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Control of Grid Connected Mode of Microgrid

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ABSTRACT

Micro grid is defined as the cluster of multiple distributed generators (DGs) such as renewable energy sources that supply electrical energy. The connection of micro grid is in parallel with the main grid. When micro grid is connected to utility system, it is said to be in Grid connected mode. In this mode, DG inverter system operates in Current control mode to provide constant current or power to the local load. The main contribution of this paper is summarized as , Design of a network based control scheme for inverter based sources, which provides proper current control during grid connected mode. From the simulation results using Simulink dynamic models, it can be shown that these controllers provide the micro grid with a deterministic and reliable connection to the grid.

KEYWORDS: Distributed generation (DG) Micro grid, Grid interface inverter, controller, result and Discussion

INTRODUCTION

Problems have led to a new trend of generating power locally at distribution voltage level by using non-conventional/renewable energy sources like natural gas, biogas, wind power, solar photovoltaic cells, fuel cells, combined heat and power (CHP) systems, micro turbines, and Sterling engines and their integration into the utility distribution network [1]-[2]. This type of power generation is termed as distributed generation (DG) and the energy sources are termed as distributed energy resources (DERs).They can supply uninterruptible power, improve local reliability, reduce feeder losses and provide local voltage support. From environmental point of view, micro grids reduce environmental pollution and global warming through utilization of low-carbon technology. The typical micro grid structure is shown in Fig 1. It also has two CHP and two non-CHP micro sources and storage devices. Micro sources and storage devices are connected to feeders A and C through micro source controllers (MCs). Some loads on feeders A and C are assumed to be priority loads, while others are non-priority loads. Feeder B, however, contains only non-priority electrical loads. The micro grid is coupled with the main medium voltage (MV) utility grid through the PCC (point of common coupling) circuit breaker CB4 as per standard interface regulations. CB4 is operated to connect and disconnect the entire micro grid from the main grid as per the selected mode of operation. The micro grid is operated in two modes: (1)Grid-connected , (2) Stand alone. In grid-connected mode, the micro grid remains connected to the main grid either totally or partially, and imports or exports power from or to the main grid. In case of any disturbance in the main grid, the micro grid switches over to stand-alone mode while still feeding power to the priority loads.

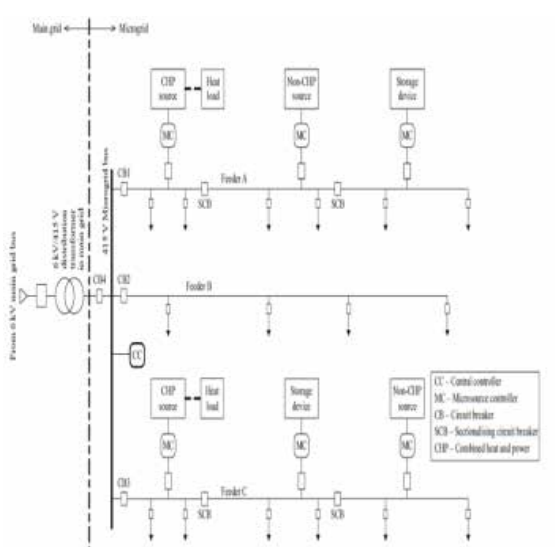


Fig.1 A Typical micro grid structure [3]

GRID CONNECTED DISTRIBUTED ENERGY RESOURCES

Many of the forms of new and renewable energy are not natural 50 hz source and the question arises of how to incorporate them into a standard electricity grid. Most of this technology has an inverter as a generator interface. Inverter-interfaced generators are not yet that mature and the modeling of inverters for network stability studies requires much more work, if grid stability is to be ensured with high penetrations of distributed generation (DG). Therefore, power control performance of the DG unit determines its impact on the utility grid it connects to. If the power control performance is good, the DG unit can be used as means to enhance the system stability and improve power quality; power control method for a grid-connected voltage source inverter which achieves good P Q decoupling and fast power response.

Design of Power flow Control of a Distributed Generation

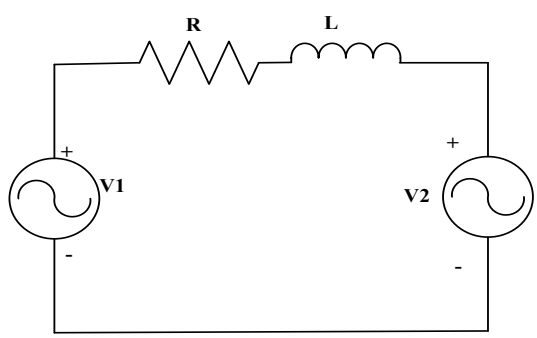


Fig.2 Grid interfaced inverter

Here the output of DG and utility grid are connected by feeder impedance $Z = R + jX\Omega$ as shown in Fig.2.

