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Operation Of Two Parallel Connected PV Inverters Using Droop And Virtual Inertia Controller

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Abstract

A detailed VSG model is presented and analyzed to investigate the virtual synchronous generator (VSG) control concept, which aims to integrate large-scale distributed generators (DGs) like photovoltaic into microgrids. DGs based on inverters can exhibit the characteristics of synchronous generators (SGs) like inertial, damping, and droop functions, and can participate in microgrid control and stability.

Additionally, the uncontrollable coupling of the distributed generation (DG) units can easily affect the efficiency and stability of the microgrid based on the traditional droop control strategy because it lacks the ability to decouple. The droop controller and adaptive virtual inertia controller are implemented in this paper to improve the efficiency and stability of the microgrid; its coupling compensation includes the angular frequency deviation compensation and voltage deviation compensation, which reduces the influence of the uncontrollable coupling; the dynamic responses are compared under equal sharing and proportional sharing of the load demand; simulation results are presented using MATLAB/simulink.

Keywords: Photovoltaic source, virtual synchronous generator, virtual inertia, droop characteristics.

I INTRODUCTION

The microgrid concept emerged as a result of the rapid growth of distributed generators (DGs) sources, including photovoltaic, wind turbines, fuel cells, small and micro turbines, and others. The majority of DGs now interface with the grid using power-electronic devices, such as inverters [1]. Because of their static feature, inverters are unable to support the frequency stability of the microgrid, which is why the virtual synchronous generator (VSG) control concept was created.

A VSG is a control technique that allows inverters to simulate the inertial, damping, and droop functions of synchronous generators (SGs) in order to improve microgrid stability and control [2]. The VSG concept has been proposed by researchers under various names, including virtual synchronous machine (VISMA) [3] and synchronverter [4]. Additionally, the VSG has been described in literature with varying orders, including second, third, fifth, and seventh order; however, the second-order voltage source voltage-reference is frequently used to simulate the SG [5].

Some SGs are still used in microgrids today, even though VSGs have largely superseded SGs. The majority of studies just believes that VSG can function in parallel with SGs and efficiently share the load with them because it resembles the SG's features. Thus, we have attempted to explore this premise below. In order to do this, the study presents the VSG model in detail as well as the design of the parameters for the paralleled VSG and SG. Each unit is used to establish the VSG model. The dynamic behavior of the VSG and the regular SG in an isolated microgrid is then compared using parallel configurations of VSG-VSG and SG-VSG. Both proportional and equal sharing of the load demand are used to compare the dynamic responses.

Numerous more efficient techniques have been put forth to further enhance the decoupling capability, such the addition of voltage correction, a unified rotation angle, a communication network, and others. A decoupling technique that combines a voltage controller and virtual inductive compensation is suggested in [19,6]. It is challenging to determine the precise value of the line impedance, even if the voltage controller can compensate for voltage.

A coordinated rotational transformation technique is suggested in [20.7] to adjust to low-voltage microgrid coupling conditions. Nevertheless, the effectiveness of this approach depends on the line impedance's precise value, which is equally challenging to determine.

A control technique for multi-variable-droop synchronous current converters is suggested in [21,8]. It adds synchronizing current and multivariable damping to the current control loop. However, excellent decoupling requires a number of precise parameters, so configuring each one may be difficult. An enhanced virtual power control technique that takes into account the unified rotation angle is put forth in [22,9]. This technique can successfully accomplish decoupling since the unified rotation angle can represent the degree of the connection. Its discrete procedure is somewhat complex, though, and the method's ability to boost dynamic performance has been overlooked.

A decoupled control approach that takes into account the load characteristics and line impedance is suggested in [10]. It is feasible for the decoupled matrix to take the load's influence into account because the load can result in power coupling. Nevertheless, it is challenging to determine the precise line impedance value, and the decoupling capability may deteriorate if the load characteristics are altered.

To separate active power from reactive power, [11] suggests a virtual frequency and voltage frame. Effective decoupling can be accomplished by establishing the right parameters, as the virtual frequency and voltage in this manner determine the precision of the power sharing. However, the fixed frame transformation angle may have an impact on the decoupling's performance because the frame transformation angle in the virtual frequency and voltage droop slopes varies for each DG unit. In order to accomplish decoupling, [12] suggests a gain-scheduled decoupling control approach that incorporates the additional control signals. The additional control signals, however, depend on the parameters of the steady-state system, which might not be appropriate for the dynamic system.

