International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189

available at : www.ijcns.com
ISSN: 0976-1345

IMPLEMENTATION OF A SINGLE PHASE BIDIRECTIONAL INVERTER WITH MPPT CONTROLLER FOR PHOT VOLTAIC SYSTE USINGCUK DC/DC CONVERTER

Khampai Wangpan[1] and A.BHARANEETHARAN
Final Year Student[1], Asst. prof[2].
Dept. Electrical &Electronics Engineering
IFET College of Engineering
Villupuram

ABSTRACT

This paper focuses on integration and operation of a single-phase bidirectional inverter with cuk maximum power point trackers (MPPTs) for dc-distribution applications. In a dc-distribution system, a bidirectional inverter is used to control the power flow between dc bus and ac grid, and to regulate the dc bus to a certain range of voltages. A droop regulation mechanism according to the inverter inductor current levels to reduce capacitor size, balance power flow, and accommodate load variation is proposed. Since the photovoltaic (PV) array voltage can vary from 0 to 600 V, especially with thin-film PV panels, the MPPT topology is formed with Cuk converters to operate at the dc-bus voltage around 380 V, reducing the voltage stress of its followed inverter. Furthermore, the controller can online check the input configuration of the MPPTs, equally distribute the PV-array output current to the two MPPTs in parallel operation, and switch control laws to flat out mode transition. A comparison between the conventional boost MPPT and the proposed Cuk MPPT integrated with a PV inverter are also presented. This project is mainly used for the DC distribution application.

Index Terms— **Bidirectional inverter, Cuk maximum power point trackers (MPPTs), dc-distribution applications.**

1. Introduction

Now a day, a dc-micro grid power distribution system combining renewable distributed generators (DG) with utility grid for efficient power has attracted a lot of attention [1]. In this project dc distribution system, including PV energy distributed generators (DG), and a bidirectional inverter are implement. In the dc- distribution applications, a power system, including renewable

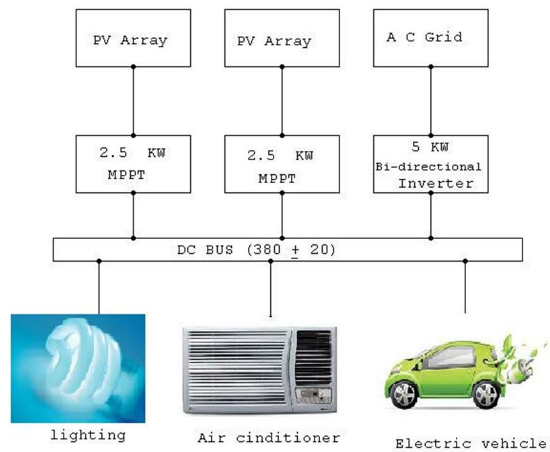


Fig. 1. Configuration of a dc-distribution system.

Distributed generators (DGs), dc loads and a bidirectional inverter, is shown in Fig. 1, in which two PV arrays with two maximum power point trackers (MPPTs) are implemented. Though, the *i*–*v* characteristics of the PV arrays are nonlinear, and they need MPPTs to draw the maximum power from each PV array. **B**esides a bi-directional inverter[2] [3] has to fulfill real power injection (sell power or grid connection) and rectification (buy power) with power factor correction (PFC) to regulate the dc bus within a certain range of 380 ± 20 V[11].

A switch-mode DC-DC converter is the heart of the MPPT hardware [6]. So a DC-DC converter is implemented to produce a constant voltage and deliver maximum power to load from solar panel. In the conventional one the MPPT is realized with the boost converter to step up the pv-array voltage closed

International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189
©gopalax Journals, Singapore
available at : www.ijcns.com
ISSN: 0976-1345

to the specific DC-link voltage as shown in fig.2 When the pv array voltage is greater than the DC link voltage the boost converter operate in by pass mode and the inverter will function as an MPPT[4]. So, it is difficult to track the maximum power point (MPP) by inverter operated in by pass mode, due to non-linear characteristic of pv-array the inverter will suffer from high voltage stress. To overcome this drawback, an MPPT topology with Cuk converter [5] is proposed in proposed project. The Perturbation & observation (P&O) control algorithm is used to track the maximum power point (MPP) [8] [9].

