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An Interleaved High-Power Fly back Inverter for Photovoltaic Applications

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Abstract:

This paper presents analysis, design, and implementation of an isolated grid-connected inverter for photovoltaic (PV) applications based on interleaved fly back converter topology operating in discontinuous current mode. In today's PV inverter technology, the simple and the low-cost advantage of the fly back topology is promoted only at very low power as micro inverter .Therefore, the primary objective of this study is to design the fly back converter at high power and demonstrate its practicality with good performance as a central-type PV inverter. For this purpose, an inverter system rated at 2 kW is developed by interleaving of only three fly back cells with added benefit of reduced size of passive filtering elements. A simulation model is developed in the piecewise linear electrical circuit simulator. Then, the design is verified and optimized for the best performance based on the simulation results. Finally, a prototype at rated power is built and evaluated under the realistic conditions. The efficiency of the inverter, the total harmonic distortion of the grid current, and the power factor are measured as 90.16%, 4.42%, and 0.998, respectively. Consequently, it is demonstrated that the performance of the proposed system is comparable to the commercial isolated PV inverters in the market, but it may have some cost advantage**.**

Index Terms—Fly back converter, harmonics, interleaved converters, photovoltaic (PV) inverters

INTRODUCTION

THE solar energy is considered as one of the most renewable and freely available source of energy and the candidate to play a greater role in the energy market of the world in the near future [1]. Therefore, the research and development in the solar technology field is in the rise [2]–[6], [8]–[20], [22]– [25]. However, the high cost of the technology still limits its usage globally. The low cost is greatly important for commercialization especially in small electric power systems including the residential applications [2]–[6]. Therefore, the primary objective of the study presented in this paper is to contribute to the research and development in the photovoltaic (PV) inverter technology by trying the fly back topology at high power. If it is implemented effectively with good performance, the developed inverter system can be a low-cost alternative to the commercial isolated grid-connected PV inverters in the market.

The simple structure of the fly back topology and easy power flow control with high power quality at the grid interface are the

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key motivations for this work. The fly back converter is recognized as the lowest cost converter among the isolated topologies since it uses the least number of components. This advantage comes from the ability of the fly back topology combining the energy storage inductor with the transformer. In other type of isolated topologies, the energy storage inductor and the transformer are separate elements. While the inductor is responsible for energy storage, the transformer on the other hand is responsible for energy transfer over a galvanic isolation [7]. The combination of these two components in a fly back topology eliminates the bulky and costly energy storage inductor and therefore leads to are education in cost and size of the converter .However ,we have to make it clear here that the cost depends on the implementation as much as the selected topology, so not every implementation of the fly back topology leads to a low-cost converter. For this reason, as we try to achieve the high-power implementation of the fly back converter with good performance, which is our primary research contribution, we will also try to preserve the cost advantage during the final implementation step.

Practical implementation of a transformer with relatively large energy storage capability is always a challenge. The air gap is where the energy is stored, so a high-power fly back converter design needs a relatively large air gap. As a result of this, the magnetizing inductance is going to be quite small. The aforementioned challenge is actually achieving such a small magnetizing inductance with low leakage inductance. A fly back converter built with a transformer that has large leakage flux and poor coupling will have poor energy transfer efficiency. Mainly for this reason, the fly back converters are generally not designed for high power. As a result, the fly back topology finds a limited role in PV applications only at very low power as micro inverter [10]–[13]. In this technology, every PV panel comes with a dedicated energy conversion unit; a micro inverter attached to the output terminals. For this reason, the technology is also named as ac PV module application [14]–[18]. In this practice, many such ac PV modules are connected in parallel to get the desired power output. The maximum harvesting of solar energy in this method is the best since there is a dedicated maximum power point tracker (MPPT) for each PV panel [19]. However, the overall cost of this application is higher compared to the central-type inverter systems.

LITERATURE SURVEY:

1. A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules

PHOTOVOLTAIC (PV) power supplied to the utility grid is gaining more and more visibility, while the world's power demand is increasing [1]. Not many PV systems have so far been placed into the grid due to the relatively high cost, compared with more traditional energy sources such as oil, gas, coal, nuclear, hydro, and wind. Solid-state inverters have been shown to be the enabling technology for putting PV systems into the grid.