To accomplish exact power sharing, a distributed cooperative control-based droop control technique is put out in [13]. It adds a secondary voltage controller, a spinning-based frequency and voltage controller, and a distributed voltage observer to the conventional droop control. However, in order to accomplish the high precision of power sharing, this technique requires high-speed communication networks. The application breadth of these decoupling techniques may be limited by their intricate structure, disregard for the system's dynamic properties, or requirement for a sophisticated communication network.

The inverter is used in PQ control to supply the necessary reactive and actual power based on their set-points. Power and current control loops make up the controller. Inductance parameter change, converter dead time, and input voltage fluctuations are among the disturbances that the inner current loop can react to quickly. As a result, the system's performance is greatly enhanced [14]. The inverter and microgrid are synchronized using a phase-locked loop (PLL). Through PQ regulation, the RES supplies the grid with steady real and reactive power. The components of the d-axis and q-axis AC currents are defined by the DQ reference frame, which is the basis for PQ control operation.

II. SYSTEM CONFIGURATION

The system consists of two PV sources, which supply the load. A boost converter is used to extract the maximum power from each PV array. The rating of each PV array is considered as 4 kW at 300V DC. A battery backup is used to supply the critical loads. The battery is charged and discharged based on the available power in the system. In this paper, a stand-alone system is considered. The two PV inverters operate parallelly and feed the load. The filter out the harmonics a capacitive filter is used of 10kVAr. The operation of each PV inverter is controlled by the droop and adaptive virtual inertia controller in order to reduce the rate of change of frequency (RoCoF) during change in loads and faults. The two inverters will supply both active and reactive power which is necessary for system stability in a grid connected system.

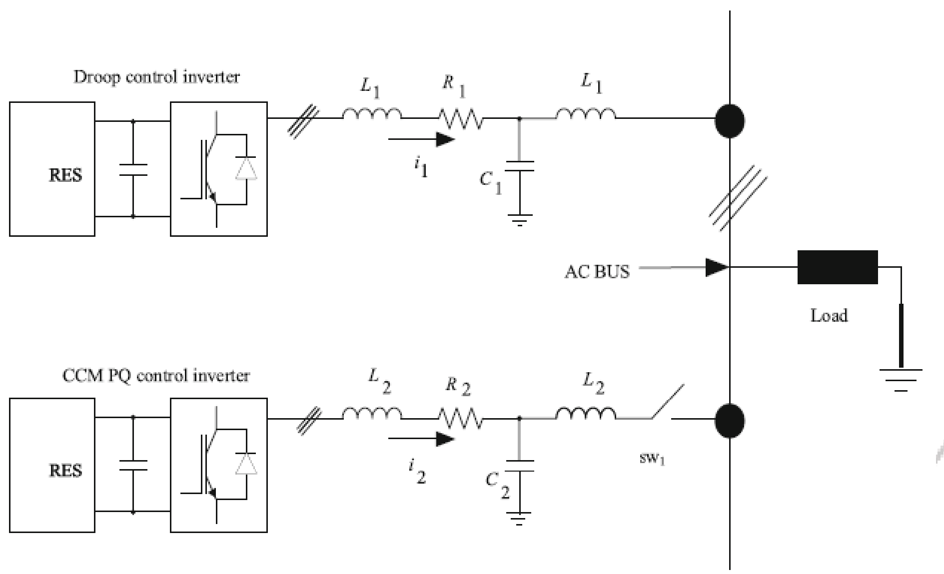


Figure 1: Proposed System configuration

To analyze the stability of parallel VSGs, a microgrid with two VSGs connected on the same bus so that their virtual rotors swing together. The prototype is shown in Figure 1. According to the small signal analysis above, for balanced power distribution among VSGs, we introduce some practical guidance on the VSG design in parallel system, as follows. For a very small variation in the system frequency, the swing equation can be expressed in linear time domain by the equation given bellow. Due to pages limitation, we could not present the derivation.

A) Modelling of PV Source

A PV cell can be represented using an equivalent electrical circuit which is shown in figure 2 typically consisting of a current source (representing the photocurrent), a diode (modeling the p-n junction behavior), a series resistance (accounting for losses in connections) and a parallel resistance (representing leakage currents).

