# Low Frequency Ripple Free MPPT Based Converter for Grid Tied PV System

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***Abstract---****A substantial increase in the energy saving measurements has led to a remarkable growth of grid tied PV systems. A grid tied PV systems consisting of modular current fed dual active bridge DC-DC converter with cascaded multilevel inverter. Due to frequency voltage variations in the DC link it affects the performance of MPPT block and thus reduces the overall efficiency. The proposed power mitigation control based CFDAB model is implemented to prevent low frequency voltage variation propagating from DC link to PV side. This module is simulated using MATLAB/Simulink. The experimental results are given to approve the performance of the system.*

***Keywords--Current Fed Dual Active Bridge, Small Dc link capacitor, low frequency ripple, MPPT, high-frequency link***

## 1. Introduction

PV has gained its importance as a reliable renewable energy source due to its cleanliness, little maintenance, no noise and its sustenance. Due to cost reduction and government incentives, installation of GCPV (Grid Connected PV system) has grown rapidly in the past few years[1]-[2].As a reliable grid connected PV system, the CMI (cascaded multilevel inverter) has advantages such as modularity, low EMI, etc. A two stage PV converter with high gain DC-DC converter with cascaded multilevel inverter[3]. The small DC link capacitor may suffer from large voltage swing, which may not only affect control system. But also result in low frequency ripple free energy propagating into the PV side and degrade MPPT performance.

In megawatt scale high voltage GCPV(grid connected PV system),a galvanic isolation between the PV panel and the grid is essential in order to prevent electric shock due to insulation damage and to suppress leakage current. Therefore the cascaded multilevel inverter integrated with high frequency link based DC-DC converters are used instead of using bulky line frequency transformer. In a three phase Y connected CMI PV system with DC-DC stage electrolytic capacitors are used as DC link energy buffers between DC-DC stage and inverter stage to provide the double line frequency power 2ω to the grid[7].The usage of electrolytic capacitor is considered as an unreliable component. Therefore capacitance reduction is essential to achieve high reliability with non-electrolytic film capacitor, especially for high voltage CMI PV system [8]-[12].

On the contrary, the small DC link capacitor will make the converter suffer from large 2ω voltage ripple on the DC link. If this voltage ripple propagates to PV side it will degrade MPPT performance and decreases its efficiency [13]-[15]. To solve this issue current fed isolated DC-DC converters are used, frequency power ripple in the PV side. Because the input current can be controlled directly, and thus it is possible to eliminate the input low input low frequency power ripple in the PV side. This paper proposes a novel single phase PV system based on CFDAB dc-dc converter with small DC link capacitor that can achieve minimized low frequency ripple effect on MPPT without adding extra components. The current topology with inherit zero voltage switching(ZVS) characteristics is particularly suitable for PV

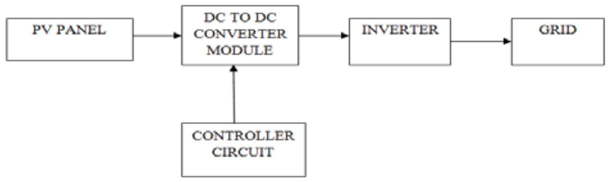


Fig 1. Block diagram of proposed system

application[16]. In the proposed approach, the input PV voltage is directly controlled by regulating duty cycle, therefore the PV arrays are immune to low- frequency power fluctuation and an optimized MPPT is achievedDue to an advanced dc-link and the dc voltage ripples are permitted in the dc-link and the dc voltage ripples between primary side and second side are symmetrical, which contributes to reduce the transformer peak current. Furthermore, the interleaved structure is also helpful to alleviate the input power ripple [17]. With the proposed technology, the PV converter can allow the film capacitor to reduce the bulky electrolytic capacitor. The validation of the proposed approach is verified by simulation results.