The price of the PV modules were in the past the major contribution to the cost of these systems. A downward tendency is now seen in the price for the PV modules due to a massive increase in the production capacity of PV modules. For example, the price per watt for a PV module was between 4.4 ~ 7.9 USD in 1992 and has now decreased to 2.6 ~ 3.5 USD [2].

The cost of the grid-connected inverter is, therefore, becoming more visible in the total system price. A cost reduction per inverter watt is, therefore, important to make PV-generated power more attractive [4]. Focus has, therefore, been placed on new, cheap, and innovative inverter solutions, which has resulted in a high diversity within the inverters, and new system configurations.

This paper starts with an examination of the demands for the inverters, set up by utility grid companies, the PV modules, and the operators. This is followed by a historical review to see how

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these demands were achieved in the past, how they are reached today, and perhaps how they will be realized in the future. Next follows an overview of some existing power inverter topologies for interfacing PV modules to the grid. The approaches are further discussed and evaluated in order to recognize the most suitable topologies .

2 .A Low Cost Fly back CCM Inverter for AC Module Application

OWADAYS, distributed power generation in residential areas, using solar panels, is well accepted and also supported by recent developments in building integrated photovoltaic (BIPV) systems as well as micro grid systems. However, when PV panels are connected in series to feed a string inverter with a global maximum power point tracker (MPPT), a considerable power loss due to modular mismatches caused by both varying panel orientations and shading would occur [1].

A major approach to solve this issue has been to package the PV panel with a module-integrated inverter, called an "ac module" [2], which directly serves the grid. Though requiring a large number of dc–ac conversion stages, the approach allows for easy "plug and play" system expansion. Also, only ac cable wiring is needed, which simplifies the installation.

In the study of inverter topologies for this application. The first is the use of a transformer less inverter [3]–[8] that is motivated by the benefits of reduction in size and cost and also by possible efficiency improvement [3]. However, the limited voltage boosting capability of such an inverter unit prevents the use of this technology in universal grid voltage range (85–265 V ac) applications.

Another trend is focused on an isolated cascaded scheme that includes one or more dc voltage boosting stage and a conventional full bridge PWM inverter [9], [10]. This type of inverter has by far the highest reported efficiencies compared to other isolated inverters. Also, the electrolytic capacitor for power decoupling can be replaced by a higher voltage film capacitor with longer lifetime. However, the penalty paid for this approach is more component count and hence higher cost.

Considerations of reducing the cost have led to a third approach based on an unfolding type inverter. Here, the voltage boosting, isolation, and output current shaping are all performed by a dc–dc converter that is then followed by a low-frequency unfolding stage. A fly back inverter with center-tapped secondary windings is often adopted leading to a simple overall system [11]. However, in this scheme, the fly back is operated in the discontinuous conduction mode (DCM) resulting in high current stress and lower efficiencies. This is particularly true in low voltage and high-current applications such as the ac module under consideration. Aware of this limitation of the fly back DCM scheme at larger power levels, Ji *et al.* [12] and Kyritsis *et al.* [13] have studied the fly back inverter operating in a dual switching mode between DCM and boundary conduction mode (BCM).

When operated in continuous conduction mode (CCM), a fly back converter has lower peak currents and hence higher efficiencies. This has been exploited before in both dc/dc power conversion and ac/dc power factor (PF) correction applications. However, the control to output current transfer function in a fly back CCM converter has a right half plane (RHP) zero, which causes difficulty in controlling the output current of the converter effectively. This may have prevented the use of the fly back CCM converter in dc/ac inverter applications. Therefore, in our approach, we investigate the feasibility of a fly back inverter operating (mainly) in CCM mode as a grid-connected ac module inverter, with a view to demonstrating that a significant efficiency improvement can be realized without adding to the complexity of both the power and control circuits.

