AN INTEGRATED BOOST RESONANT CONVERTER FOR PHOTOVOLTAIC APPLICATIONS

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ABSTRACT

The aim of this study is the Effective photovoltaic power conditioning requires efficient power conversion and accurate maximum power point tracking to counteract the effects of panel mismatch, shading, and general variance in power output during a daily cycle. In this project an integrated boost resonant converter with low component count galvanic isolation, simple control, as well as high efficiency across a wide input and load range. The simulation is carried over by the MATLAB-SIMULINK software. The hardware design is implemented by PIC16F877A controller circuit.

I INTRODUCTION

Power conversion for photovoltaic (PV) applications, as opposed to more conventional dc–dc converter configurations, requires an adaptable system that is capable of responding to a wide range of input voltage and current conditions. As previously stated in the literature, PV voltage varies significantly with panel construction and operating temperature, while the PV current changes largely due to solar irradiance and shading conditions [1]. If a converter is designed only for high peak efficiency, oftentimes the range of conditions common to many PV installations will force the converter into another operating region where it is much less efficient.

Also of interest in the PV PCS design process is the necessity of galvanic isolation between the PV panel and the electric utility system. While an ungrounded, grid-connected PV array is permitted by many electric codes, galvanic isolation can be preferred for various reasons. Most notable among these are improved voltage boost ratio, reduced ground leakage current, and overall safety improvement during fault conditions [4]–[6]. As several authors have already proposed, distributed maximum power point tracking (MPPT) can achieve much better energy harvesting over systems that are completely centralized [7]. Researchers have also concluded that a system structure with the PV panels connected in parallel can be much more productive in low-light and partially shaded conditions than a series-connected system [8]–[12]. These concerns arguably make the single-panel PV micro inverter (dc–ac), or at least an isolated micro converter (dc–dc), an attractive option from a strictly performance-based analysis. In either system, the dc–dc stage implements local MPPT optimization, while the second stage attempts to regulate the dclink voltage by sending power to the utility grid. Block diagrams showing the micro inverter and micro converter system structures are provided in Fig. 1.

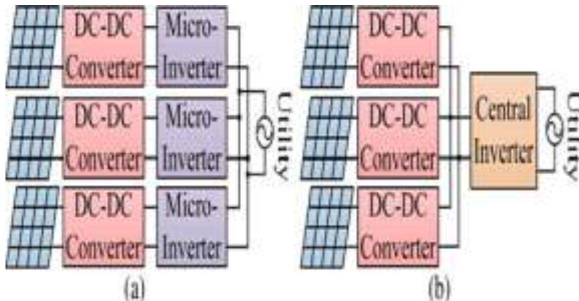

Fig. 1. Distributed (a) micro inverter and (b) micro converter system structures.

In the distributed PV PCS, the isolated dc–dc stage must operate efficiently at full power, while maintaining high performance at light load, across a range of PV voltages. In order to maintain high efficiency under low-power conditions, it is necessary to minimize the amount of circulating energy in the system. An alternate definition of this characteristic would be producing a system with a high "power factor" at the isolation transformer. Also critical to light load efficiency is mitigating the device switching loss. Finally, reduction of the control and gate drive complexity allows for lower fixed losses due to auxiliary power requirements. When considering potential PV conversion solutions, addressing these loss mechanisms is critical to a successful design.

II CONVERTER SYNTHESIS AND OPERATION

When considering the series-resonant DCX as part of this new hybrid circuit, it is important to notice the half-wave resonant behavior by which it operates. During the on-period of either switch a resonant circuit is formed by a combination of the input-side capacitors, the output-side capacitors, and the transformer leakage inductance. The unidirectional nature of the output diodes prevents this circuit from resonating perpetually, and instead, only a resonant period consisting of one half-sine wave is visible. Provided that this resonant period is allowed to complete fully before the primary-side switches change states, the series-resonant circuit is naturally soft-switching on both turn-on and turn-off (ZVS and ZCS). If both resonant periods are allowed to fully complete, the system has no method by which to regulate the output, and the output is simply a reflection of the input. Hence, the necessary addition of another "regulating element," in this case a boost converter, is shown in Fig. 2. The boost converter regulates the effective input voltage to the series-resonant converter, allowing it to run as a DCX with high efficiency.

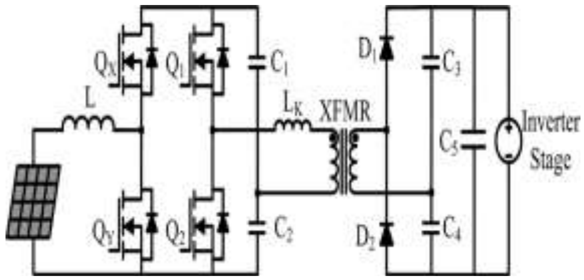

Fig. 2. Resonant half-bridge with separate boost input stage.

