International Journal For Technological Research In Engineering
Volume 2, Issue 4, December-2014 ISSN (Online): 2347 - 4718

PHOTOVOLTAIC GRID CONNECTED INVERTER WITH ADAPTIVE HYSTERESIS BAND CONTROL TECHNIQUE – A COMPREHENSIVE REVIEW

Mr. Dharmesh K. Patel[1], Mrs. Disha D. Bhatt[2], Mr. Suvas Vora[3]
Mr. Niketan Dobariya[4], Mr. Dipak H. Bhatt[5]
[1,2,3]P.G Student, [4,5]Assistant Professor (Power System)
Electrical engineering Dept.
[1,4]Hashmukh Goswami College of Engineering, Vahelal(Gujarat),India
[3]Merchant Engineering College, Basana(Gujarat),India
[2,5]Saraswati College of Engg. & Tech. Rajpur, Kadi(Gujarat),India

Abstract: Mainly type of renewable energy systems works in conjunction with the existing electrical grid. In Photovoltaic (PV) grid connected inverter system, power quality is big issue. The evaluation of inverter is developed with focus on high reliability, low cost and mass-production for converting electrical energy from the PV module to the grid. Different types of inverter topologies are present, compare and evaluated against demand, component rating and cost. Inverter connected PV system to explain electrical performance subjected to different operating condition. This paper describes adaptive hysteresis technique for solar PV system grid connected inverter to mitigate the current related problem. Basically the adaptive hysteresis current control technique changes the hysteresis band width according to modulation frequency, supply voltage, dc capacitor voltage and reference current wave. The hysteresis current controller also determine the switching time of the shunt active power filter.
Keyword: power quality, grid, inverter, photovoltaic, adaptive hysteresis

I. INTRODUCTION

Centralized power generation systems are facing the identical constrains of shortage of fossil fuel and the necessitate to reduce emission. In the Long transmission lines are one of the main issues for electrical power losses. Thus, importance has increased on distributed generation network with integration of renewable energy systems into the grid, which guide to energy efficiency and reduction in emissions. With increase of the renewable energy saturation to the grid, PQ (power quality) of the medium to low voltage power transmission system is becoming major area of interest [1]. The majority of the integration of renewable energy systems to the grid takes place with the aid off power electronics inverter and converter. Now a day, solar energy can be used as an alternative resource due to the worldwide crisis on fossil fuel and increasing concern about worldwide environment problems. PV (Photovoltaic) is basically works to convert solar energy into electricity directly and recently is widely used. With nonlinear characteristics, concerning loads to PV will issue the power generated by PV is not maximum. Another important problem is due to cost of PV arrays. There are many problems when PV connected grid using inverter, one of the main problem is current fluctuation. Applications of PV can be classified into two stages, stand-alone and grid-connected systems. The first one is applications where PV systems are separated from utilities and the second one is applications where PV and grid are integrated [2]. The technical key aspects that will drive improvements in cost, efficiency and reliability of PV inverters, which are means to success, will be addressed in this paper. The paper will point out current related challenges in power quality assurance and overview of to mitigate the different technique.

II. ISSUES OF POWER QUALITY

Around 70 to 80 % of all power quality related issues can be attributed to faulty connection and wiring [4]. There are different problem to grid connected inverter is used like frequency disturbances, electromagnetic interference, transients, harmonics and low power factors and other problems are shown in below table-1[5].

Table-1 Categories of Power Issues

Power freq. Disturbance	Low Freq. phenomena Produce Voltage sag/swell
Electromagnetic Interference	High Freq. phenomena Interaction between electric and magnetic field
Power System Transient	Fast, short duration event Distortion like notch, impulse
Power System Harmonics	Low frequency phenomena Produce waveform distortion
Electro Static Discharge	Current flow with different potentials Caused by direct current or induced electrostatic field
Power Factor	Low power factor cause damage the equipment

Among these procedures, harmonics are the most leading one. The effects of harmonics on power quality are specially described in [6]. According to the IEEE standard, harmonics in the power system should be limited by two various method, first one is the limit of harmonic current that a user can inject into the utility system at the PCC (point of common coupling) and the other one is the limit of the harmonic voltage that utility can supply to any customer at the PCC [7]. Generally there are two way to reduce the power quality problems- either from the customer side or from the supply side. The first one is called load conditioning, which makes certain that equipment is less sensitive to power distribution, allowing the operation even under significant voltage distribution. Other one is to install line conditioning system that suppress or counteracts the power system disturbances.

III. SOLAR CELL

A working of solar cell system converts sunlight into electricity.