In the industry, efficiency figures weighted over a range of operating conditions (California efficiency [14] or European efficiency [1]) are used to characterize the inverter performance. Additional techniques are usually used to prove this figure

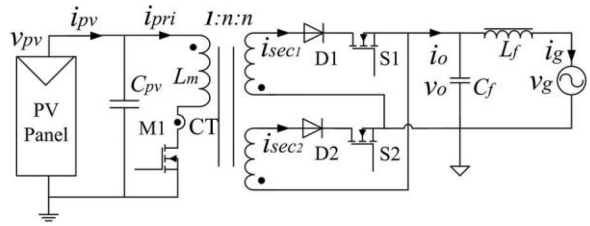

Fig. 1.Circuit topology of fly back inverter.

over what can be obtained with a straightforward power converter topology. Our approach is not targeted at these weighted efficiency (California or European) improvement technologies, but at the efficiency improvement due to change in the basic operating mode of the fly back inverter itself. In order to provide a fair comparison, the designs of the power topology for both the proposed CCM approach and the DCM-only approach (used as a benchmark) are presented and compared in Section II. The control challenges faced in this application and ways of resolving them are discussed in Section III. An open-loop control of the secondary side current, based on the feedback control of the primary side current, is proposed in order to bypass the difficulties posed by the moving RHP zero in the transfer function.

3. Topologies of Single-Phase Inverters for Small Distributed Power Generators

GLOBAL electricity consumption will increase from13 934 TWh in 2001 to 24673 TWh in 2025 at an average annual rate of 2.4% according to the Energy Information Administration of the U.S. [23]. As more countries have ratified the Kyoto Accord aiming at a reduction in greenhouse gas emissions, the requirements for adding new generation capacity can no longer be met by traditional power generation methods of burning the primary fossil fuels such as coal, oil, natural gas, etc. [1]. This presents a significant opportunity for the development of distributed power generation (DG) systems. Both

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consumers and power utilities can benefit from the widespread deployment of DG systems which offer secure and diversified energy options, increase generation and transmission efficiency, reduce greenhouse gas emissions, improve power quality and system stability, cut energy costs and capital expenditures, and alleviate the bottleneck caused by distribution lines.

DG systems are usually small modular devices close to electricity users, including wind turbines, solar energy systems, fuel cells, micro gas turbines, and small hydro systems, as well as the relevant controlling/managing and energy storage systems. Such systems commonly need dc–ac converters or inverters as interfaces between their single-phase loads and sources as shown in Fig. 1, which depicts a typical renewable DG system using photovoltaic (PV) as energy source. DG inverters often experience a wide range of input voltage variations due to the fluctuations of energy sources, which impose stringent requirements for inverter topologies and controls. Functions of inverters for small DG systems can be summarized as follows.

1) Power conversion from variable dc voltage into fixed ac voltage for stand-alone applications or ac current output following the grid voltage and frequency for grid-connected applications. The variable dc voltage can be higher or lower than the ac voltage in one system, which is observed normally in a wind-turbine energy system.

2) Output power quality assurance with low total harmonic distortion (THD), voltage and frequency deviation, and flickering.
3) Protections of DG generators and electric power systems from abnormal voltage, current, frequency and temperature conditions, with additional functions such as anti is landing protection and electrical isolation if necessary.
4) Control of DG systems and accomplishment of certain objectives such as maximum power extraction from wind energy, maximum power point tracking (MPPT) of PV modules, optimum efficiency for fuel cell systems, optimal energy flow control [2], etc.

Based on the electrical isolation between the input and output, inverters can be classified as isolated inverters or non isolated inverters. While electrical isolation is normally achieved using transformers, a choice can be made between using line-frequency transformers as in Fig. 2 or high-frequency transformers as in Fig. 3. The dc-link voltage of inverters for DG systems may vary over a wide range. Depending on the input dc voltage range in comparison to the output ac voltage, inverters can be buck inverters, boost inverters, or buck-boost inverters. It should be noted that although the inverters in Fig. 2 and Fig. 3 are buck inverters by themselves, the whole

Fig. 1.Block diagram of a photovoltaic system.

topologies eventually represent boost or buck-boost inverters due to PWM operations and voltage step-up in either low frequency or high frequency.

Traditional full-bridge buck inverters are used in many existing high power applications with bulky and heavy line-frequency transformers. However, modern power electronic converters tend to use “more silicon and less iron.” This leads to the pursuance of compact designs with wide input voltage ranges and improved overall efficiency.

