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Fuzzy Controlled Based PV Three Phase Inverter For Grid Connected System

Manchiraju M.S.S.S.M. Phanindra, D.prakasa rao
PG Student, Department of EEE, Adarsh, Chebrolu, India.
Asst.Professor and HOD, Department of EEE, Adarsh, Chebrolu, India.

Abstract- Distributed Generation (DG) is presently broadly utilized in numerous power age systems. It is generally in light of sustainable power sources and vitality stockpiling, for example, photovoltaic cells (PV), wind turbines (WT) and energy components to limit contamination and ozone harming substance emanations. For expansive scale establishments, a three stage control electronic inverter used to interface the wellspring of sustainable power source to the utility network. The related control framework and inverter are at the center of the vitality change process and their task is basic for low consonant contortion and to infuse high power quality current to the matrix. Consequently worldwide consonant and power quality proposals, for example, IEEEStandard519and1547,are often in place to limit the harmonic currents injected into the grid. Typically, 5% current total harmonic distortion (THD) limit is imposed. A Fuzzy controller is also implemented in this project in order to reduce the THD. In addition, the fuzzy and adaptive PR controller offers superior output power regulation, and improved power quality performance. Results are analyzed through MATLAB/SIMULINK environment.

Key words- Fuzzy control, distributed generation.

INTRODUCTION

Distributed Generation (DG) is now widely employed in many electricity generation networks. It is mostly based on energy storage and renewable energy sources such as wind turbines (WT), photovoltaic cells (PV) and fuel cells to minimize pollution and greenhouse gas emissions [1]. For large scale installations, a three phase power electronic inverter utilized to interface the source of renewable energy to the utility grid. The inverter and the associated control system are at the core of the energy conversion process and their operation is essential to inject high power quality, low harmonic distortion, current to the grid [2]. For this reason international harmonic and power quality recommendations, such as IEEE Standard 519 and 1547, are often in place to limit the harmonic currents injected into the grid [3]. Typically, 5% current total harmonic distortion (THD) limit is imposed. Numerous inverter current control techniques have been proposed to achieve improved power quality waveforms.

The proportional-integral controller (PI controller) is perhaps the best understood and commonly applied control strategy. In three phase systems, the d-q rotating synchronous reference frame (SRF) approach, based on classic Park transformations, is often applied [4]. As a consequence of the shortcomings of the PI controller such as steady state output error when tracking sinusoidal reference signals [5], alternative control solutions have been presented. Of these, the Proportional Resonant (PR) controller has become a popular strategy in renewable energy applications. For example, in [6], the PR controller is successfully employed in the stationary reference frame of a three phase grid connected system. Significantly, the reported advantages of the PR controller include the capability to remove steady state errors when tracking AC signals by generating an infinite gain at a known resonant frequency of the controlled signal[7],and a highly attenuated gain at other frequencies, such as the harmonic frequencies. Furthermore, the Park transformation is not necessary, and there is less cross coupling of the control axis, hence de-coupling strategies are not required [8]. As a result, in grid connected applications, significant reduction in the harmonic content of the controlled current is possible. Additional elimination of the harmonic content can be achieved by implementing Harmonic Compensation (HC) terms in parallel with the main control effort [9]. However, a sudden drop inthe voltage could further increase the error between the reference signal and the controlled signal causing considerable deviation from its nominal value. The performance of the conventional PR controller will not keep up with the increase in the error which weakens the controller performance. To overcome this issue, this project presents an improvement in current control using a novel adaptive PR controller. It demonstrates and compares the performance of the adaptive PR controller during normal and abnormal grid voltage conditions. The proposed control technique is capable of providing low total harmonic distortion (THD) of the injected current even during the occurrence of abnormal grid conditions. The proposed method also achieves lower overshoot, settling time as well as steady-stateerror.

In addition, this project presents a simple method to decompose the voltage and the current into their positive and negative sequence components based on adaptive delayed filter with one-quarter period delay. The performance of the adaptive control strategy is verified by simulation. A three phase grid connected inverter is modeled and controlled using adaptive PR controller strategy based on the stationary reference frame point of view with space vector modulation technique (SVM). As a result, a phase locked loop (PLL) is used here in this control to detect the transformation angle and enhance the synchronization of the inverter output current with the grid voltages achieved. Two adaptive PR current controllers together with harmonic compensators are applied in the current controller. The control scheme does not have any coupling between active and reactive components, and the results show that it provides excellent dynamicresponse.

In recent years, there has been a rapid increase in the number of grid connected three phase inverter systems being connected to the distribution network. As a result, the need for high quality, low harmonic distortion, current injection into the grid is essential. To achieve this, careful consideration of the inverter controller is necessary. Many control methods are based on the traditional proportional-integral controller (PI), or the more recently adopted Proportional Resonant controller (PR). This project presents a new technique of minimizing the error of the current control in a three phase gridconnectedinverter using a readily implementable Adaptive Proportional Resonance controller.

