RESEARCH ARTICLE OPEN ACCESS

An Improved Reactive Power Sharing Strategy in Islanded Microgrid

Tran Thi Nhu Ha
Faculty of Electrical and Electronics Engineering Technology, Ho Chi Minh City University of Food Industry (HUFI), Ho Chi Minh City, Vietnam

ABSTRACT
In this paper, proposed an adaptive droop controller using compensate for the mismatch in voltage drops across line impedance, to enhance reactive power sharing accuracy in island microgrid. Communication is used to facilitate the tuning of adaptive controller for the change of load. The method will ensure in accurate reactive power sharing even the communication is interrupted if the load does not change during this time. If the load change while the communication is interrupted, the accurate sharing is reduced, but the proposed method is better than the conventional droop control method. In addition, the accuracy reactive power sharing base on the proposed method is not affected by the time delay in the communication channel. The feasibility and effectiveness of the proposed method are demonstrated by using simulation on Matlab/Simulink.
Keywords: Droop control, microgrid control, reactive power control, Kalman filter.

Date Of Submission: 22-06-2019 Date Of Acceptance: 08-07-2019

Variables

Variables	Unit	Meaning
V	Voltage	The voltage measured at the output of the inverter.
V_{PCC}	Voltage	The voltage measured at the point of common coupling.
δ	Radian	Voltage phase angle of the output of the inverter.
δ_{PCC}	Radian	Voltage phase angle at the point of common coupling.
P	W	The actual active power output of inverter
Q	Var	The actual reactive power output of inverter.
V_0, ω_0	V, Radian/s	The nominal amplitude voltage and frequency of inverter.
V, ω	V, Radian/s	The measured amplitude voltage and frequency of the inverter.
ΔV_{max}		Maximum voltage deviation allowed.
R_f, L_f, C	Ω, H, F	Parameters of filters.
R, L	Ω, H	Parameters of line impedance.

Abbreviations

DG	Distributed generation
PCC	Point of common coupling
SOGI-PLL	Second-order generalized integrator-phase-locked loop

I. INTRODUCTION

Distributed generation has recently received as a potential solution to meet the increasing demand for electricity, to reduce the overload on the existing transmission system. Since then, the microgrid concept has emerged to coordinate the different types of distributed energy. However, control problems islanded microgrids remain the problem are concerned, such as the difficulty of maintaining generation or load power balance and reactive power sharing. To achieve this frequency, and voltage droop control technique is one of the methods common power sharing because it does not need the monitoring system, flexible has been presented in [1]. The droop control method can be used for communication. However, be used in addition to the droop control method to enhance the system performance without reducing reliability [2]–[3]. Although the frequency droop technique can achieve accuracy for real power sharing, the voltage droop technique often results in poor reactive power sharing due to the mismatch in the impedances of the DG unit feeders and also due to the difference in the rated power of the DG units [4]. Therefore, the problem of reactive power sharing in island microgrids has received considerable attention in the articles and many control's methods have been developed to solve this problem [5] - [7]. A virtual impedance method is presented in [5], virtual impedance to mitigate the error of reactive power sharing due to mismatch in the output impedances of the inverters. However, the analysis in [5] did not consider the mismatch in the line impedance. One approach is proposed in [8] to achieve accurate reactive power sharing, the proposed strategy will require an injection of a small AC voltage signal, it may reduce the quality of the output voltage and line current [9]. On the other hand, the analysis and control strategy was introduced in [6] requires that the line impedance is resistive, and control strategy result in accurate power sharing if this condition is satisfied. In practice, the line impedance may have both nonnegligible inductive and resistive components [5]. Communication links are also used in [10] to enhance the performance of conventional droop control, this proposed technique can reduce the sharing error but cannot eliminate it completely. A droop control is proposed in [7] to reduce the power sharing error, the sharing error can be reduced, but not completely eliminated and the improvement in performance is not significant if local loads are connected at the output of each unit. Communication links are also used in [11] to improve the accurate power sharing, but the implementation of this technique is sensitive to delays in communication; for example, a delay of 16 ms to reduce the power sharing accuracy. Communication links are also used in [12] to restore the frequency and the voltage, and also to ensure accurate reactive power sharing. However, in the paper the scenario of a complete communication failure is not investigated. Some studies in [13] are used to compensate for the voltage drop across the transmission lines, to hold the system stability and improve reactive power sharing.In this paper, an adaptive droop control method using compensate for the mismatch in voltage drops across line impedance, to enhance reactive power sharing accuracy. The method will ensure in accurate reactive power sharing even if communication is interrupted and the load has not changed during this time. If the load change while the communication is interrupted, the accurate sharing is reduced, but the proposed method is better than the conventional droop control method. In addition, the accurate reactive power sharing base on the proposed method is not affected by the time delay in the communication channel. The SOGI-PLL is used to monitor the voltage amplitude and frequency at the PCC to support for adaptive droop controller. An example structure of a microgrid is shown in Figure 1. The microgrid is consists of n DG systems. Each DG system comprises an energy source, an energy storage system, and an inverter. The microgrid can operate in grid-connected mode or islanding mode. When microgrid is disconnected from the utility as fast as possible and picks up the loads and operate in islanding mode. In standalone mode, microgrid immediately to perform power sharing for the DGs to stable the frequency and voltage.

