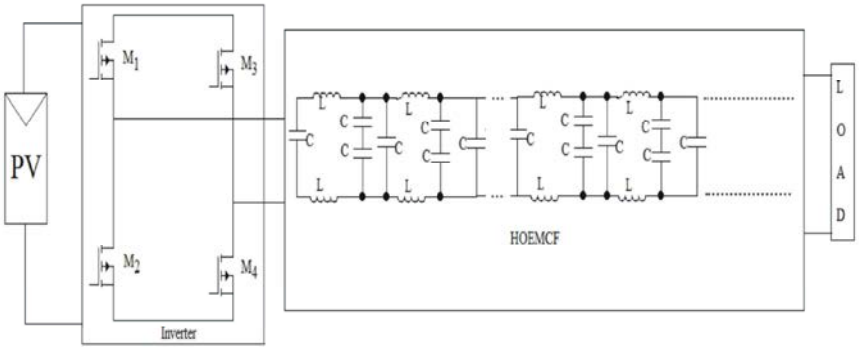

Fig. 7: Applying EMCF with load.

four switch based inverter is used and these four switches are operated in an alternative way. Here we used 12V DC that is actually produced by the single cell solar after DC/DC conversion for getting pure DC.

Figure 4 shows the effect of high pass filter in the PV transformer less inverter topology where high order high pass filter is used with the inverter. Meanwhile, Figs. 5, 6 and 7 shows the use of High Order (HO) Band Pass Filter (BPF), Band Stop Filter (BSF) as well as electromagnetic compatibility Filter (EMCF) respectively.

WAVE SHAPING AND ANALYSIS

This section is basically based on wave shaping of the previously discussed circuit diagram. In Fig. 8 it is shown that a square wave shape that was achieved from simulation using inverter circuit using the input of 12V DC.

It works in two cycles. In the first cycle works in positive where M1 and M4 is worked and the second part is worked using the rest of two MOSFETS. Here we

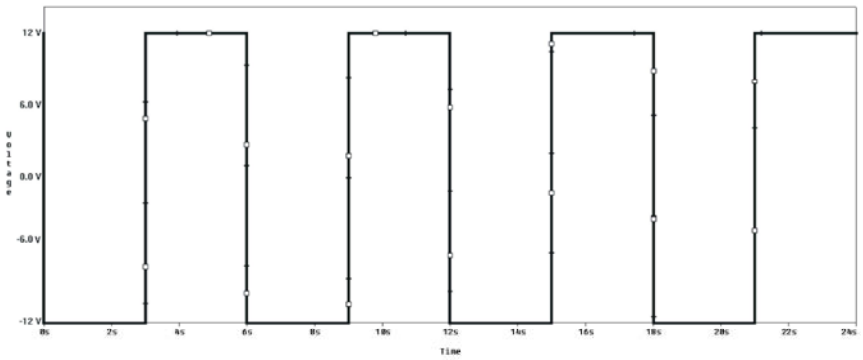

Fig. 8: Square wave shape.

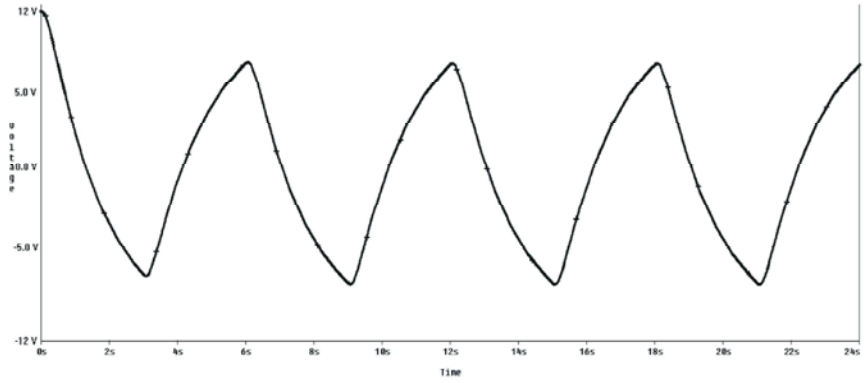

Fig. 9: Output of HOLPF with load.

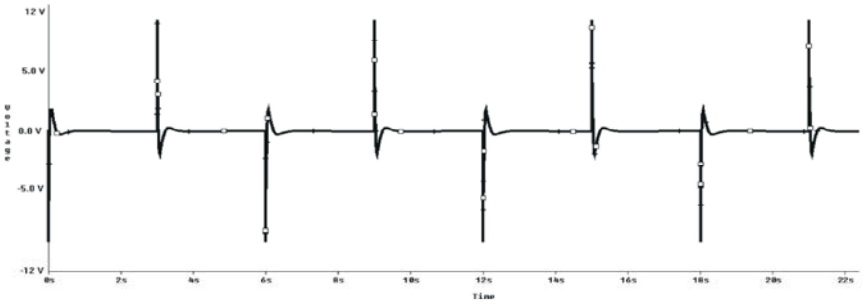

Fig. 10: Output of HOHPF without load.

