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

Mr. Dharmesh K. Patel¹, Mrs. Disha D. Bhatt², Mr. Suvas Vora³
1,4 Hashmukh Goswami College of Engineering, Vahelal(Gujarat),India
2,5 Saraswati College of Enng. & 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

<table>
<thead>
<tr>
<th>Power freq. Disturbance</th>
<th>Low Freq. phenomena</th>
</tr>
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<tbody>
<tr>
<td>Electromagnetic Interference</td>
<td>High Freq. phenomena</td>
</tr>
<tr>
<td>Power System Transient</td>
<td>Fast, short duration event</td>
</tr>
<tr>
<td>Power System Harmonics</td>
<td>Low frequency phenomena</td>
</tr>
<tr>
<td>Electro Static Discharge</td>
<td>Current flow with different potentials</td>
</tr>
<tr>
<td>Power Factor</td>
<td>Low power factor cause damage the equipment</td>
</tr>
</tbody>
</table>

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. 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].

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).
\[ e_0 = e_a - L_a (\text{dia/dt}) \quad \text{....1} \]
\[ i_a = i_0 - i_b \quad \text{....2} \]
where
\[ e_a = \text{the source voltage, } e_0 \text{ is the AC voltage of the load,} \]

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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).
\[ e01 = e_{a1} - L_a \frac{di01 - ib1}{dt} \] …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](image)

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 states 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](image)

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.

C. Hysteresis Control:

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

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

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):

\[ F = \frac{1}{1 - Z^{-1}} \]  

Then, new reference current is:

\[ i^* = F(i^* - i) \]  

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