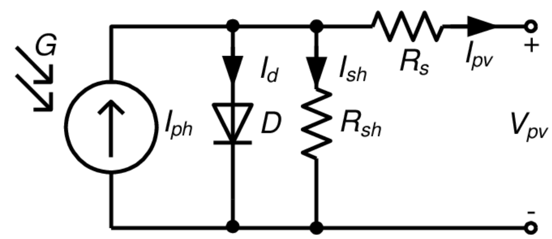


Figure 2: Solar Cell Equivalent Circuit

$$I = I_{ph} - I_s\left(e^{\frac{V+IR_s}{\eta V_t}} - 1\right) - \frac{V+IR_s}{R_{sh}}$$

I_{ph} = Photogenerated current (depends on irradiance and temperature)

I_s = Reverse saturation current; R_s = Series resistance

R_{sh} = Shunt resistance; V_t = Thermal voltage

n = Ideality factor: T = Temperature in Kelvin

k = Boltzmann's constant

B) Modelling of PV Inverter

To reduce the influence of the uncontrollable power coupling, coupling compensation is introduced into the traditional droop control strategy. And its formula is written:

C) Design of Boost Converter

Figure 3 is the basic structure and control topology of the boost converter. This converter divides the dc-link into two levels: dc-link voltage at the output terminals of the diode rectifier, which is a variable dc voltage, and the dc-link voltage at the input terminals of the voltage source inverter, which is a constant voltage.

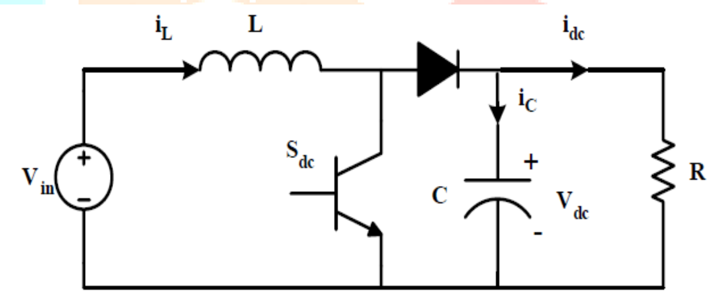


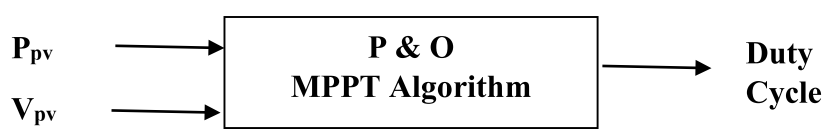
Figure 3: Boost converter for PV inverter

$$V_{out} = \frac{V_{in}}{1-D} \quad (1)$$

$$L_{min} = \frac{(1-D)V_{out}}{\Delta I_L\, f_s} \quad (2)$$

$$C_{min} = \frac{D I_{out}}{\Delta V_{out}\, f_s} \quad (3)$$

The duty cycle of the Boost converter is controlled to get the maximum power output from the PV array. P&O method is used to the maximum power output.



III CONTROL ALGORITHM

A) Droop Control Methodology

Droop control method is used to share the power between the two or synchronous generators in a conventional alternator. In this paper also the Two PI Inverters are operated separately but the power is shared according to their droop coefficients. Figure 4 is the enhanced droop controller The operation of these inverters is based on conventional generators only. The following is the control block diagram of the enhanced droop controller.

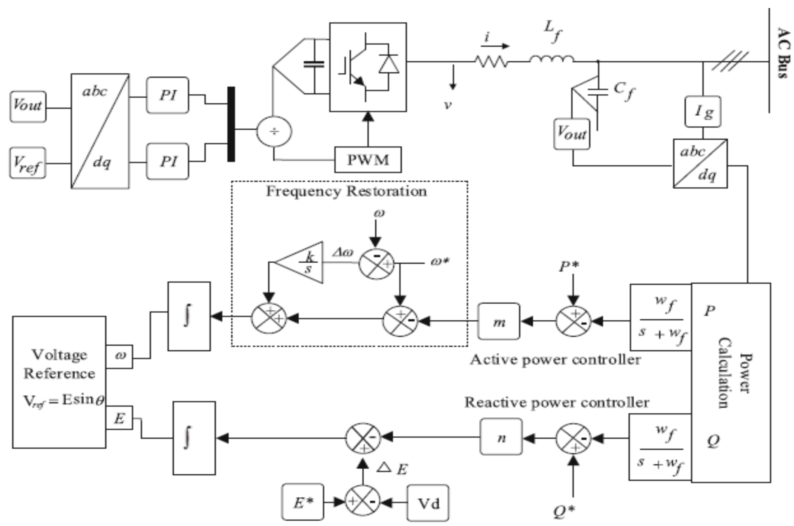


Figure 4: Enhanced Droop controller

C) Virtual Inertia Controller:

