iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** III **Month of publication:** March 2016

DOI:

The combined V-F , P-Q and Droop control of PV in microgrid

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Abstract—this paper provides the solution for critical problems surrounded in PVmicrogrid in the field of control. The main requirement in operating modes ofPVmicrogrid are voltage and frequency maintained constant and both real and reactive power flow should be balanced and also includes the soft transition between two modes of operation and to avoid transient surge in power system. This paper proposes the control scheme of PVmicrogrid with hierarchical coordination for both grid connected and stand-alone mode of operation. To enhance the system V-F, P-Q, droop controls are provided at control system. The distributed generation can be used as an ancillary service at the required situation. The numerical simulations can be carried out to demonstrate the effectiveness of the proposed system in MATLAB.

Index terms—active and reactive power control, voltage and frequency control, distributed generators(DG's), solar photovoltaic(PV), microgrid.

I. INTRODUCTION

The photovoltaic generators provides the clean, green and environment friendly energy in generation of electricity and harmful gases like water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone(O_3) and chloro flurocarbons (CFCs) are not emitted to the nature. The energy produced by the photo-voltaic generators are depends upon size of the panel, capacity, temperature and insolation. The common distributed generations used in the power system are Solar Photo Voltaic (PV), Fuel Cell (FC), Wind EnergyConversion System (WECS) and small turbines connected at the distribution voltage level.

The control ofPV microgrid will be different from other distribution generators. The operating modes of PV (photo voltaic)systemare standalone mode of operation and grid connected mode of operation. The control has to be provided for both standalone and grid connected modes of operation and transition between these two modes. This paper provides the Voltage-Frequency (V-F) control for standalone mode of operation and Real-Reactive power (P-Q) control for grid connected mode of operation. The traditional droop control provides the voltage sag mitigation. It also provides the control for battery and super capacitor i.e. charging and discharging of both battery and super capacitor. The controls strategies mentioned above will provide the perfect solutions for problems faced in the microgrid.

Microgrid has attracted increasing attention as an effective means of integrating Distributed Generation(DG) units into the power systems. A micro-grid is defined as an independent low- or medium-voltage distributionnetwork comprising various DG units, energy-storage units,power-electronic interfaces, controllable loads, and monitoringand protection devices.The voltageprovided by the PV generators which will depend on radiation and temperature aregiven by the equation (1)

$$I_{PV} = (I_{PV,n} + K_1 \Delta T)\frac{G}{G_n} \quad (1)$$

Although the fast response of power electronic devicesenables flexible micro-grid control, their low-inertia interfacesmake the micro-grid sensitive to disturbances. Therefore,it is necessary to investigate the stability of inverter-dominatedmicro-grid. Previous research shows that a large range of dynamic modes can be observedin a micro-grid. The reason for this is the timescale separationbetween different inverter control loops.

In previous work, the coordinated optimization process fordroop coefficients requires to solve an eigen value problemrepeatedly, which is extremely tedious and time-consuming.Furthermore, such a method poses difficulties in studying themanner and degree of the parameters' influence on systemdynamics. To overcome these limitations, a novel approachbased on matrix perturbation theory is proposed for the coordinated optimization of droop coefficients. As an efficient method for the calculation and reanalysis of eigen solutions, matrix perturbation theory aims to describe variations of a system's characteristics in small-signal stability under perturbations of structure parameters. Nowadays, it is widely used in electromagnetic problems, structure dynamics, automation control, and vibration problems. Compared with other methods of solving eigen value problems, such as the QR algorithm, the matrix perturbation technique adopted in this paper possesses the following many advantages.

The chapter I provide the introduction to the PV (photo voltaic) generators, the requirement of microgrid and the need of the control scheme for PVmicrogrid. The chapter II provides the systematic three layer hierarchical control and also provides the control algorithm provided for the system. The chapter III provides the PV grid topology for the design of simulation and the test system. The chapter IV gives the simulation results and its discussion.

II. HIERARCHICAL CONROL

A. PV system control

The two operating modes of PV generators are grid-connected mode and stand-alone mode of operation in thepower system. To satisfy the main requirements of Photo voltaic microgrid the hierarchical control structure is given in thebelow architecture as shown in the fig.1.