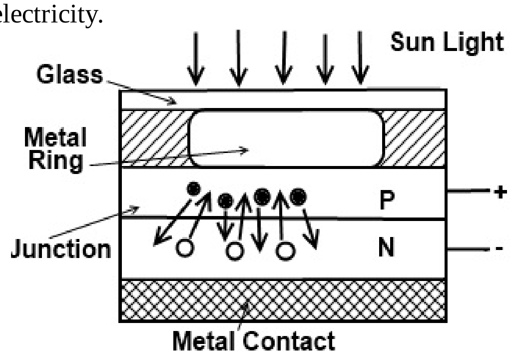

Figure1. Solar Cell

Solar cells may be grouped to call panels or modules. Panels can be grouped to call large solar cell arrays. The word array is usually working to describe a solar cell panel (with numerous cells connected in series and/or parallel) or a group of panels. Mainly of time one are interested in modeling solar cell panels, which are the commercial solar cell devices [8].

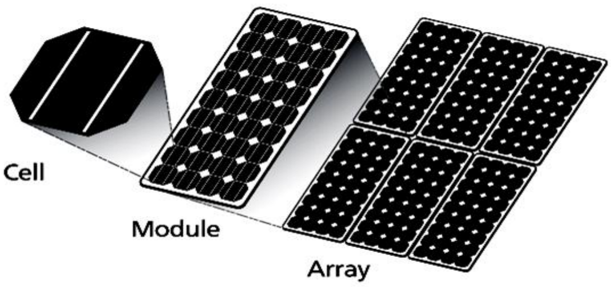

Figure2. Solar cell ladder

The voltage generated by a solar cell is very low, approximately 0.5v. So more than one of solar cells are used to connect both in series and parallel connections to get the desired output. In biased shading case, diodes may be necessary to avoid reverse current in the array. In solar cell, good ventilation behind the solar panels is provided to reduce the possibility of less efficiency at high temperatures. The most of practical purpose, over production of the power by a single PV (photovoltaic) module is not enough to meet the power demands. Inverters use in the PV array can to convert the dc output into ac and another use to apply it for motors, lighting and other loads. The modules are connected in series for more voltage rating and it connected in parallel to meet the current specifications.

IV. GRID CONNECTED PHOTOVOLTAIC GENERATION SYSTEM

Grid-connected PV generation system is mostly composed of the PV array, the inverter device with the function of maximum power tracking and the control system, whose structure shown in Figure3 [10].

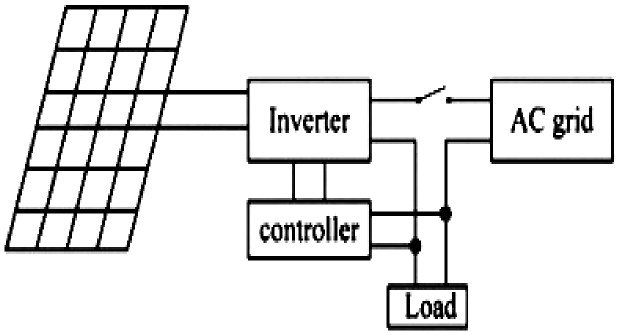

Figure3 Grid connected PV power generation structure

The function of the inverter maximum power point tracking can inverse the electric power into sinusoidal current, and connect to the grid [9]. The control system generally control the maximum power point tracking of photovoltaic, current waveform and power of the output of grid-connected inverter, which makes the output to the grid correspond with the export by PV array.

V. INVERTER CONTROL THEORY

Generally control of Inverter can the switch state of shut and conduct, thus the system may form two different working ways which are parallel operation and separately operation. While the system is working in parallel operation way, the inverter belongs to the current mode. Corresponding circuit of the inverter in parallel operating mode is shown in below figure4.

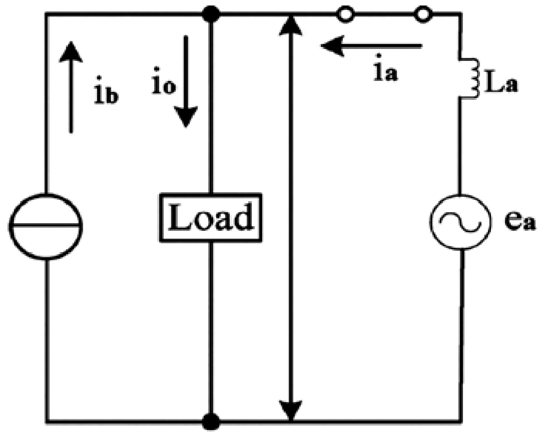

Figure4. Corresponding circuit of the inverter in parallel operating mode

The equation can be easily got from the circuit combing with Kirchoff's Law, as in (1), (2).

e0=ea-La(dia/dt) ….1

ia=i0-ib ….2

where

ea = the source voltage, e0 is the AC voltage of the load,

ia = the contact current, i0 is the load current,
ib = the output current of the inverter.
According to equations 1 &2, the relation equation of fundamental component of voltage and current is easily got, as in equation (3).

e01 = ea1 – La[d(i01-ib1)/dt] ….3

The voltage fundamental Eal seen as the baseline vector, thus the fundamental value Eol by the output of inverter and its phase.