This paper reviews the recent development in single-stage and multiple-stage power circuit topologies of single-phase inverters appropriate for small distributed power generators. A single stage inverter is defined in this paper as an inverter with only one stage of power conversion for both stepping-up the low dc voltage and modulating the sinusoidal load current or voltage. Based on the number of power switches, single-phase inverters can be classified as

1.Four switch topologies

2 Six switch topologies

A multiple-stage inverter is defined as an inverter with more than one stage of power conversion, in which mostly one or more stages accomplish voltage step-up or step-down or electrical isolation, and the last stage performs dc–ac conversion. In the paper, multiple-stage inverters are listed as

1) dc–dc–ac topologies;
2) dc–ac–dc–ac topologies; 3) dc–ac–ac topologies.

These topologies will also be discussed regarding the capabilities to meet certain challenging requirements of DG resource and ac utility.

HARDWARE/SOFTWARE REQUIREMENTS

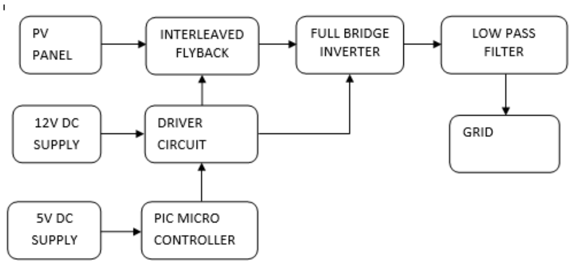
SOFTWARE REQUIREMENTS:

- MATLAB – SIMULINK
- Or cad / P Spice
- MPLAB

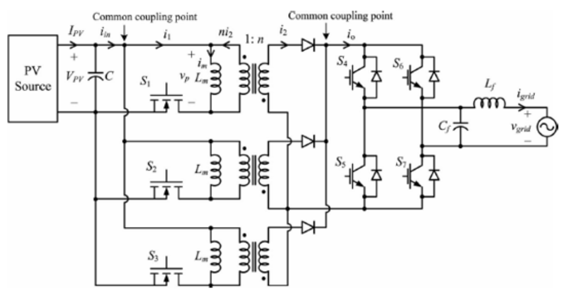
HARDWARE REQUIREMENTS:

- PIC Controller
- DRIVER BOARD

BLOCK DIAGRAM



CIRCUIT DIAGRAM



CIRCUIT DIAGRAM DESCRIPTION

The PV source is applied to a three cell interleaved fly back converter through a decoupling capacitor. Each fly back converter uses a metal–oxide–semiconductor field-effect transistor(MOSFET)for switching at the primary side, a fly back transformer, and a diode at the secondary side. The topology also has to employ a full-bridge inverter and a low-pass filter for proper interface to the grid. When the fly back switches (S_1,S_2,S_3) are turned ON, a current flows from the common point (the PV source) into the magnetizing inductance of the fly back transformers, and energy is stored in the form of magnetic field. During the on time of the switches, no current flows to the output due to the position of the secondary side diodes; therefore, energy to the grid is supplied by the capacitor C_f and the inductor L_f. When the fly back switches are turned OFF, the energy stored in the magnetizing inductances is transferred into the grid in the form of current. So, the fly back inverter acts like a voltage-controlled current source.

The converter is operated in DCM for easy and stable generation of ac currents at the grid interface. The DCM operation of converter under open-loop control produces triangular current pulses at every switching period. If sinusoidal pulse width modulation (PWM) method is used for control, the inverter will regulate these current pulses into a sinusoidal current in phase with the grid voltage [22]. Such currents are shown in Figs. 3 and 4 for a conceptual case. Specifically, Fig. 3 shows the conceptual fly back converter input currents the output currents. As it is seen, the instantaneous currents are composed of discontinuous current pulses with peaks that fall within a sinusoidal envelope since their pulse widths are sinusoidally modulated.

Fig. 3 also shows the three components of the instantaneous fly back converter input current (i_1): the high frequency (switching frequency) components, the low frequency (twice the line frequency) component ($\bar{i}_1$) which is the instantaneous average of i_1 over one switching period, and the dc component (I_1) which is the average over one grid period. In practice, a PV source is not an ideal voltage source; so any ac current that is supplied by it will cause variations at its terminal voltage.

