Multistring PV inverters by fuzzy based MPPT and CPG mode

PARTHIBAN.S, P.KARTHIKEYAN
Assistant Professor
Department of EEE

NANDHA COLLEGE OF TECHNOLOGY
ERODE, INDIA

Abstract

With a still increasing penetration level of grid connected photovoltaic (PV) systems, more advanced active power control functionalities have been introduced in certain grid regulations. A delta power constraint, where a portion of the active power from the PV panels is reserved to support frequency deviation. In this paper , Multistring PV inverter configuration is adopted to realize delta power control (DPC) for grid-connected PV systems. This control strategy is a combination of maximum power point tracking (MPPT) and constant power generation (CPG) modes.This paper proposes intelligent fuzzy logic control (FLC) method for maximum power point tracking of photovoltaic systems. In this control scheme, one PV string operating in the MPPT mode estimates the available power, whereas the other PV strings regulates the total PV power by the CPG control strategy in such a way that the delta power control for the entire PV system is achieved. Simulations have been performed on a 3-kW single-phase grid connected PV system. The results have confirmed the effectiveness of the proposed DPC strategy, where the power reserve according to the delta power control is achieved under several operating conditions.

Index Terms—Delta power control, maximum power point tracking (MPPT), fuzzy logic control ,photovoltaic (PV) system, constant power generation (CPG) control, grid-connected power converters.

I. INTRODUCTION

The increasing renewable energy penetration together with the price reduction of photovoltaic modules supported the development of large scale photovoltaic power plants connected to the medium and low voltage grid. Many concerns are emerging about the electrical system stability when it is connected to renewable sources. Once, photovoltaic plants where thought to reach always the maximum power point and to extract the maximum power available [4] [5]. Nowadays, there are new challenges that photovoltaic plants have to overcome for ensuring the production and control with a variable energy resource as solar radiation. Photovoltaic generation components and control are being investigated according to new grid requirements proposed by Puerto Rico and South Africa [2]. The control of active power should match the variability of solar energy during the day and it is divided into absolute production, delta production and power gradient . In the requirements of PREPA it is established that in normal operating conditions the system should be able to provide a reduction of active power in the connection point with steps of 10% of the estimated power [2]. Besides, in grid codes of NERSA, the active power capability value shall not be less than 3% of the available power in order to guarantee a reserve for frequency stabilization [3] .

First of all the literal review starts with a focus into the PV generator topologies. Then, there is a description of the principal typologies of PV plants currently diffused. Each technique has its own advantages and basically there are three main topologies: central, string and multi-string. This section analyzes the main characteristics of different topologies with a particular focus on their principal advantages and disadvantages.

Central topology:

This topology interconnects several thousands of PV panels to one inverter. Each array has several strings connected in parallel, the strings are composed by PV panels connected in series and strings are connected with inverters. Generally, it is used for large PV systems with high power output [2]. The main characteristics of this topology are low MPPT efficiency and flexibility but high robustness.

String topology:

This technique connects one inverter per string. It generates more power than the central topology in non-uniform conditions but costs of installation are high due to greater number of inverters [2].

Multi-string topology:

The multi-string topology connects one PV string to a dc-dc converter for tracking the maximum power point and then several converters are connected to one inverter via a dc bus. This technique is featured by higher efficiency because there is one dedicated MPPT per string [2].

When looking into the prior artwork, there are mainly three approaches [1] to realize delta power control (DPC).Firstly, integrating energy storage system where surplus PV power can be stored but it is not feasible as it cost high and limited life time. Second solution is by dumping a load to dissipate surplus PV power which increases overall Complexity of the system. The third approach is by modifying the MPPT algorithm offers a more cost-effective solution.

The rest of this paper is arranged as follows: Section 2 explains control scheme for DPC strategy. Section 3 describes the fuzzy based MPPT control. Section 4 describes grid connected PV system. Simulation results obtained by matlab software are presented in Section 5.

Control scheme for DPC strategy

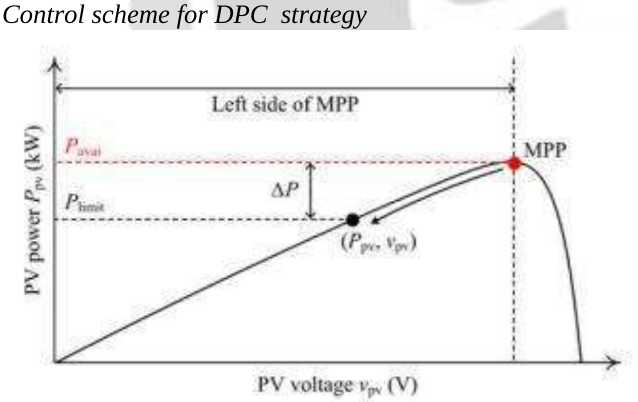

Fig.1 PV characteristics of pv panel

In this approach, the operating point of the PV system in the power–voltage (P–V) curve is regulated below the maximum power point (MPP) in order to limit the

