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Design and Development of an AC/DC Microgrid For Isolated Power System and grid connected system

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Abstract- **A micro grid is an individual power generation unit, which contains DistributedGeneration System to supply power for local loads. In other words, Microgrid is a unit ofintegration of the Distributed generators and loads which can operate either connectedto or isolated from the main grid. In this paper voltage and frequency, V-f or Q-f method is being used to share the power of parallel connected Voltage source invertersin isolated micro grid by droop control method. In another mode which is grid connected, in this mode available power is being feed into the grid. Micro grid operation is influenced by the control strategy.So, in this study, two typical control schemes active and reactive power feed into grid inconnected mode and voltage-frequency in isolated mode are discussed. In connected modeof operation, micro grid voltage and frequency is decided by grid. In the Voltage-frequency modedistributed generators units share the remained power according to the droop controlstrategy. In solar power plants which are grid connected, in this case poweris being feed by PQ mode of inverter. In this mode inverter works in constantcurrent mode and inverter voltage and frequency is decided by the grid. In islandingmode of operation power sharing of two parallel connected inverters is being done by local measurement. Simulation is being done in Matlab/Simulink software.**

Index Terms – Droop control; P-Q mode; V-f control.

I. INTRODUCTION

This section introduces, distributed generation resources (DGRs) in Microgrid shown in Fig.1. Microgrids are introduced into electric power system for managing the widespreadpenetration of renewable energy and Distributed Generators (DGs) in powerdistribution networks. All the renewable sources are connected with voltage sourceinverters.Various forms of DGs such as fuel cells, photo voltaic and micro turbines are jointedto the Microgrid through inverters. Microgrid can be operated in both grids connected andisolated modes to increase reliability and power quality [1], [10]. AC micro grids, whichare connected to the utility grid at the point of common coupling (PCC), represent themost studied micro grid structure. DC micro grids have attached additional attentionin recent years due to the solar photovoltaic(PV) and energy storage and growth of DCloads such as data centers and LED lighting. Because of DC sources and loads AC/DCmicro grid are growing rapidly. Regulation of voltage and frequency in an autonomous Microgrid will be performed by the DGs operated under VF control (VFDGs). In this case, at least one VSI should be operated in VF control mode to regulate the system voltage andfrequency within the acceptable limits. The excellence of this control strategy is that nocommunication infrastructure is needed, thereby using only local measurements for the Microgrid control in a decentralized method, and plug-and-play operation [4]. Results are taken from MATLAB software.

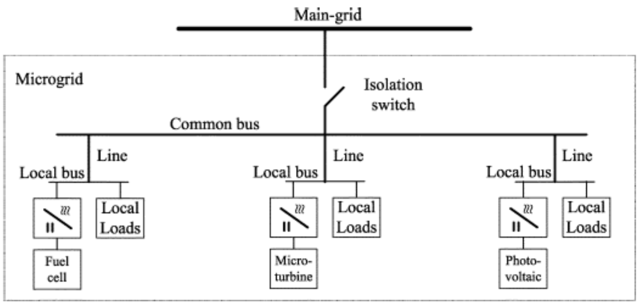

Fig. 1 Structure of a Microgrid.

II. CONTROLLING METHOD OF MICROGRID

In the proposed network shown in Fig. 2, all the renewable sources are connected to the Grid through Voltage source Inverter.Also, harmonics and inverter losses are negligible. Since in a fast Microgrid, the power regulation of each inverter should be not determined by the load demand, but also the available power from renewable sources, we are presenting the two control strategies of Microgrid,for islanding operation of a Microgrid by VF control method and in second mode of operation Microgrid is connected to the Grid by PQ control method. In this method available power is being feed into the Grid. To feed active and reactive power into grid, connecting inverter should have same voltage and frequency of grid. To synchronize the inverter and grid with same frequency we need PLL (Phase Locked Loop) shown in Fig. 3. On the other hand, PQ control aims at adjusting active and reactive power of RES at MPPT reference point.

A. Microgrid connected to grid and inverter is working in PQ mode

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Up to now, many scholars have been done regarding the fast control strategies of RES operated in PQ mode [15-17].As it is discussed in above section that invertersdeliver constant active andreactive power to the Grid by PQ control mode. The block diagram of a Voltage source inverter adopted PQcontrol is shown in Fig. 2. These control strategies have beenused implemented based on dq0 reference frametransformation that determines d-and q-axis components of the ac side currents using PLL.