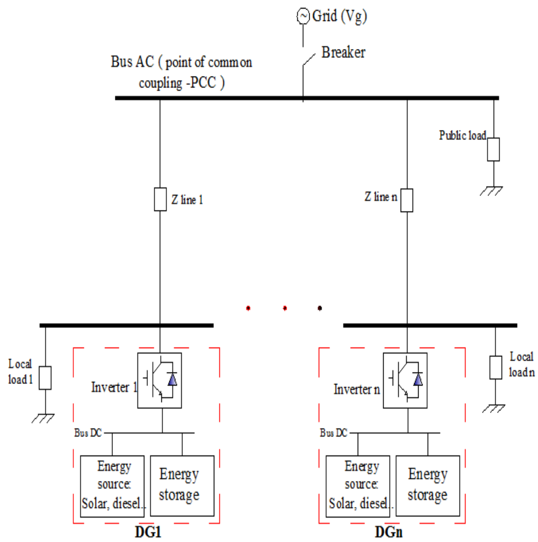
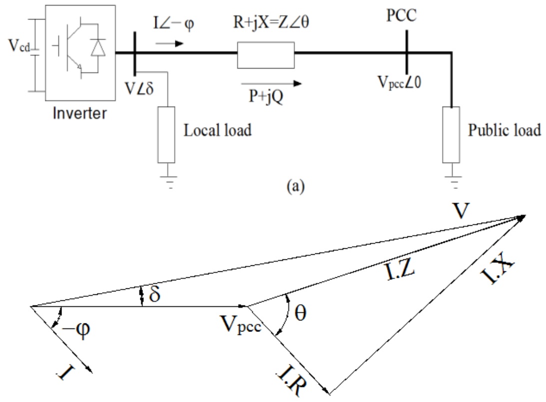


Figure 1. Configuration of microgrid consist parallel DGs

II. CONTROL METHOD

The principle of the droop control method is explained by considering an equivalent circuit of an inverter connected to the PCC.The analysis method is based on the Thevenin theorem in Figure 2.



(b)

Figure 2. (a) Equivalent schematic of the inverters connected to the load, (b) Vector diagram of voltage and current

The power provided by the inverter is calculated:

$$P = \frac{V}{R^2 + X^2}[R(V - V_{PCC}\cos\delta) + XV_{PCC}\sin\delta] \quad (1)$$

$$Q = \frac{V}{R^2 + X^2}[-RV_{PCC}\sin\delta + X(V - V_{PCC}\cos\delta)] \quad (2)$$

The equation (1) and (2) are rewritten as:

$$\sin\delta = \frac{XP - RQ}{VV_{PCC}} \quad (3)$$

$$V - V_{PCC}\cos\delta = \frac{RP + XQ}{V} \quad (4)$$

In the general case, both X and R are to be considered. The use of an orthogonal linear, rotational transformation matrix T of active and reactive power P and Q to the active and reactive power P' and Q' is proposed:

$$\begin{bmatrix} P' \\ Q' \end{bmatrix} = [T]\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} \sin\theta & -\cos\theta \\ \cos\theta & \sin\theta \end{bmatrix}\begin{bmatrix} P \\ Q \end{bmatrix}$$

$$\begin{bmatrix} P' \\ Q' \end{bmatrix} = \begin{bmatrix} \frac{X}{Z}P - \frac{R}{Z}Q \\ \frac{R}{Z}P + \frac{X}{Z}Q \end{bmatrix} \quad (5)$$

When the power angle δ is small, the equation (3), (4), (5) are rewritten as:

$$\delta \cong \frac{ZP'}{VV_{PCC}}; \quad V - V_{PCC} \cong \frac{ZQ'}{V} \quad (6)$$

Equation (6) shows that the voltage depends reactive power Q', whereas the frequency depends active power P'. In other words, the voltage can be controlled by regulating Q', whereas the inverter frequency is controllable through P'. Thus, by adjusting P' and Q' independently. These conclusions form the basis for the well-known frequency and voltage droop regulation through respectively active and reactive power:

$$\omega = \omega_0 - m_p P' \quad (7)$$

$$V = V_0 - m_q Q' \quad (8)$$

m_p and m_q are the active and reactive droop coefficients, respectively.

$$m_p = \frac{\omega_{max} - \omega_{min}}{P_{max}}; m_q = \frac{V_{max} - V_{min}}{Q_{max}} \quad (9)$$

In the case the line impedance from inverters to the PCC is different, we can see that the implementation of accurate power sharing, as well as the adjustment the deviation of voltage and power is very difficult because it depends on the parameters of the system. Indeed, from the formula (6) we have:

$$Q' = \frac{V^2 - VV_{PCC}\cos\delta}{Z} \quad (10)$$

Assuming perform power sharing for two inverters, according to (8) we have:

$$m_{q1}Q'_1 = V_0 - V_1 = \Delta V_1 \quad (11)$$

$$m_{q2}Q'_2 = V_0 - V_2 = \Delta V_2$$

According (11), we show that:

$$\Delta V_1 = \Delta V_2 = \Delta V_{max} \text{ when} V_1 = V_2 \quad (12)$$

$$m_{q1}Q'_1 = m_{q2}Q'_2 \quad (13)$$

Substitution (10) to (13), we have:

$$\frac{m_{q1}(V_1^2 - V_1 V_{PCC}\cos\delta_1)}{Z_1} = \frac{m_{q2}(V_2^2 - V_2 V_{PCC}\cos\delta_2)}{Z_2} \quad (14)$$

Combining (12) and (14), we have the conditions for the two inverters reactive power sharing accuracy is:

$$\frac{m_{q1}}{Z_1} = \frac{m_{q2}}{Z_2} \qquad (15)$$
$$\delta_1 = \delta_2$$
$$V_1 = V_2$$

So to realize the accurate power sharing, they must qualify under (15), means we must choose the droop coefficients m_{q1} and m_{q2} so that the ratio of the line impedance. It is very difficult to implement.