For a sake of simplicity assumed that

$$|V_1| = V_i = Inverter\ output\ voltage$$

$$|V_2| = V_g = Grid\ voltage$$

Let the phasor voltage be $V_1 = |V_1|\angle\delta$ and $V_2 = |V_2|\angle 0°$. For assumed direction of current

$$I_{12} = \frac{|V_1|\angle\delta - |V_2|\angle 0}{|Z|\angle\gamma} \quad (1)$$

$$I_{12} = \frac{|V_1|}{|Z|}\angle(\delta-\gamma) - \frac{|V_2|}{|Z|}\angle -\gamma \quad (2)$$

The complex power given by,

$$S_{12} = |V_1| I_{12}^* \quad (3)$$

$$S_{12} = |V_1|\angle\delta\left[\frac{|V_1|}{|Z|}\angle(\gamma-\delta) - \frac{|V_2|}{|Z|}\angle\gamma\right] \quad (4)$$

$$S_{12} = \frac{|V_1|^2}{|Z|}\angle\gamma - \frac{|V_1|-|V_2|}{|Z|}\angle\gamma+\delta \quad (5)$$

Thus the real and reactive powers at the sending end are

$$P_{12} = \frac{|V_1|^2}{|Z|}\cos\gamma - \frac{|V_1|-|V_2|}{|Z|}\cos(\gamma+\delta) \quad (6)$$

$$Q_{12} = \frac{|V_1|^2}{|Z|}\sin\gamma - \frac{|V_1|-|V_2|}{|Z|}\sin(\gamma+\delta) \quad (7)$$

$$P_{12} = \frac{|V_1|-|V_2|}{X}\sin\delta \quad (8)$$

$$Q_{12} = \left(\frac{|V_i|^2-|V_i|\,|V_g|\cos\delta}{X}\right) \quad (9)$$

small inductance compared to the resistance. Assuming R=0, the above equations become,

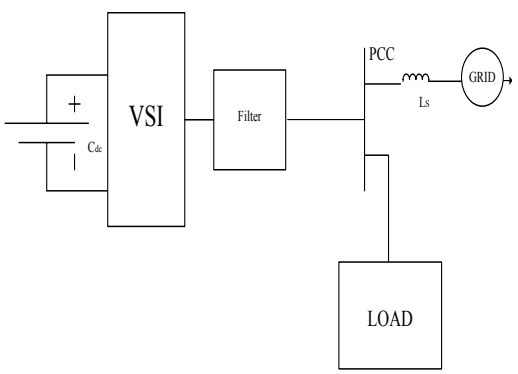


Fig.3 Block diagram of the grid connected system

Under grid-connected mode, the DG unit conducts

$$P = \frac{V_i - V_g}{X}\sin\delta \quad (10)$$

$$Q = \left(\frac{|V_i|^2-|V_i|\,|V_g|\cos\delta}{X}\right) \quad (11)$$

Where Vi is the output voltage of the inverter, X is the equivalent line reactance where the resistance is ignored, and δ is the power angle. δ the phase angle difference between phase angle associated Vg and phase angle associated vi.

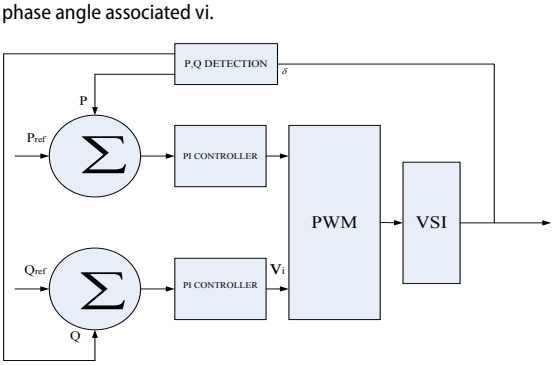


Fig.4 Control system block diagram for the proposed power controller

the task of the power controller is to generate voltage command for the voltage controller based on the desired power values Pref and Qref and actual values P and Q. the desired DG output voltage V and the power angle δ can be calculated from equation (10) and (11) given desired P and Q values and system parameter X. Practically, the value of X cannot be precisely known and may change due to the operation of the power system. Once an inaccurate value of X is used in the control, the error of X will lead to poor tracking and even instability. Therefore, power control solutions requiring knowledge of X cannot be practically used. It can be observed from equation (10) and (11) that both P and Q will be affected by only adjusting one of V and δ, which is so called coupling between P and Q. However, variations of V and δ have different levels of impact on P and Q as described in the following partial derivatives.

