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A Review of the Single-Phase Photovoltaic Inverter Topology with a Series-Connected Energy Buffer

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ABSTRACT:

By using Module integrated converters (MICs) we have to control the speed of induction motor been under rapid development for single-phase grid-tied photovoltaic applications. The capacitive energy storage implementation for the double-line-frequency power variation represents a differentiating factor among existing designs. This paper introduces a new topology that places the energy storage block in a series-connected path with the line interface block. This design provides independent control over the capacitor voltage, soft-switching for all semiconductor devices, and the full four-quadrant operation with the grid. The proposed approach is analyzed and experimentally demonstrated.

Index Terms: *Microinverter, PV panel, Smart grid, Power quality.*

I.INTRODUCTION

The smart grid is incorporated with the digital and intelligence devices to replace the old analog devices in power network. In the traditional grid, there exists a string inverter, in which the inverters are connected in series. When one inverter gets affected, then the following inverter next to the fault inverter gets disconnected from the system. This is called as DOMINO EFFECT. To overcome this effect, this paper deals with the micro inverter, in which each inverter is placed behind the panel and are connected in parallel.

So that, the domino effect gets neglected. The PV Array is connected to the micro inverter. The PV panel must deliver the constant power. This can be done with the help of the maximum Power Point Tracking (MPPT) system which is placed in placed in between the PV panel and the micro inverter circuit. The cycle converter is used to adjust the frequency of the alternate supply and it is fed into the micro grid. Traditionally, Photovoltaic systems (PV) installed around the world are grouped in on-grid and off-grid. The first developed presented greater growth worldwide [1]. They are distinguished by the absence of a storage device, such as battery. One of its main features is the possibility of improving the quality of service of the energy supplied by the electrical grid. There are three configurations of installation of PV systems that can to be connected to the electrical-grid, are: central inverter, string inverter and multi-string inverter [2], [3], [4], [5], [6], [7]. An improvement that is achieved in PV system consists on the implementati on of a PV module with a DC-AC converter small or Module Integrated Converter, MIC, the union of this two is called "AC Module". The AC module easily connects to the electrical-grid under the operate mode of plug and play. It is suitable for use in powers of 40 to 200W and supports multiple connections in domestic applications with a maximum theoretical power of 2 kW [8]. Its advantages are: small size, modular and low cost. The main limitation of AC module is that MIC power will be equal to the delivered power by the PV module. To improve the delivered power the converter requires an element that elevates the voltage, such as: Low Frequency Transformer (LFT), High Frequency Transformer (HFT) and Without Isolation (WI). The MIC with a conventional inverter uses a LFT in order to obtain

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electrical isolation between the PV module and the electrical-grid, as well as raise the low voltage supplied by the DC-AC converter (Fig.1). Its advantage is to have a simple system and with the disadvantage that it is very heavy. This limits the system to reduce size and weight. One solution to solve the problem of MIC with a heavy transformer is to use a DC-DC converter with a transformer smaller operating at high frequency (Fig. 2). However, requires two different control circuits with switching processes and losses higher due to the cascade connection of two power stages. Another option for high performance is to remove the LFT or HFT (WI), with them the weight is reduced, the price down, the size is smaller, the arrangement is simple and to obtain a 2% decrease in losses related to HFT [9] this topology is recommended for power less than 1 kW (Fig. 3).

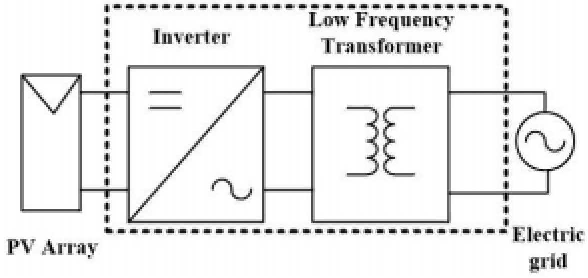

Fig. 1. MIC with LFT.

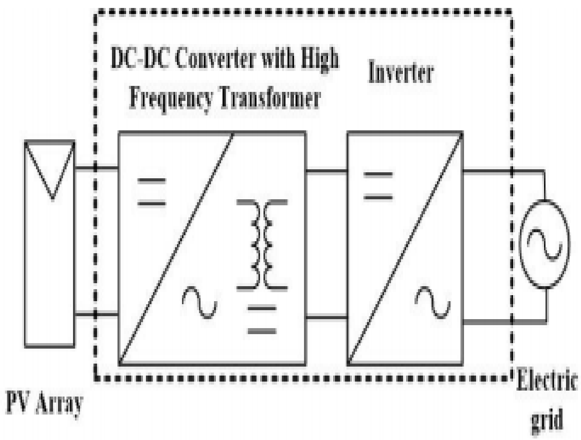

Fig. 2. MIC with HFT.