So, for good performance of the converter as far as the power utilization and output current distortion, the voltage variations (ripple) across the PV module terminals should be as small as practically possible [20], [23]. For this reason, a decoupling capacitor is placed at the fly back converter input and sized in such a way that both the low and the high frequency ac components are bypassed sufficiently and only the dc (average) component I_1 is allowed to be supplied by the PV source. More explanations about this problem and sizing of decoupling capacitor are provided in the analysis section. Fig. 4 shows the instantaneous fly back converter output current (i_2) after unfolded by the full-bridge inverter and its instantaneous average ($\bar{i}_2$).

The full-bridge inverter is only responsible for unfolding the sinusoidally modulated dc current packs into ac at the right moment of the grid voltage. Since the switches of the inverter are operated at the grid frequency, the switching losses are insignificant. Only conduction losses are concerned. For this reason, the bridge can use thyristor or even transistor switches for lower cost .However ,for easy control also the availability in the laboratory for fast prototyping, we prefer using insulated-gate bipolar transistor (IGBT) switches for this design. But, the final prototype will not use IGBTs. The low-pass filter after the IGBT inverter is responsible for supplying a current to the grid with low THD by removing the high frequency harmonics of the pulsed current waveforms.

EXISTING SYSTEM:

The energy storage inductor and the transformer are separate elements. While the inductor is responsible for energy storage, the transformer on the other hand is responsible for energy transfer over a galvanic isolation. The combination of these two components in a fly back topology eliminates the bulky and costly energy storage inductor and therefore leads to a reduction in cost and size of the converter.

DISADVANTAGES:

Practical implementation of a transformer with relatively large energy storage capability is always a challenge. A fly back converter built with a transformer that has large leakage flux and poor coupling will have poor energy transfer efficiency. Mainly for this reason, the fly back converters are generally not designed for high power. As a result, the fly back topology finds a limited role in PV applications only at very low power as micro inverter.

PROPOSED SYSTEM:

In this project, an interleaved high-power fly back inverter for photovoltaic applications is proposed. The simple structure of the fly back topology and easy power flow control with high power quality at the grid interface are the key motivations for this work. The fly back converter is recognized as the lowest cost converter among the isolated topologies since it uses the least number of components. This advantage comes from the ability of the fly back topology combining the energy storage inductor with the transformer. The converter is operated in DCM for easy and stable generation of ac currents at the grid interface. Maximum power point is a unique operating point supplying maximum power to the load which is present in a PV array. Tracking the maximum power point of the PV array is done to improve the efficiency of the photovoltaic energy system MPPT is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power capable of PV module. The operations of this project can be implemented in Matlab / Simulink.

ADVANTAGES:

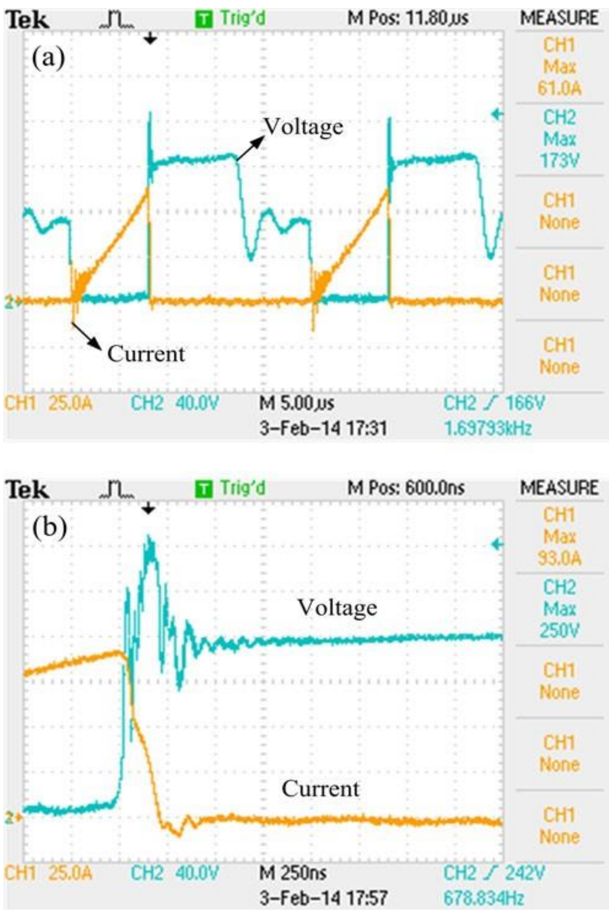
- Simple control loop
- Low cost
- High efficiency