VI. VOLTAGE SOURCE INVERTER CONTROL METHOD

The working of the PV array voltage is set to Ed, the standard voltage Edr should be matched with the working voltage Ed while the PV array is in the maximum power output state. The standard current should be kept to sinusoidal at the same time as the power factor should be kept to one which can be realized by PWM control method. Sw is a switch, the switch mostly protects the inverter and also cuts the inverter from the system when the system power off. The basic block diagram of the voltage source inverter and its control method are shown in Figure5 [10].

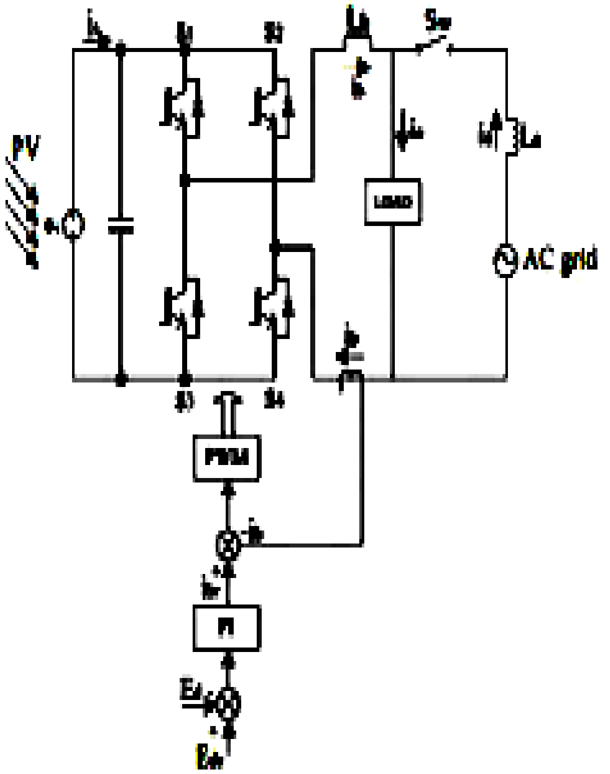

Figure5. Basic Idea about Voltage Source Inverter

From the above Figure5, the process of inverter control system is quite complex which used the former class system voltage fluctuations and waveform distortion signal to control the next class system. To make sure power supply, the switch or reenter of inverter output will create frequency management control complex and difficult. It will increase the difficulty of the control system of the main circuit if setting another AC switch; temporarily the single phase system will have a big power fluctuation.

VII. CURRENT CONTROL TECHNIQUES

The current controller mainly used for getting triggering pulse as per the reference value. Here we discussed only the current control method. Basically the numerous techniques for nonlinear current control like Predictive control, Dead-Beat control and Hysteresis control techniques as discussed in below:

A. Predictive Control:

Current Controller principal on prediction is one of the nonlinear grid connected controllers. The strategy of predictive control is based on the fact that only a finite number of possible switching states can be generated by a static power converter, and also the models of the system can be used to predict the performance of the variables for each switching state. So to select the suitable switching state to be applied, a selection principal must be defined. This switching sates selection principle is expressed as a quality function that will be evaluated for the predicted values of variables to be controlled. Prediction of the prospect value of these variables is calculated for all possible switching state. The minimized the switching state that the quality function is also selected.

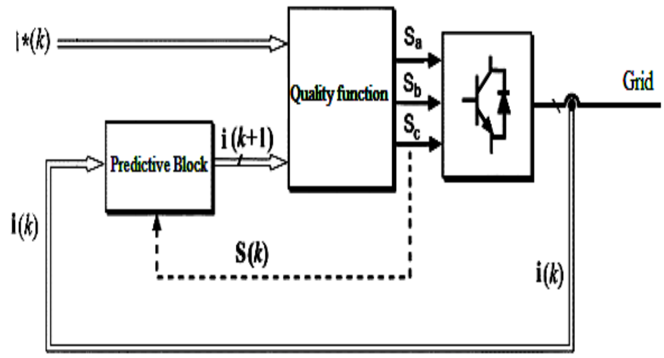

Figure6. Block diagram of the predictive control

Shown in figure6, a predictive current control block is applied to calculate the next value of the output current by using the accessible output current. After that, the quality function determines the error between the reference current and the predicted output current. Lastly, the voltage which minimizes the current error is selected and applied to the output current. This type of controller is well known for their possibility to consist of nonlinearities of the system in the predictive model. Predictive controllers provide a better performance while the mathematical model is linear, accurate, and time invariant. since of complicated computationally of the predictive controller, controller wants a large control loop time period.