This circuit may be further simplified by integrating the system so that the boost converter function is implemented by the original two MOSFETs. A straightforward method to understand this is to directly tie the input inductor to the midpoints of both active switching legs simultaneously. Note that this change directly ties the inductor to one terminal of the transformer. This additional connection renders the upper MOSFETs (QX andQ1) as well as the lower MOSFETs (QY andQ2) in parallel, so long as their switching patterns are synchronized. Thus, the circuit may be simplified, with the additional connection and the removal of QX and QY, into the topology shown in Fig. 3. Because the now single upper and lower FETs (Q1 and Q2) are effectively replacing two parallel FETs, they carry the combined current from the original four switches. Also, as long as the resonant behavior is allowed to complete, the output diodes, D1 and D2, still achieve ZCS.

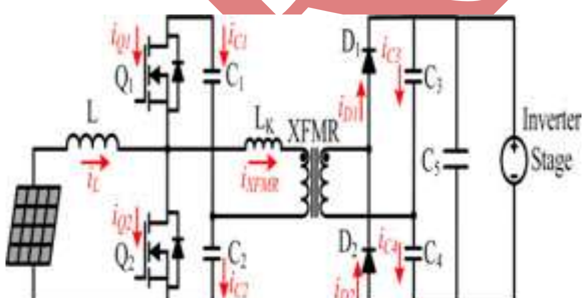

Fig. 3. IBR Converter.

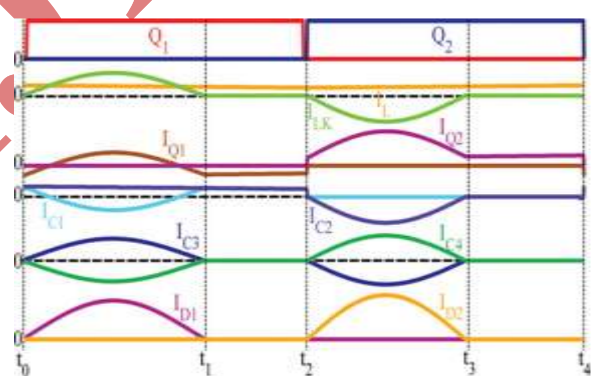

Fig. 4. Timing diagram showing circuit operating modes

This particular circuit topology is similar to that of the “boost half-bridge” (BHB); however, the actual operation of this circuit is quite different. In the BHB, the operating currents are that of the hard-switching half-bridge, giving the converter a poor power factor at the transformer. This makes it difficult for the converter to achieve a wide range of operation, even with ZVS. Also, the voltage transfer ratio is highly nonlinear, leading to much more complex control requirements.

III DESIGN PROCEDURE AND LOSS ANALYSIS

The most critical element of this design procedure is the identification of the input voltage requirements, so that the duty cycle range is fully utilized. With this converter, there is a direct tradeoff between increased input range and lower RMS currents in the circuit. The most basic method involves setting the maximum and minimum duty ratios such that the middle of the input range results in a 50% duty cycle at the converter, an approach provided by the following equations.

$$D_{\text{max}} = \frac{V_{\text{in,max}}}{V_{\text{in,min}} + V_{\text{in,max}}}$$

$$D_{\text{min}} = 1 - D_{\text{max}}.$$

With the nominal input assigned to have a 50% duty cycle, the bus voltage Vbus which is measured across C1 and C2 can be calculated by

$$V_{\text{bus}} = V_{\text{in,max}} + V_{\text{in,min}}.$$

However, it may be necessary to adjust Vbus to accommodate voltage stress requirements on devices or to meet certain standards. If this is necessary, Vbus, Dmax, and Dmin can be altered by using the following equations

$$V_{\text{bus,adj}} = V_{\text{bus}} + V_{\text{offset}}$$

$$D_{\text{max,adj}} = 1 - \frac{V_{\text{in,min}}}{V_{\text{bus,adj}}}$$

$$D_{\text{min,adj}} = 1 - \frac{V_{\text{in,max}}}{V_{\text{bus,adj}}}.$$

IV EXPERIMENTAL RESULTS

During the course of this development, a 250-W prototype converter was designed and built in order to validate the presented analysis and to serve as a core element in a new distributed PV generation system. A photograph of the prototype is provided in Fig. 5.