In this paper, an adaptive droop control method using compensate for the mismatch in voltage drops across line impedance, to enhance reactive power sharing accuracy. Control block diagram of the adaptive droop control is shown in Figure 3. The controller consists of the following blocks:

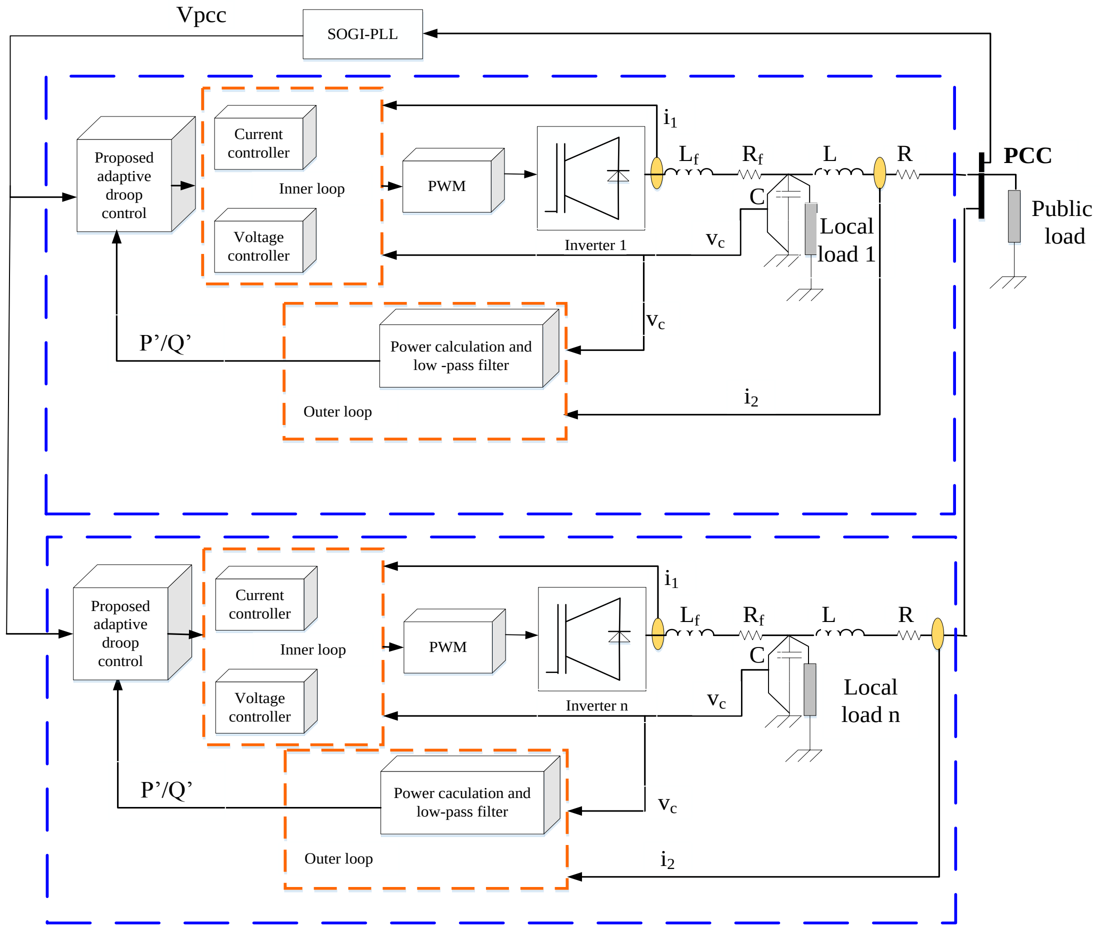


Figure 3. Block diagram of the proposed adaptive droop controller for island microgrid

2.1 Block of power calculation and low-pass filter

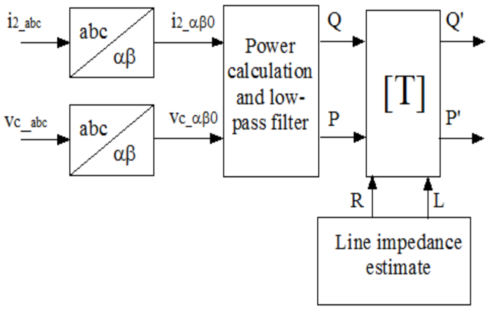


Figure 4. Block of power caculation and low-pass filter

The power in the virtual coordinate system is calculated according to (5):

$$\begin{bmatrix} P' \\ Q' \end{bmatrix} = \begin{bmatrix} \frac{X}{Z}P - \frac{R}{Z}Q \\ \frac{R}{Z}P + \frac{X}{Z}Q \end{bmatrix}$$

2.2 Block of the SOGI-PLL

Figure 5 shows the structure of the SOGI-PLL. Both the adaptive filtering technique and in-quadrature phase detection technique are used in the SOGI-PLL to generate the frequency and phase outputs. This system has a double feedback loop, the frequency generator provides both the phase-angle to the Park transform and the central frequency to the SOGI-QSG. Figure 6 shows the responses of the SOGI-PLL.

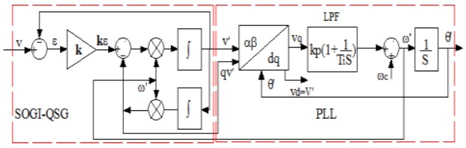


Figure 5. The structure of the SOGI-PLL

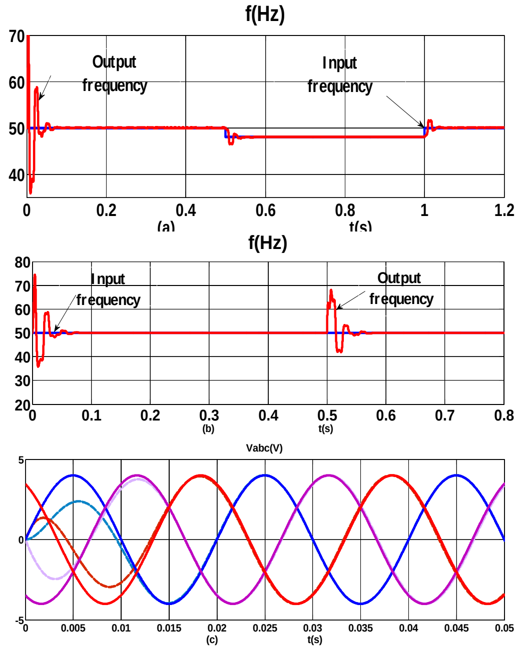


Figure 6. The simulation results for the response of the input and output of SOGI-PLL