B. Dead-Beat Control:

When the selection of the voltage vector is ordered to a zero (null) error with a one sample delay, the predictive controller called dead beat controller. In this control, among the further information given to the controllers, non-available state variables like flux and speed can also be included. As a result, observer or other control blocks are required to determine these variables which often may be shared in the control of the complete scheme.

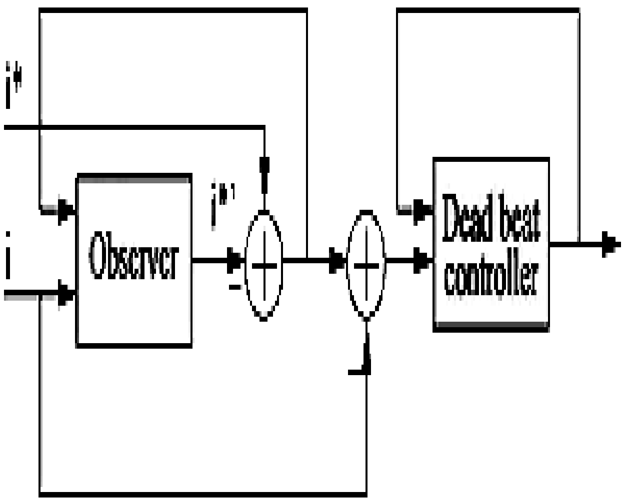

Figure7. Block Diagram of Dead-Beat Control

The controller gain is achieved by the bellow's formula:

….1

$$G = \frac{1 - aZ^{-1}}{b(1 - Z^{-1})}$$

Where,

$$a = e^{-\frac{RT}{LT}Ts}$$

$$b = -\frac{1}{RT}(e^{-\frac{RT}{LT}Ts} - 1)$$

Here,

RT= equivalent interfacing resistance

LT= inductance seen by the inverter

This controller has a sample delay time, since it regulates the current when it achieves its reference at the end of the next switching period. In that case, the controller indicates one sample delay time. In some cases similar to [11] an observer can be used by controller to make difficult this time delay which is shows in Figure. The TF (transfer function) of this observer can be obtained by (2):

$$F = \frac{1}{1 - Z^{-1}}$$

….2

Then, new reference current is:

$$i^* = F(i^* - i)$$

….3

Dead-beat controller is fast, simple and it is suitable for microprocessor-based application [12].