$$\frac{\partial P}{\partial\delta} = \frac{V_g(V_i\cos\delta)}{X} \quad (12)$$

$$\frac{\partial P}{\partial V_i} = \frac{V_g(\sin\delta)}{X} \quad (13)$$

$$\frac{\partial Q}{\partial\delta} = \frac{(V_g\cdot V_i\sin\delta)}{X} \quad (14)$$

$$\frac{\partial Q}{\partial V_i} = \frac{(2V_i - V_g\cos\delta)}{X} \quad (15)$$

When δ is small which is true for large capacity power systems, $\frac{\partial P}{\partial\delta}$ is close to $\frac{V_g V_i}{X}$ and is $\frac{\partial P}{\partial V_i}$ close to 0 and reversely, is close $\frac{\partial Q}{\partial\delta}$ to 0 and is $\frac{\partial Q}{\partial V_i}$ close to $\frac{(2V_i - V_g)}{X}$. This fact indicates that P is more sensitive to δ and Q is more sensitive to Vi especially when the DG unit is connected to a large capacity system where the power angle δ is usually small. The different levels of sensitivity Of P and Q to δ and Vi provide a chance to control P and Q relatively indepen- dently, Not completely independently though. The voltage and phase angle references can be generated as

$$\delta_{ref} = \int K_P\left(P_{ref} - P\right)dt \quad (16)$$

$$V_{ref} = \int K_q\left(Q_{ref} - Q\right)dt$$

In the proposed power regulation approach, P and Q controls are decoupled under steady state due to the integration of the errors. However, in the transient, the P and Q coupling cannot be eliminated. Both P and Q are nonlinear function of Vi and δ. Evolution of Stability of the power control loop,

$$\dot{\delta} = K_P\left[P_{ref} - \left(\frac{V_i - V_g}{X}\sin\delta\right)\right] \quad (17)$$

$$\dot{V}_i = K_q\left[\left(Q_{ref} - \left(\frac{|V_i|^2-|V_i|\,|V_g|\cos\delta}{X}\right)\right)\right] \quad (18)$$

The stability of the power loop can be evaluated using Lyapunov's direct method. To check stability take $P_{ref} = Q_{ref} = 0$. A Lyapunov function can be defined as,

$$\Psi(V_i,\delta) = \frac{1}{2}(V_i - V_g)^2 + \frac{1}{2}\delta^2 \quad (19)$$

The derivative of the above function is,

$$\dot{\Psi}(V_i,\delta) = \dot{V}_i(V_i - V_g) + \dot{\delta}\,\delta$$

$$= \frac{-K_q V_i(V_i - V_g)^2}{X} - \frac{K_p{}^2 V_i V_g}{X}$$

It can be observed that, $\dot{\Psi}(V_i,\delta) < 0$ holds true when $(V_i - V_g) \neq 0$ and $\delta \neq 0$. Given positive values of Kp,Ki, Vi and X. therefore it shows that the designed power control loop is stable.

RESULT AND DISCUSSION

A. Control of single DER unit in Grid connected mode

The comments and discussion on the output results are written in well manner. The system parameters considered for simulation are given in Table-1 below.

Table-1 System parameters which are considered in Grid connected system.

Parameter	Value
Nominal Grid voltage	400 (l-l) Vrms
Grid frequency	50 HZ
Coupling impedance	(0.2+j 0.01) Ω
DC bus voltage	814 V
Filter inductance	3.312Mh
Switching frequency	1.35 KHZ
Active power controller proportional gain (Kp)	0.5
Active power controller integral gain (Ki)	1
Reactive power controller proportional gain (Kp)	0.1
Reactive power controller integral gain (Ki)	2

B. Control of Active Power and Reactive Power for a Given Fixed Reference Value.

Fig.5 shows the sharing of active and reactive powers between inverter and grid to the specified value of the load. The fixed load get switched to another higher value but the injection of active and reactive are same as adjusted the reference values respectively. As shown in Fig.**5** Pref are set to supply 2500kW, so it is clearly visible that inverter supply the same amount of power to the load, after 8.0 seconds load is stepped up but inverter keeps on supplying the same amount of power.

