Microinverter for wireless charging

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Abstract. This paper presents a multi stages grid connecting single phase micro-inverter for photo voltaic utilisation. Conventional single switch flyback inverter suffers from high voltage transients across switch, which leads to a significant reduction in efficiency, the stress on the device causes an increase in cooling arrangements and also underutilization of the device as far as the ratings are concerned. The proposed topology will have an additional switch and two clamped diodes at the primary side so as to have a reduction in the switch stress which increases the efficiency. Converter is operated in Discontinuous conduction mode to have a simple control and to avoid the stability issues. Simulation results authenticate the concert of the proposed method.

1. Introduction

With the increasing demands for the renewable energy sources, solar energy has become promising to generate electricity in a bulk amount. Most of the countries have already getting majority of their energy from the solar power plants. In the countries like India (where the sun’s presence is there throughout the year) this can be more. Due to issues such as initialization costs, reliability and payback period, there was less interest for solar energy utilization. But due to advancements in the photovoltaic technology and semiconductor devices, most of the researchers have started concentrating on converters for PV applications. So solar inverters have become an essential topic for the research. There are 3 types of solar inverters. They are 1. Central inverters 2. String inverters 3. Micro inverters. Of all, Micro-inverters have become the emerging topic for its unique qualities such as efficiency, simplicity and maintenance. Micro inverter means each solar module consists of an inverter as shown in Fig 1. Conventional micro inverters suffer from lot of problems such as high voltage transients across the switch, efficiency, complex control techniques [1]. So, there is a need for the development micro inverter which provides solution for the above mentioned issues. Fly-back converter topology has been proposed by most of the authors because of its simplicity and less component count. It was also proved that interleaved topology reduces the conduction losses of the device. Due to the occurrence of resonance among the transformer outflow inductance and MOSFET output capacitance, large voltage spikes get generated at the switch which leads to the high switching losses. And also to withstand these transients, switch should have higher voltage rating, which increases the on state resistance of the Mosfet. And also high switching frequency is also the cause of switching losses though it can reduce the size of the transformer significantly.
Conventionally, Snubber circuits have been used to eliminate the problem of the voltage thorns across the flyback switch [3], nevertheless the problem is the dissipation of power in the resistor. Several other techniques have been proposed to eliminate this problem such as active clamp circuits and zero current transition methods but with these methods, the circuit complexity is getting increased. So, to overcome this problem, the two switch flyback inverter topology is much simpler. In this paper, it has been clearly given how this topology is superior compared to the conventional topology [6]. The purpose of this paper is to find a simple solution for voltage spikes across the flyback switch in a single phase grid associated flyback micro-inverters. Simulations are given to validate the theoretical analysis.

2. System Description

Fig 2 shows the circuit topology that is going to be analyzed. Single phase grid tied two stage microinverter mainly consists of phase-1 converter, phase 2 converter, single phase bridge inverter, the second order passive filer and a controller to provide pulses to the Mosfets. The S1, S2 are the main power switches and D1,D2 are the clamping diodes of the phase 1 converter and S11,S21 are the main power switches and D11,D21 are the clamping diodes for the phase 2 converter. Lk1,Lk2 are the leakage inductances for the converter 1 and converter 2 respectively. Lm1,Lm2 are the magnetizing inductances for the converter 1 and converter 2 respectively. D3 and D4 are the flyback secondary diodes for converter 1, converter 2 respectively. Sa1-Sa4 represents the switches for the grid connected inverter.

And it is also observed that as the turns ratio is smaller, the primary current stress and secondary voltage stress are more and if it is high, primary voltage stress and secondary current stress are high.
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3. Control Strategy

The benefits of two-phase process in interweaved method is current distribute among two phases which decreases conduction and switching losses [5]. Dipping the driving loss of the power MOSFETS and the transformer core loss are the best topographies of one phase process. So by combining these two phases by using interleaved converter, the efficiency is much more. It can be observed that the output power shape is a squared sine wave.

\[ P_{out} = 2P \sin(\omega t) \]

Where P is the average output power. Fig.3 showing the working region of mono phase and poly phase operation during a bisecting line duration. As it is shown poly phase process is employed when output power is higher and mono phase processes employed when Po is under a convinced level as shown at middle line in Fig 3. It could be noticed that mono and poly phase operation is done suddenly. Phase locked loop is to detect the phase angle, magnitude and frequency of grid voltage precisely and quickly. The output of the MPPT control is \( i_{out} \) which will be adjusting the reference current \( i_{ref} \). The reference signals \( i_{ref1} \) and \( i_{ref2} \) are used to have the current shape in a control technique as described by the following equations.