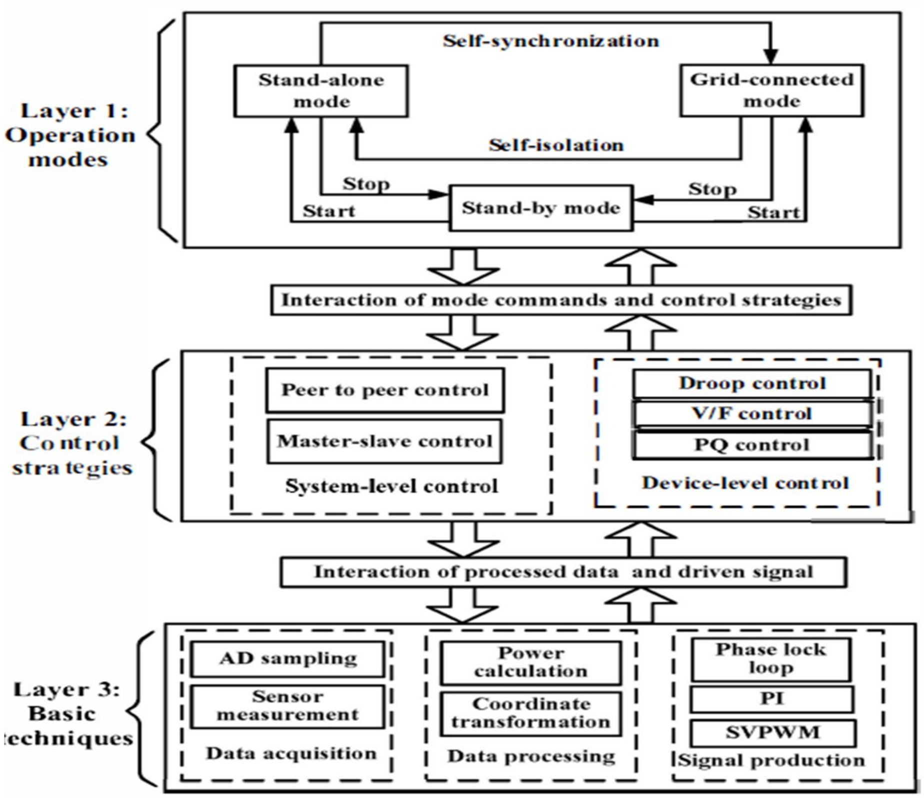

Fig.1 Control structure of PV microgrid.

The requirementsof PV microgrid operation modes include: 1) The rnicrogrid voltage and frequency should be stable and the power flowshould be balanced, so as to realize the independent operationin different modes; 2) The two modes can transfer smoothlyfrom one to the other, which can help avoid transient surge in the microgrid.

This provides the V/F control to the stand-alone mode of operation and PQ control to the grid connected mode in the power system. For transition between the two modes are provided by the soft transition i.e. from stand-alone mode to grid connected mode and vice versa by the transition of control.

B. Control for modes of operation

1) *Stand-alone mode:* The battery is the main source of supply for the load in the power system. The type of battery used in this paper is Li-ion battery. The proposed V/F control is provided for this mode as shown in the Fig.2.

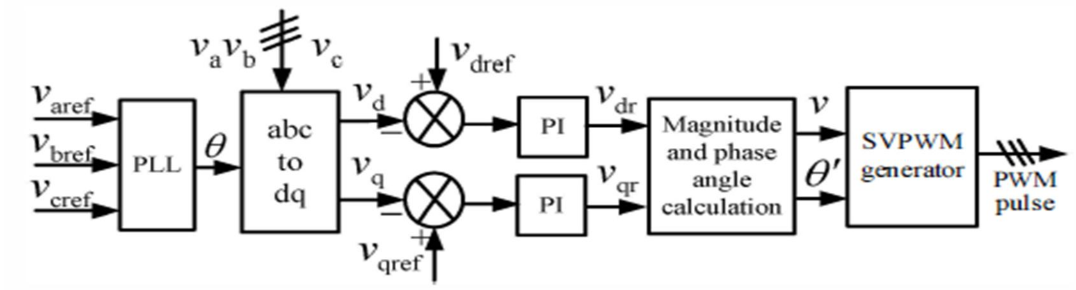

Fig. 2 V/F control block diagram.

In Fig. 2, varef, Vbref, and Vcref denote the reference of the three-phase output voltage of BESS. Vd and Vq represent the d axis and q axis component of the measured threephase voltage (va, Vb, and vc) based on the dq coordinate transform, respectively. Vdref and Vqref are the d axis and q axiscomponent of the reference voltage (Varef, Vbref, and Vcref), respectively.