## 2. System Configuration And Low Frequency Ripple

Fig 2 presents the system configuration of a proposed MW-scale grid tied PV system with CFDAB converter. It consists of two phases, one is i cascaded multilevel inverter modules, and each inverter module is connected to j cascaded CF-DAB modules compared with conventional PV system. This system shows many advantages. PV system can be connected directly to the high voltage with ac grid due to high-frequency isolated dc-dc converters. Each module were interfaced with PV arrays which are having separate MPPT, is used to extract more solar energy. Due to isolated CF DAB converter, the ground leakage current is reduced and the reliability of PV system is improved. Small capacitance will result in large voltage ripple in DC link capacitor. This large low-frequency voltage ripple on dc-link imposes challenges on PV system operation and also decreases MPPT efficiency.

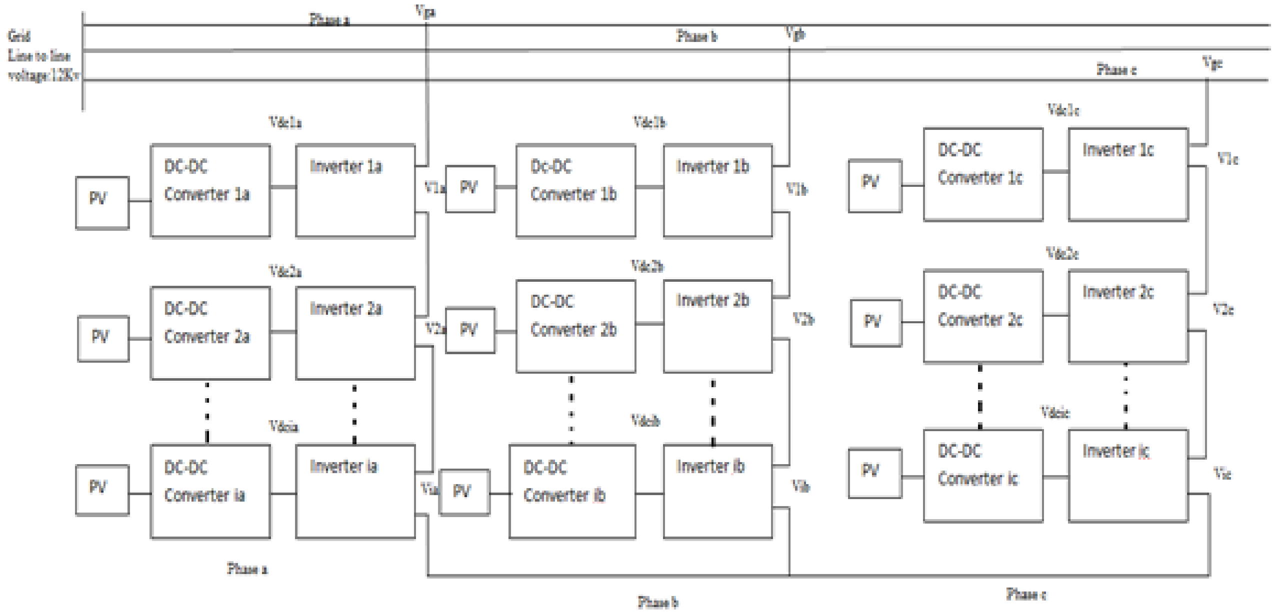


Fig.2. Grid-tied PV system with CFDAB and CMI

Fig 3 illustrates how this low frequency ripples affects PV power where it diminishes from maximum power at (Vmpp, Impp). But by using CF-DAB, voltage ripples can be attenuated effectively.

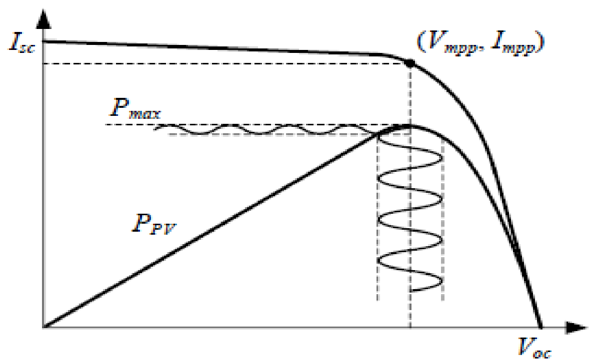


Fig.3. Low-frequency ripple free effect on MPPT

*A.OPERATING PRINCIPLE OF CFDAB DC-DC CONVERTER*

The operating principles of CFDAB converter have been presented in [17].figure3 shows the operation areas of DC-DC converter. It has four operating modes and each one has two conditions: D<0.5 and D>0.5.In order to achieve high efficiency the duty cycle is maintained in the range within 0.25-0.75.and the phase shift angle is smaller than $\pi/3$.TheCFDAB which mainly operates in mode I and mode II..Figure 5shows the key waveforms of mode I and mode II in CFDAB converter.