Figure 6a shows the frequency response of the SOGI-PLL when the frequency of input signal change from 50Hz to 48Hz at t=0.5s and from 48Hz to 50Hz at t=1s. Figure 6b shows the frequency response of the SOGI-PLL when the phase angle of input signal change from 0^0 to 45^0 at t=0.5s. Figure 6c shows the response of the input and output voltage of the SOGI-PLL. The simulation results in Figure 6 show SOGI-PLL can be obtained amplitude voltage and frequency at the PCC correctly.

2.3 Block of the proposed adaptive droop control

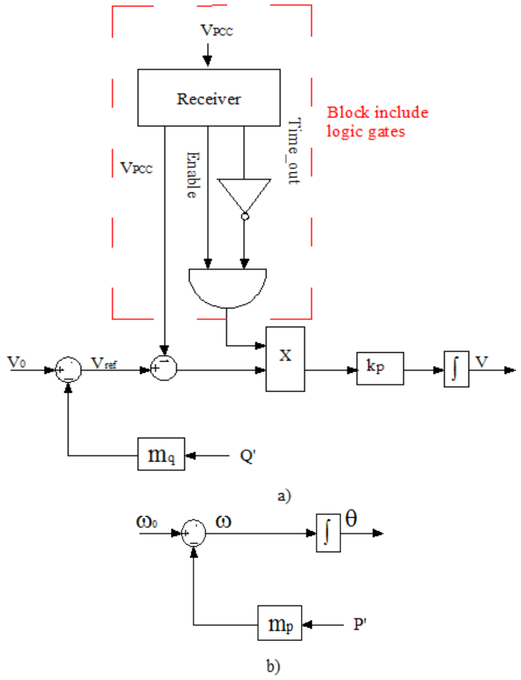


Figure 7. Block of the proposed adaptive droop control a)reactive power sharing, b) active power sharing

The cause of deviation voltage droop due to mismatch line impedance between the inverters, and compensate for the mismatch in voltage drops across the line impedance by adjusting the voltage at the output of voltage droop controller (8) to the voltage at the PCC through the integral stages as follows:

$$V = k_p \int (V_{ref} - V_{PCC})\, dt \qquad (16)$$

Where : V_{ref} is calculated by the formula (8):

$$V_{ref} = V_0 - m_q Q' \qquad (17)$$

Where: k_p is integral gain.

Vpcc is taken from the output of the SOGI-PLL.

Formula (16) shows the voltage of the inverters will come to value common reference voltage when steady-state. So proposed adaptive droop control method has eliminated the mismatch of line impedance without having to comply with the conditions (15).

In order to study the dynamics of the system, a small-signal model is synthesized by linearizing (16), (17), and (10) at an operating point $Q', V, V_{PCC}, \delta, \delta_{PCC}$, and we have:

$$\Delta V = k_p \int (\Delta V_{ref} - \Delta V_{PCC})\, dt \qquad (18)$$

$$\Delta V_{ref} = \Delta V_0 - m_q \Delta Q' \qquad (19)$$

$$\Delta Q' = A\Delta V + B\Delta V_{PCC} \qquad (20)$$

$$A = \frac{2V - V_{PCC}\cos(\delta - \delta_{PCC})}{Z}$$

$$B = -\frac{V}{Z}\cos(\delta - \delta_{PCC})$$

The formula (18), (19) and (20) shown in Figure 8.

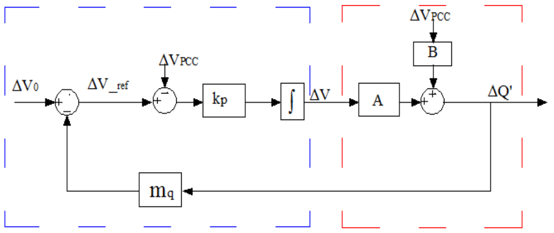


Figure 8. Small-signal representation of the reactive power sharing with proposed adaptive droop control

Figure 8 shows a block diagram representing the complete small-signal model of the controller. The closed-loop transfer function relating the output ΔQ' to ΔV and ΔV_{PCC} in the block diagram is given by (21):

$$\Delta Q'(S) = \frac{k_p A}{S + k_p.m_q.A}\Delta V_0(S) + \frac{SB - k_p A}{S + k_p.m_q.A}\Delta V_{PCC}(S) \quad (21)$$

The equation (21)shows that the closed-loop eigenvalue of the linearized system is:

$$\lambda = -k_p.m_q.A$$

We show the eigenvalue of the closed-loop system depends on the droop coefficient m_q and integral gain k_p. So we can adjust integral gain k_p to the reactive power control to achieve the desired dynamics without affecting voltage regulation.