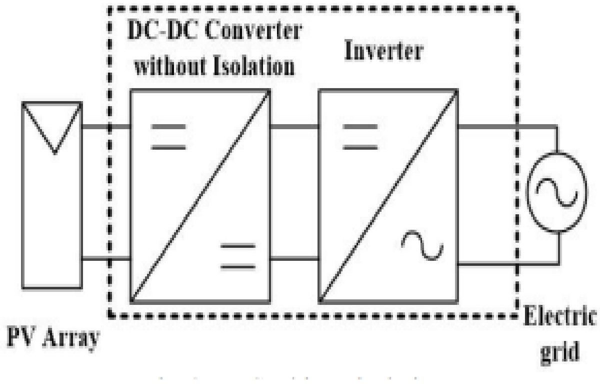

Fig. 3. MIC without isolation.

In [10] is presented a converter with the characteristics that must submit as: being small, light-weight and efficient, its disadvantage is having a low voltage gain. Therefore, it is necessary to develop a DC-DC converter without isolation with high gain, in order to generate voltage quality in the electrical-grid from a single PV Module (Mark, Conergy C1251P) [11], with typical output voltage of 14V to 17V, so it is necessary to have a MIC with a large gain to inverter. To do this, it is established that, it must have a minimum voltage to the inverter input of 180V. To obtain this high voltage is necessary to have a converter with the ability to raise the voltage, and then you must have a maximum gain of 12.85 for a voltage of 14VDC and a minimum gain of 10.58 in the case of 17VDC. It should be mentioned that the maximum gains obtained in the traditional conditioner without isolation converters reported do not cover the above needs [12-17].

II. SELECTION OF PROPOSED TOPOLOGY BY DESIGN OF MIC

The MIC is divided into several stages of conversion [18]. When the converter is a single stage there are two builtin functions: firstly developed the conversion of DC-DC with voltage gain and second is developed the inverter (Fig. 4). For its domestic implementation, is required that the MIC has low weight, high efficiency, high gain and high power density.

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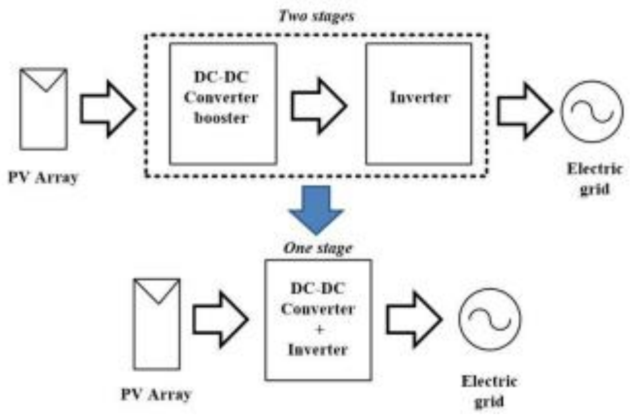

Fig. 4. MIC with reduction stages.

The trend in PV conditioners consisting principally of a single stage, with range of efficiency from 87% to 93.26%, range of switching frequency from 9.6 kHz to 70 kHz. Here are the three alternatives with the best performance gain by inverter without isolation. The first inverter analyzed was proposed by Cáceres et al. [12]. It consists of two DC-DC converters type boost, operating in a complementary mode. However, it has the following disadvantages: low gain, all its transistors operate at High Frequency with hard switching technique, the switching loss increases and the system is susceptible to generation electromagnetic interference. The second inverter analyzed was proposed by Kusakawa et al. [13], this converter operates with PWM signal and hard switching technique and control on both sides: on one hand you have the DC-DC conversion and on the other hand the inverter, it eliminates asymmetry problems. Furthermore, this inverter is appropriate for small power. Its disadvantage is having a single inductor L to provide the energy for each half cycle of the output voltage; this increases the losses due to heating. The third inverter analyzed was proposed by Jain et al [14]. The converter has as function boost and inverts the waveform of the input voltage. This converter operates with two transistors which operate at high frequency and two transistors which operate at low frequency. Its reported efficiency is 87% due to losses in the inductors, works in Discontinuous Conduction Mode operation (DCM) and has implemented tracking Maximum Power Point MPP [19]. According to Table 1, the idea development by Jain presents better characteristics as: its higher gain, fewer components, lower inductance and capacitance and low switching frequency. Based on the reported characteristics by Jain, this proposal is more viable for the purpose of study, which is connected to the electrical-grid a MIC-PV. However, its gain of 3.6 is not adequate, requires a voltage conversion of 10.58 (minimum). The technique to use to obtain VAC is a differential connection of the load across the outputs of two converters, Fig.5. Where the converter 1 will produces V1 and converter 2 will produces V2, the load voltage VO will be given by Vo= V1-V2. While V1 and V2 may both be individually positive, the voltage across the load can be positive or negative. The converter 1 will operate the positive half cycle of the AC signal and the converter 2 will operate in the negative half cycle.