The proposed V/F control mainly corresponds to layer2 in Fig. 1, which is based on the coordinate transform and proportion integration (PI) regulation with some basictechniques, such as magnitude and phase angle calculation and space vector pulse width modulation (SVPWM). The proposed VF control has good dynamic response though it only adoptsvoltage loops. Moreover, only two PI regulators are included in the V /F control, which is more effective than the traditional V /F control.

2) Grid-connected mode: The BESS is controlled as a power buffer to provide power flow with PQ control when the microgrid operates in grid connected mode. Based on the fact that the current can be obtained from power and voltage, a simplified PQ control is proposed as in Fig. 3. In Fig. 3, the quantities of current reference are obtained by utilizing the instantaneous power theory, and the current loops are used to regulate the output value with PI regulators. In addition, the SVPWM technique is also adopted in generating PWM signals. The proposed PQ control strategy, as shown in Fig. 3, with two PI control units reduced and the decoupling control of active and reactive power realized, has more applicability inengineering and is equivalent to the traditional control methodsin both power loops and current loops.

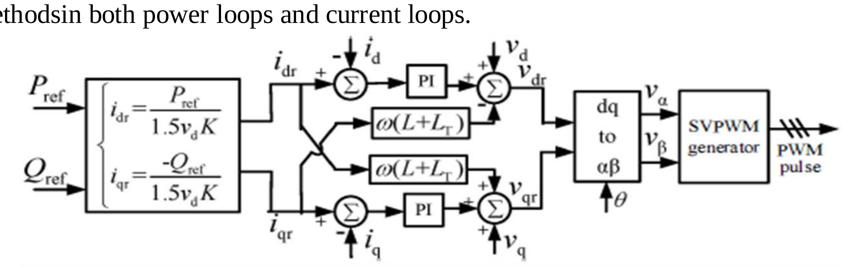

Fig. 3 PQ control block diagram

3) Transition from stand-by mode to grid-connected mode: Self-synchronization control is adopted to realize the seamless transfer from stand-alone mode to grid-connected mode. The detailed stages are demonstrated as follows.

Step1: preparation of voltage regulation

The microgrid voltage is regulated through V/F control with the calculated voltage reference. Take the voltage magnitude control scheme as an example; the control block diagram is shown in Fig. 4.

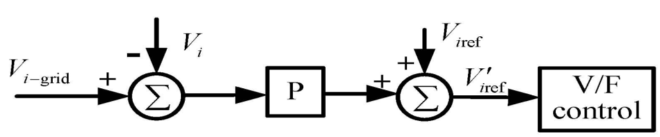

Fig. 4 The voltage magnitude regulation control

In Fig. 4, Vi-grid represents the power grid voltage magnitude of phase A/B/C, and $V_i$is the voltage of phase A/B/C of the microgrid, respectively. In the control block,only proportion control is utilized due to the fact that thevoltage is of AC sinusoidal quantity. The regulated voltage is applied to V /F control.

Step2: contactor states transition

After the voltage is synchronized with the main grid, thegrid-connected contactor should be turned off by the BESS, in which an I/O output signal for turning off the contactorinstalled on the point of common coupling (PCC) is generated.

Step3: control modes transition:

Hence by tuning on the contactor at PCC, V/F control gets shifted to PQ control at the transition of stand-alone mode to the grid-connected mode.

4) *Transition from grid-connected mode to stand-by mode:* When load gets decreases in the grid-connected mode of operation then the system shifts from grid-connected mode to the stand-alone mode. The self-isolation is adopted for the seamless control at the transition from grid-connected mode to stand-alone mode. This is a step by step process and it is given as

Step1: preparing for power regulation

The hybrid energy storage system (HESS) can achievereal and reactive power flow control by adjusting the power reference.P_{pcc} and $Q_{pcc}$are the realand the reactive power at PCCrespectively.The P_{limit} and Q_{limit}denote the real and reactive power limit respectively or it can be stated as threshold values.

Step2: contactor states transition:

After regulating the real and reactive power flow regulation, the BESS is used to turn off the contactor at the point of common coupling (PCC). The voltage oscillations may occur at the time of contactor switching. To reduce this oscillations the V/F control is required for the system.

Step3: control modes transition:

Hence by tuning off the contactor at PCC, PQ control gets shifted to V/F control at the transition of grid-connected mode to the stand-alone mode of operation.