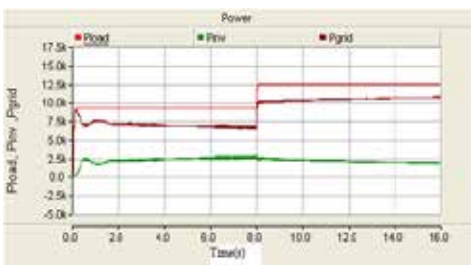


Fig.5 Control of active power and reactive power for a given reference value

As **per Fig.6** and **Fig.7** we can observe that for the changing in the load doesn't affect the frequency and the load voltages as VSI is connected to the grid. So, it remains constant but the load **currents go down as load changed to the lower values. Fig. 5** are shown for the values P1=10kW and Q1=1kvar decrease to P2=5kW and Q2=0.5kvar

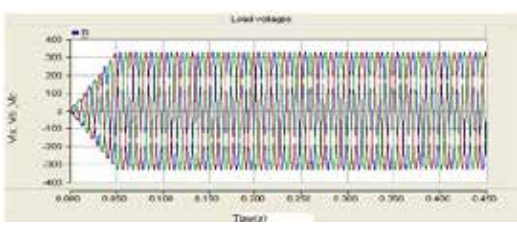


Fig.6 Load voltages as load Stepped down at 8.0 second

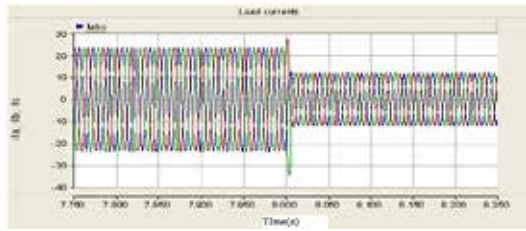


Fig.7 Load currents as load Stepped down at 8.0 second

C. Sharing of Active and Reactive Power for a Different Reference Values.

Fig.8 shows the injected active and reactive power from the source and grid to the specified load. The main aim of the grid connected controller is to control and sharing of the active and reactive power to either grid or the load. As we seen in the previous section, the values of the load is predefined so that we can fixed our reference values for active and reactive power controller, which is not there in practical case. The active power controller reference is set to 2500kW and reactive power controller value is set to 1000kvar up to 8 seconds after 8 seconds, these values got changed to 2000kW and 500kvar respectively. The results are shown in **Fig.8** and **Fig.8**. It shows that controllers are working properly for the given reference values of load.

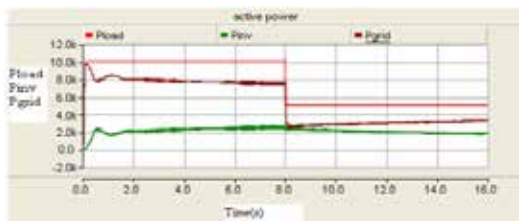


Fig.8 Reference Active power switched at 8 second

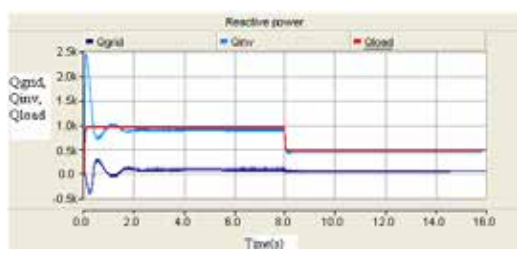


Fig.9 Reference Reactive power switched at 8 second

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CONCLUSION

At present there are three major issues with Micro grid structure.1)Power sharing between utility grid and micro grid 1) Islanding and 2) Interfacing with the utility grid. In Grid connected mode critical or local load require constant current supply. In the islanded mode of operation critical or local load requires constant voltage with constant frequency. As the power mismatch, there is sudden change in supply frequency, due to it, equipment get damage. As load changes there is a sudden drop in voltage and frequency which are undesirable. Also by LC filter we can keep the frequency up to it's permissible limit, because output of inverter having harmonic, To reduced that harmonic contain and get sinusoidal waveform here we had design LC filter. Also we design SPWM for switching operation of Inverter, SPWM produced gate pulse by comparing carrier wave (Triangular wave) and reference wave (Sinusoidal wave).

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