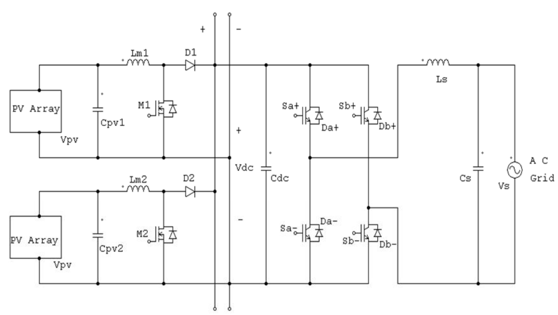


Fig.2. Conventional two stage PV inverter with boost mppts.

The bidirectional full bridge inverter is operate in bipolar modulation to avoid the leakage current and to save the power component in this project. In the last couple of year to eliminate the leakage ground current circulating through PV array and ground, several transformerless [7] inverter topology were proposed [6] and to get the high efficiency also, but they required more component than this proposed full bridge topology.

In this paper, operational principle and control laws of the system are first described, then MPPT control algorithm, online configuration check[8], uniform current control, buck/boost mode transition of cuk converter, and dc-bus-voltage regulation mechanism are describe, and simulation of the boost and cuk MPPT to compared the output efficiency between conventional system and this proposed project.

2. Operational principle and control laws for the inverter:

configuration of single bidirectional inverter with two Cuk MPPTs, which can fulfill the grid-connection and rectification mode with power factor control (PFC) [3] [4].

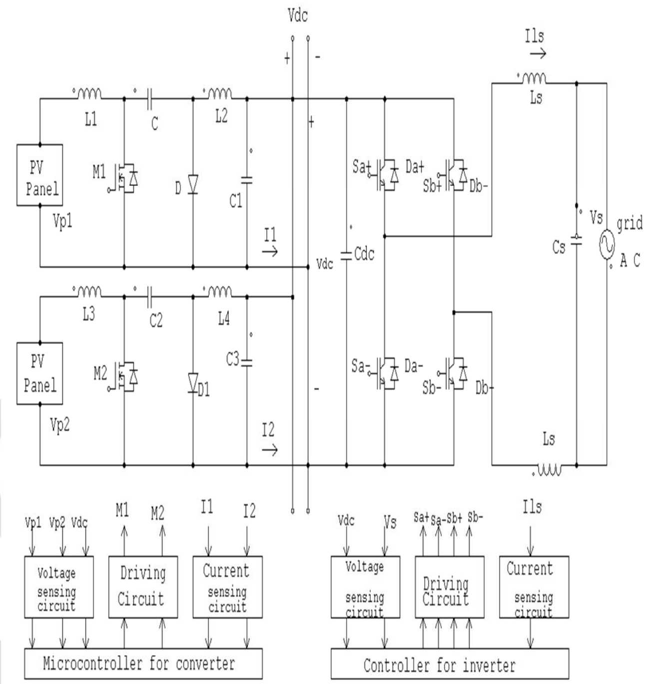


Fig.3. Configuration of studies PV inverter with Cuk mppts.

The inverter senses inductor current *iL*, dc-bus voltage *vdc* and line voltage *vs*, and uses the tabulated variable inductance to determine a control for operating the inverter stably. When the output of the PV panel is higher than the load require in the DC-link than inverter operate in the grid-connection (GC) to inject the surplus power to the AC grid. Or when the PV panel output is less than the load requirement the inverter will operated in rectification mode with PFC to convert the ac source to the DC supply and given to the DC-link. The control laws with bipolar modulation are derived as follows:

(For grid connection mode) (1)

And

dre =–

International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189
©gopalax Journals, Singapore
available at : www.ijcns.com
ISSN: 0976-1345

In order to achieve the desired performance of inverter functions, describing the operational principal of the inverter and control law for inverter operation are presented. Fig.3. show the proposed(For rectification mode) (2) Where T_s is the switching period and d_{gc} and d_{re} are the duty ratios (controls).