2.4Block of voltage and current controller

The current and voltage controller is established based on equations according circuit diagram in Figure 3:

$$i_{1d} = i_{2d} + C\frac{dv_{cd}}{dt} - \omega Cv_{cq} \quad (22)$$

$$i_{1q} = i_{2q} + C\frac{dv_{cq}}{dt} + \omega Cv_{cd} \quad (23)$$

$$v_{inv,d} = L_f\frac{di_{1d}}{dt} + R_f i_{1d} - \omega L_f i_{1q} + v_{cd} \quad (24)$$

$$v_{inv,q} = L_f\frac{di_{1q}}{dt} + R_f i_{1q} + \omega L_f i_{1d} + v_{cq} \quad (25)$$

2.5 Proposed controller performance during a communication failure

Proposed adaptive droop controller in Figure 7 was added to the block composed of logic gates in order to improve reliability for the controller in case of communication failure. The time out/enable logic is shown in figure 7, when the communication failure, in which case the control loop is disabled and the integrator output will remain constant until the communication is restored. The amplitude voltage at output of proposed adaptive droop are held at the last value before the communication failure occurred due to the integral action of the controller. The power sharing is still accurate if the operating point remains unchanged after the communication failure, but if the load changes the power sharing error is still acceptable. The case of a communication failure is illustrated in figure 11.

2.6The effect of the communication and information update delay

The time delay is called the information update delay. The proposed adaptive droop controller is immune to the time delay in the communication channel. Communication link only used to set the value of the reference voltage for tuning the output voltage of the controller. Moreover, the reference voltage is the amplitude value therefore the system will reach steady state despite is slower than usual. If delays occur in steady state, it will not affect the power sharing accuracy. The reference voltage depends on the load so it is a fixed reference voltage until the load changes. Therefore, the accurate power sharing at steady state is unaffected by time delays in the communication channels. The case of information update delay is illustrated in figure 12, 13 and 14.

III. SIMULATION RESULTS

The proposed adaptive droop control has been verified in Matlab/Simulink. The simulations a microgrid as shown in figure 1. The system parameters for simulation as shown in Table 1.

Table 1. Parameters for the controllers

Parameter	Value	Parameter	Value
Input source voltage V_{cd}(V)	600	Rate frequency f_0(Hz)	50
Filter inductance L_f(mH)	1.2	Rate power P_0(kW)	4
Filter resistance R_f(Ω)	0.2	Rate voltage V_0(V)	310
Filter capacitance C(μF)	50	Droop coefficient m_p	0.0001
Switching frequency f_0(kHz)	5	Droop coefficient m_q	0.0017

3.1 Simulation in the case of the communication without interruption

3.1.1 Simulation to power sharing for two identical inverters, different line impedance (R_1=0.8Ω, L_1=0.8mH; R_2=1Ω, L_2=1mH), different local loads ($P_{local-1}$=1500W, P_{local_2}=750W, Q_{local_1}=1450Var, Q_{local_2}=600Var) and public load (P_{public}=3350W, Q_{public}=2200Var). Simulation results are illustrated in figure 9.