A Virtual Inertia Controller (VIC) is used in grid-connected inverters to mimic the inertial response of traditional synchronous generators. This helps improve grid stability by supporting frequency regulation during sudden load changes or faults. It is obtained from the swing equation which are given by the following equation 3.

$$\omega = \omega_N - m\,(P - P_{ref}) \quad (4)$$

$$V = V_N - n\,(Q - Q_{ref}) \quad (5)$$

$$2H\frac{d\omega}{dt} = \frac{d(\omega-\omega_N)}{dt} = P_{ref} - P_0 - k((\omega - \omega_{grid}) + \frac{1}{D}\,(\omega_{ref} - \omega_{grdi}) \quad (6)$$

The below figure shows the control block diagram of the implementation of virtual inertia controller used in this research paper. Sometimes it is difficult to decide the value of the virtual inertia "H". A higher value of virtual inertia will make the system respond slowly.

Therefore, a smaller H results in a better output active power dynamic performance with faster response and lower oscillations. Larger inertia decreases the overshoot of power, yet it results in more fluctuations of the angular frequency. Hence an adaptive inertia controller is implemented in this paper along with the droop controller. This makes the operation of PV inverter mimic as synchronous generator and gives better frequency regulation characteristics.

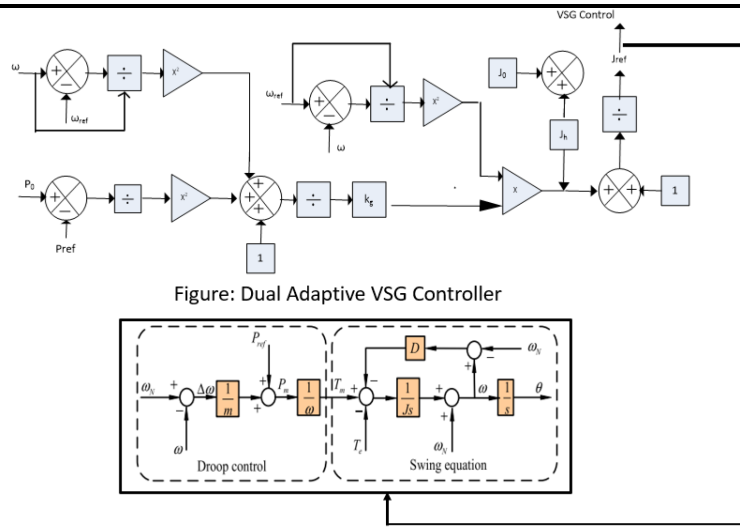


Figure 5: Adaptive controller for Virtual Inertia controller

c) Overall Controller (Integration of Enhancing Droop Controller and Dual Adaptive Inertia Controller)

To mimic as conventional synchronous generator both the droop controller and virtual inertia controller is integrated. The virtual inertia controller will act as a primary frequency controller, where the effect of sudden changes in the power is reduced by its inertia and the droop controller is used to share the power based on the ratings of the frequency. The change in the frequency dependent loads is controlled by the droop controller. Two PV inverters are operated using the integration of these controllers to achieve frequency regulation by each inverter. The control block diagram gives the overall control structure of two inverters connected in parallel. Also to increase the performance of the frequency regulation

IV SIMULATION AND ANALYSIS

The following are the system parameters considered for the simulation of the proposed system. The PV insolation is kept constant throughout the insolation.

Table 1: System parameters

S. No	Parameter	Rating
1	PV Array	4 kW, 300V
2	Boost converter	4.5 kW, 650V
3	Load	4kW, 1kVAR
5	Droop coefficient	m_1= 1% and m_2 = 1%
6	Virtual inertia	H1= 2sec and H2= 2sec
7	PV Filter	10 kVAr (Leading)
8	PWM	SPWM
9	f_{sw}	10 kHz

Initially the Solar inputs to the PV arrays are varied and the PV delivers the active power to the Boost converter. The following figure 6 and 7 shows the PV power output..