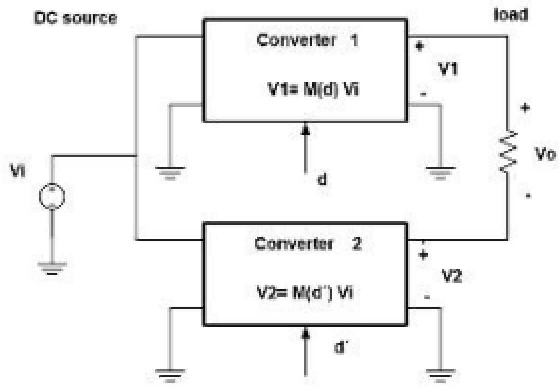

Fig 5. Differential connection of the invertors

III. SELECTION OF DC-CD CONVERTER

Of the various existing options to elevation the voltage, there are three viable alternatives for DC/DC converter. In the Table II are represents the most important characteristics of the three converters above. In it, we can see what is interesting to explore the tapped-inductor scheme, which while not a new technique has been recently taken [28-31], in order to obtain higher gain than for traditional converter To develop a DC-DC converter without isolation we have two options practices: a) traditional with ground output and b) modified without ground output [32]. In the arrangement of a differential output inverter is

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necessary that the inverter has without ground output. This characteristic only presented the family the boost converters. This configuration allows a greater gain than conventional converter. The relationship between the number of turns of primary (Np) and number of turns of secondary (NS) of tapped-inductor is designated by the letter N (Fig.6). The variant of converter that presents a better performance when working in two modes of driving is TIST-BB converter. Which has the advantage of having a duty cycle greater than the others, this is important for control l, because during the operating cycle of the converter to change the DCM to MCC, through the Case Critical CC. Table II. - Comparative analysis with the values reported for DC-DC converters without isolation,

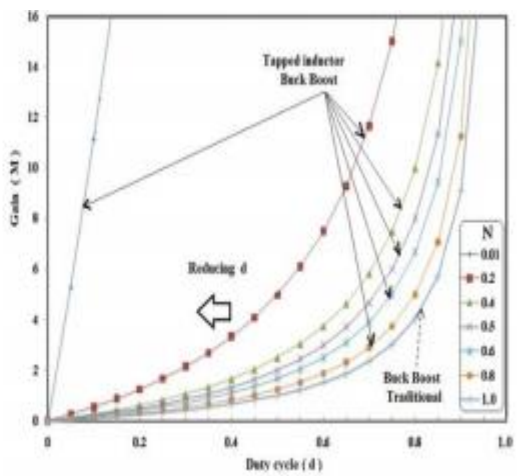
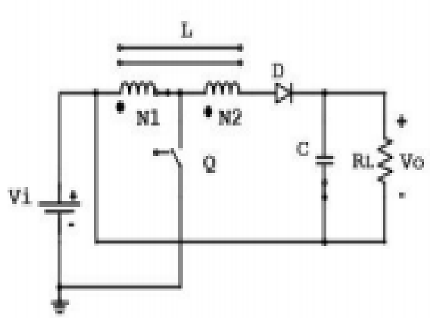