\[ i_{ref1} = 2\sin(\omega t)\sqrt{(Po)/(Lp * fs)} \quad (t < t_{c1}, t > t_{c2}) \]
\[ i_{ref1} = \sin(\omega t)\sqrt{(Po)/(Lp * fs)} \quad (t_{c1} < t < t_{c2}) \]
\[ i_{ref2} = \sin(\omega t)\sqrt{(2Po)/(Lp * fs)} \quad (t_{c1} < t < t_{c2}) \]

Figure 3: Operating regions of the interleaved microinverter

Best boundary condition of mono phase and poly phase operation is considered \( P_t = 100 \) W. As a consequence, \( t_{c1} \) and \( t_{c2} \) can be attained as

\[ t_{c1} = (1/\omega)\sin^{-1}(\sqrt{(50/Po)}) \]
\[ t_{c2} = (1/\omega)(\pi - \sin^{-1}(\sqrt{(50/Po)}) \]

Under low load condition, phase 1 discontinuous conduction modes of operation decreases the driving loss of the power MOSFETS and transformer core loss. As the power level rises, the conduction losses
and turn-off loss of power MOSFETs, diodes and the loss of transformer become the dominant losses. Whereas 2 phase discontinuous conduction mode of operation shares the current between two interleaved phases. So the basic interest is to minimize the leading losses depends on load ailment.

4. Simulation data used in the proposed system

| Data                                    | Value | Unit |
|-----------------------------------------|-------|------|
| Switching frequency                     | 50    | KHz  |
| Nominal power                           | 200   | W    |
| Transformer turns ratio                 | 0.5   |      |
| PV module voltage at MPPT               | 50    | V    |
| PV module current at MPPT               | 4.1   | A    |
| Leakage inductance                      | 0.01  | mH   |
| Mutual inductance                       | 0.980 | mH   |
| Filter inductance                       | 1.3   | mH   |
| Filter capacitance                      | .33   | μF   |

5. Input Capacitor Selection

For the mono-stage grid-connected micro-inverter, the MPPT delivers the continual output power from the PV panel \( P_{ppv} \), whereas the power transported to the grid \( p_{out} (t) \) is a vivacious waveform as shown in (2). Normally, the electrolytic capacitor is to measure the unhinge of the input and output power. When \( P_{ppv} \) is excess to \( p_{out} (t) \), the rest of the power is stored into the decoupling capacitor. On the contrary, when \( P_{ppv} \) is smaller than \( p_{out} (t) \), the decoupling capacitor delivers the power to the output. For \( P_{ppv}=200 \) W, \( \omega=2\pi f=100\pi \), \( V_{dc}=50 \) V and \( \Delta V=2 \) V, the essential input capacitance is \( C_{dc}=6.3 \) mF. Four 1.7 mF electrolytic capacitors are paralleled with lower ESR.

P and O technique has been utilized to provide the maximum power point tracking.

6. Simulation Results

To support academic investigation, Matlab simulation analysis has been done for the ratings taken. Conventional flyback inverter switch voltage can be observed from Fig 4.

![Fig 4: Conventional flyback converter switch voltage.](image)
It has been observed that the switch voltages have been reduced significantly as shown in Fig 5, and so the switching losses which results in improved efficiency. The efficiency calculated is with this topology is 89% and is calculated under full condition by considering $R_{\text{ds(on)}} = 0.1$ Ohm. Simulation results can be observed from the following Fig 5-10.

**Figure 5:** Interleaved converter switch voltage

**Figure 6:** Flyback converter primary converter voltage

**Figure 8:** Dc link voltage

**Figure 7:** Load current for full load

**Figure 9:** Inverter output voltage synchronized with grid

The system is integrated to grid with the help of PLL which is useful to provide synchronization. Each figure should have a brief caption describing it and, if necessary, a key to interpret the various lines and symbols on the figure.
7. Conclusion
This paper presents the analysis of interleaved flyback inverter which reduces the switching transients and from the simulation results, it can be observed that switching transients have been reduced significantly compared to the conventional fly-back inverter. And it was observed that the number of devices are getting increased but simple control and efficiency are the results. Still, the converter can be well tuned to decrease the transformer ratings. There has to be an optimization between the current transient levels and voltage transients and the transformer ratings.

8. References
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