Original Research Article

Droop Control of Inverter Interfaced Distributed Generation

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ABSTRACT

In recent times, interest in renewable energy based distributed generation (DG) is increasing rapidly. The paper presents a control strategy for parallel connected distributed sources. It deals with active power-frequency and reactive power-voltage (P-f/Q-V) droop control strategy for sharing of active and reactive power between parallel connected DG units. Droop control can be implemented for communication-less control of inverter-based DG units. The control adjusts voltage and frequency of individual generating unit for regulating power flow between parallel connected units. P-f droop used real power(P) of the DG unit to decide operating frequency and reactive power(Q) to decide operating voltage. The simulation is conducted in the MATLAB Simulink and results are analyzed. Results show droop control is an effective technique for the control of inverters that are interfaced with distributed generation sources.

Keywords: Distributed generation, droop control, inverter control, islanded control

1. INTRODUCTION

The energy demand of the world is continuously growing. In the present scenario, integration of renewable energy based distributed generation has resulted into evolutionary change in the conventional grid structure. Unlike conventional power system of large capacity and large distance transmission network, the concept of small capacity, low voltage distribution line network, capable of operating independently are marking their presence. Due to flexibility of installation location and better efficiency related to transmission power, distributed generation can be effectively used as solution to the problems associated with conventional centralized grid structure. Therefore, microgrids are coming into picture with the advent of distributed generation. Microgrids consist distributed generation sources supplying power to the loads of a small local area as well as managing and controlling that network as a whole. Microgrids have another feature to operate in grid connected and islanded mode. Due to their capability to operated and control their network independently they can operate in islanded mode. Depending upon mode of operation the basic function of a microgrid are;

- To regulate voltage and frequency of the network within their acceptable limit during islanded mode.
- To control active and reactive power flow of each DG unit to supply loads during islanded mode.
- To manage power flow between microgrid and main grid during grid-connected mode.

To manage operation of microgrid proper control actions needs to be applied. As most DG units are connected in the network through power electronic converters (via inverter for DC/AC conversion), control strategies are implemented for inverter control to accomplish the energy management and microgrid parameter (voltage, frequency etc.) regulation [1]. One such control scheme is droop control of individual inverter [2].

2. DROOP CONTROL

The droop control strategy in inverter control of DG units simulates drooping characteristic of conventional power system [3]. If $V\angle 0$ and $E\angle\delta$ be output voltage of inverter and common AC bus voltage respectively and assuming δ to be small. The active(P) and reactive(Q) power expression for inductive line are;

$$P = \frac{VE}{X}\delta \quad (1)$$

$$Q = \frac{VE - V^2}{X} \quad (2)$$

In the expressions, X is line reactance and equation (1) and (2) shows that active power is varying with change in power angle(δ) and reactive power is varying with output voltage(V). Same behavior is utilized in P-f/Q-V droop control of DG based inverter control[4]. The relation between voltage frequency and magnitude and output active and reactive power is represented by following equations,

$$f = f^* - m(P - P^*) \quad (3)$$

$$V = V^* - n(Q - Q^*) \quad (4)$$

Where, f^* and V^* are nominal frequency and voltage of inverter operation, P^* and Q^* are active and reactive power references respectively and m and n are frequency and voltage droop coefficients. These coefficients are calculated from,

$$m = \frac{\Delta f}{P_{max}} \quad (5)$$

and,

$$n = \frac{\Delta V}{Q_{max}} \quad (6)$$

Where, P_{max} and Q_{max} are maximum active and reactive power supplied by inverter respectively and Δf and ΔV are maximum allowable deviation in frequency and voltage.

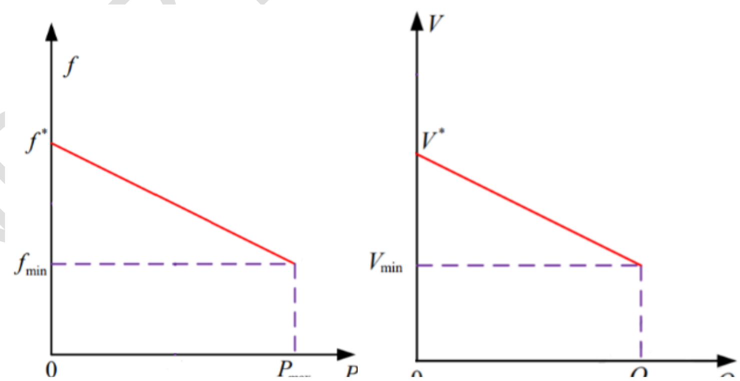


Fig.1:P-f /Q-V droop characteristics

Fig.1 shows frequency-active power and voltage-reactive power drooping characteristics respectively. The f_{min} is minimum allowable frequency deviation and similarly, V_{min} is minimum allowable voltage.