3.Operation and analysis of the proposed cuk mppts

Cuk converter has several advantages[10] over the boost converter. Such as it provide capacitive isolation which protect against switch failure. Other advantage is, the input current of the Cúk is continuous, and they can draw a ripple free current from a PV array that is important for efficient Maximum power point tracking (MPPT). For various PV-array applications, the two MPPTs will be connected separately or in parallel. The MPPT senses PV voltage vPV, dc-bus voltage vdc, and inductor current iL into the single-chip microcontroller (TMS320LF2406 A) to determine operational mode and duty ratio for tracking the maximum power point accurately.

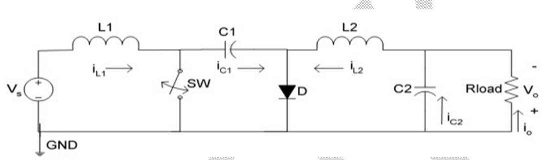


Fig. 3: Circuit Diagram of basic cuk converter

The circuit arrangement of the Cuk converter using MOSFET switch is shown in Figure.3. In case of Cuk converter the output voltage is opposite to input voltage. When the input voltage turned on and MOSFET (SW) is switched off, diode D is forward biased and capacitor C1 is charged through L1–D. here the operation of converter divided into two modes.

Mode-1:- When MOSFET switch is turned on at t=0. The current through L1 rises. And at the same time the voltage of C1 reverse biases diode D and turn it off. The capacitor C1 discharges its energy to the circuit C1-C2-load-L2.

Mathematical Analysis:

Assuming that the capacitor (C1) is large enough and its voltage is ripple free even though it stores and transfer large amount of energy from input to output (this requires a good low ESR capacitor. The current through inductor iL1 rises linearly from L1 to L2 in time t1. Now voltage across inductor can be calculated by applying KVL.

Mode-2:- When MOSFET switch is turned off at t= t1. The capacitor will start to charge from input supply Vs and the energy stored in the inductor transferred to the load. The capacitor C1 is the medium for transferring energy from source to load.

Mathematical Analysis:

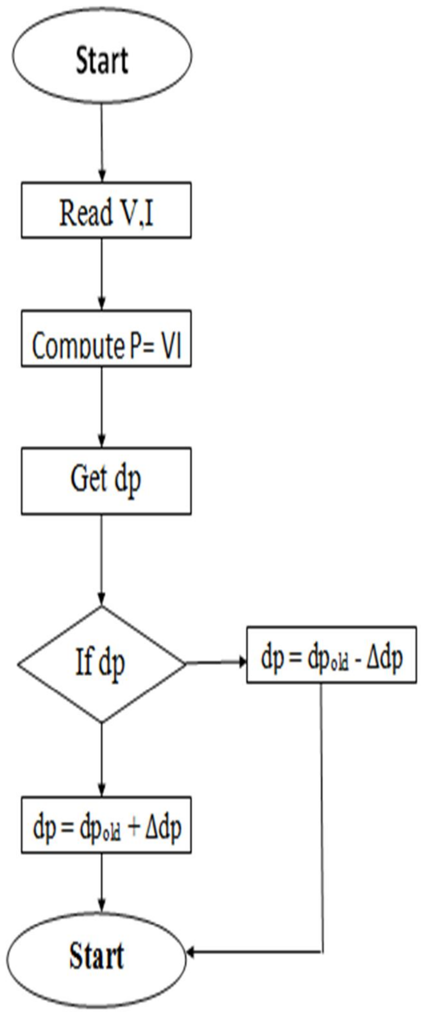
Due to charged capacitor C1, the current of inductor L1 falls linearly from L2 to L1 in time t2. Now voltage across inductor can be calculated by applying KVL.

4. Perturbation and Observation Tracking Method

In this study, the MPPT controller tracks the maximum output power of a PV array based on the perturbation and observation tracking method. P&O [8] is one of the most effective algorithms for MPPT. The algorithm involves introducing a Perturbation in the panel operating voltage. Modifying the panel voltage is done by adjusting the converter duty cycle. They operate by periodically perturbing (i.e. incrementing or decrementing) the PV array voltage and comparing with the previous PV array output power perturbation cycle. If the power is increasing, the perturbation will continue in the same direction for the next cycle, else the perturbation direction will be reversed. This means the array terminal voltage is perturbed every MPPT cycle, therefore when the P&O is reached, the P&O algorithm will oscillate around it resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions.