*<u>Mode I:</u>*

$0<D^T<0.5,\ 0<\varphi<\min\{2D^T\pi\pi-2D^T\pi\}$

The dc inductor current is depicted together when D<0.5 and D>0.5. One switching cycle is divided into 8 tie intervals, where 1-4 and 4-8 are symmetrical. The initial transformer current can be derived in(1)according to the periodicity and the current for each time interval

$$i_{Ls}(0)=-\frac{V_{LV}}{\omega L_s}(1-d)D^T\pi \qquad (1)$$

where $\omega$ is the angular switching frequency, $d=V_{HV}/n\cdot V_{LV}$, and $D^T$ is the minimal value of $D$ and $1-D$.

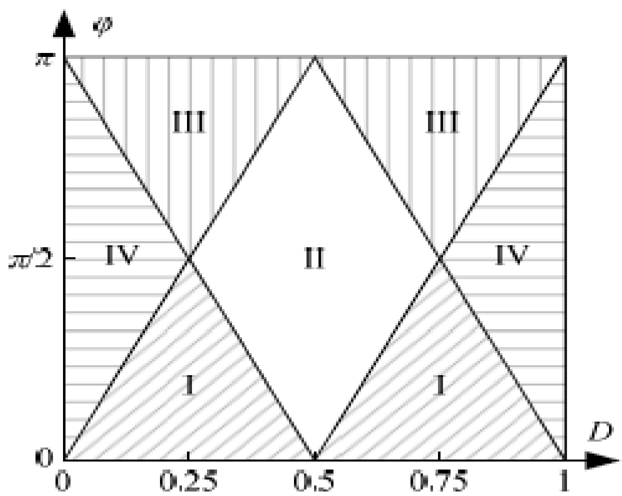


Fig.4.Operating Modes of CF DAB converter

*Mode II:*

$0.25<D^T<0.5,\ 2D^T\pi<\varphi<\pi-2D^T\pi$

Fig.6 shows the key waveforms of CF-DAB dc-dc converter operating in the area II, where there is no zero voltage level overlapped in the transformer primary and secondary voltages. As well known, soft switching is an essential technology for reaching an optimal efficiency.

The ZVS condition for CF-DAB dc -dc converter is more critical compared with VFDAB dc-dc converter. The analysis of ZVS condition for CF-DAB dc-dc converter will not be discussed in this paper.