Control structure sense voltage and current at local ends and calculate active and reactive power from those quantities. Then operating voltage and frequency set points are decided as per active and reactive power demand according to droop curve settings.

3. SYSTEM DESCRIPTION

Microgrids can operate in grid connected mode and islanded mode. In grid connected mode inverter operate as constant current mode [5].The reference voltage and frequency are provided by main grid and then output active and reactive power of inverter is coordinated to its output current respectively. During islanded mode inverter operates as constant voltage mode. The reference voltage and frequency are calculated from droop characteristics. The inverter output voltage and current are measured and hence active and reactive power inverter is calculated. Then voltage and frequency references are achieved from drooping relations. This paper considers islanded operation of inverter based DG [6]. Single inverter unit is considered and droop control is implemented to analyze the response of controller to the change in active and reactive power demand.

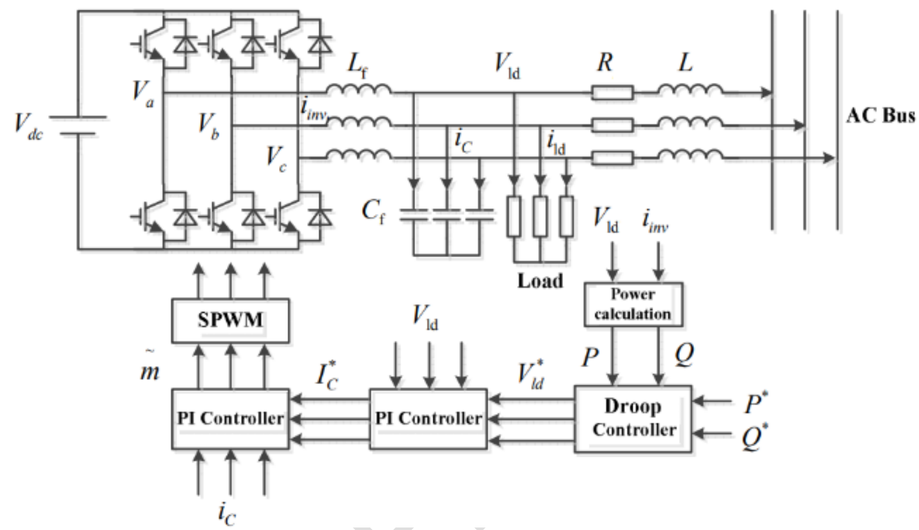
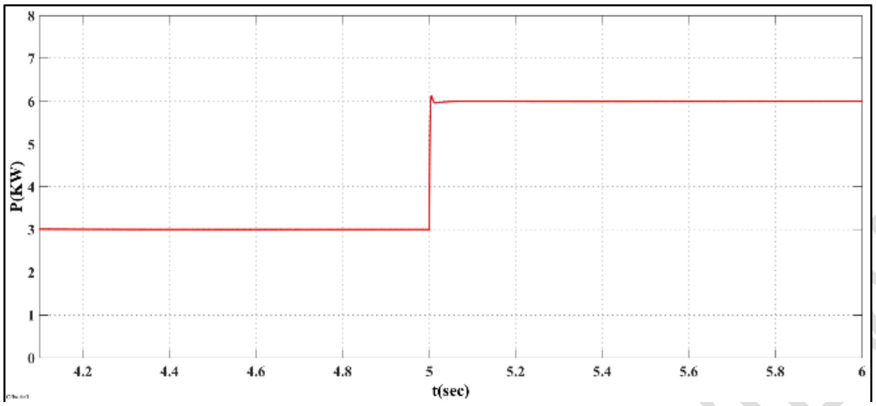