Fig 6. Gain in CCM converters



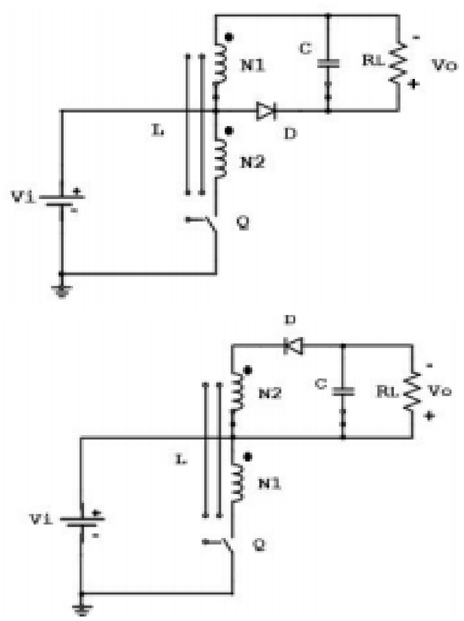


Fig. 7. a) Tap-Switch, ST b) Tap-Diode, DT c) Rail-Tap, RT

The MIC selected consists of two DC-DC converters of the family TIST-BB, without isolation and with output without grounded (Fig. 8). The conversion of DC-AC is carried through four MOSFET and two diodes. Where two transistors work at Low Frequency (LF) and others two transistors work at High Frequency (HF) together alternately.

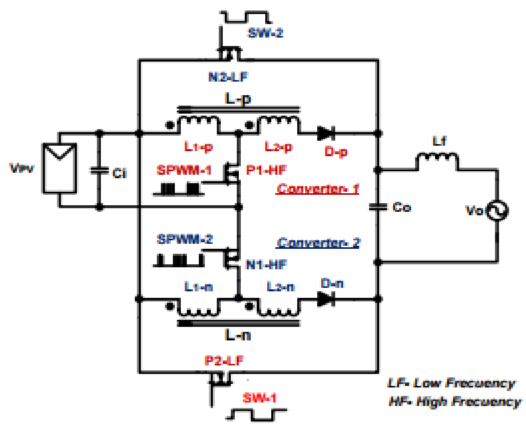


Fig. 8. Elements that switch at different frequencies TIST-BB

IV. TOPOLOGY OPERATION AND ANALYSIS

The solar PV panel would deliver the variable DC source and it is subjected to the MPPT controller. In

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MPPT Controller block, the maximum power is track by using the maximum power tracking algorithms. Then the dc component is passed through the chopper, which would convert the fixed dc to a variable dc. Then it is subjected to the micro inverter. In the micro inverter there are two modes of operation. 3.1 Operation in Mode-I In this mode, the operation is divided into 4 circuit stages in each switching cycle. They are,

- ✓ Storing energy into the transformer am magnetizing inductance.
- ✓ Charging the decoupling capacitor.
- ✓ Transferring the power to the output.
- ✓ Waiting for next switching circuit