PV power P_{pv} [1] to a certain level P_{limit}. The paper is focussed on active power control of PV string, where the MPPT and the CPG operation are co-ordinately controlled

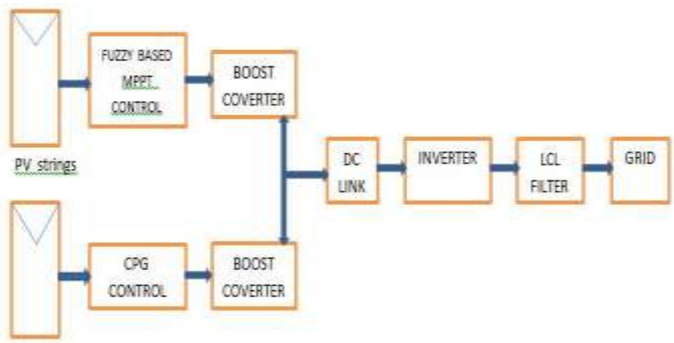

Fig.2 Block diagram for control scheme of DPC Strategy

Fuzzy based maximum power point tracking

The input variables of MPPT are the PV module output voltage and current. In this paper implemented the fuzzy logic based P&O MPPT algorithm. A fuzzy logic based MPPT control is implemented to generate the optimal voltage reference from the PV system by modulating the duty cycle applied to the boost converter. The output voltage and current of the PV panel are measured and fed to the fuzzy based control unit for MPP tracking. Based on the change of power with respect to change of voltage dp/dv and Δdp/dv, fuzzy determines the voltage reference and compared with the modulating signal which generate pulse and is applied to the gate of IGBT[10].

Fuzzy model of the system is designed based on prior expert knowledge of the system. The fuzzy logic controller is divided into four sections: Fuzzification, rulebase, inference and defuzzification. The inputs to the fuzzy logic controller are change in PV array power (ΔP_{pv}) and change in PV array voltage (ΔV_{pv}) and the output is the change in reference voltage (ΔV_{ref}) [10] [11].

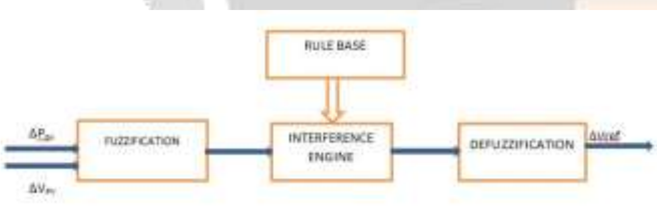

Fig.3 Block diagram of Fuzzy logic controller

A. Fuzzification

The process of converting a crisp input value into a fuzzy value is called “fuzzification”.The membership function values are assigned to the linguistic variables using seven fuzzy subset called as negative big (NB), negative medium (NM), negative small (NS), Zero (ZE), positive small (PS), Positive medium (PM), Positive Big (PB).

B. *Membership Function*

The membership function is a curvature that describes each point of membership value in the input space. The number of membership functions are used depends on the required accuracy of the controller.

The fuzzy logic based MPPT technique the error (E) and change in error (CE) are taken as input variables which are as below for Kth sample time [9].

$$E(k) = \frac{dp}{dv} \quad \frac{P(k) - P(k-1)}{V(k) - V(k-1)}$$

$$CE(k) = P(k) - P(k-1)$$

Inference Method

The Inference method determines the output of the fuzzy controller. Mamdani's inference method is used in the considered system along with the max-min composition method. This is because this method is computationally more efficient and is usually popular for most control engineering applications.

Defuzzification

The output of the fuzzy controller is a fuzzy set. However a crisp output value is required. Hence the output of the fuzzy controller should be defuzzified. The centroid method is one of the commonly used defuzzification methods and is the one being employed for the proposed system.

Fuzzy logic controller outputs a larger incremental reference voltage to speed up the transient response but outputs almost zero incremental reference voltage near the peak power region to reduce oscillations about the MPP.

Estimation of available output power in MPPT mode

If master PV string operate in MPPT mode, its P_{pv1} can be used to estimate available power of the rest PV strings [1]. Total available power of the PV plant Pavai can be simply estimated by

Pavai =Npv Ppv1

if the PV system consists of two PV string with the equal rated power the power ratio can be determined as Npv = 2. the rated power of master PV string is half of total PV system rated power.