Fig.2: Control structure of inverter

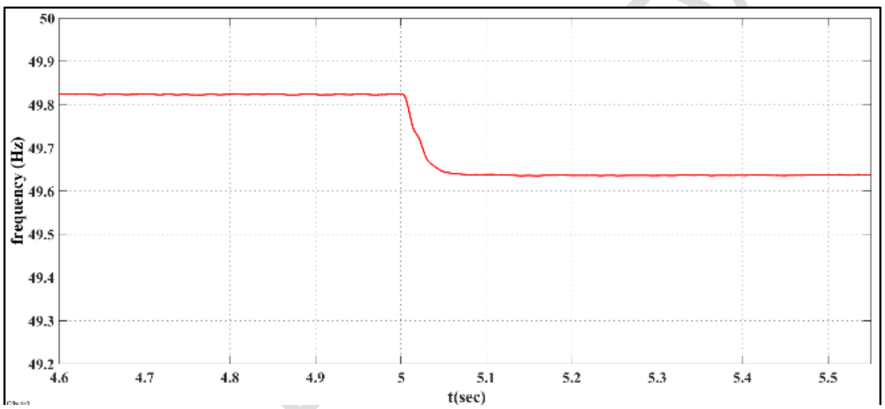
Sensors locally measure current and voltage values to measure active and reactive power demand. Depending upon those values operating frequency and voltage reference for voltage control block are generated. This block consists PI controller to eliminate error between reference and measured value and generate current reference for next PI control block which is current control block. Finally, output of current controller block is utilized to generate modulating signal for inverter.

4. RESULTS AND DISCUSSION

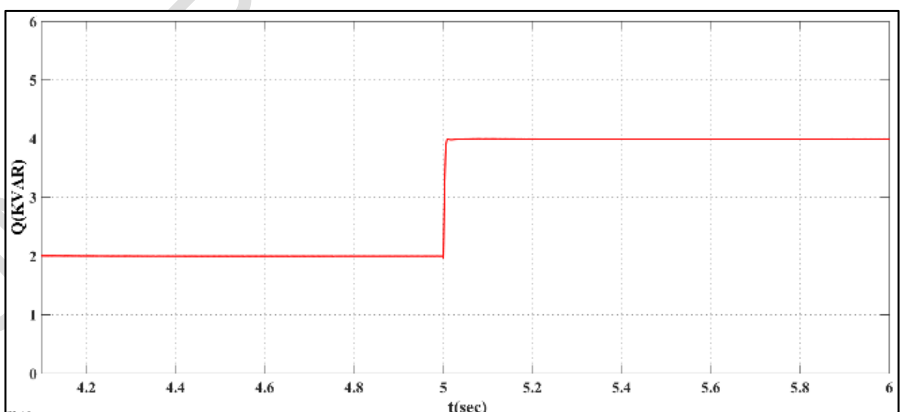
In order to analyze the performance of the controller the inverter model was developed in MATLAB/Simulink. Model was built by modelling the dynamical equation of inverter and filter network. Inverter is modelled in off-grid mode and adopts P-f/Q-V droop control scheme. Control model is illustrated in fig.2 for single inverter unit. Standard line voltage at no load is considered to be 380V and frequency is 50hz. It is considered that for an increase in active and reactive power there is decrease in operating frequency and voltage from no load value. Step load is applied to analyze response of controller. Initially a load of 3KW and 2KVAR is connected to the inverter and another 3KW and 2KVAR load is stepped in at 5sec. From the results in fig.3 it can be seen that the increase in active power load leads to decrease in operating frequency (fig.3(a), (b)) as per selected frequency droop coefficient and similarly increase in reactive power demand leads to corresponding decrease in output voltage of inverter (fig.3(c), (d)). Fig.3(e) shows peaks of output voltage of inverter. It shows that at t=5sec when reactive load increases a drop is introduced by controller in the operating voltage to respond to the load change. Fig.3(f) shows steady state three phase current produced by inverter. Result shows increase in current output at t=5sec for the increase in load demand.