From the above over all controllers the voltage, frequency, real and reactive power is within the specified limits are provided for the system.

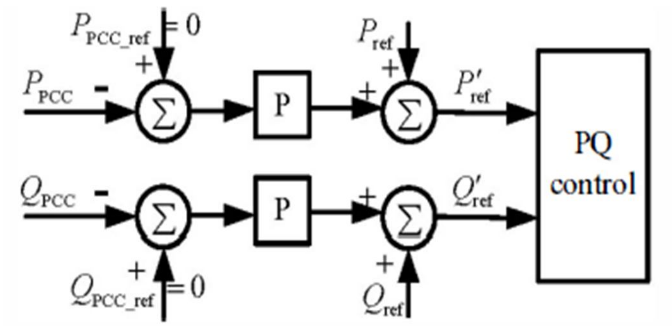

Fig. 5 The power flow regulation control

III. PV GRID TOPOLOGY

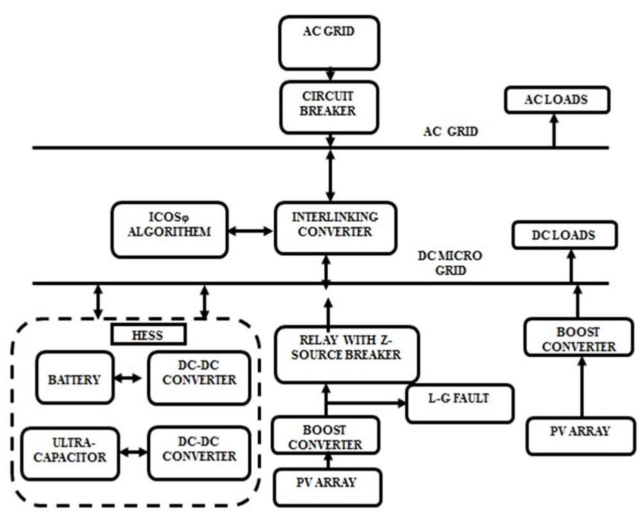

Fig.7. topology of PV generators in microgrid

IV. RESULTS AND DICUSSIONS

A. PV in stand-alone mode

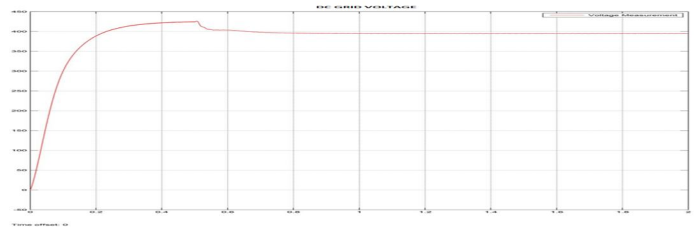

Fig.7. Voltage across DC grid

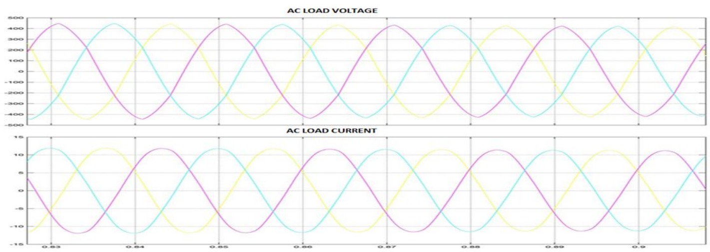

Fig.8. Voltage and current across AC load

The time from 0 to 0.5 the PV works in stand-alone mode of operation. The PV and battery has the capacity to satisfy the load. At this mode the V/F control is provided. From the fig.7 it is clear that the voltage at DC microgrid is constant and from fig.8 AC voltage as well as frequency regulation is obtainedwithin the limits.

B. PV in grid connected mode

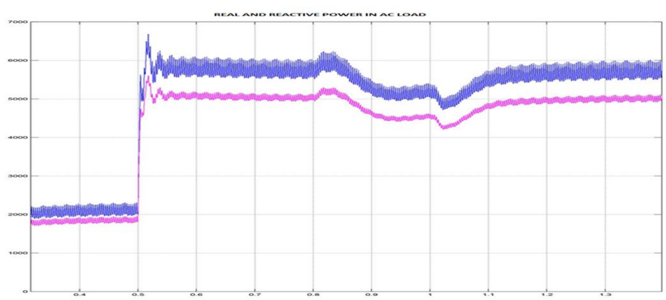

Fig.9. Real and reactive power across ac load

When load gets increased beyond the limit the system shifts from stand-by mode to grid connected mode. At the grid connected mode from the fig.9 it is clear that self-synchronization happens at the system with real and reactive power (PQ) control.