Output power compensation by CPG mode

In CPG mode PV voltage can be regulated at the left side of the MPP by reducing the PV power to a certain set point. when the PV power is below the set point (i.e., Ppv2 ≤ Plimit), the MPPT algorithm is employed in order to allow the PV power to reach the set point shown in Fig.1. However, once the PV power reaches and starts to exceed the set point (i.e., Ppv2 > Plimit), the PV voltage is continuously perturbed toward the left side of the MPP until the PV output power is equal to the setpoint [6][7]. DPC method dynamically

changes the value of the set point P_{limit} during the operation in order to achieve the delta power control.

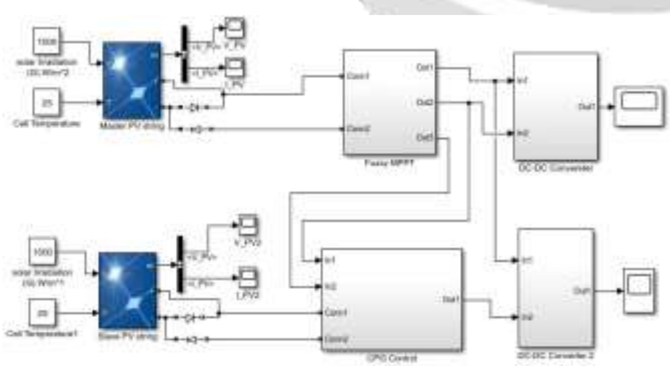

Fig.5 Proposed fuzzy based MPPT and CPG mode

Grid connected system

In grid-connected PV applications, a two-stage conversion system, consisting of a dc–dc and a dc–ac conversion stages, is usually referred to as a multistring inverter configuration. Each PV string, consisting of several PV panels connected in series and/or parallel, is equipped with a dc–dc boost converter to step up the PV voltage Vpv to match the required dc-link voltage Vdc [1].

The boost converter also performs the active power control for each PV string individually. This gives a possibility to coordinate the active power control of each PV string in order to achieve the delta power constraint. Dc–ac inverter is employed to inject the extracted PV power to the ac grid. This is normally achieved by regulating the dc-link voltage to be constant through the control of the grid current Ig. In order to produce a pure sine wave output with low harmonics, an LCL-filter is used. The inverter output voltage can be utilized for grid integration.

Simulation Results

The solar PV system simulated in MATLAB/Simulink. The PV module has the variable temperature and the irradiance. For analysis purpose, irradiance level of 500W/m2 is considered. Fig 6 shows the fuzzy logic control output which is change in duty cycle to boost converter. Fig .7 shows boost voltage of the converter. Fig.8 shows power variations with FLC control.

