Third harmonic distortion and Phase shift analysis of Improved Transformless Voltage Source Inverter For Photovoltaic Grid-Connected System with Common-Mode Leakage Current Elimination

Mohammed Safique[1]
Electrical Department
Anjuman College Of Engg & Tech.
Nagpur,India
safique.acet@gmail.com

Dr. Harikumar Naidu[2]
Electrical Department
T.G.P.college of Engg & Tech.
Nagpur,India
cghhar@gmail.com

Abstract- This paper analysis the phase shift between output volatge and current in the grid connectd tranformerless inverter due to existece of the filter inductanc. For the elimination of the common-mode leakage current in thetransformerless photovoltaic grid-connected system, an improved single-phase inverter is desined by adding two addional switches and filter inductance due to which phase shift occurs at the grid. For eliminating common mode leackege current in the transformerless inverter by two strategy one is unipolar sinusoidal pulse width modulation (SPWM) control strategy and another Bipolar sinusoidal pulse width modulation (SPWM) control strategy.By applying both this method with diffent inductance value we analysis the optimize value so that we willgenerate a sine wave with fewer harmonics,low phase between grid voltage and grid current,less cost and a simpler design.

Keywords — *Common-mode leakage current, junction capacitance,phase shift, photovoltaic (PV) system, unipolar sinusoidal pulsewidth modulation (SPWM) strategy, , bipolar sinusoidal pulsewidth modulation (SPWM) strategy ,transformerlessinverter, filterinductance. Harmonics distortion.*

*****

I. INTRODUCTION

Nowadays, the world needs the electricity to beincreased. The main reasons for the energyincrease demand are the population, theeconomy growth and the rapid depletion offossils based on energy reserve and rapidgrowth of energy demand. Then, it must research for an alternative source of powergeneration. One of these sources is a renewableenergy which possibly has no harm on the environment.

Energy technology plays a very important role in economic and social development of any country. Presently maximum electrical energy demands are fulfilled by natural gas, coal, petroleum and hydro. To mitigate the negative environmental impact from the electricity supply industry, now there is increasing its efforts to promote renewable energy (RE) and energy efficiency (EE). Solar energy is the world's most abundant permanent source of energy that is also an important and environmentally compatible source of renewable energy.

In this context, lots of research needs to be done in order to achieve a reliable and efficient energy. So that at the the gird-connected photovoltaic (PV) systems is introduced with many topology, Different types of photovoltaic cell will yield different energy output, meanwhile the controlling technique of inverter is very crucial in the PV system. Inverter design should consider the size and capacity of the plant, on the other hand choosing the right controlling technique is needed as well in order to achieve an efficient renewable energy system.

In a normal transformer, inverter PV grid system combination transformers consist of several stages so due to this system system complexity and reduces the system efficiency also making the whole system bulky and tough to install. Hence to reduce the size I and increasing the efficiency the best way is to remove the isolation transformer. But due to this removing of transformer there is common mode leakage current is presence of parasitic capacitance between the PV panel and the ground. The common-mode leakage current flows via parasitic capacitance of the panel to the system which is not meant to be energized. It causes personal several problem like safety problems, degradation in panels, system losses, reduces the grid-connected current quality and induces the severe conducted and radiated electromagnetic interference.

In order to minimise the common-mode leakage current, thebest method of controling are eitherwith unipolar sinusoidal pulse width modulation (SPWM) or bipolar sinusoidal pulse width modulation (SPWM).But due to all this method There is actually a phase shift between the output voltage U_{AB} and output current Ig in the grid-connected inverter due to the existence of the filter inductance.

II. PWM method

An inverter contains electronic switches, it is possible to control the output voltage aswell as optimize the harmonics by performing multiple switching within the inverter with the constant dc input voltage Vd. The PWM principle to control the output voltage is explained in figure 1.The fundamental voltage

 ISSN: 2454-4248
01 – 05

V_1 has the maximum amplitude (4Vd / π) at square wave,but by creating two notches as shown, the magnitude can be reduced. If the notch widths are increased, the fundamental voltage will be reduced.Circuit model of a single-phase inverter with a center-taped grounded DC bus, andFig 1.1 illustrates principle of pulse width modulation.