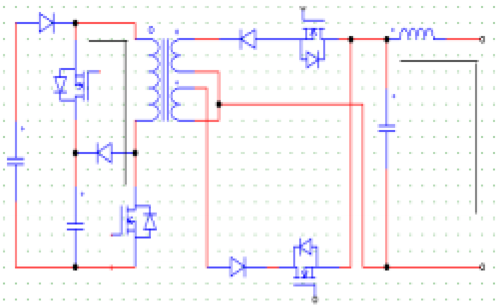

Fig. 9. Energy Stored in an Inductor

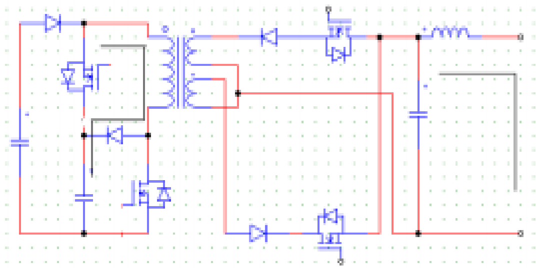

Fig. 10. Charging of Decoupling Capacitor

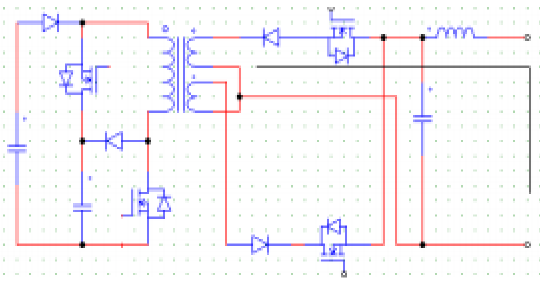

Fig 11. Transferring Power to Output

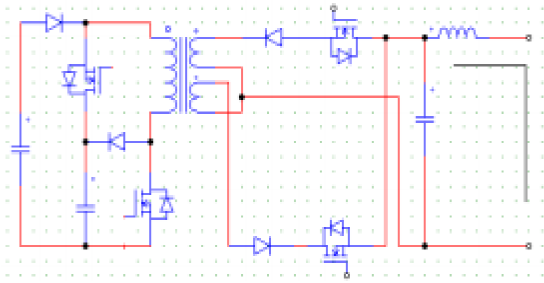

Fig 12. Waiting for Next Switching

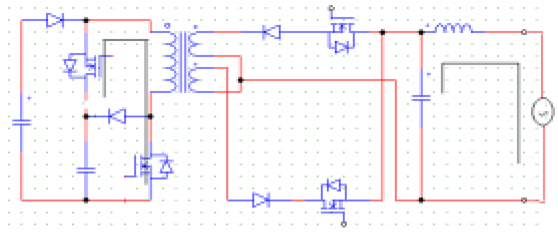

Fig. 13. Charging of Decoupling Capacitor

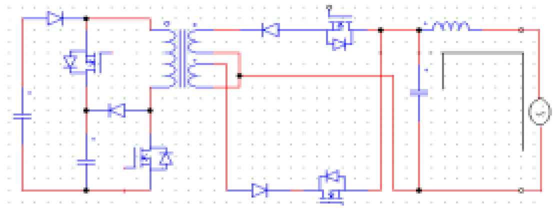

Fig. 14.Transferring Power to Output

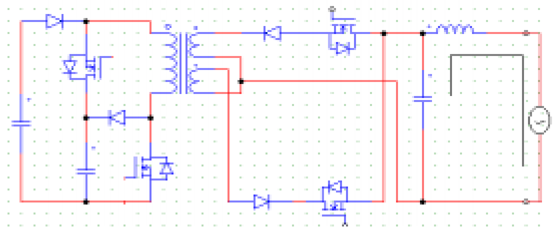

Fig. 15. Waiting for Next Switching

V.SIMULATION RESULTS

To verify the proposed topology, simulation was done in PSIM software. The injected current into the grid is a pure sinusoidal, and the voltage ripple across the decoupling capacitor is 35 V peak to peak, which matches the calculation result. In mode I, when switch S1 turns OFF, the magnetizing energy is partially released to the decoupling capacitor through D1 and D2 .When the energy stored in the magnetizing inductor equals the energy that is needed to be injected into the grid, in one switching cycle, the switch S3 turns ON. Then the remaining magnetizing energy will be released into the secondary side, and finally, into

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the grid. In mode II, the magnetizing current still increase by turning ON switch S2. S2 does not switch OFF until the energy in the magnetizing inductor matches the energy required at the grid side in one switching cycle. The simulation results verify the proposed topology and its control strategy.

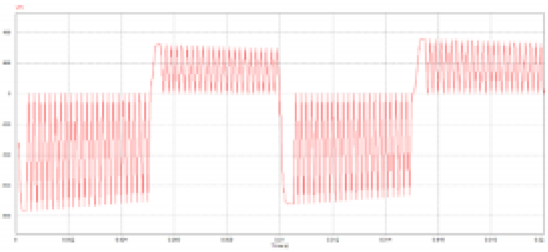

Fig. 16. Simulated Waveform of MPPT

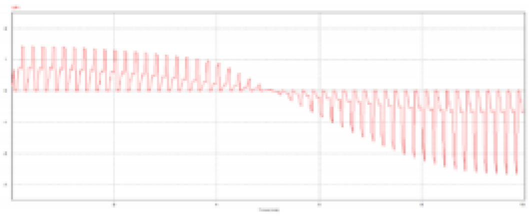

Fig. 17.Simulated Output Waveform

VI. CONCLUSIONS

New single phase PV grid connected micro inverter topology is presented. It is primarily intended for the ac– module PV systems. The proposed topology employs a new power decoupling technique where a small film capacitor can be used instead of the bulky, low reliable electrolytic capacitor. Hence, it will have a long lifespan comparable to the PV panel. It also consists of the micro inverter which would have more advantages than the string inverters, in which if one inverter gets damaged it will affect the whole system. But in micro inverter topology this would be neglected, because all the micro inverter is connected in parallel, and it is placed back of the PV panel. The transformer leakage energy is handled by the decoupling circuit itself so there is no need for additional dissipative circuits, which leads to reduced power losses and improved efficiency. The wind and solar power are infinite and effective power utilization can be done.

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