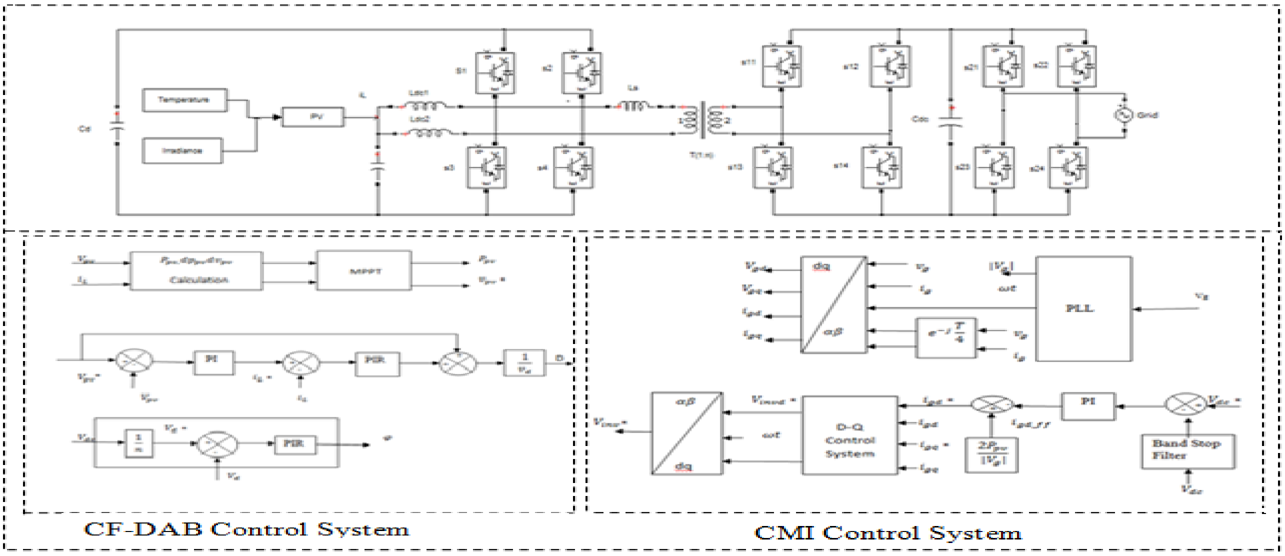


Fig.5. Proposed PV controller for CF-DAB and CMI

However, similar to three-phase CF-DAB dc-dc converter [13], the ZVS condition is guaranteed for both the primary and secondary switches with $d$ = 1 control which is adopted in this paper.

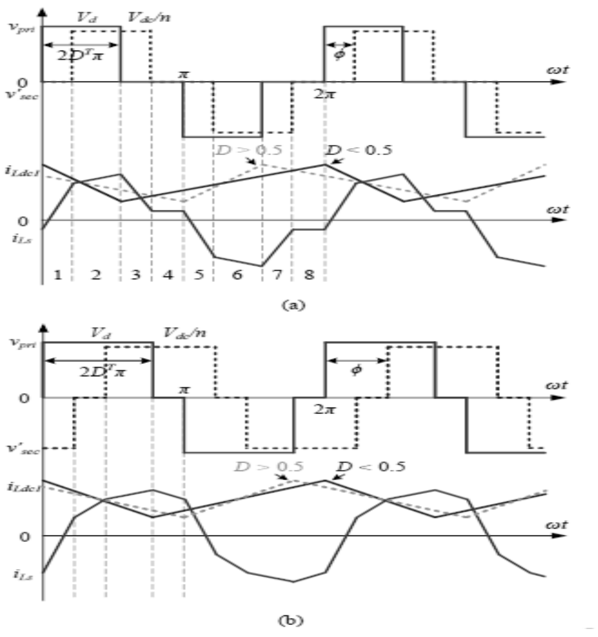


Fig.6 Waveforms of CF DAB converter

## 3. Proposed Control System

The proposed control system of PV system is developed in fig.4, which can be divided into CFDAB dc-dc converter and the cascaded multilevel inverter control system. The high voltage side dc-link voltage is regulated by the inverter module and the CFDAB converter controls the input PV voltage. The MPPT algorithm which increases the efficiency.

*A.CFDAB dc-dc converter Control*

The operation principle is presented in [17].The CF-DAB converter can be considered as a boost converter cascaded by a voltage fed DAB converter. The control of CFDAB dc-dc converter has two degrees of freedom due to its dual active bridge structure: the duty cycle D and the phase shift angle $\varphi$,by which the voltage from PV side and the LVS dc link voltage are controlled. To keep the reference voltage, the duty cycle controls the PV voltage directly. The double frequency component in the LVS or the HVS is blocked and high utilization factor is achieved in the PV side.The PV voltage and the current are both sensed for the calculation of $P_{pv,}$ $i_{pv}/v_{pv}$ and $\Delta i_{pv}/\Delta v_{pv}$ which are used in the P&O algorithm. The MPPT function block generates a reference voltage $V_{pv}*$ to regulate the PV voltage. The power transferred from LVS to HVS is determined by the phase shift angle $\varphi$ when PV and LVS voltage are at the rated values.By regulating the LVS voltage through $\emptyset$, the power generated from the PV arrays and the power delivered to HVS are matched.