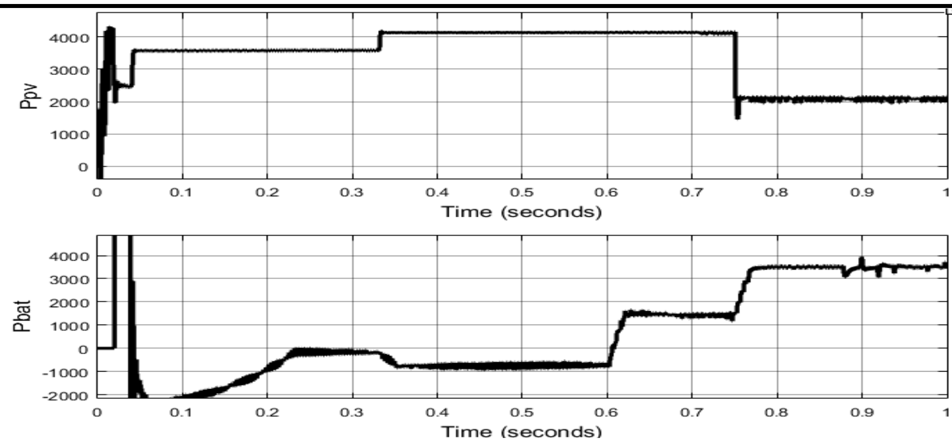


Figure 6: PV-1 and Battery output power

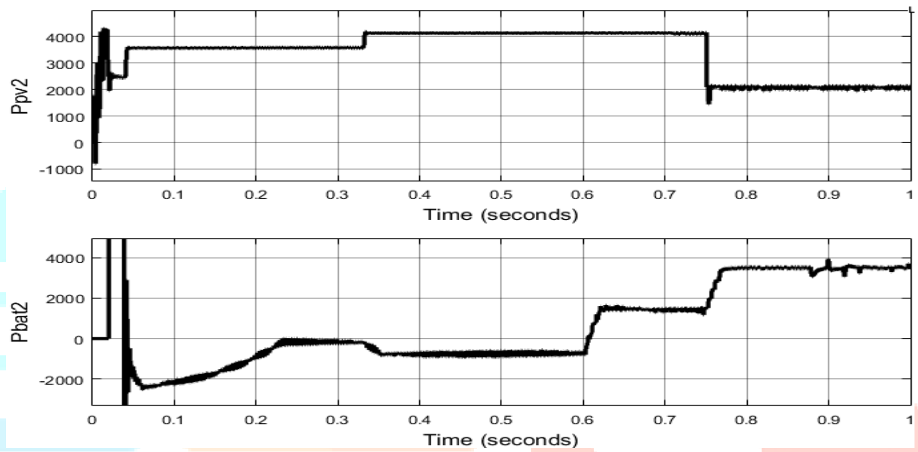


Figure 7: PV-2 power and its corresponding battery output power

The following figure is the load voltage and current. At t= 0.6 sec the load is increased to 4 kW and 500 kVAr. Hence the current is increased at t= 0.6 sec but the voltage is constant. Due to the dynamics of the system, there is ripple in the output waveforms. An adaptive controller is also used in this system whose results are compared figure 9 and 10