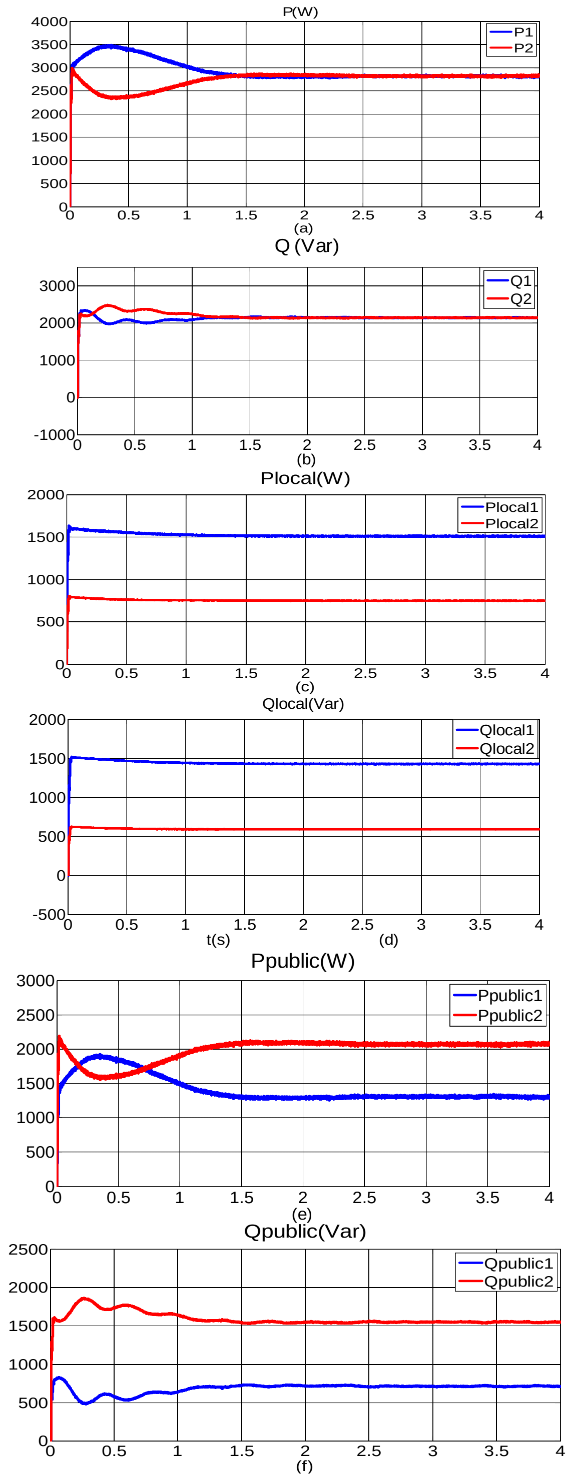


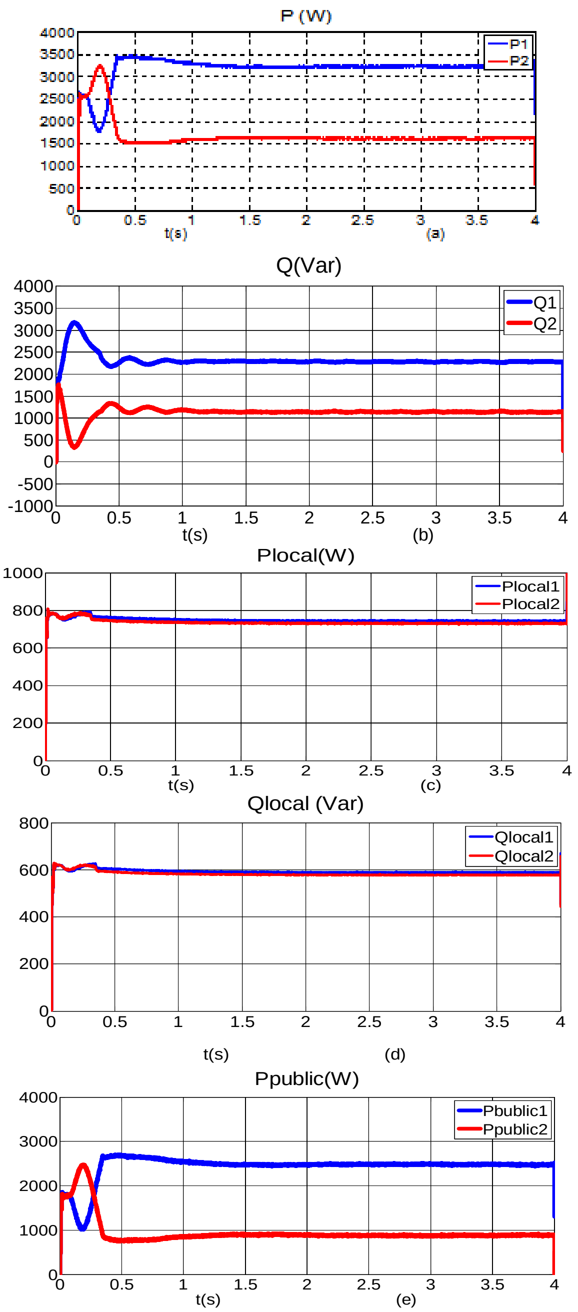
Figure 9. (a) Active power of inverter (b) Reactive power of inverter, (c) Active power of local loads , (d) Reactive power of local loads, (e) Active power of public load, (f) Reactive power of public load

Figure 9a and 9b show the proposed controller has done accurate power sharing in case of different line impedance and the different local loads. The power at output of each inverter:

$$P = 0.5(P_{local\ 1} + P_{local\ 2} + P_{public}) = 0.5(1500 + 750 + 1350 + 2000) = 2800W$$

$$Q = 0.5(Q_{local\ 1} + Q_{local\ 2} + Q_{public}) = 0.5(1450 + 600 + 1500 + 700) = 2125Var$$

3.1.2 Simulation to power sharing for two different inverters, ratio 2:1; different line impedance (R_1=0.8Ω, L_1=0.8mH; R_2=1Ω, L_2=1mH), identical local loads ($P_{local\text{-}1,2}$=730W, $Q_{local\_1,2}$=600Var) and public load (P_{public}=3400W, Q_{public}=2250Var). Simulation results are illustrated in figure 10.



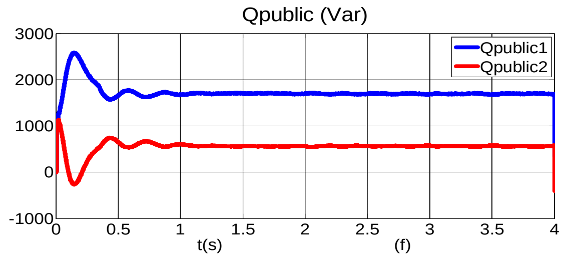


Figure 10. (a) Active power of inverter (b) Reactive power of inverter, (c) Active power of local loads , (d) Reactive power of local loads, (e) Active power of public load, (f) Reactive power of public load

Figure 10 shows the proposed controller has done accurate power sharing in case of different line impedance and the identical local loads. The power at output of each inverter:

$$P_1 = \frac{2}{3}\left(P_{local\ 1} + P_{local\ 2} + P_{public}\right) = \frac{2}{3}(730 + 730 + 2500 + 900) = 3240W$$

$$P_2 = \frac{1}{3}\left(P_{local\ 1} + P_{local\ 2} + P_{public}\right) = \frac{1}{3}(730 + 730 + 2500 + 900) = 1620W$$

$$Q_1 = \frac{2}{3}\left(Q_{local\ 1} + Q_{local\ 2} + Q_{public}\right) = \frac{2}{3}(600 + 600 + 550 + 1700) = 2300Var$$

$$Q_2 = \frac{1}{3}\left(Q_{local\ 1} + Q_{local\ 2} + Q_{public}\right) = \frac{1}{3}(600 + 600 + 550 + 1700) = 1150Var$$

3.2 Simulation in the case of the communication failure

3.2.1 Simulation to power sharing for two identical inverters, different line impedance (R_1=0.8Ω, L_1=0.8mH; R_2=1Ω, L_2=1mH). The communication interruption at t=5s and the communication restored at t=9s, the load and line impedance unchanged in the period from t=5s to t=7s, the loads are changed in the period from t=7s to t=9s. Simulation results are illustrated in figure 11.