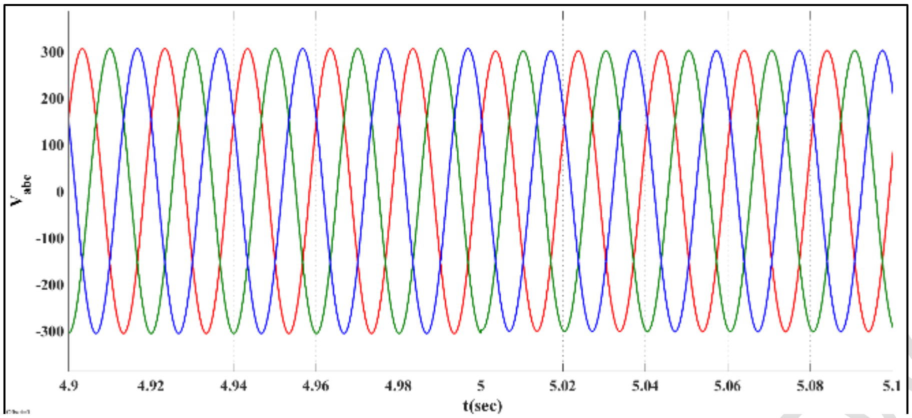
(a)



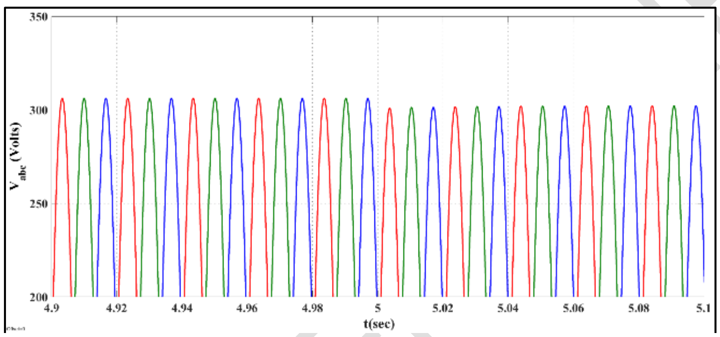
(b)



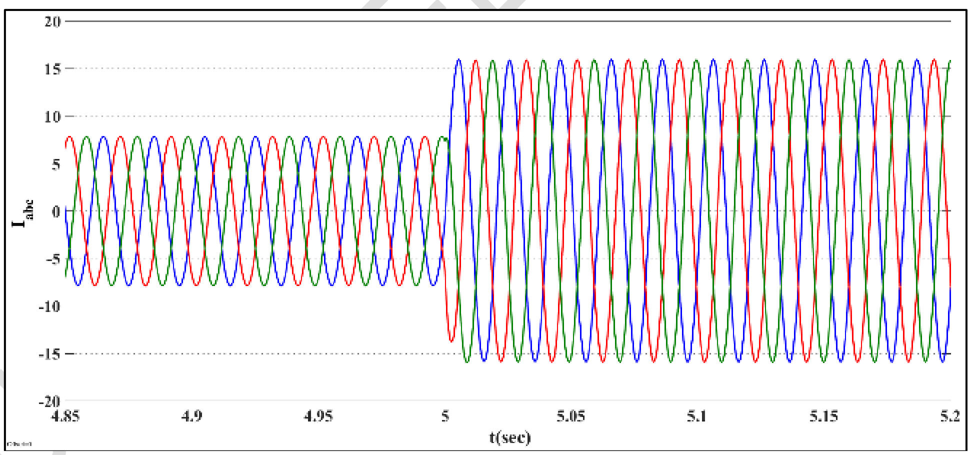
(c)



(d)



(e)



(f)

Fig.3: Simulation results of the response of controller to the variation in load

4. CONCLUSION

The paper presented inverter model for distributed generation based network consisting of droop control scheme. This control scheme makes inverter responsive to the change in load demand by incorporating change in voltage and frequency. To analyze response of controller stepped loads with active and reactive power demand were applied in the network.

It is demonstrated that P-f/Q-V droop introduces droop in operating frequency for increase in active power demand and introduces droop in voltage for increase in reactive demand. Results also shows that control scheme is capable of maintaining stable operation during the change in load demand and during steady state as well. As this control decides operating points for individual inverter based on locally calculated values hence it can also be extended for the inverter control of parallel connected distributed generation network. Each inverter unit locally measure voltage and current values and accordingly decides operating voltage and frequency.

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