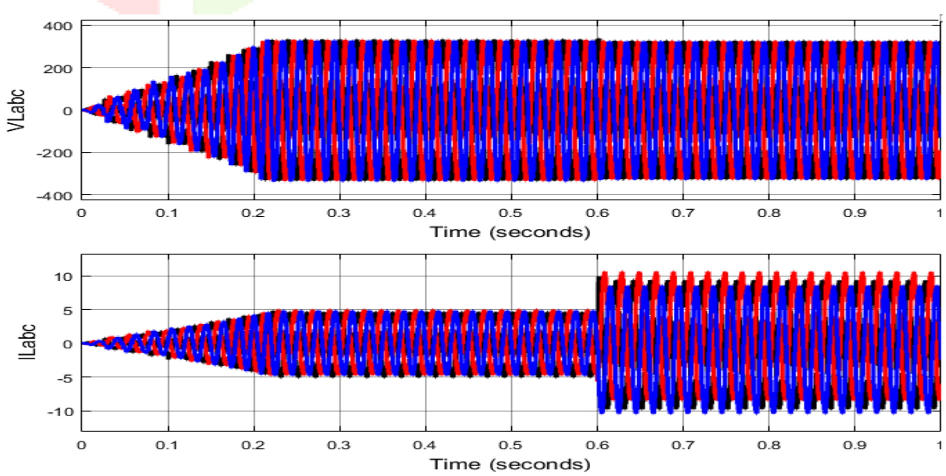


Figure 8: Load Voltage and Load current waveforms

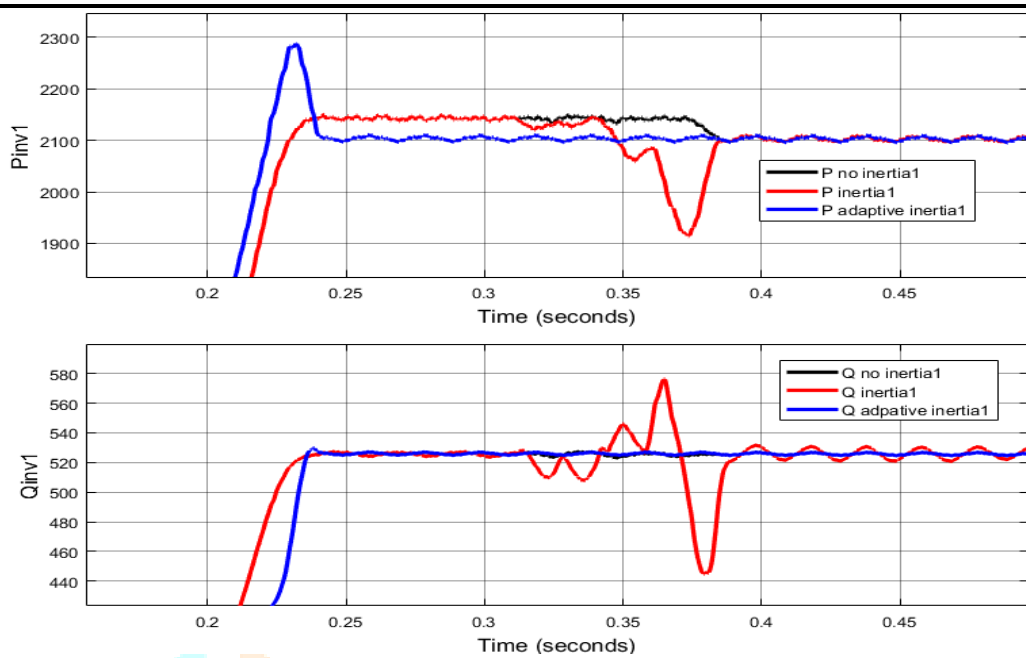


Figure 9: PV-1 Inverter output comparison with different controllers

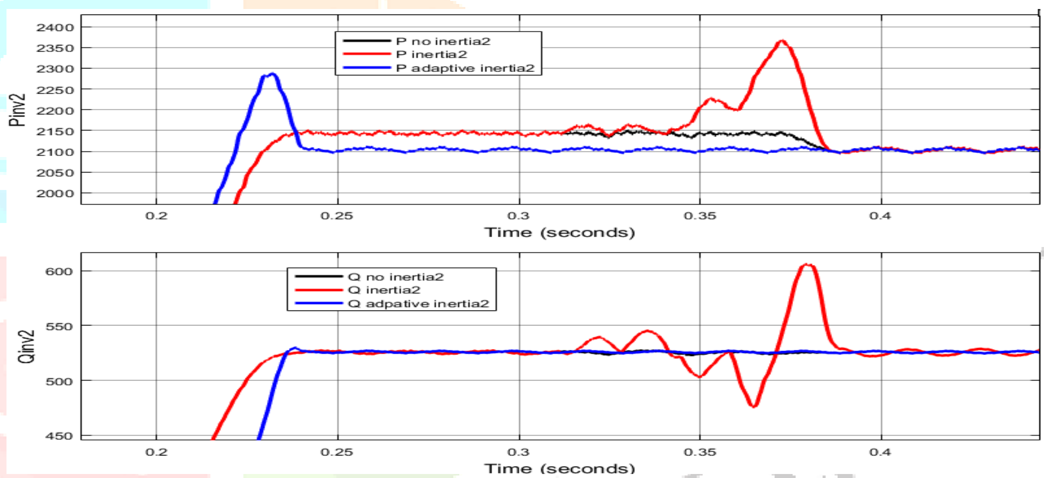


Figure 10: PV-2 Inverter output comparison with different controllers

Conclusion

In this paper, the parallel operation of the two inverters is successfully simulated. The two PV inverters are controlled using the droop controller and virtual inertia controller. The virtual inertia and droop values are considered by trial and error in this paper. Therefore a adaptive system is necessary for the changes in the system load.