In this studied PV inverter system, there is a shared auxiliary power supply for the MPPTs and the inverter. Because the switching frequencies of the MPPT (25 kHz) and the inverter (20 kHz) are different, their switching noises might affect the

International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189
©gopalax Journals, Singapore
available at : www.ijcns.com
ISSN: 0976-1345



inverter, and the controller will update the duty ratio of the MPPT power stage in every ten line cycles at the zero crossing of the line voltage. Additionally, since the single-phase PV inverter system has a twice line-frequency ripple voltage on the dc bus, this synchronization approach can also eliminate the ripple voltage effect and determine accurate output power of the PV arrays. When the output power of the PV arrays can be determined accurately, the proposed controller can track the maximum power point precisely.

5.Online MPPT Configuration Check

Online MPPT configuration check scheme is proposed to track the maximum power point more effectively and efficiently. A flowchart of the check algorithm is shown in Fig. 4. First, the MPPT determines if there is any PV array plugged in or removed from the system by checking voltage for 100 ms.

When the PV voltage Vpv is higher than the threshold voltage Vth, the controller determines that the new PV array is plugged in to an MPPT. And when the PV voltage Vpv is lower than the Vth, then it means that a PV arrays is released from the MPPT or there is no PV array. Next if the input voltage of both the MPPTs is very close the MPPT configuration as a parallel mode. On the other hand the two MPPTs will be operated in separate mode. The controller will perturbed the duty ratio of each MPPT to identify the PV array connection mode.

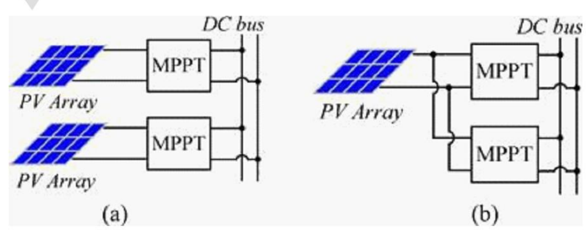


Fig.5 Input configuration of MPPTS, a) separate b) parallel

In every switching cycle the system controller check the configuration of MPPTs. If the PV arrays are connected to the MPPTs separately, as shown in Fig. 5(a), the MPPTs will calculate their PV output power and adjust their duty ratios individually. If the maximum power level of a PV array is higher than that of an MPPT, the two MPPTs will be connected to this PV array and operated synchronously, as shown in Fig. 5(b). When tracking the maximum PV output power, the MPPTs will

International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189
©gopalax Journals, Singapore
available at : www.ijcns.com
ISSN: 0976-1345

sum up their input currents and equally distribute the total current to the two MPPTs based on a uniform current control scheme.

6.Buck–Boost Mode Transition

The buck-boost mode transition of the cuk converter is depends on the duty ratio to the converter. Since the operation range of the dc-bus voltage is limited within 380 ± 20 V (including ripple voltage) in the dc distribution system, operational-mode transition between the buck and boost modes will be a critical control issue to accommodate a wide PV input voltage variation (0–600 V). So, the duty ratio of the converter is control by the single chip microcontroller (TMS320LF2406 A) by MPPT senses PV voltage Vpv, dc-bus voltage Vdc, and inductor current iL. Thus when the proposed MPPT is operated in boost mode and voltage Vpv is close to vdc, the duty ratio of converter is in between 50-100%. On the other hand when it will operate in buck mode and voltage Vpv is less to Vdc, the duty ratio is in between 0-50%. Therefore, the MPPT can achieve smooth mode transition by tuning the duty ratios of the converter switch.

7.DC-bus Voltage Regulation

In dc-distribution system, a droop dc-bus voltage regulation mechanism is proposed, for reducing dc-bus capacitance and mode change frequency. Fig. 8, show the voltage regulation mechanism in which the dc-bus voltage is regulated according to the inductor current linearly. When the bi-directional inverter sells higher power, which means less load power requirement, the dc-bus voltage will be regulated to a higher level. If there is a heavy step load change suddenly, this mechanism can avoid a voltage drop below 380 V abruptly and it will not change the operation mode from grid connection to rectification, or can even avoid under voltage protection. On the other hand, when the bi-directional inverter buys higher power, the dc-bus voltage is regulated to a lower level, reducing the frequency of mode change.