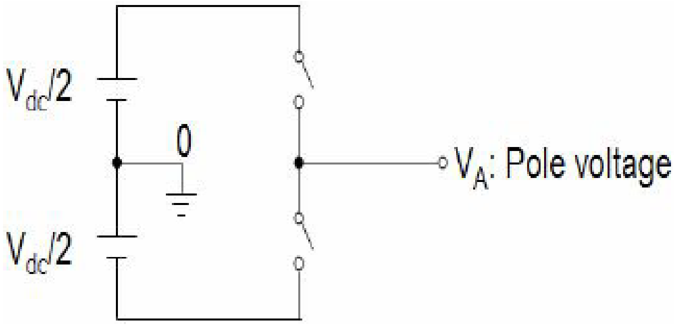


Fig.1.1.Circuit model of a single-phase inverter.

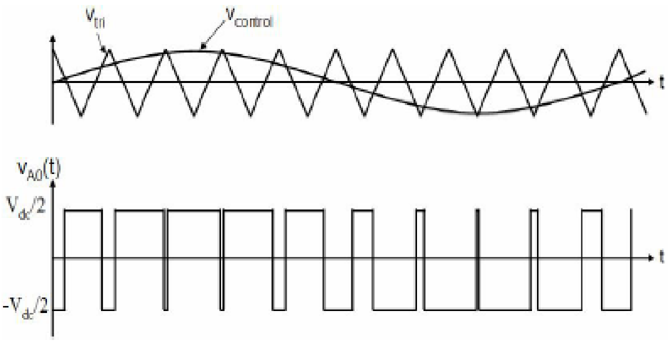


Fig.1.2. Pulse width modulation

The inverter output voltage is determined in the following:

When Vcontrol is greater than Vtri, VA0 = Vdc/2
When Vcontrol is less than Vtri, VA0 = −Vdc/2

The modulation method is very crucial part of control structure. As the following parameter can feature Low content of higher harmonics in voltage and current,Low frequency harmonics. etc.

The average value of voltage (and current) fed to the load is controlled by turning the switch

between supply and load on and off at a fast pace.

The basic advantage of PWM is that power loss in the switching devices is very low. When aswitch is off there is practically no current, and when it is on, there is almost no voltage dropacross the switch. Power loss, being the product of voltage and current, is thus in both casesclose to zero.

III. Basic Spwm method:

The sinusoidal PWM technique is very popular for industrial converters.The basic principle of SPWM is that where an isosceles triangle carrier wave of frequency fc is compared with the fundamental frequency of sinusoidal modulating wave, and the points of intersection determine the switching points of power devices.This method is also known as the triangulation, sub harmonic, or sub oscillation method. The notch and pulse widths of Vao wave vary in a sinusoidal manner so that the average or fundamental component frequency is the same f and its amplitude is proportional to the command modulating voltage. The same carrier wave can be used for all three phases,as shown.The typical wave shape of line and phase voltages for an isolated neutral load can be plotted graphically as shown in figure 1.3. the Fourier analysis of the Vao wave is somewhat involved and can be shown to be of the following form:

Van = 0.5mVd sin (ωt + Φ) + high-frequency (Mωc + Nω) terms

In spwm, the pulse width is a sinusoidal function of the angular position of the pulse in a cyclethe desired output voltage is achieved by comparing the desired reference waveform(modulating signal) with a high-frequency ‘triangular carrier’ wave as depicted schematicallyin Fig.1.3 Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output.