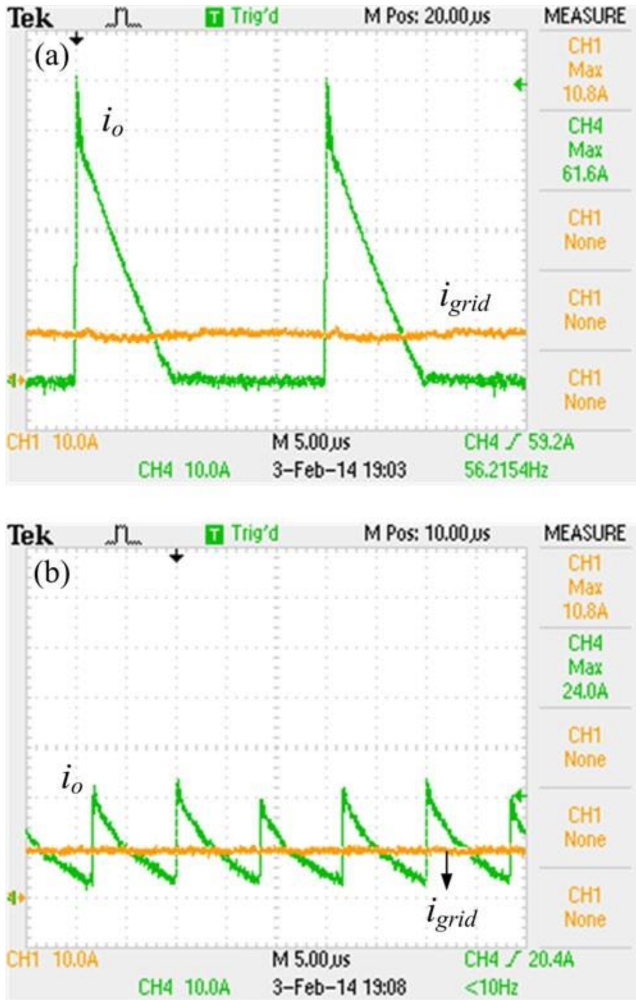
- Lower the conduction losses
- Reduce the current
- ripplesImproving the power factor correction
-

APPLICATIONS:

- Grid Applications
- Renewable Energy Application

EXPECTEDRESULT





CONCLUSION

A central-type PV inverter for small electric power system applications rated at 2 kW is implemented based on the interleaved fly back converter topology. The 2 kW power level is achieved by interleaving of three fly back cells each rated at 700 W. The fly back topology is selected because of its simple structure and easy power flow control with high power quality outputs at the grid interface. The experimental results prove the successful operation of the inverter and compliance to the specifications. The energy harvesting efficiency of the MPPT controller and the inverter static efficiency are measured as 98.5% and 90.16%, respectively. Also, the THD of the grid current is measured as 4.42% and the power factor is 0.998, which are confirming the high power quality interface to the grid. Consequently, it is demonstrated that interleaved fly back topology is practical at high power as a central-type PV inverter, which is the main contribution of this study. Furthermore, the performance of the proposed system is comparable to the commercial isolated grid connected PV inverters in the market, but it may have some cost advantage due to its topological benefit.

.REFERENCES

[1] Solar energy (2013, July 23). [Online]. Available: http://www.conserveenergy- future.com/Solar Energy .php.

[2] Europe Photovoltaic Industry Association (EPIA) (2013, July 23) *Global market outlook for photovoltaics 2013–2017*, [Online]. Available: http://www.epia.org/news/publications

[3] Y. Xue, L. Chang, S. B. Kjaer, J. Bordonau, and T. Shimizu, "Topologies of single-phase inverters for small distributed power generators: An overview," *IEEE Trans. Power Electron.*, vol. 19, no. 5, pp. 1305–1314, Sep. 2004.

[4] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of singlephase grid-connected inverters for photovoltaic modules," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep. 2005.

[5] Y. Li and R. Oruganti, "A low cost fly back CCM inverter for AC module application," *IEEE Trans. Power Electron.*, vol. 27, no. 3, pp. 1295–1303, Mar. 2012.