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Improvement of Micro grid Load Demand Sharing Strategy by Using Fuzzy Logic

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***Abstract*— The important task for the operation of autonomous micro grids, is to share the load demand using multiple distributed generation units. In this paper to realize satisfied power sharing without the communication between DG units, the voltage droop control and its different variations have been proposed. Generally in low voltage micro grids, due to the effects of feeder impedance, the droop control is subject to the real and reactive power coupling and steady-state reactive power sharing errors. The complex micro grid configurations often make the reactive power sharing more challenging. To improve the reactive power sharing accuracy an enhanced control strategy that estimates the reactive power control error through injecting small real power disturbances, which is activated by the low-bandwidth synchronization signals from the central controller The proposed compensation method achieves accurate reactive power sharing at the steady state. Simulation and experimental results validate the feasibility of the proposed method.**

***Index Terms*— Distributed Generation (Dg), Droop Control, Low Band width Communication, Micro grid, Reactive Power Compensation, Real And Reactive Power Sharing.**

I. INTRODUCTION

From the past decades onwards the distributed power generation application has been increasing rapidly. Related to the conventional centralized power generation, clean and renewable power close to the customer's end can be supplied by distributed generation(DG) units. So, the stress of many conventional transmission and distribution infrastructures alleviated by this. As most of the DG units are interfaced to the grid using power electronics converters, they have the opportunity to realize enhanced power generation through a flexible digital control of the power converters. On the other hand, high penetration of power electronics based DG units also introduces some issues, such as system resonance, protection interference, etc. The microgrid concept has been proposed to overcome this snags, which is realized through the control of multiple DG units. When compared to a single DG unit, the microgrid can achieve greater power management within its distribution networks. The islanding operation of microgrid offers high reliability power supply to the critical loads. So, microgrid is considered to pave the way to the future smart grid.The loads can be properly shared by multiple DG units in an islanded microgrids. Conventionally, the frequency and voltage magnitude droop control is adopted, which aims to achieve microgrid power sharing in a decentralized manner. However, the droop control governed microgrid is prone to have some power control stability problems when the DG feeders are mainly resistive. The real power sharing at the steady state is always accurate while the reactive power sharing is sensitive to the impacts of mismatched feeder impedance. Moreover, the existence of local loads and the networked microgrid configurations often further aggravate reactive power sharing problems. A few improved strategies had proposed to solve the power sharing problems. The proposed strategy first identifies the reactive power sharing errors through injecting small real-reactive power coupling conflicts, which are actuated by the low-bandwidth synchronization flag signals from the central controller. By deploying the injected transient real-reactive power coupling using an intermittent integral control the accurate reactive power sharing is realized. The reactive power sharing errors are significantly decreased with this proposed scheme. The proposed droop controller will automatically switched back to the conventional droop controller after compensation. We can note that the proposed accurate power control strategy is active for micrograds with all types of configurations and load locations, and it does not require the detailed microgrid structural information. Simulation results are provided to verify the proposed load demand sharing strategy.

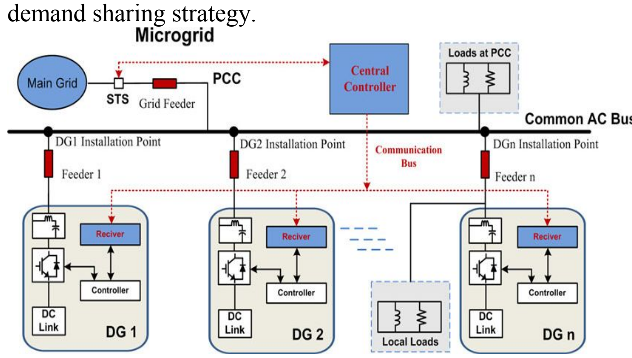

Fig. 1. Illustration of the micro grid configuration

II. ANALYSIS OF THE CONVENTIONAL DROOP CONTROL METHOD

A. Operation of Micro grid:

As shown in Fig. 1, the micro grid is composed of a number of DG units and loads. Each DG unit is interfaced to the micro grid with an inverter, and the inverters are connected to the common ac bus through their respective feeders. The micro

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grid and main grid status are monitored by the secondary central controller. According to the operation requirements, the micro grid can be connected (grid-connected mode) or disconnected from the main grid by controlling the static transfer switch (STS) at the point of common coupling (PCC). During the grid-connected operation, real and reactive power references are normally assigned by the central controller and the conventional droop control method can be used for power tracking. However, to eliminate the steady-state reactive power tracking errors, the PI regulation for the voltage magnitude control was developed. So, power sharing is not a real concern during the grid-connected operation. When the micro grid is switched to islanding operation, the total load demand of the micro grid must be properly shared by these DG units.