C. Hysteresis Control:

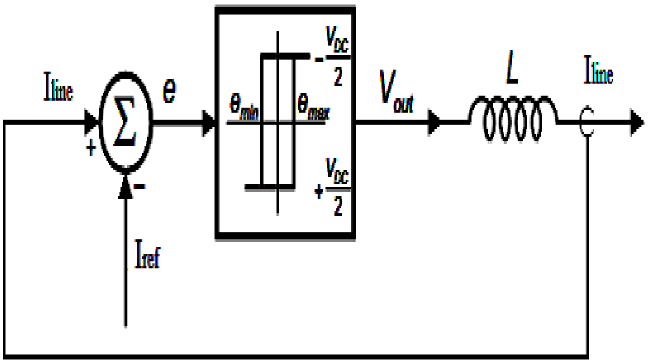

Figure8. Block Diagram of Hysteresis Control

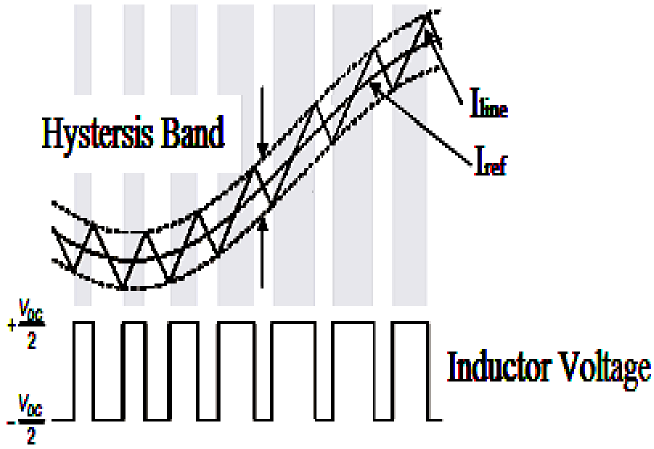

Figure9. Controller operational waveform of Hysteresis control

Basically, Hysteresis current control is a method for controlling a VSI (voltage source inverter) to force the grid injected current follows a reference current. A hysteresis controller block diagram is shown in Figure 8. The reference current and line current are used to control the inverter switches. Upper and lower hysteresis band limitations are correlated to the minimum and maximum error directly (min, max). While the changed the reference current, line current has to stay within these limits. The error signal range directly controls the amount of ripples in the output current from the inverter which is called the hysteresis band. The current ramping between the two limits is shown in Figure 9. Hysteresis controllers not only are simple and robustness but also have a good transient response. Due to the relations between the phases, the current error is not limited to the value of the hysteresis band. The switching frequency of hysteresis controller changes by load parameter's variations which is changed the bandwidth and it can cause resonance problems. Furthermore, the losses of switching resist the application of hysteresis control to lower power level. This type of problem can be solved by employing variable limitation as mentioned in [13]. Yet, it needed system parameter's details.

VIII. CONCLUSION

Pollution and weather change are powerful reasons to reduce our use of coal, oil and natural gas. Conversely, the environment is not the only the reason to substitute the fossil fuel sources with renewable. In fact, if fossil fuels are released no pollution whatsoever, they would still be issue big problems for modern society. Renewable energy is very flexible because of renewable can be used in small systems for distributed generation or in truly substantial installations for centralized generation. As the majority of renewable energy systems are connected to the grid, so using controlled inverter is essential to have a reliable and safe grid interconnection. In this way, this type of the current control inverter is more commonly used, then in this paper the structure of the important current control techniques like hysteresis, predictive and dead beat control were described. Finally, their ability to give a high power quality generation to the grid was explained. Shown the different current control technique describe in this paper, we concluded that the current related issue hysteresis control is appropriate and easy to implementation.

REFERENCES

[1] S.K.Khadem, M.Basu and M.F.Conlon, “Power Quality in Grid Connected Renewable Energy Systems: Role of Custom Power Device”, International Conference on Renewable Energy and Power Quality (ICREPQ), Granada (Spain), 23rd to 25th march, 2010.

[2] Slamet Riyadi, “Single-Phase Single-Stage PV-Grid System Using VSI Based on Simple Control Circuit”, International Journal of Power Electronics and Drive System (IJPEDS), vol.3, No.1, March 2013, ISSN: 2088-8694

[3] Xiaoming Yuan and Yingqi Zhang, “Status and Opportunities of Photovoltaic Inverters in Grid-Tied and Micro-Grid Systems”, IEEE, 1-4244-0449-5, 2006.

[4] S.M Halpin, L.L. Grigsby, The Electric Power Engineering Handbook, CRC Press LLC (2001), pp 15.4

[5] C. sankaran, Power Quality, CRC Press (2002), pp. 12-13

[6] R.D. Henderson P.J. Rose, “Harmonics: The Effects On Power Quality And Transformers”, IEEE trans Industry Appl, 1994, vol 30(3), pp. 528-532.

[7] S.M Halpin, L.L. Grigsby, The Electric Power Engineering Handbook, CRC Press LLC (2001), pp 15.22-23.

[8] Pritam Chowdhury, Indrajit Koley, Sougata Sen Dr.Pradip Kumar Saha, Dr.Gautam Kumar Panda, “Modlling, Simulation and Control of a Grid Connected Non Conventional Solar Generation System using MATLAB”, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 4, April 2013.

[9] H.S.Bae, S.J.Lee, K.S.Cho, S.S.Jang, “Current Control Design for a Grid Connected Photovoltaic/Fuel cell DC-AC Inverter, IEEE, Trans On Energy Conversion, pp. 1945-1950, 2009.

[10] Yanqing Li, “Research of An Improved Grid-Connected PV Generation Inverter Control System”, International Conference on Power System Technology, 2010.

[11] P. Mattavelli, G. Spiazzi, and P. Tenti. Predictive digital control of power factor preregulators with input voltage estimation using disturbance observers. IEEE Trans. Power Electron. 2005, 20(1): 140–147.

[12] Y. Ito and S. Kawauchi. Microprocessor based robust digital control for UPS with three-phase PWM inverter. IEEE Trans. Power Electron.1995, 10(2): 196–204.

[13] G.H. Bode, D.G. Holmes. Load independent hysteresis current control of a three level single-phase inverter with constant switching frequency. In: Proceedings of IEEE power electronics specialist conference. 2001. p. 14–9.