To minimize the peak current of transformer, the LVS dc-link voltage is controlled to follow the HVS voltage so that they are balanced.$i_{Ldc1}$ is the current of the dc-dc converter inductor, and $i_{Ls}$ is the transformer primary side current. Proportional integral resonant(PIR) controller is employed to obtain enough gain at double-frequency to ensure the LVS voltage

*B. Cascaded Multilevel Inverter Control*

The cascaded multilevel inverter operating principle is presented in [3].At the inverter side, the high voltage side voltage is regulated by the outer voltage controller. A large double frequency voltage ripple occurs in the bus voltage, as small dc capacitor is used. The band stop filter $V_{HV}$ is used to stop the 120Hz component for mitigating the influence of double frequency introduced to the control loop. The grid current is regulated under dq axis where the active current and reactive current are decoupled and controlled separately. In this way, the PV converter can supply reactive power to grid when desired as well as active power generated. In order to achieve fast dynamic response, a current corresponding to the PV power, is added to the active current reference. Phase locked loop (PLL) is implemented to extract the exact phase angle of $\omega t$ of grid voltage.

## 4. SIMULATION MODEL

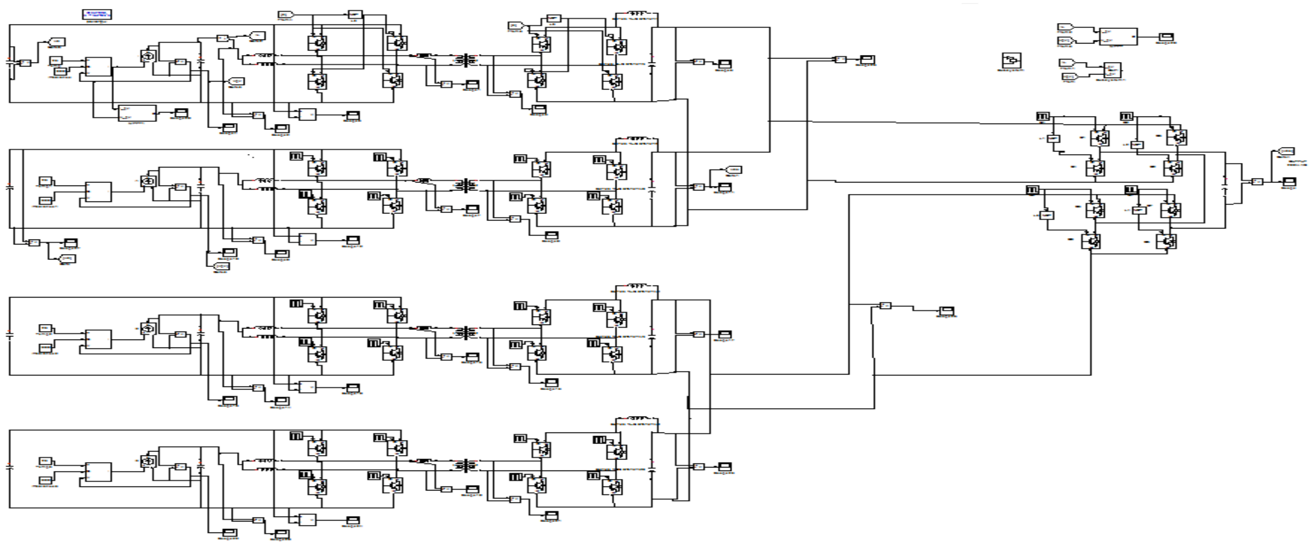

Fig.7 Overall System Model

| ITEMS | DESCRIPTIONS | VALUES |
|---|---|---|
| $P_{pv}$ | Rated PV power | 5 KW |
| $V_{pv}$ | MPPT voltage range | 100-200v |
| $V_d$ | LVS dc link voltage | 300v |
| $V_{dc}$ | HVS dc link voltage | 600v |
| $V_g$ | Grid voltage | 440v |
| n | Transformer turns ratio | 16:32 |
| $L_s$ | Converter leakage inductance | 28.5$\mu H$ |
| $L_{dc1}$ $L_{dc2}$ | DC inductor | 143mH |
| $C_d$ | LVS dc link capacitor | 0.03F |
| $C_{dc}$ | HVS dc link capacitor | 1$\mu F$ |
| $L_f$ | Line filter inductor of inverter | 300$\mu H$ |

The system consists of a PV module, a boost converter which is current fed dual active bridge, and a cascaded multilevel inverter is shown. Fig. 7 shows the entire Simulink model of the proposed system with the controller module.