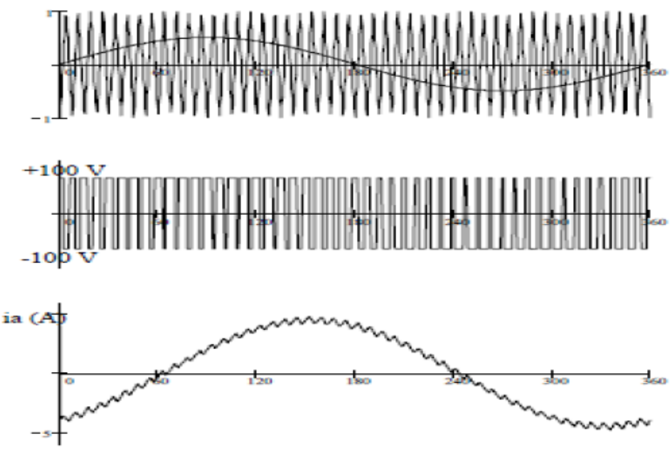
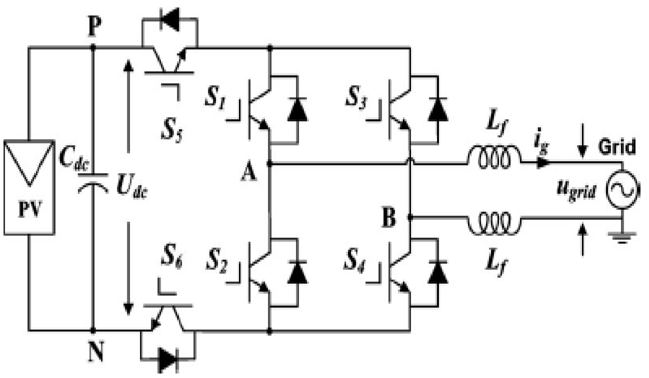


Fig 1.3Sinusoidal PWM

Note that over the period of one triangle wave, the average voltage applied to the load isproportional to the amplitude of the signal (assumed constant) during this period.The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies of a close to the carrier frequency.However, a higher carrier frequency does result in a larger number of switching’s per cycleand hence in an increased power loss.Typically switching frequencies in the 2-15 kHz range are considered adequate for power systems applications.Also in three-phase systems all three waveforms are symmetric.

 ISSN: 2454-4248
01 – 05

IV. Improved inverter topology.



V. Phase Shift Between Output Voltage and Current

As filter inductance present in the circuit hence due to this phase shift between the output voltageU_{AB} and output current ig in the grid-connected inverter.

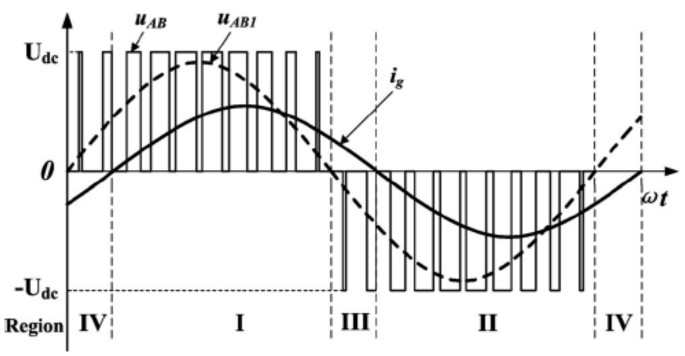
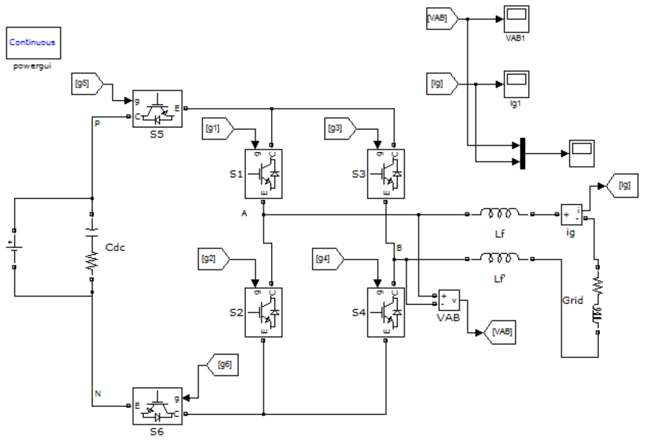


Fig. 1.4

Practical waveforms of the improved inverter considering phase shift.