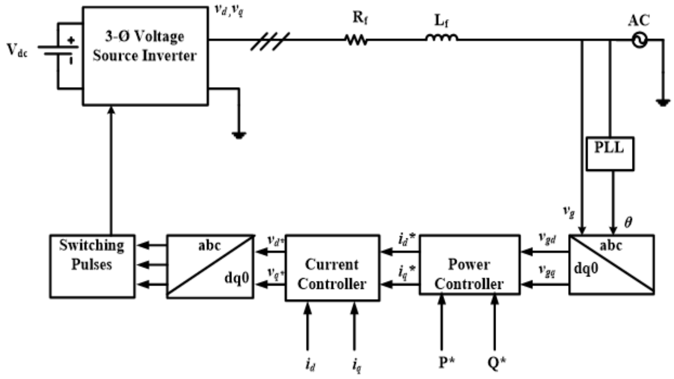

Fig. 2Block diagram of the VSI controller based on PQ theory.

All the voltage and current are converted to dc quantity using dq0 transformation. Voltage source inverter is translated to this common reference frame.*DQ* is the common reference frame rotating at Grid frequency.

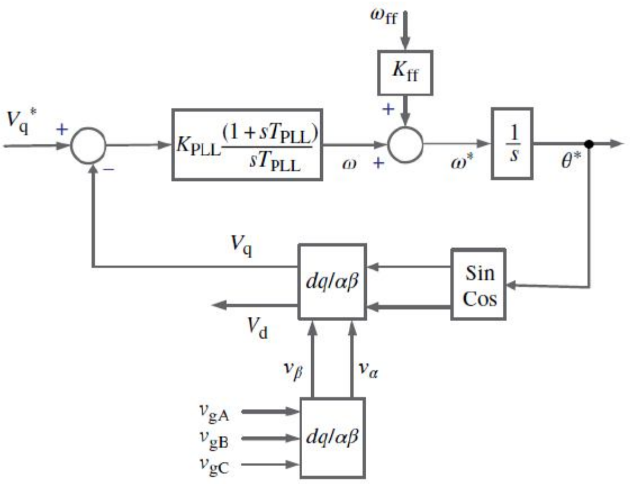

Fig. 3Block diagram of PLL.

A PLL is employed to synchronize the Renewable Energy Sources with Grid. Also the frequency of this unit is dictated by the Grid. We have used the PLL model in [18] and reproduced in Fig. 3.

The controller contains two loops as shown in Fig. 2. The first is power controlloop and the second is current control loop. The power controlloop determines current set-points. The d-axis component ofcurrent is used for active power control and the q-axiscomponent for reactive power control by doing the d-axis parallel with the grid voltage [9].So, the set-point of d-axis current component is fixed byactive power control loop and the q-axis current component isfixed by reactive power control loop.The active power and reactive power transferred to the AC system by Microgrid are calculated according to(1) and (2).

$$i_d^* = \frac{2}{3v_{gd}} P^* \quad (1)$$

$$i_q^* = \frac{2}{3v_{gq}} Q^* \quad (2)$$

So i_d follows i_d^* properly if the control system canprovide fast reference tracking. P^* and Q^* which are the outputs of MPPTcontroller.These are reference active and reactive power for power controller. ω is the angular frequency of grid voltage. Current control loop has been considered asconventional proportional-integral (PI) controller which isrepresented in (3) and (4). The output of the Current controller is used to generate the switching pulse for the inverter.

$$v_d^* = -\omega L_f i_q + (k_p + \frac{k_i}{s})(i_d - i_d^*) \quad (3)$$

$$v_q^* = -\omega L_f i_d + (k_p + \frac{k_i}{s})(i_q - i_q^*) \quad (4)$$

Usingthe v_d^* and v_q^* switching pulses are generated for inverter switching. In grid connected mode, Sine Triangle Pulse Width Modulation is being used for switching pulses generation.

B. V-f mode of operation for islanding operation of Microgrid

Regulation of voltage and frequency in an islanding Microgrid will be performed by the voltage source Inverters operated under Voltage-frequency method or (V-f control mode). In this case, at least one VSI should be operated in VF control mode to regulate the system voltage and frequencywithin the acceptable limits [10], [19]. The importance of this control strategy is that no communication is required between parallel connected inverters only using droop control. Inverters are sharing the total load power. The block diagram of a VSI adopted VF control is shown in Fig. 4.

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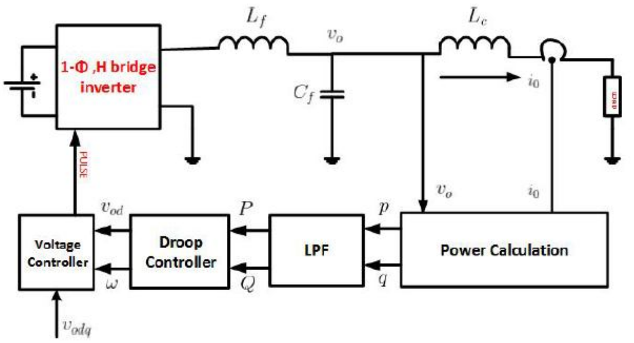

Fig. 4Block diagram of the VSI in V-f mode.