TABLE I

CIRCUIT PARAMETRES OF MATLAB SYSTEM

## 5. RESULTS AND DISCUSSIONS

*A) PV Voltage*

In this proposed system, the PV power is fed to the grid via a boost converter (CFDAB) and an inverter (CMI) without using bulky line frequency transformers. The PV array has been designed taken into considering various factors such as irradiance, temperature, number of PV cells connected in series and parallel. MPPT algorithm is built to track the maximum power. The waveform in the Fig 8 describes the output voltage from PV which is 150V.

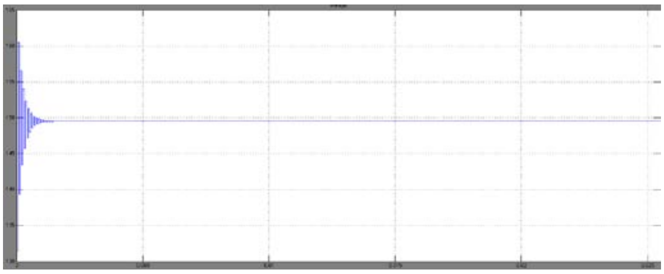

Fig.8. PV output voltage

*B) CFDAB Output*

The current fed dual active bridge module which boosts the voltage and prevents large low frequency voltage propagating from dc link to PV side. It is designed in such a way that if there is a deficiency in PV output, the inductor will boosts the voltage and also it reduces ripples in the converter circuit. A step up transformer which also helps in stepping up of the voltage. The input given to the converter is 150V DC and the output voltage which got is 300V DC as shown in Fig 9.

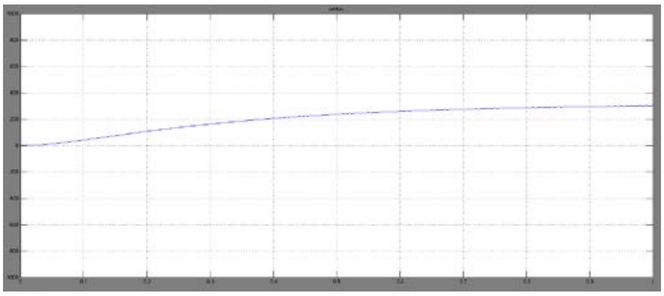

Fig.9. CF DAB output voltage

*C) Grid Voltage*

The cascaded multilevel inverter gives a five level multilevel output. Two H bridge inverters which are connected in series to the circuit. The CMI synthesizes its output near to sinusoidal voltage waveforms by connecting many isolated voltage levels. Therefore in this system a five level output of 600V is obtained is shown in Fig 10.

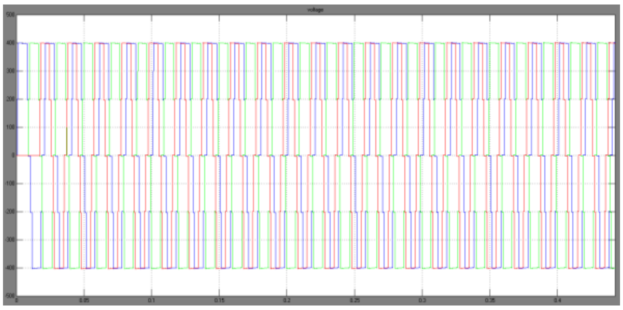

Fig 10 Voltage across grid

## 6. CONCLUSION

In this paper, a grid-tied CMI PV system established on CF-DAB dc-dc converters using small dc-link capacitors has been proposed and was applied to minimize the peak current stress in the converter by synchronizing the LVS dc-link voltage with HVS dc-link voltage. An entire low-frequency power mitigation control for the CF-DAB converter was proposed based on the dynamic model of the converter. With the proposed dual-loop control using PIR controller, the large low-frequency voltage ripple on the dc-link can be cut off from the PV side. This proposed power mitigation control can be extended to other current-fed topologies. An MPPT method was also proposed. Fast tracking speed under rapid irradiation change and high MPPT efficiency were realized for the PV system.