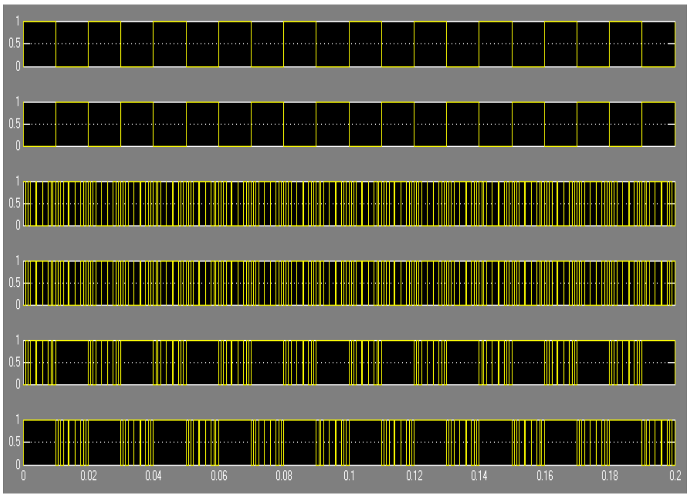
Fig. 1.4 shows the practical waveforms of the improved inverter when considering the phase shift, where $U_{AB1}$is the fundamental component of the output voltage U_{AB} . In Region I and Region II the output voltage and current are in the same direction. In Region III, the output current is positive Meanwhile, the output voltage is negative and modulated according to the operation principle in the negative half cycle. Therefore, if the unipolar SPWM strategy continuously rotate to generate −Udc and zero states and the double-frequency SPWM strategy is used, continuously rotate to generate −Udc and zero states