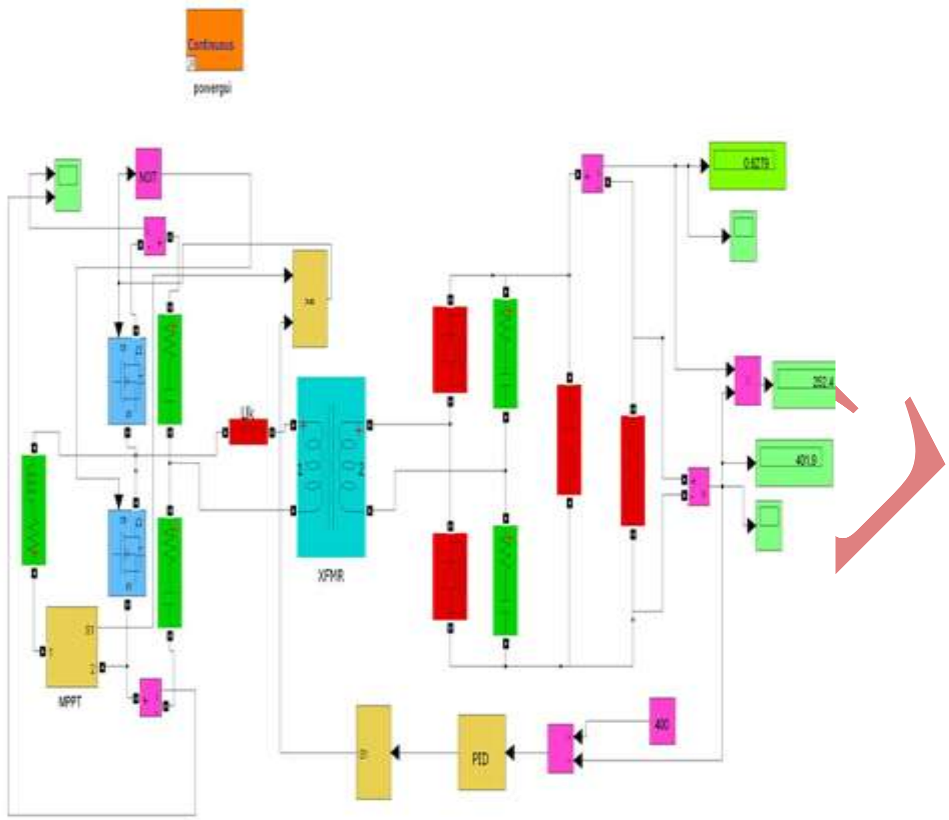

Fig 5: Simulation of a CLOSED loop with MPPT circuit of IFBR Converter

Figs. 6 and 7 demonstrate the consistency of the converter operation over both high and low power. Under each condition, both the inductor current and the transformer current retain their general wave shape while demonstrating CCM and resonant behavior, respectively.