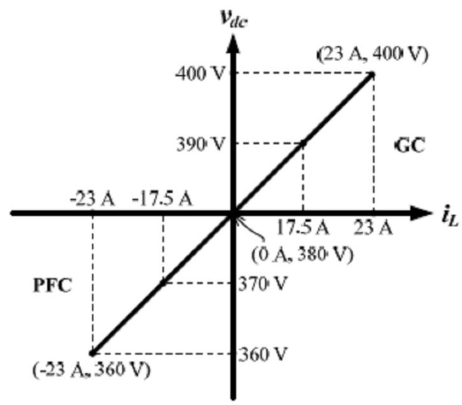


Fig.6. Illustration of a dc-bus voltage regulation mechanism with a linear relationship between inductor current *iLs* and dc-bus voltage *v*dc.

The proposed regulation mechanism can be further illustrated by the current command and voltage variation shown in Fig. 7. When there exists a power imbalance between sourcing and loading, for instance, dc-bus voltage increases from v_1 to v_2 in a line cycle. We can determine the current difference ΔI between the source and the load from the voltage variation, and it can be expressed as

Where line frequency f_l = $1/T_l$, C_{dc} is the dc-bus capacitance, and v_1 and v_2 are as indicated in Fig. 4. From the linear dc-bus voltage regulation relationship shown in Fig. 3, the new steady state voltage v_{set} can be obtained. Therefore, the adjustment current command I_A and steady state inductor current I_{set} canbe determined. The control laws, which can adjust inductor-current command to a new set value I_{set} and can regulate the dc-bus voltage to its corresponding voltage V_{set} simultaneously, are derived as follows:

where I_c is the current command given at t_1, and I_A is the adjustment current command given at t_2. At t_2, the inverter applies I_A to control the system power flow, and the dc-bus voltage can be regulated to the corresponding voltage v_{set} at next line cycle t_3 which achieves power balance on the dc side. At t_3, the current command is changed to I_{set} and the dc-bus voltage can be regulated to v_{set}, if there is no further load change. In (3) ~ (6), currents I_c, I_A and I_{set} denote the average values of their full-wave rectified sinusoidal current waveforms.

International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189
©gopalax Journals, Singapore
available at : www.ijcns.com
ISSN: 0976-1345

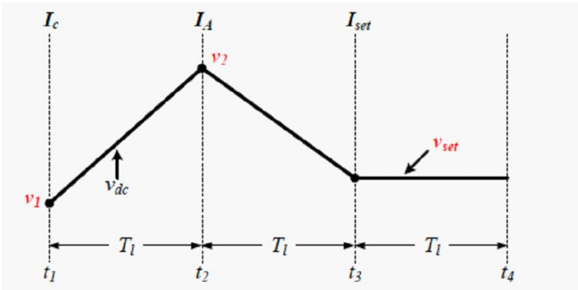
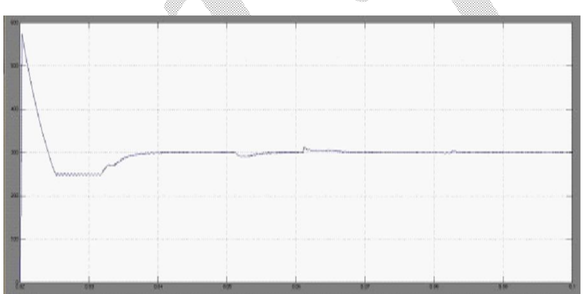


Fig. 7. Illustration of the one-line-cycle dc-bus voltage regulation mechanism for the inverter under power imbalance.