## REFERENCES

[1] B. K. Bose, "Global warming: Energy, environmental pollution, and the impact of power electronics," *IEEE Ind. Electron. Mag*., vol. 4, no. 1, pp. 6-17, Mar. 2010.

[2] M. Malinowski, K. Gopakumar, J. Rodriguez and M. A. Perez, "A survey on cascaded multilevel inverters," *IEEE Trans. Ind. Electron.*, vol. 57, no. 7, pp. 2197-2206, Jul. 2010.

[3] S. Harb, and R. S. Balog, "Reliability of candidate photovoltaic module-integrated-inverter (PV-MII) topologies - A usage model approach," *IEEE Trans. Power Electron.*, vol. 28, no. 6, pp. 3019-3027, Jun. 2013.

[4] L. Liu, H. Li, Y. Xue, and W. Liu, "Decoupled active and reactive power control for large-scale grid-connected photovoltaic systems using cascaded modular multilevel converters," *IEEE Trans. Power Electron*., vol. 10, no. 1, pp. 176-187, Jan 2015.

[5] L. Liu, H. Li, Y. Xue, and W. Liu, "Reactive power compensation and optimization strategy for grid-interactive cascaded photovoltaic systems," *IEEE Trans. Power Electron*., vol. 10, no. 1, pp. 188-202, Jan 2015.

[6] H. Hu , S. Harb , N. Kutkut , I. Batarseh and Z. John Shen, "Power decoupling techniques for micro-inverters in PV systems-a review," in *Proc IEEE Energy Convers. Congr. Expo*., Sep. 2010, pp. 3235-3240.

[7] "Reliability prediction for electronic equipment," *Doc. MIL-HDBK-217X*, United States Dept. Defence, Washington, DC, Dec. 1991.

[8] G. Petrone, G. Spagnuolo, R. Teodorescu, M. Veerachary and M. Vitelli, "Reliability issues in photovol taic power processing systems," *IEEE Trans. Ind. Electron*., vol.55, no.7, pp. 2569-2580. Jul. 2008.

[9] T. Shimizu, K. Wada, and N. Nakamura, "A flyback-type single phase utility interactive inverter with low-frequency ripple current reduction on the DC input for an AC photovoltaic module system," in *Proc. IEEE 33rd Annu. Power Electron. Spec. Conf.*, Jun. 2002, vol. 3, pp. 1483-1488.

[10] J. Knight, S. Shirsavar, and W. Holderbaum, "An improved reliability Cuk based solar inverter with sliding mode control," *IEEE Trans. Power Electron*., vol. 21, no. 4, pp. 1107-1115, Jul. 2006.

[11] W. Bower, R. West, and A. Dickerson, "Innovative PV micro-inverter topology eliminates electrolytic capacitors for longer lifetime," in *Proc. IEEE 4th World Conf. Photovolt. Energy Convers*., May 2006, vol. 2, pp. 2038-2041.

[12] C. Sullivan, J. Awerbuch, and A. Latham, "Decrease in photovoltaic power output from ripple: Simple general calculation and the effect of partial shading," *IEEE Trans. Power Electron*, vol. 28, pp. 740-747, Feb. 2013.

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

[ 14 ] N. Femia , G. Petrone , G. Spagnuolo and M. Vitelli "A technique for improving P&O MPPT performances of double-stage grid-connected photovoltaic systems", *IEEE Trans. Ind. Electron*., vol. 56, no. 11, pp. 4473-4482, Nov. 2009.

[ 15 ] B. York , W. Yu and J.-S. Lai, "An integrated boost resonant converter for photovoltaic applications," *IEEE Trans. Power Electron*., vol. 28, no. 3, pp. 1199-1207, Mar. 2013.

[ 16 ] Y. Shi, L. Liu, H. Li, Y. Xue, "A single-phase grid-connected PV converter with minimal dc-link capacitor and low-frequency ripple-free maximum power point tracking," *in Proc. IEEE Energy Convers. Congr. Expo., Sep*. 2013, pp. 2385-2390.

[ 17 ] Yuxiang Shi,Yaosuo Xue, Optimized operation of Current-Fed Dual Active Bridge DC-DC Converter for PV Applications," IEEE Transactions on Industrial Electronics,Vol.62,NO.11,November 2015