Modulation Method For A Dual-Buck Inverter Which Minimizes Zero Crossing Distortion And Circulating Current

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This paper presents a low cost dual buck inverter with high efficiency without any reverse recovery issues for the MOSFET. It is ideal for super junction Power MOSFET application, when used for bipolar PWM in case of PV applications, the duty cycle will be around 50% at zero crossing and there will be distortion of current. As low cost, high reliability, high efficiency and low output distortion of alternating current are very crucial in the design of inverters. This paper proposes a novel method for modulation of bipolar PWM, which will minimize the current distortion at zero crossing and achieves low circulating current. The simulation results validate the method.

Keywords: Inverter, High Efficiency, Zero Crossing Distortion.

INTRODUCTION

With the advances in the renewable sector, there is a large potential for renewable sources like wind solar, PV etc. There is a great growth in PV sector with the intervention of government policies, subsidies for using PV for generation of electricity. There are many products using PV, one of them is the topology without a transformer less to eliminate the 50Hz transformer to achieve high efficiency and low cost. The inverters without a transformer are low cost as they use silicon device and have high efficiency as they have less switches and use super junction Power MOSFETs

The efficiency of the inverter can be improved by many ways, such as by designing a new inverter circuit, by using advanced devices like super junction power MOSFET, SiC devices. These devices are widely used in power factor correction circuits, battery chargers etc because of their low conduction and switching losses. In this paper a dual buck inverter without reverse recovery problem for MOSFETs is introduced and it is also useful for the application in super junction power MOSFET. (S. K. Chowdhury and M. A. Razzak, 2014; Xiangdong Zong, 2011; Frede Blaabjerg et al., 2004; Zhilei Yao et al., 2009; Soeren Baekhoej Kjaer et al., 2005; Tamas Kerekes et al., 2009).

In case of dual buck PV inverter, bipolar PWM method is used. This is because of the leakage current in transformer less PV inverters. This paper is organized as (A)-Introduction of high reliability and efficiency dual-buck full bridge transformer less inverter. This uses a conventional bipolar PWM method (CB-PWM).

(B)-Introduces an improved bipolar PWM with distortion at zero crossing current, but solves the inverter circulating current and also the leakage current of the PV panel. (IB-PWM) (C)-Takes care of the distortion at zero crossing current, by introducing a novel nonlinear bipolar PWM. (D)-All the inverter topologies are analysed and compared based on the THD values of each topology.

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DUAL BUCK INVERTER

The Fig.1 shows a Dual-buck full-bridge PV inverter. It is very reliable as it will eliminate the reverse recovery problems, dead time and shoot-through. This dual buck full bridge inverter is proposed so that the properties and advantages of power MOSFETs can be utilized. The size of the passive components, resistive nature of the conduction voltage drops, lower switching losses, instant switching speed are all the benefits of power MOSFETs. As seen from Fig.1, it has unidirectional inductor current and works for positive and negative half cycle current. But it has a drawback that four separate inductors are required. (B. F. Chen, 2012; Henry Benedict Massawe et al., 2013; Zhilei Yao et al., 2009; Ahmed Abdalrahman et al., 2012; S. K. Chowdhury and M. A. Razak, 2013; Marco Liserre et al., 2005).

SIMULATION AND RESULTS

A-TRADITIONAL BIPOLAR PWM METHOD

The block diagram of the conventional bipolar PWM (CB-PWM) is shown in Fig.2. In order that the proposed dual buck full bridge inverter must adopt to the CB-PWM for applications of PV, the dual to common mode voltage from CB-PWM is always fixed to Vdc/2.

Fig. 2: Conventional bipolar PWM (CB-PWM) method

Fig. 3(a) and 3(b) show the operating mode and equivalent circuit for the CB-PWM when switches S1 and S4 are turned ON and when switches S2 and S3 are turned ON respectively.

When S1 and S4 are conducting, freewheeling current of L2 and L3 would circle back to DC bus through D1 and D4. Similarly, When S2 and S3 are conducting, freewheeling current of L1 and L4 flow back to DC bus through D2 and D3, it leads to a circulating current and decrease efficiency.

The simulation results for dual buck inverter using CB-PWM are shown in Fig.4 without filter. The highlighted circle in the waveform indicates the presence of circulating current in the negative half cycle.

Fig. 3(a): Operating mode and equivalent circuit during S1 and S4 turn on.

Fig. 3(b): Operating mode and equivalent circuit during S2 and S3 turn on.
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**B. IMPROVED BIPOLAR PWM METHOD**

The improved bipolar PWM (IB-PWM) is shown in Fig.5. Here the current polarity is taken into consideration (Frede Blaabjerg et al., 2004; Zhilei Yao et al., 2005; Soren Baekhoej Kjaer et al., 2005) and each inductor operates under both positive and negative half cycle currents. Hence PWM is fed to the switches considering the polarity.

![Fig. 5: Improved bipolar PWM (IB-PWM) method](image)

The Fig.6 (a),6 (b), 6(c), 6 (d) all show the operating model and equivalent circuits for the IB-PWM. During the positive half cycle, the switches S1 and S4 will be switching and the freewheeling current will pass through D2 and D3. During the negative half cycle, the switches S2 and S3 will be switching and the freewheeling current will pass through D1 and D4.

The simulation results for IB-PWM are shown in Fig.7. We see that the circulating current is eliminated and switching power loss is also reduced. But, the current in zero-crossing region would have an obvious distortion, which originates from the discontinuous-conduction mode (DCM) condition.
When current is negative and S2-S3 are conducting, the relationship between the duty cycle (D) and Vref is:

$$D = \frac{1 - V_{\text{ref}}}{2}, \quad V_{\text{ref}} \leq 0 \quad (8)$$

When Vref = 0, D will be 50%, it will let current in boundary mode [-ibm] which depends on the current ripple.

The current changes from +ibm and –ibm at the zero crossing over of the current, the duty cycle will be 50%. Due to the distortions at the zero crossing over the THD of the output AC current is 29.66%. These simulation results are shown in Fig.7.

### C. NOVEL PWM MODULATION METHOD FOR CURRENT ZERO-CROSSING

The proposed method combines the advantages of both CB-PWM without distortion and IB-PWM with high efficiency. The Fig.8 shows the proposed method, which uses the unipolar method.

Fig. 8: Proposed Novel PWM Modulation Method in Dual Buck Inverter

In this paper a new modulation method is proposed to provide a duty cycle of 0% at zero cross over. This in turn makes the inductor current to enter DCM instead of boundary mode.

Though the PWM gating pattern is bipolar, but this proposed modulation method will adopt a unipolar method. This method makes the duty cycle zero at the point of zero cross over, which improves the distortion in current at zero cross over.
CONCLUSION

Nowadays the inverters are without transformers with high efficiency and less cost. This paper introduces a dual buck inverter to reduce the distortion and circulation current at zero cross over.

Detail discussion and analysis point out:
- In case of Traditional bipolar PWM technique, there will be circulating current and current distortion will not be present.
- With the Improved bipolar PWM technique, there will be no circulating current, but significant current distortion will be present.

REFERENCES


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