LCL FilterDesign

Fig.1 shows a three-phase grid connected inverter with a third order LCL filter. The LCL filters improve the power quality of the current injected to the grid compared to lower order L and LC filters

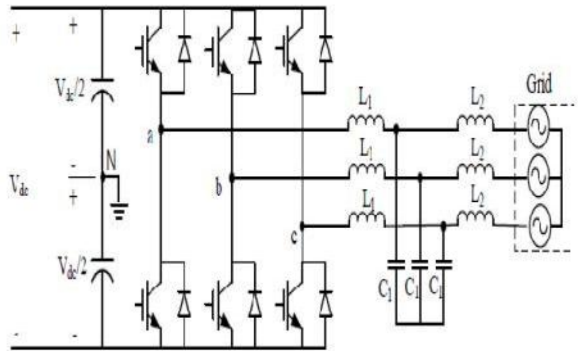


Fig.1 Three phase inverter connected with LCL filter

The differential equation representing of theLCL filter can be found from the single phase equivalent circuit in Fig.2. Here, the filter is defined by the inverter-side inductor L1, filter capacitor C1, grid side inductor L2, and the resistive elements represent the ohmic losses in the passivecomponents.Since SVM is used in this system, the LCL filter isdesigned in the stationary reference frame (αβ) using space vectors to make it easier and more convenient. By applying Kirchhoff's voltage and current laws, the following equations can be used to represent the voltages and currents within the circuit of Fig.2 [11].Inverter vector equations, dc voltage, capacitor voltage and LCL filter current equations are given by paper [1].

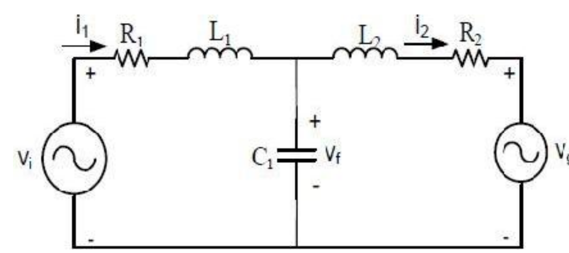


Fig.2 Equivalent circuit of single phase LCL filter

III Control Scheme

In this work, the applied control system is a cascaded system with an inner current control loop controlled by an outer voltage control loop. The block diagram of the adaptive PR current control scheme is presented in Fig.3. The system consist of PV array with maximum power point comprised of dc-dc converter following by three phase dc-ac inverter [3, 4]. The voltage control loop comprises of two PI regulators; one for the dc link voltage control and the other for the grid voltage control. The measured dc voltage is compared with the reference dcvoltage

Fig.3: Adaptive PR controller in stationary

Reference control

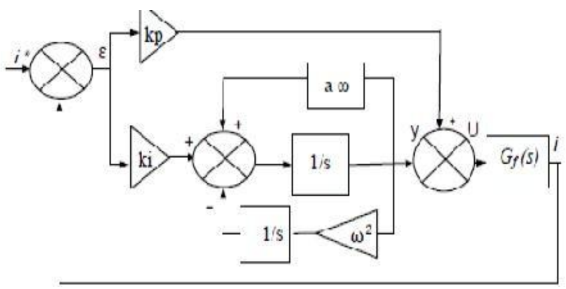


Fig.4: Controller diagram of PR Controller

The measured voltage is converted to the synchronous reference frame, and the q-component, *vq* is comparedwith the reference *vq* * which is equal to zero and controlled by a PI controller. The nominal grid frequency ω is added to the output of the PI controller, and the sum is integrated to obtain the gridvoltage angle θ.

BRIEF OF THE

INSTANTANEOUSPOWER THEORY

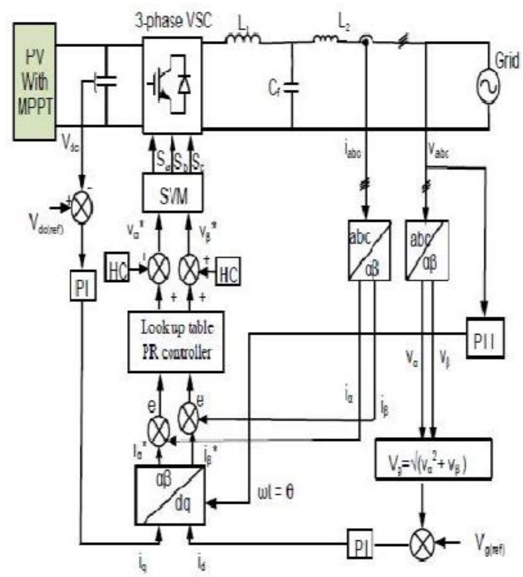
As the name implied, the instantaneous power theory is based on a definition of instantaneous real and reactive powers in time domain. It is very useful not only in the steady-state but also in the transient state analysis for both three-phase systems with or without a neutral conductor. To illustrate the theory, let consider a set of instantaneous three phase quantity, for example *a v* ,*b v* and *c v* . It starts with transforming a set of three-phase variables in the *abc* into αβ *0* coordinates. This transformation is so-called as the Clark transformation as described follows.