VI. MATLAB / SIMULINK MODEL



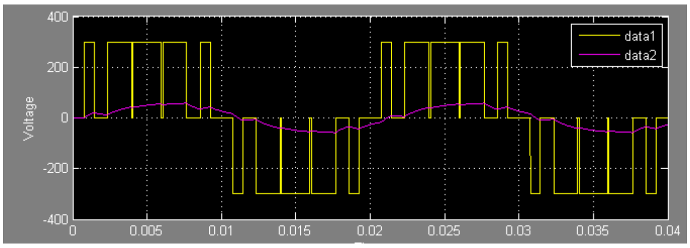
Improved inverter simulation model

VII. Unipolar Spwm Control and results

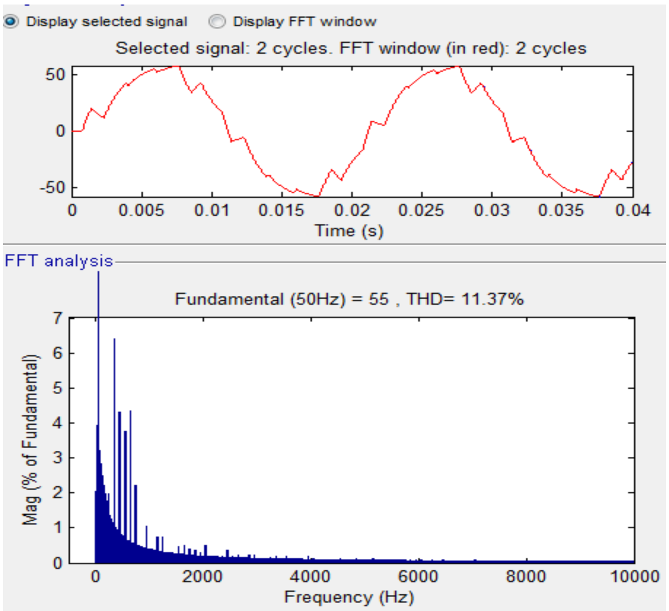


Switching technique waveform

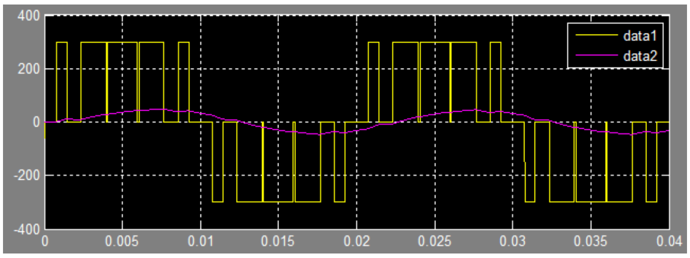
For Filter Inductance L = 4mH



ISSN: 2454-4248
01 – 05



For L= 8mH

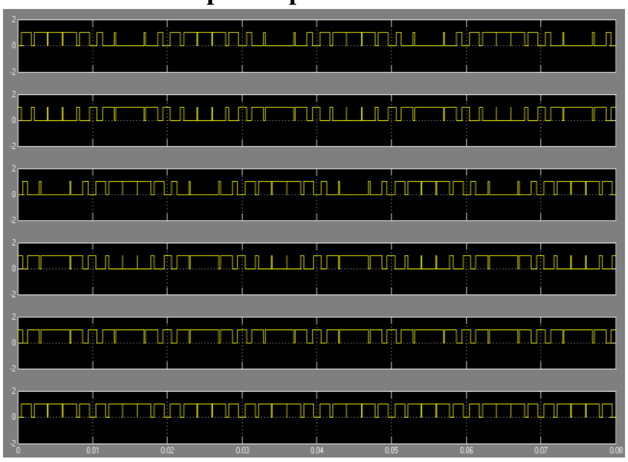


Table

Unipolar spwm inductance Vs THD of grid cuurent

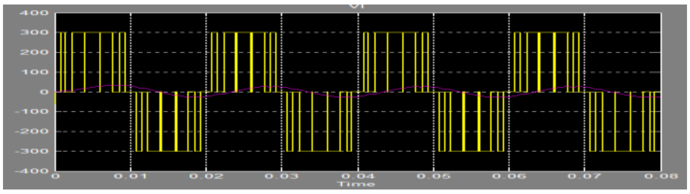
Inductance	THD
4mH	11.37
8mH	9.31
12mH,	6.27
16mH	6.14
20mH	6.02