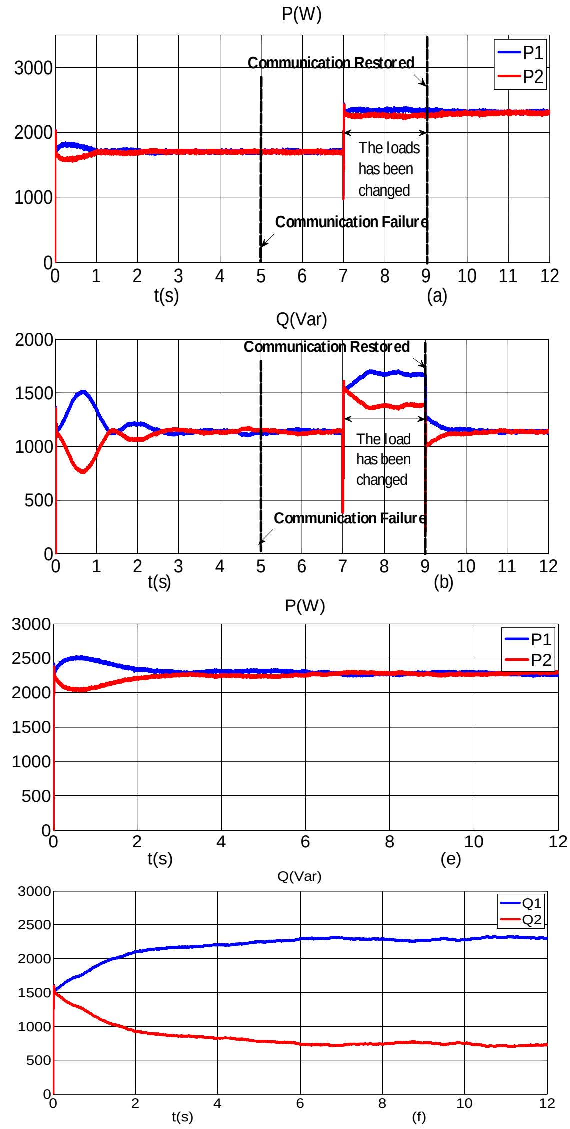


Figure 11. (a) Active power of the proposed controller (b) Reactive power of proposed controller, (e) Active power of conventional droop control, (f) Reactive power of conventional droop control

Figure 11a, 11b show that in the period from 5s to 7s, although communication failure, but the load are not changed so the power sharing has been implemented correctly; in the period from 7s to 9s, the communication failure and the load are changed so the power sharing hasn't been implemented correctly, but still better than the conventional droop controller in Figure 11f. The communication be restored after the 9s, so the power sharing has been implemented correctly.

3.3 Simulation in the case of the information update delay

3.3.1 Simulation to power sharing for two identical inverters, different line impedance (R_1=0.8Ω, L_1=0.8mH; R_2=1Ω, L_2=1mH).

The effect of time delays in communication is investigated by introducing a delay in the signal sent to proposed controller 1, not delay for proposed controller 2. In this case, the proposed controller 2 receives the Vpcc reference and starts acting before proposed controller 1. Which has more effect on the transients in comparison to the case when the delays are identical. The introduced time delay is chosen as 0.02s, which is significant given that the reference update period is 200µs. Simulation results are illustrated in figure 12.

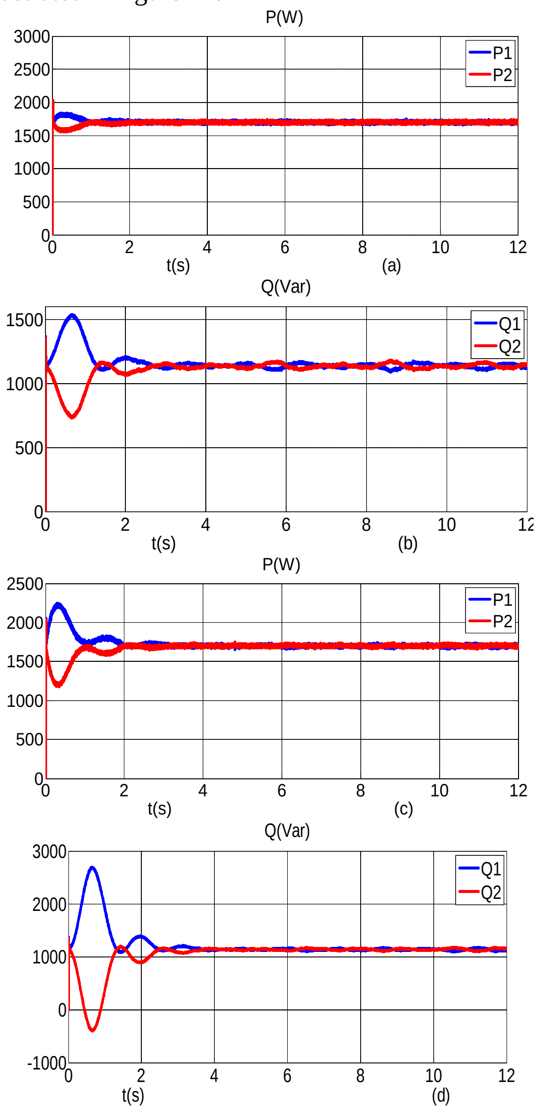


Figure 12. (a) Active power of the proposed controller don't get delay (b) Reactive power of proposed controller don't get delay,(c) Active power of the proposed controller get delay, (d) Reactive power of proposed controller get delay,

3.3.2 The effect of time delays in communication is investigated by introducing a delay in the signal sent to proposed controller 2, not delay for proposed controller 1. The introduced time delay is chosen as 0.1s, a delay occurs at time t = 5s. Simulation results are illustrated in figure 13.

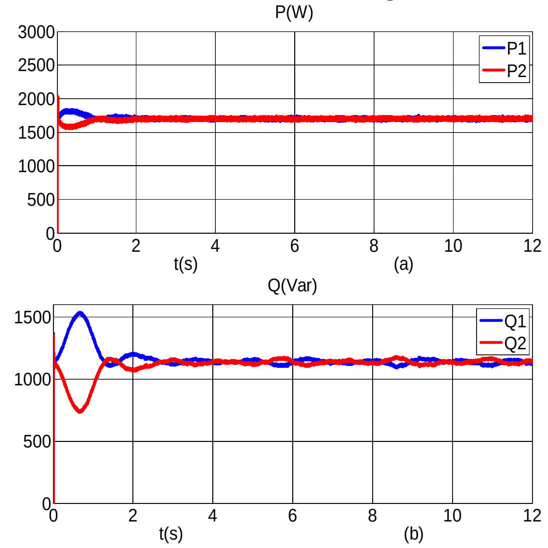


Figure 13. (a) Active power of the proposed controller get delay (b) Reactive power of proposed controller get delay

3.3.3 The effect of time delays in communication is investigated by introducing a delay in the signal sent to proposed controller 1, not delay for proposed controller 2. The introduced time delay is chosen as 0.1s, a delay occurs at time t = 5s and the load change at this time. Simulation results are illustrated in figure 14.