Power is being calculated p and q after measuring the voltage and current. Calculated p and q are being passed through the low pass filter with cut-off frequency (ω_c).

$$P = \frac{\omega_c}{s+\omega_c} p \quad (5)$$

$$Q = \frac{\omega_c}{s+\omega_c} q \quad (6)$$

The real power sharing between inverters is obtained by introducing an artificial droop inthe inverter frequency. The frequency ω is set according to the droop gain m_p and phase is set by integrating the frequency. This is similar to governor droop of steam turbine and inertia characteristicsof conventional generators and provides a degree of negative feedback. For instance, ifthe power drawn from a generator increases then the rotation of its voltage slows andits angle retards. In the following equations ω_n will represent the nominal frequencyset-point seen that the angle of the invertervoltagechanges in response to the real power flow in the required negative sense andwith a gain set by the droop.

$$\omega = \omega_n - m_p P \quad (7)$$

$$V_{od}^* = V_n - n_q Q \quad (8)$$

$$V_{oq}^* = 0 \quad (9)$$

To share the reactive power among multiple inverters, a droop is introduced in thevoltage magnitude as given in (8) and (9). Here, V_n stands for the nominalset point of d-axis output voltage. The control strategy is chosen such that the outputvoltage magnitude reference is aligned to the d-axis of the inverter reference frame, andthe q-axis reference is set to zero. Hence getting the ω and V_{od}^* switching pulses are generated for Voltage source Inverter.

The droop gains m_p and n_q are calculated using (10) and (11) forthe given range of frequency and voltage magnitude.

$$m_p = \frac{\omega_{\max} - \omega_{\min}}{P_{\max}} \quad (10)$$

$$n_q = \frac{V_{od\max} - V_{od\min}}{Q_{\max}} \quad (11)$$

Then voltage controller which contains PI controller, generates the PWM pulses for Voltage Source Inverter.

III. MICROGRID SYSTEM

Simulation for Microgrid is being done for two different modes. Grid connected mode and islanding mode. Parameters, which are used are shown in Table 1. For simulation dc link voltage is taken 800 V.

TABLE I
PARAMETERS USED FOR SIMULATION IN GRID CONNECTED MODE

Parameters	**Value**
Grid voltagee (Vgd)	340 V
Grid frequency	50 Hz
Filter resistance (R_f)	0.1 ohm
Switching frequency	4 kHz
Filter inductance (L_f)	6.75 mH
DC link voltage	800 V

TABLE II
PARAMETERS USED FOR SIMULATION IN ISLANDING MODE

Parameters	**Value**
Output Voltage	230 V
Grid frequency	50 Hz
Filter resistance (R_f)	0.1 ohm
Switching frequency	4 kHz
Filter inductance (L_f)	6.75 mH
DC link voltage	800 V
kp	0.2
ki	10
Filter Capacitance	6.8 uF
m_1, m_2	2.66e-5, 4e-5
n_1, n_2	3.25e-5, 5e-5

IV. SIMULATION RESULT

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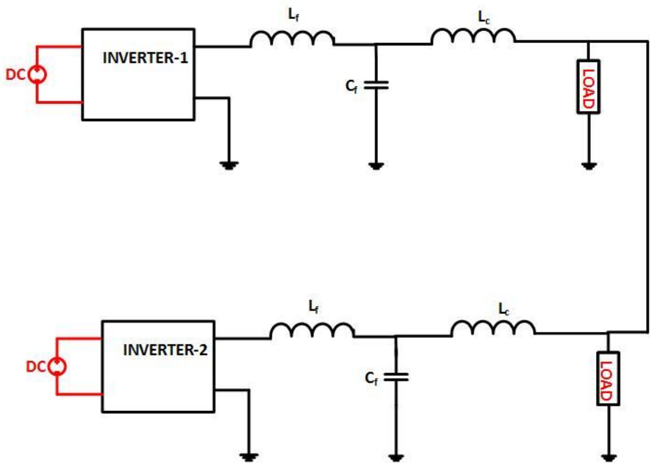

Fig. 5 Block diagram of parallel connected Inverter

TABLE III
SIMULATION RESULT IN GRID CONNECTED MODE

Parameters	Value
Grid Current (i_d)	14.70 A, 8.82 A
Active Power (P)	5 kW, 3 kW
Reactive Power (Q)	0 VAR

In Figure 6, it is shown that the current is flowing from micro grid to grid, after 0.02 scurrent is changed from 8.2 A to 14.70 A. It is taking very less time in current transition.

