Investigation of microinverter based on the two-switch DC-DC flyback converter topology

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Abstract. This paper presents an investigation of a novel scheme of the single stage flyback microinverter based on two-switch [1]. The purpose of this topology of microinverter is to transform the DC power generated by the DC voltage input to a standard electric grid AC voltage. The single stage two-switch DC-DC flyback microinverter for the case CL output filter ensures the isolation between the DC power sources and the AC sources by a flyback transformer; has high efficiency (more than 96%) if the parameters of dual two-transistor stage: M1 to M4 are chosen correctly and Total Harmonic Distortion THD less than 5 %. However, the design of this microinverter is characterized by a low number of components.

1. Introduction
Due to their non-sustainability and harmful effects on the environment, fossil fuels no longer stand as attractive sources of energy. Hence, photovoltaic (PV) power management concepts are necessary to derive as much energy as possible from the solar power. PV energy systems are being widely studied because of its profits of environmentally friendly and renewable features. Moreover, solar cells are unique in that they directly convert the incident solar irradiation into electricity. Thereby, photovoltaic (PV) power management insights are necessary to draw as much power as possible from the solar energy. PV energy systems are being widely advised because of its advantage of environmentally friendly and renewable features.

Several PV systems are used in different configurations to achieve high DC voltage [1], [2]. These configurations include following connection methods: parallel series (SP), total-cross-tied (TCT), Honey Comb (HC), bridge linked (BL) and Su-do-ku [1]– [3]. Nevertheless, the PV panels frequently operate in mismatching conditions due to various panel adjustments and shadowing effects. This mismatching problem can cause serious problems for the power-conditioning system. To overcome this drawback, several publications has proposed a module-integrated converter concept [4]. Such a PV systems composed of a PV panels with an individual Photovoltaic DC-AC inverters are called PV flyback microinverters [5]–[8]. For the voltage source inverter (VSI), the
The mildest output line filter has just one inductor. Toward the better performance of a filter, the CL and LCL filters can be constructed with mixtures of capacitors and inductors. The output filter is a critical component of the microinverter to improve the output power quality and reduce total harmonic distortion (THD). This is because the output current of the system contains high-frequency harmonic caused by the pulse width modulation (PWM) switching. For inverter type voltage source inverter (VSI), the mere output filter has just one inductor. Therefore, in order to get the best performance of the filter, the CL and LCL filter take place and can be configured with mixtures of capacitors and inductors [9].

2. The microinverter with the Two-Switch DC-DC flyback converter topology

2.1. System operation

Figure 1 shows the topology of investigated single stage microinverter based on two-switch DC-DC flyback microinverter [10]. The DC side circuit is made up around the dual two-transistor stage: M1 to M4 and the transformer magnetizing inductance. The Mosfets of single stage microinverter topology are operated at high frequency 25 kHz. The Mosfet transistor M5 side output is on while the entire positive grid cycle, and vice versa for Mosfet transistor M5. The diodes in series with M5 and M6 are inserted in order to block reverse power flow from the grid. Supposing a negative grid voltage, and that all currents are zero (Discontinuous Current Mode DCM): A new cycle is started by switching Mosfet transistors M1 and M4 on (respectively Mosfet transistors M2 and M3 for a negative grid voltage). Besides, this lets the magnetizing current to rise up from zero. The Mosfet transistors are retained on in a pre-specified amount of time (a function of requisite power transfer, and DC voltage). They are switched off then, and the stored power in the magnetizing inductance is carried in the secondary-side of the transformer. Further, the stored power is injected into the grid, within Mosfet transistor M5, where the body-diode of the Mosfet transistor M6, and the filter (vice versa for a positive grid voltage). Besides the high frequency harmonics of the formed AC voltage caused by the switching of converter switches are filtered by the low pass filter. The microinverter output voltage waveforms, Total Harmonic Distortion (THD) spectrum and microinverter yield were reviewed. The investigation was performed for two low pass filter types: LCL and CL. However, in this paper, we will focus just on CL filter.

![Two-switch DC-DC flyback microinverter topology](image)

Fig. 1: Two-switch DC-DC flyback microinverter topology

2.2. Operation Principle

The high switching frequency provides high-order harmonics to output [11]. Therefore, an output filter is required for the rejection of switching frequency components. CL filter is extensively used for current source inverters (CSI) and LCL filter which has an extra inductor element to the typical CL filter, is designed in [10]. The interests of LCL filter appear on the system size and the component's capacity. Although, we will focus on the characteristics of CL filter. The investigation was performed for 50 Hz microinverter output voltage frequency 25 kHz switching frequency. Usually, a CL filter is used for both current and voltage inverters grid connected. For the mitigation
of switching frequency elements, the CL and LCL filters are designed as an output filter. Figure 1 shows the circuit of the microinverter topology with the CL filter [11]. As the grid impedance remain unknown, to fix up the transfer function of the circuit and parameters of design, the additional inductive reactance (Lg) expression is defined and used with the CL filter parameters (L and C) as shown in Figure 2. The performance of CL filter corresponds to resonant frequency location. Therefore, the key of designing parameters is that the frequency of harmonics that have to be filtered would be behind the resonant frequency of the filter [11]. The transfer function of CL filter as follow:

\[
A_{lc} = \frac{U_g}{U_c} = \frac{1}{S^2 CL + 1}
\]  

(1)

where \(U_c\) is the voltage side of flyback converter and \(U_g\) is the output voltage side of grid connected of the filter CL. According to the control theory of the second-order system, the frequency is equal to:

\[
f_c = \frac{1}{2\pi \sqrt{LC}}
\]

(2)

3. Simulation results

The investigation was performed using simulation based on the software Matlab/Simulink. The microinverter output voltage waveforms and spectrum and converter efficiency were investigated. The waveforms of output voltage are reached and their spectrum is explained in Figure 3(a, b, c). The results show that the Total Harmonic Distortion (THD) of the output voltage for different voltage amplitude (amp) at 25000 Hz switching frequency (fs) is not higher than 5% and respect the requirements of IEEE standard 1574. The results show that the low pass (CL) filter plays an important role in grid-connected converter when trying to reduce switching-frequency voltage ripples injected into the grid.

![Fig. 2: Circuit diagram of CL Filter](image)

a) THD of the output voltage for amp (400 RMS).
b) THD of the output voltage for amp (600 RMS).

c) THD of the output voltage for amp (800 RMS).

**Fig. 3.** The spectrum and Total Harmonic distortion THD of the output voltage at switching frequency 25000 Hz.

The obtained output voltage waveforms and spectrum are illustrated in Figure 3. The results showed that the THD of the output voltage at 25000 Hz switching frequency is not higher than 4% and respect the requirements of IEEE. The dependences of investigated single stage microinverter efficiency on output power at various internal resistances of flyback converter switches M1-M4 in state ON are shown on Figure 4. It is seen that the efficiency of converter decreases when internal resistance of switch transistors in state ON increases.
4. Conclusion

In this The results of investigation of microinverter based on the couple of two-switch DC-DC flyback converters show that the THD of the output voltage at 25000 Hz is not higher than 4%
and respect the requirements of IEEE. Furthermore, the efficiency of microinverter reaches 0.96 at 100W output power at 25 kHz switching frequency when the internal resistance of MOSFET switches M1-M4 are around 0.008 Ω. Finally, it can be concluding that the investigated grid connected microinverter Is characterized by the high efficiency and provides low THD of output voltage.

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