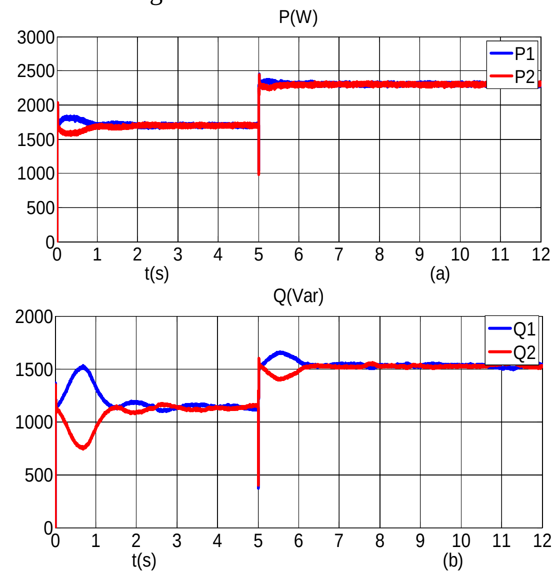


Figure 14. (a) Active power of the proposed controller gets delay (b) Reactive power of proposed controller get delayed

Figure 12, 13, 14 shown that the time delay has little effect on the system transients. Most importantly, the time delay does not affect the accurate power sharing of the proposed controller, and during a load change. If delays occur in a steady state as Figure 13, it will not affect on the system transients.

IV. CONCLUSION

In this paper has been proposed adaptive droop control to improve reactive power sharing in an island microgrid. The controller uses compensate for the mismatch in voltage drops across the line impedance and the effect of local loads. It is also insensitive to time delays in the communication channels. It has been shown that the proposed controller is tolerant of disruptions in the communication links and still better than the conventional droop control method. The proposed controller has been simulated in a microgrid with two paralell inverters, the different local loads in a microgrid also are considered, and has been verified to be effective under operating point changes and realistic communication failures.

REFERENCES

[1]. R. H. Lasseter, J. H. Eto, B. Schenkman, J. tevens, H. Vollkommer, D. Klapp, CERTSmicrogrid laboratory test bed,IEEE Trans. Power Del., vol. 26, no. 1, pp. 325–332, Jan. 2011.

[2]. J. M. Guerrero, M. Chandorkar, T.-L. Lee, Advanced control architecture for intelligent microgrids—Part I: Decentralized and hierarchical control,IEEE Trans. Power Electron., vol. 60, no. 4, pp. 1254–1262, Apr. 2013.

[3]. J. M. Guerrero, J. C. Vasquez, J. Matas, Hierarchical control of droop-controlled ac and dc microgrids—A general approach towards standardization,IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 158–172, Jan. 2011.

[4]. J. Kim, J. M. Guerrero, P. Rodriguez, Mode adaptive droop control with virtual output impedances for an inverterbased flexible AC microgrid,IEEE Trans. Power Electron., vol. 26, no. 3, pp. 689–701, Mar. 2011.

[5]. W. Yao, M. Chen, J. Matas, Design and analysis of the droop control method for parallel inverters considering the impact of the complex impedance on the power sharing,IEEE Trans. Ind. Electron., vol. 58, no. 2, pp. 576–588, Feb. 2011.

[6]. Q.-C. Zhong, Robust droop controller for accurate proportional load sharing among inverters operated in parallel, IEEE Trans. Ind. Electron.,vol. 60, no. 4, pp. 1281–1290, Apr. 2013.

[7]. J. He and Y. W. Li, An enhanced microgrid load demand sharing strategy, IEEE Trans. Power Electron., vol. 27, no. 9, pp. 3984–3995, Sep. 2012.

[8]. A. Tuladhar, H. Jin, T. Unger, Control of parallel inverters in distributed AC power systems with consideration of line impedance effect, IEEE Trans. Ind. Appl., vol. 36, no. 1, pp. 131–138, Jan./Feb. 2000.

[9]. J. He and Y. W. Li, An enhanced microgrid load demand sharing strategy,IEEE Trans. Power Electron., vol. 27, no. 9, pp. 3984–3995, Sep. 2012.

[10]. Y. Zhang and H. Ma, Theoretical and experimental investigation of networked control for parallel operation of inverters,IEEE Trans. Ind. Electron., vol. 59, no. 4, pp. 1961–1970, Apr. 2012.

[11]. Song CI and Junjie Qian, Impact of wireless communication delay on load sharing among distributed generation systems through smart microgrids, IEEE 2012.

[12]. Q. Shafiee, J. M. Guerrero, Distributed secondary control for islanded microgrids—A novel approach, IEEE Trans. PowerElectron., vol. 29, no. 2, pp. 1018–1031, Feb. 2014.

[13]. E. Rokrok and M. E. H. Golshan, Adaptive voltage droop scheme for voltage source converters in an islanded multi-bus microgrid,IET Gener. Transmiss. Distrib., vol. 4, no. 5, pp. 562–578, May 2010.

Tran Thi Nhu Ha" An Improved Reactive Power Sharing Strategy in Islanded Microgrid " International Journal of Engineering Research and Applications (IJERA), Vol. 09, No.07, 2019, pp. 36-45