References

[1] Hou, X., Han, H., Zhong, C.*, et al.*: 'Improvement of transient stability in inverter-based AC microgrid via adaptive virtual inertia'. Energy Conversion Congress and Exposition (ECCE), Milwaukee, USA, September 2016, pp. 1–6.

[2] Van, T.V., Visscher, K., Diaz, J.*, et al.*: 'Virtual synchronous generator: an element of future grids'. IEEE PES Innovative Smart Grid Technologies Conf. Europe (ISGT Europe), Gothenberg, Sweden, October 2010, pp. 1–7

[3] Beck, H.P., Hesse, R.: 'Virtual synchronous machine'. 9th Int. Conf. on Electrical Power Quality and Utilisation (EPQU), Barcelona, Spain, October 2007, pp. 1–6

[4] Zhong, Q.C., Weiss, G.: 'Synchronverters: inverters that mimic synchronous generators', *IEEE Trans. Ind. Electron.*, 2011, **58**, (4), pp. 1259–1267 [5] D'Arco, S., Suul, J.A.: 'Virtual synchronous machines—classification of implementations and analysis of equivalence to droop controllers for microgrids'. IEEE Grenoble InPowerTech (POWERTECH), Grenoble, France, June 2013, pp. 1–7

[5] D'Arco, S., Suul, J.A.: 'Virtual synchronous machines—classification of implementations and analysis of equivalence to droop controllers fomicrogrids'. IEEE Grenoble InPowerTech (POWERTECH), Grenoble,France, June 2013, pp. 1–7.

[6] M. Kallamadi and V. Sarkar, "Enhanced real-time power balancing of an ac microgrid Through transiently coupled droop control," IET Generation, Transmission Distribution, vol. 11, no. 8, pp.1933–1942, 2017.

[7] P. Li, X. Wang, W. J. Lee, and D. Xu, "Dynamic power conditioning method of microgrid via adaptive inverse control," IEEE Transactions on Power Delivery, vol. 30, no. 2, pp. 906–913, April 2015.

[8] M. Ashabani, Y. A. R. I. Mohamed, M. Mirsalim, and M. Aghashabani,"Multivariable droop control of synchronous current converters in weak grids/microgrids with decoupled dq-axes currents," IEEE Transactions on Smart Grid, vol. 6, no. 4, pp. 1610–1620, Jul. 2015.

[9] T. Wu, Z. Liu, J. Liu, S. Wang, and Z. You, "A unified virtual power decoupling method for droop-controlled parallel inverters in microgrids," IEEE Transactions on Power Electronics, vol. 31, no. 8, pp. 5587–5603, Aug. 2016.

[10] X. Sun, Y. Tian, and Z. Chen, "Adaptive decoupled power control method for inverter connected dg," IET Renewable Power Generation, vol. 8, no. 2, pp. 171–182, March 2014.

[11] Y. Li and Y. W. Li, "Power management of inverter interfaced autonomous microgrid based on virtual frequency-voltage frame," IEEE Transactions on Smart Grid, vol. 2, no. 1, pp. 30–40, March 2011.

[12] A. Haddadi, A. Yazdani, G. Jos, and B. Boulet, "A gain-scheduled decoupling control strategy for enhanced transient performance and stability of an islanded active distribution network," IEEE Transactions on Power Delivery, vol. 29, no. 2, pp. 560–569, Apr. 2014.

[13] J. Lai, H. Zhou, X. Lu, X. Yu, and W. Hu, "Droop-based distributed cooperative control for microgrids with time-varying delays," IEEE Transactions on Smart Grid, vol. 7, no. 4, pp. 1775–1789, Jul. 2016.

[14] Suleman Haider, Guojie Li and Keyou Wang, "A Dual control strategy for power sharing improvement in islanded mode of AC microgrid" Protection and Control of Modern Power Systems https://doi.org/10.1186/s41601-018-0084-2