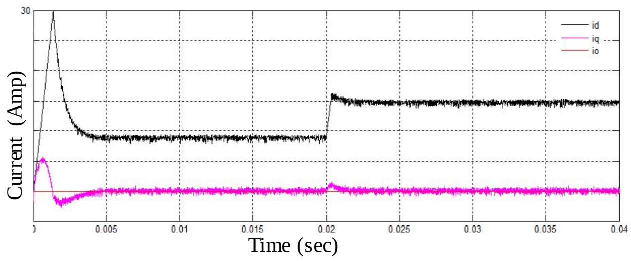

Fig. 6 Waveform of current, flowing inverter to grid

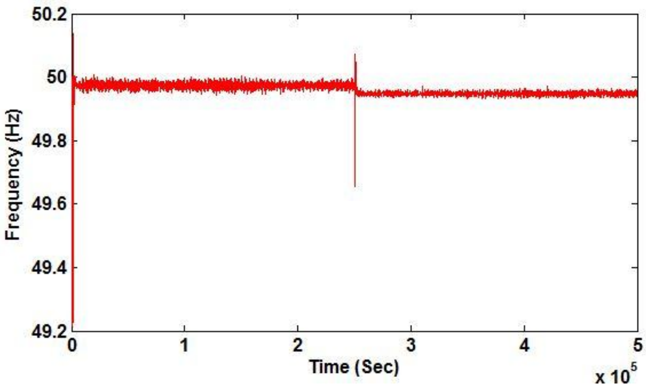

Fig. 7 Waveform of frequency under steady state

Figure 7 shows the waveform of frequency of parallel connected inverters. After 25 sec when laod is changing than frequency is reducing according to the droop co-efficient shown in equation 10.

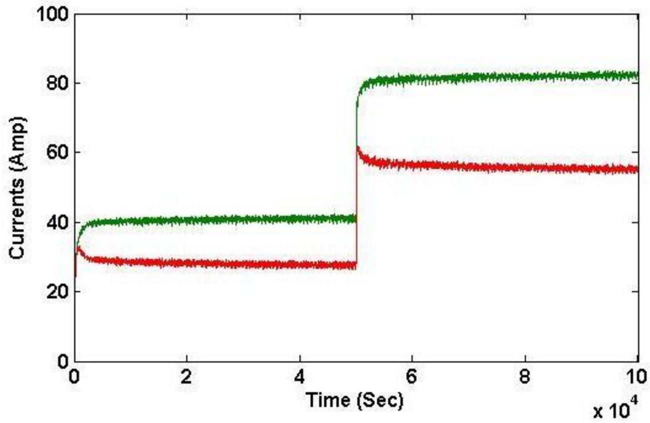

Fig. 8 Waveform of current of Inverter-1 and Inverter-2

In figure 8 waveforms of currents is shown for the inverter-1 and inverter-2. Both are sharing the power 40% and 60% according to the droop coefficient.

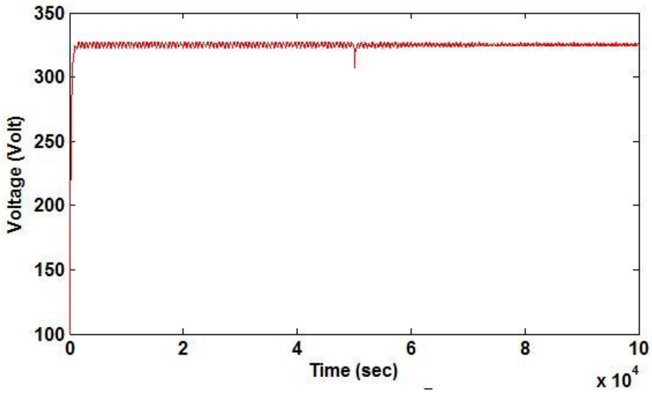

Fig. 9 Waveform of voltage of inverter under steady state

In figure 9 it is shown that the steady state voltage across load is constant through out the operation of microgrid.

CONCLUSION

We can make small small micro grids and we can connect them to each other.It may be a part of smart grid also. Many renewable energy resources are connected tothree phase voltage source inverter and controlling of inverters is being done for constantcurrent mode and these inverters are feeding power into grid in connected mode of microgrid at the point of coupling and other loads in islanding mode of microgrid. Controlling of switching pulse of inverter is beingdone in rotating reference frame and stationary reference frame. In grid connected modeof operation, power sharing of inverters for solar power plants can be done by PQ method.

And in islanding mode, parallel connected inverters feed power to the load. In this modepower is being shared by droop control of inverter. Inverter is sharing 60 percent and

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Inverter-2 is sharing 40 percent of total load. This technique is useful to share powerwithout any communication required between two inverters. Only at filter output, wemeasure the power to control the inverter.

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