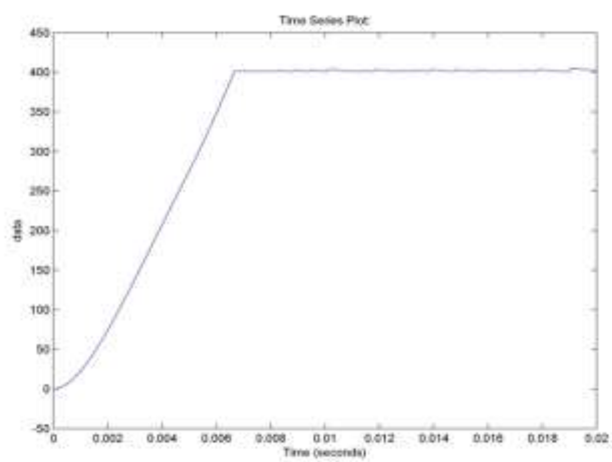

Fig 6: Output Voltage Waveform

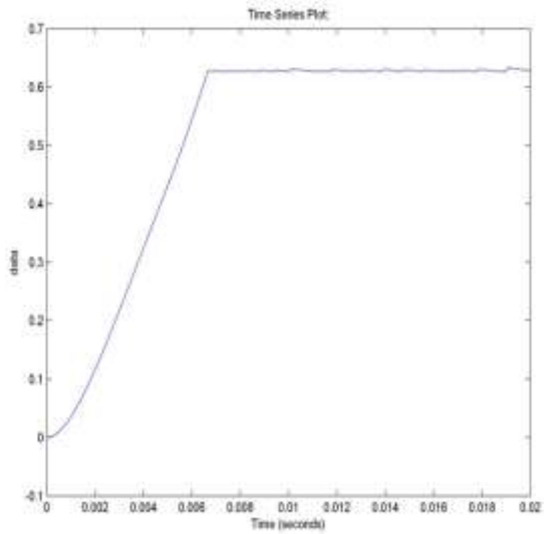

Fig 6: Output Current Waveform

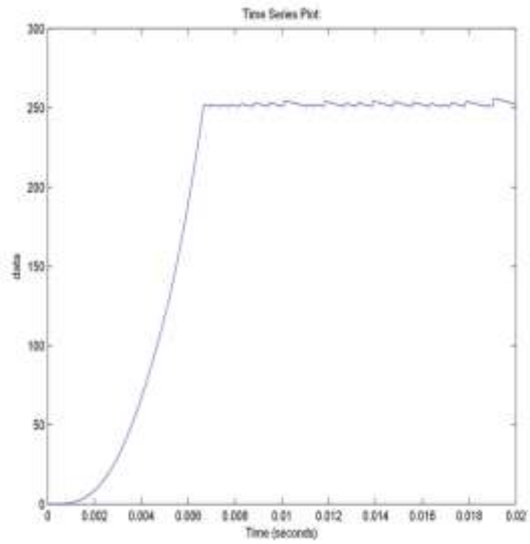

Fig 6: Output Power Waveform

V CONCLUSION

As a solution for providing efficient, distributed PV conversion, an isolated boost resonant converter has been proposed. The system is a hybrid between a traditional CCM boost converter and a series-resonant half-bridge, employing only two active switches. The synthesis of the converter was described along with the circuit operating modes and key waveforms. The design process was then defined, with a focus on the unique combined resonant and PWM behavior. The result was a simple process, requiring only consideration of the resonant period length in selecting a valid converter duty cycle range. Also provided was a detailed theoretical loss analysis, along with formulas for calculating the rms values of important waveforms. Finally, the loss and theoretical analysis were verified by the design, construction, and testing of a 250-W experimental prototype.

REFERENCE

[1] W. Yu, J.-S. Lai, H. Qian, and C. Hutchens, “High-efficiency MOSFET inverter with H6-type configuration for photovoltaic non isolated ac-module applications,” IEEE Trans. Power Electron., vol. 26, no. 4, pp. 1253–1260, Apr. 2011.

[2] L. Gao, R. A. Dougal, S. Liu, and A. P. Iotova, “Parallel-connected solar PV system to address partial and rapidly fluctuating shadow conditions,” IEEE Trans. Ind. Electron., vol. 56, no. 5, pp. 1548–1556, May 2009.

[3] R. Gules, J. De Pellegrin Pacheco, H. L. Hey, and J. Imhoff, “A maximum power point tracking system with parallel connection for PV stand-alone applications,” IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2674–2683, Jul. 2008.

[4] B. Liu, S. Duan, and T. Cai, "Photovoltaic dc-building-module-based BIPV system: Concept and design considerations," IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1418–1429, May 2011.

[5] W. Xiao, N. Ozog, and W. G. Dunford, "Topology study of photovoltaic interface for maximum power point tracking," IEEE Trans. Ind. Electron., vol. 54, no. 3, pp. 1696–1704, Jun. 2007.

[6] T. Kerekes, R. Teodorescu, and U. Borup, "Transformer less photovoltaic inverters connected to the grid," in Proc. IEEE Appl. Power Electron. Conf., 2007, pp. 1733–1737.

[7] Q. Li and P.Wolfs, "Recent development in the topologies for photovoltaic module integrated converters," in Proc. IEEE Power Electron. Spec. Conf., 2006, pp. 1–8.

[8] L. Gao, R. A. Dougal, S. Liu, and A. P. Iotova, "Parallel-connected solar PV system to address partial and rapidly fluctuating shadow conditions," IEEE Trans. Ind. Electron., vol. 56, no. 5, pp. 1548–1556, May 2009.

[9] R. Gules, J. De Pellegrin Pacheco, H. L. Hey, and J. Imhoff, "A maximum power point tracking system with parallel connection for PV stand-alone applications," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2674–2683, Jul. 2008.

[10] B. Liu, S. Duan, and T. Cai, "Photovoltaic dc-building-module-based BIPV system: Concept and design considerations," IEEE Trans. Power Electron., vol. 26, no. 5, pp. 1418–1429, May 2011.

[11] W. Xiao, N. Ozog, and W. G. Dunford, "Topology study of photovoltaic interface for maximum power point tracking," IEEE Trans. Ind. Electron., vol. 54, no. 3, pp. 1696–1704, Jun. 2007.

[12] L. Zhang, K. Sun,Y. Xing, L. Feng, and H.Ge, "A modular grid-connected photovoltaic generation system based on dc bus," IEEE Trans. Power Electron., vol. 26, no. 2, pp. 523–531, Feb. 2011.