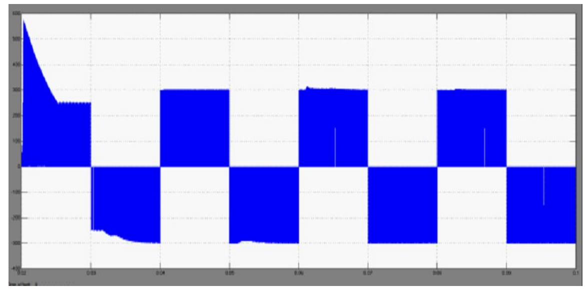
With the proposed regulation mechanism, it takes only one line cycle to adjust the dc-bus voltage to a new set point. In next iteration, current I_{set} is treated as a new I_c command and time t_3 is a new t_1. However, if at t_3, dc-bus voltage v_{dc} is not close to v_{set} enough (due to new power imbalance), current I_A is treated as a new I_c, time t_2 is t_1 and a new I_A can be determined at t_3 based on above eqn. achieving one-line-cycle regulation mechanism. The controller adjusts current command I_A continuously until v_{dc} comes back to the load line and balances the power on the dc bus. With one-line-cycle regulation mechanism, current distortion can be minimized. However, if there is an abrupt load change, the controller will update current command immediately to avoid under- or overvoltage

8.Simulation Result



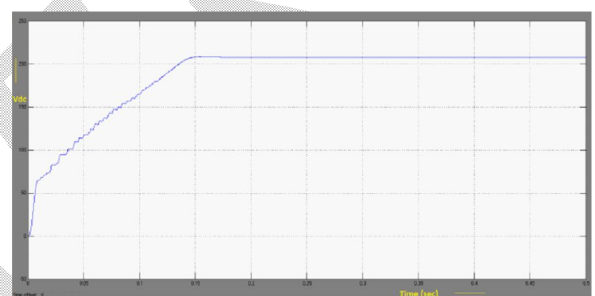
Waveform1. Boost connected dc link output

The waveform.1 is the boost converter output voltage by boosting the pv voltage and given to the dc bus a constant voltage of 300v.



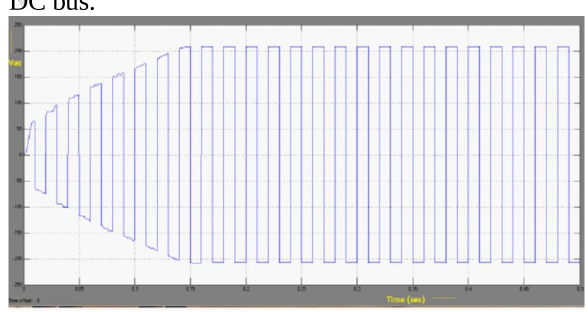
Waveform.2.Boost connected inverter output.

The waveform.2 is the injection mode output of the inverter which converts the 300v dc to the ac voltage and given to the ac grid.



Waveform.3. cuk connected dc link output

This is the propose cuk converter output at dc bus. Here the pv array output is controlled by the mppt controller and adjust the gate pulse duty ratio to the MOSFET switch of the cuk converter. And do the operation according to duty ratio and give the constant output at DC bus.



Waveform.4. Inverter output to ac-grids

This waveform is the output of inverter when the inverter operates in the injection mode. Then the dc bus output is converter to ac and given to the ac grid for supporting the grid efficiency.

International Journal of Technology and Engineering System (IJTES)
Vol 6. No.2 – Jan-March 2014 Pp. 183-189
©gopalax Journals, Singapore
available at : www.ijcns.com
ISSN: 0976-1345

9.Conclusion

In this paper, a single-phase bidirectional inverter with two Cuk MPPTs has been designed and implemented. The inverter controls the power flow between dc bus and ac grid, and regulates the dc bus to a certain range of voltages. A droop regulation mechanism according to the inductor current levels has been proposed to balance the power flow and accommodate load variation. Since the PV-array voltage can vary from 0 to 600 V, the MPPT topology is formed with buck and boost converters to operate at the dc-bus voltage around 380 V, reducing the voltage stress of its followed inverter. Additionally, the controller can online check the input configuration of the MPPTs, equally distribute the PV-array output current to the two MPPTs in parallel operation and switch control laws to smooth out mode transition. Integration and operation of the overall inverter system have been discussed in detail, which contributes to dc distribution applications significantly. Simulation results for a single-phase bidirectional inverter with the two MPPTs have verified and discussed.

References

[1] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, Ma. A. M. Prats, J. I. Leon, and N. Moreno-Alfonso, "Power-electronic systems for the grid integration of renewable energy sources: a survey," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 10021016, Aug. 2006.

[2] T.-F. Wu, K...H. Sun, C.-L. Kuo and C.H. Chang. "Predictive current controlled 5 kW single-