V. CONCLUSION

Thus the three layer hierarchical control is proposed for the control on the modes of operation of the photo-voltaic generators in the microgrid. The results provide the need of integrated control and protection to the PV microgrid. The proposed system ensures the stable and the reliable operation of the microgrid though the severe fault present in the system.

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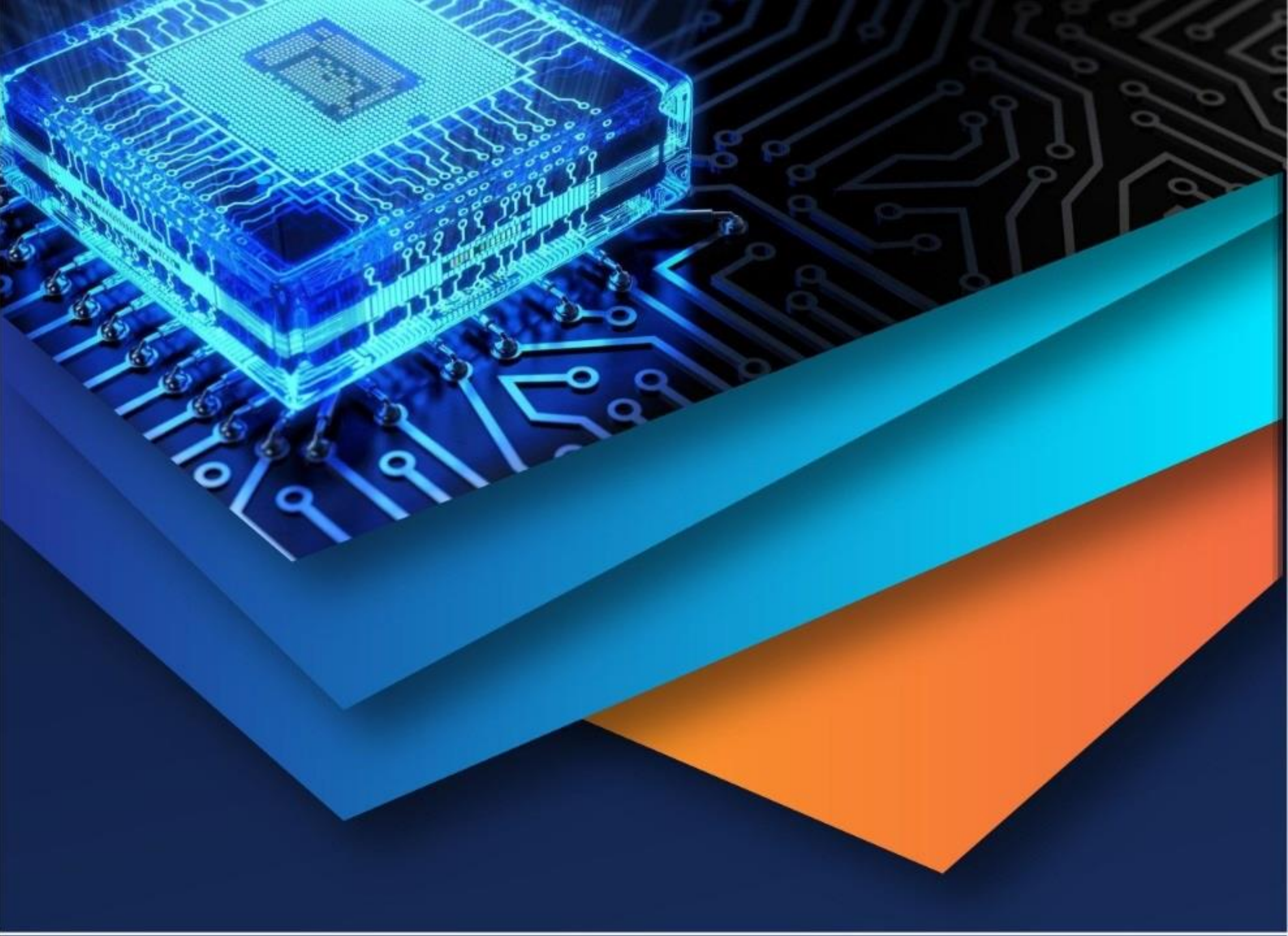

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