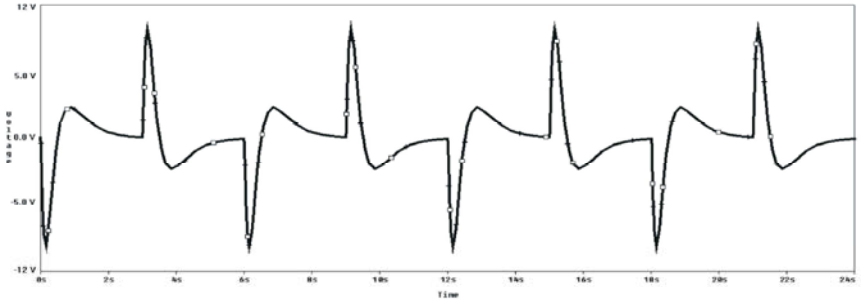

Fig. 11: Output of HOBPF with load.

simulated all filters based circuit that was shown in previous sections for comparing the effect of filters and achieving high voltage pure sine wave. To do so, in Fig. 9 we see the simulated figure after using HOLPF. Here we achieve the pure sine wave with appropriate voltage that we applied as a DC voltage. In Fig. 10 we see

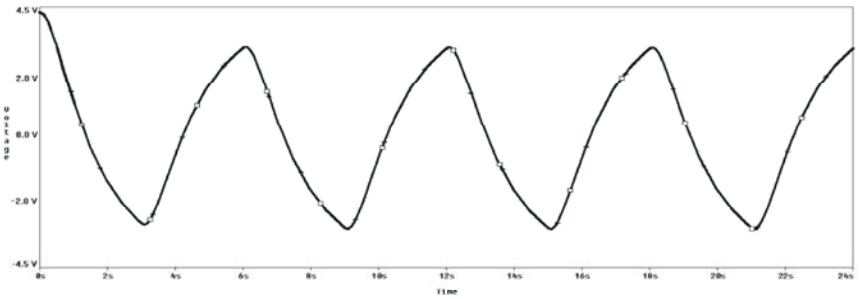

Fig. 12: Reduce of voltage after adding HOBSF with load.

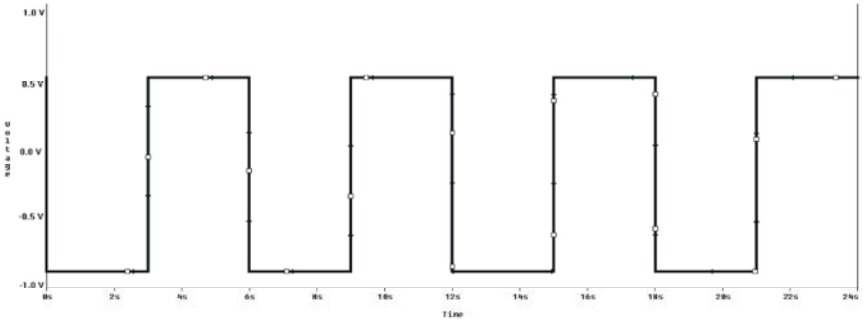

Fig. 13: Square wave with low voltage after using EMCF with load.

the output from HOHPF which is shown as having a spike in the starting point and Fig. 11 shows the combination of spike and sine wave that is achieved after simulating the PV transformer less inverter with HOBPS based circuit. However, in Fig. 12 it is clearly shown that the sine wave is being achieved but the output voltage is nearly 4.5V, the applied voltage being 12V DC. In contrast, the simulated figure in Fig. 13 which is after simulating EMCF based circuit where achieve a square wave but the output voltage is very low.

RESULTS AND DISCUSSION

When a square wave, as shown in Fig. 8 is passed through different kinds of filters we get a great deal of variation in the output, both in its shape and magnitude. Figure 9 shows the output when HOLPF is used. The output is a sine wave with noticeable but quite acceptable level of shape distortion. The wave has a peak to peak value of 18 V, which is also quite acceptable.

The output of HOHPF (Fig. 10) is simply voltage spikes of 12V peak magnitude. They are occurring twice in opposing polarity for every one full cycle of source voltage. HOBPF output (Fig. 11) closely resembles that of HOHPF for the fact that it too consists of spikes, but in addition to spikes, a heavily distorted wave shape is also present.

The output of HOBSF (Fig. 12) is an acceptable sinusoidal wave shape but with diminished magnitude; with the output comprising of a 3V peak value. The output of EMCF (Fig. 13) is simply a square wave AC with approximately 1.5V peak to peak magnitude.

CONCLUSION

Today's solar cell technology is in widespread use all over the world in both the transformer based and transformer less topology systems and increasingly we are feeling the need to introduce the transformer-less systems, thus increasing both the efficiency and cost-effectiveness. But there are also some challenging issues that need to be addressed and the most important being the issue of absent galvanic isolation. This has profound and adverse consequences when it comes to producing pure sinusoidal waveform.

In order to address this issue, this paper has proposed and investigated the application of different filters in conjunction with load with the hope of achieving an ideal sinusoidal waveform. Different filters including High Order Low Pass Filter (HOLPF) are compared with other filters and their output waveforms

are analyzed. The results of the comparisons are as such that HOLPS produces substantially better and more accurate output waveform that resembled a pure sine wave.

Abbreviations:

CM	Common Mode
CMLC	Common Mode Leakage Current
EMCF	Electromagnetic Compatibility Filter
EMI	Electromagnetic Interference
HOBPF	High Order Band Pass Filter
HOBSF	High Order Band stop Filter
HOHPF	High Order High Pass Filter
HOLPF	High Order Low Pass Filter
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PV	Photovoltaic
PWM	Pulse Width Modulation
TRX	Transformer

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