During the islanding operation, DG units as illustrated in Fig. 1 can operate using the conventional real power frequency droop control and reactive power–voltage magnitude droop control as

$$\omega = \omega 0 - DP \cdot P \quad (1)$$

$$E = E0 - DQ \cdot Q \quad (2)$$

where $\omega 0$ and $E0$ are the nominal values of DG angular frequency and DG voltage magnitude, P and Q are the measured real and reactive powers after the first-order low-pass filtering (LPF), DP and DQ are the real and reactive power droop slopes. With the derived angular frequency and voltage magnitude in (1) and (2), the instantaneous voltage reference can be obtained accordingly.

B. Reactive Power Sharing Analysis:

The configuration for this analysis is shown in Fig. 2(a), where each DG unit has a local load. $R1$, $X1$ and $R2$, $X2$ are the feeder impedances of DG1 and DG2, respectively. Further considering that DG units are often equipped with series virtual inductors to ensure the stability of the system, the corresponding equivalent circuit is sketched in Fig. 2(b).

For the sake of simplicity, this section first considers a simplified micro grid with two DG units at the same power rating. Fig. 2(b). As shown, the virtual reactances $XV1$ and $XV2$ are placed at the outputs of voltage sources. The magnitudes of the voltage sources are obtained in (3) and (4) as

$$E1 = E0 - DQ \cdot Q1 \quad (3)$$

$$E2 = E0 - DQ \cdot Q2 \quad (4)$$

where $E1$ and $E2$ are the DG voltage magnitudes regulated by the droop control, and $Q1$ and $Q2$ are the output reactive powers of DG1 and DG2, respectively.

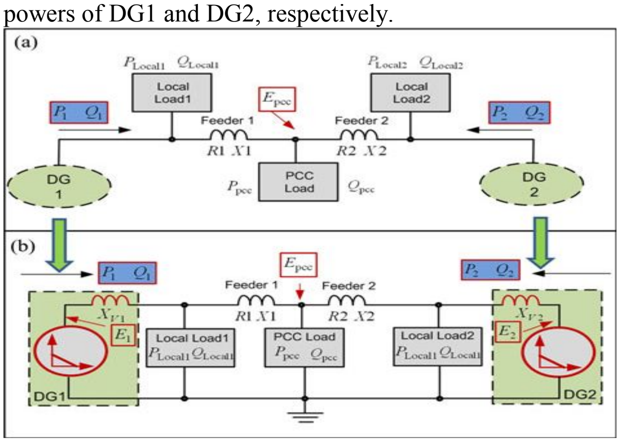

Fig. 2. Power flow in a simple microgrid: (a) configuration of the microgrid; (b) equivalent circuit model considering a virtual impedance control

For the power flowing through either physical or virtual impedance, its associated voltage drop on the impedance yields the following approximation as

$$\Delta V \approx \frac{X \cdot Q + R \cdot P}{E0} \quad (5)$$

Where P and Q are the real and reactive powers at the power sending end of the impedance, R and X are the corresponding resistive and inductive components of the impedance, E0 is the nominal voltage magnitude, and ΔV is the voltage magnitude drop on the impedance. Applying the voltage drop approximation in (5) to the presented system in Fig. 2, the relationships between DG voltages (E1 and E2) and the PCC voltage (EPCC) can be established in (6) and (7) as

$$E1 = \frac{EPCC + X1 \cdot (Q1 - QLocal1) + R1 \cdot (P1 - PLocal1)}{E0} + \frac{XV1 \cdot Q1}{E0} \quad (6)$$

$$E2 = \frac{EPCC + X2 \cdot (Q2 - QLocal2) + R2 \cdot (P2 - PLocal2)}{E0} + \frac{XV2 \cdot Q2}{E0} \quad (7)$$

It is important to note that with system frequency as the communication link, the real power sharing using the conventional droop control is always accurate. Therefore, for the illustrated system at the steady state, the output real powers of DG1 and DG2 are obtained as

$$P1 = P2 = 0.5 \cdot PTotal = 0.5 \cdot (Ppcc + PLocal1 + PLocal2 + PFeeder1 + PFeeder2)$$

where $PTotal$ means the real power demand within the islanded microgrid, and $PFeeder1$ and $PFeeder2$ are the real power loss on the feeders. Similarly, the reactive power demand ($QTotal$) is defined as

$$QTotal = Qpcc + QLocal1 + QLocal2 + QFeeder1 + QFeeder2$$

where $QFeeder1$ and $QFeeder2$ are the reactive power loss on the feeders.