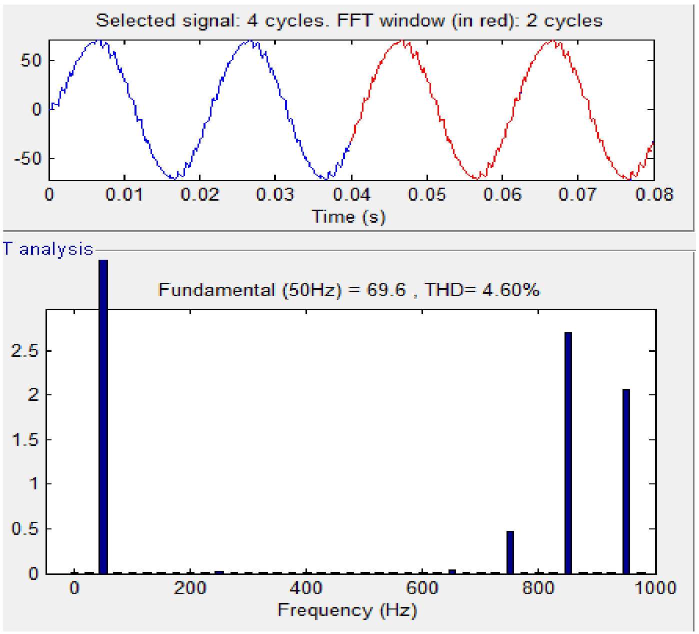
VIII. Bipolar Spwm Control and results



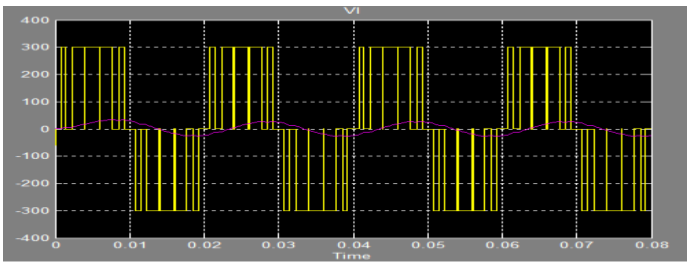
Switching technique waveform

For Filter Inductance L = 4mH





8mh

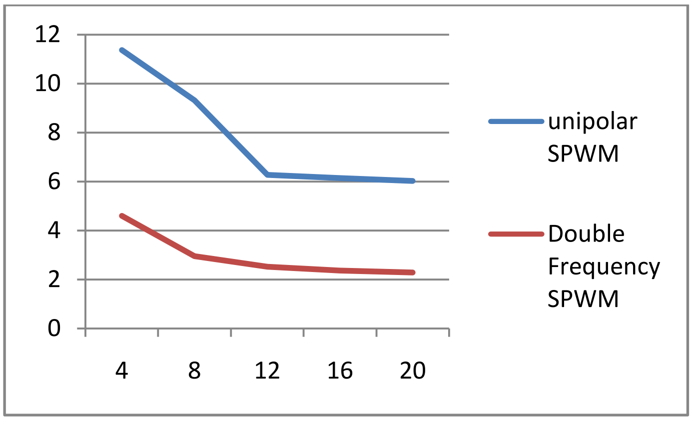


Bipolar spwm inductance Vs THD of grid cuurent

Inductance	THD
4mH	4.60
8mH	2.95
12mH,	2.52
16mH	2.36
20mH	2.28

IX. Comparison Between Unipolar and Bipolar SPWM Technique

Filter Inductance in mH		4	8	12	16	20
Unipolar SPWM	THD(Ig)	11.37	9.31	6.27	6.14	6.02
Double Frequency SPWM		4.6	2.95	2.52	2.36	2.28



X. Conclusion

This paper compare the Third harmonics value of improvedtransformerless inverter photovolatic grid conneted system with different indctance vlaue of the filter and also obser the phase shifting of output voltage and output current that for grid. The unipolar SPWM control techniqueisapplied with three-level output with different indctance vlaue of filter is copmared with the bipolar SPWM control technique.From the result we obsev that the THD value is less in case of bipolar SPWM control technique but as switching is high incase of bipolar SPWM to that of unipolar SPWM.Hence efficiecny od unipolar is high as switching losses are less at unipolar.

REFERENCES

[1] Q. Li and P.Wolfs, “A review of the single phase photovoltaic module integrated converter topologies with three different DC link configurations,” *IEEE Trans. Power Electron.*, vol. 23, no. 3, pp. 1320–1333, May 2008.

[2] Mohammed Safique andDr.Harikumar Naidu , “Improved Single Phase Transformless Voltage Source Inverter for Photovoltaic Grid-Connected System with Common-Mode Leakage Current Elimination,”International Journal on Recent and Innovation Trends in Computing and Communication ,Volume: 4, Issue: 12,pp. 05 – 08.

[3] D Chauhan, S Agarwal, Suman M.K, "Policies For Development Of Photovoltaic Technology:A Review" International Journal of software & hardware research in engineering, Vol. 1, pp. 52-57, December 2013.

[4] Lin Chen, AhmadrezaAmirahmadiQian Zhang, Nasser Kutkut, and IssaBatarseh, “Design and Implementation of Three-Phase Two-Stage Grid-Connected Module Integrated Converter,” IEEE transactions on power electronics, vol. 29, no. 8, august 2014

[5] O. Lopez, F. D. Freijedo, A. G. Yepes, P. Fernandez-Comesaa, J. Malvar, R. Teodorescu, and J. Doval-Gandoy, “Eliminating ground current in a

[6] transformerless photovoltaic application,” IEEE Trans. Energy Convers.,vol. 25, no. 1, pp. 140–147, Mar. 2010.

[7] 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.

[8] O. Lopez, R. Teodorescu, and J. Doval-Gandoy, “Multilevel transformerless topologies for single-phase grid-connected converters,” in Proc. 32nd Annu.Conf. IEEE Ind. Electron. Soc., Nov. 2006, pp. 5191–5196.

[9] Z. Yao, L. Xiao, and Y. Yan, “Seamless transfer of single-phase gridinteractiveinverters between grid-connected and stand-alone modes,” IEEE Trans. Power Electron., vol. 25, no. 6, pp. 1597–1603, Jun. 2010.

[10] M. Calais, J. Myrzik, T. Spooner, and V. G. Agelidis, “Inverters for singlephase grid connected photovoltaic systems—An overview, ” in Proc. IEEE Annu. Power Electron. Spec. Conf., 2002, vol. 2, pp. 1995–2000.

[11] J. M. A. Myrzik and M. Calais, “String and module integrated invertersfor single-phase grid connected photovoltaic systems: A review,” in IEEE Bologna Power Tech. Conf. Proc., Jun. 2003, vol. 2, p. 8.

[12] T. Kerekes, R. Teodorescu, and U. Borup, “Transformerless photovoltaic inverters connected to the grid,” in Proc. IEEE 22nd Annu.Appl. Power Electron. Conf., 2007, pp. 1733–1737.

[13] B. Yang, W. Li, Y. Zhao, and X.He, “Design and analysis of a gridconnectedphotovoltaic power system,” IEEE Trans. Power Electron., vol. 25, no. 4, pp. 992–1000, Apr. 2010.