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

………………… (2)

In three-phase, three-wire systems, there is no zero



sequence components. If *0 v* and *0 i* are both neglected, instantaneous voltage, **v**, and current phasors, **i**, can be defined from their corresponding instantaneous α and β components as follows

$v=v_\alpha + jv_b$……….. (3)

$i=i_\alpha + ji_\beta$………. (4)

From (3) and (4), instantaneous complex powers, **s**, can be defined as the product of the instantaneous voltage phasor and the complex conjugate of the instantaneous current phasor given in(5).

$s=vi^{*}=(v_\alpha + jv_\beta)(i_\alpha - ji_\beta)=p+jq$ …………… (5)

Where,

$P=v_\alpha i_\alpha+ v_\beta i_\beta p$ is the instantaneous active power

$q=v_\beta i_\alpha - v_\alpha i_\beta$ is the instantaneous reactivepower

The instantaneous complex power is useful. It can be applied for transient or steady-state analysis. The following equation is a compact form for the instantaneous real and reactive power definition and itsinversion

FUZZY CONTROLLER

The word Fuzzy means dubiousness. Fluffiness happens when the limit of snippet of data isn't obvious. In 1965 Lotfi A. Zahed propounded the fuzzy set hypothesis. Fuzzy set hypothesis shows massive potential for compelling illuminating of the vulnerability in the issue. Fuzzy set hypothesis is an astounding numerical device to deal with the vulnerability emerging because of dubiousness. Understanding human discourse and perceiving written by hand characters are some basic examples where fluffiness shows.

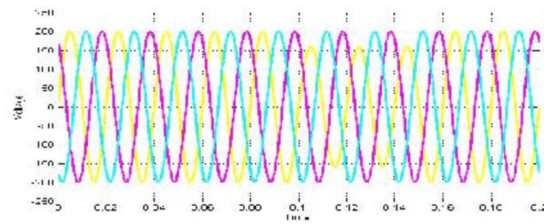
Fuzzy set hypothesis is an expansion of traditional set hypothesis where components have fluctuating degrees of participation. Fuzzy rationale utilizes the entire interim in the vicinity of 0 and 1 to portray human thinking. In FLC the information factors are mapped by sets of enrollment capacities and these are called as "Fuzzy SETS".

Fuzzy set involves from a participation work which could be characterizes by parameters. The incentive in the vicinity of 0 and 1 uncovers a level of participation to the fuzzy set. The way toward changing over the fresh contribution to a fuzzy esteem is called as "fuzzificaton." The yield of the Fuzzier module is interfaced with the standards. The essential activity of FLC is built from fuzzy control rules using the estimations of fuzzy sets as a rule for the mistake and the difference in blunder and control activity. Essential fuzzy module is appeared in fig.5

The outcomes are consolidated to give a fresh yield controlling the yield variable and this procedure is called as "DEFUZZIFICATION."

Simulation Results:

It can be seen that the voltage drops when a voltage droops occurs in the framework at 0.1 sec until 0.15 sec.Fig.10 demonstrates three stage current waveform. Obviously the currenthas expanded when the sudden voltage happen at 0.1 sec with a specific end goal to adjust the dynamic power exchange from the PV source. Fig.13 demonstrates the stationary reference outline (alpha)currentwaveform and Fig.14 demonstrates the stationary reference frame(beta) current waveform for regular PR controller. They demonstrate huge deviation when variety in the present waveform.



CONCLUSION

This thesis has considered the impact of an adaptive PR current controller and fuzzy controller scheme of a three phase grid connected inverter. In particular, this work has shown the performance of the adaptive PR controller compared with the conventional PR controller which is popular in grid connected inverters. Simulation studies confirm that the adaptive PR controller demonstrates better performance under normal and abnormal operating conditions. There is no steady state error output, and the harmonic content of the current waveform is very low. A Fuzzy controller is also implemented in this project in order to reduce the total harmonic distortion. In addition, the fuzzy and adaptive PR controller offers superior output power regulation, andimprovedpower quality performance. Overall, it can be concluded that the adaptive PR and fuzzy controllers are better suited in the event of grid faults, or operation in weak grid environments, compared to fix gaincontrollers.

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