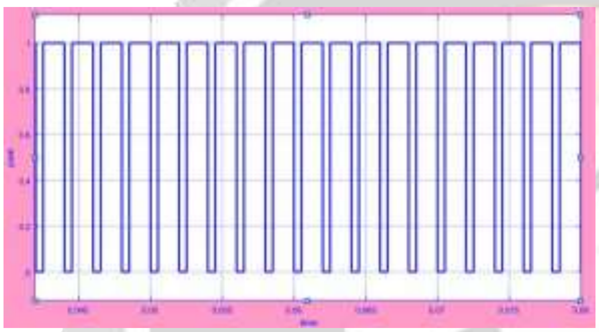

Fig.6 Proposed fuzzy logic control output

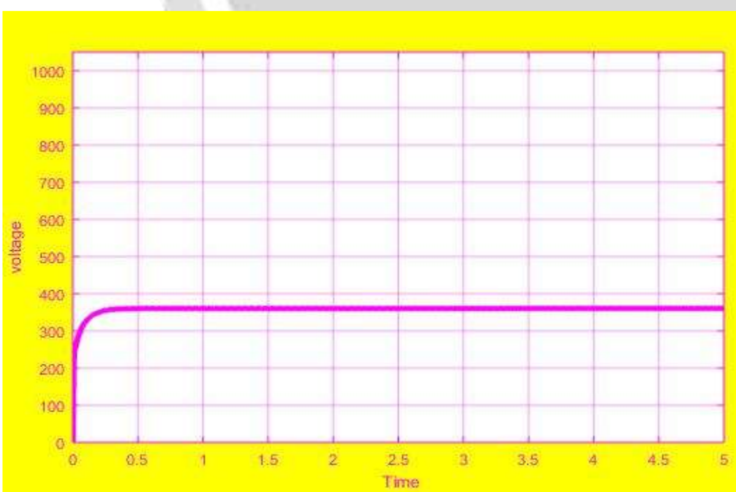

Fig.7 Boost voltage

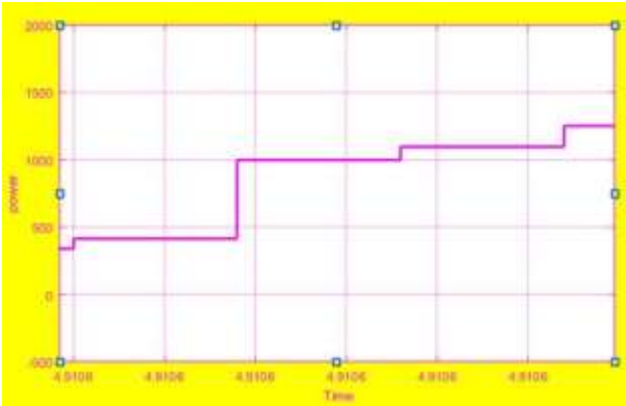

Fig.8 Power variations with FLC control

Conclusion

The performance of DPC with fuzzy based MPPT and CPG mode is examined with temperature and solar irrandiance through simulation.The total P_{pv} active power is injected in to grid when PV system operates at unity power factor.The frequency of output AC voltage can be controlled by controlling the frequency of gate pulses.

Fuzzy logic based MPPT controller is developed in Matlab/Simulink in this paper. Fuzzy logictoolbox of Simulink is used to achieve the FLC. The proposed FLC can track the MPPT very fast and accurately even if the environment changes abruptly. The simulation results show that the FLC-based MPPT method can quickly track the maximum power point (MPP) of the PV module at the transient state and shows better response with less power oscillation around the MPP at steady state.

References

[1] A. Sangwongwanich, Y. Yang, and F. Blaabjerg, “Delta power control strategy for multistring grid connected PV inverters,” IEEE Transactions on industry applications., vol. 53, no. 4, July/August 2017.

[2] Nicolò Zanatta,Prof.fabio Bignucolo, “active power control of a pv generator for large scale photovoltaic power plants” anno accademico 2016/2017.

[3] A. Hoke, E. Muljadi, and D. Maksimovic, “Real-time photovoltaic plant maximum power point estimation for use in grid frequency stabilization,” in 16th Workshop Control Model.

Power Electron., Jul. 2015, pp. 1–7. [10] S..

[4]] S. Nanou, A. Papakonstantinou, and S. Papathanassiou,

“Control of a PV generator to maintain active power reserves during operation,” in Proc. Eur. Photovolt. Solar Energy Conf. Exhib., 2012, pp. 4059–4063. [11]

[5] B.-I. Craciun, T. Kerekes, D. Sera, and R. Teodorescu,

“Frequency support functions in large PV power plants with active power reserves,” IEEE J. Emerg. Sel. Topics Power

Electron., vol. 2, no. 4, pp. 849–858, Dec. 2014

[6] A. Sangwongwanich, Y. Yang, and F. Blaabjerg, “High-performance constant power generation in grid-connected PV systems,” IEEE Trans. Power Electron., vol. 31, no. 3, pp. 1822–

1825, Mar. 2016.

[7] A. Sangwongwanich, Y. Yang, F. Blaabjerg, and H. Wang,

“Benchmarking of constant power generation strategies for single-phase grid-connected photovoltaic systems,” in Proc. IEEE

Appl. Power Electron. Conf. Expo., Mar. 2016, pp. 370–377.

[8] Hussein, Muta, T. Hoshino, and Osakada, "Maximum Photovoltaic Power Tracking Algorithm for Rapidly Changing

Atmospheric Conditions", IEEE Power .Generation, Transmission and Distribution, Vol.8, pp. 1359-1361, 2007

[9] Prince Jose, Priya Rani Jose, ―Grid Connected Photovoltaic System with Fuzzy Logic Control Based MPPT‖ International

Journal of Engineering and Innovative Technology (IJEIT) Vol 3, Issue 8, February 2014 ISSN: 2277-3754.

[10] Saravana selvan.D, Mohammed feros khan.J, Umayal.V, and Indumathi.M “Simulation of Fuzzy Logic Control Based MPPT Technique for Photovoltaic System”, (ICCET’2014) Sept. 19-20, 2014 Penang (Malaysia).

[11] T.Bogaraj , J.Kanagaraj , E.Shalini,” Fuzzy Logic Based MPPT for Solar PV Applications” international journal of innovative research in electrical, electronics, instrumentation and control engineering vol. 2, issue 6, june 2014.

.