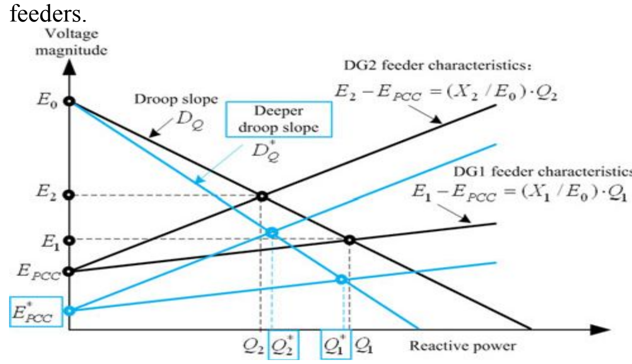

Fig. 3. Reactive power sharing of two DG units with mismatched feeder reactance.

It can also be observed that deeper droop slope D^*Q might alleviate the reactive power sharing errors ($Q^*1 - Q^*2$). However, the nontrivial feeder impedance may affect this error as well. Also, a deeper droop slope will cause many issues, such as a too low PCC voltage ($E*$ PCC), reactive power demand variations (due to voltage change), etc., and therefore, it is not considered as a good option [7].

III. PROPOSED REACTIVE POWER SHARING ERROR COMPENSATION METHOD

Since the reactive power sharing errors are caused by a number of factors and micro grids often have complex configurations, developing the circuit model-based reactive power sharing error compensation strategy is difficult. Therefore, the objective of this section is to develop an enhanced compensation method that can eliminate the reactive power sharing errors without knowing the detailed micro grid configuration. This feature is very important to achieve the "plug-and-play" operation of DG units and loads in the micro grid.

A. Proposed Compensation Control:

To initialize the compensation, the proposed method adopts a low-bandwidth communication link to connect the secondary central controller with DG local controllers. The commutation link sends out the synchronized compensation flag signals from the central controller to each DG unit, so that all the DG units can start the compensation at the same time. This communication link is also responsible for sending the power reference for dispatch able DG units during the micro grid grid-tied operation. The communication mechanism can be realized using power line signalling or smart metering technologies, or other commercial infrastructures, such as digital subscriber lines, or wireless communications.

The enhanced power control strategy is realized through the following two stages.

1) Stage 1: Initial Power Sharing Using Conventional Droop Method:

Before receiving the compensation flag signal, the conventional droop controllers (1) and (2) are adopted for initial load power sharing. Meanwhile, the DG local controller monitors the status of the compensation flag dispatched from the micro grid central controller. During this stage, the steady-state averaged real power (*P*AVE) shall also be measured for use in *Stage 2*. Note that although the first-order LPFs have already been used in measuring the real and reactive powers (*P* and *Q*) for the conventional droop controller in (1) and (2), the cut off frequency of LPFs cannot be made very low to get the ripple free averaged real power (*P*AVE) due to the consideration of system stability. It is important to point out that although the averaged real power (*P*AVE) is measured at this stage, the real and reactive powers used in droop controller (1) and (2) are still conditioned by only first-order LPFs as shown in Fig. 4.

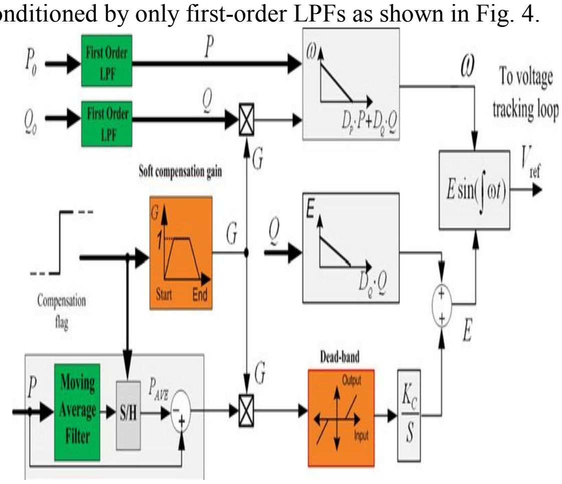

Fig. 4. Synchronized reactive power compensation scheme.

2) Stage 2: Power Sharing Improvement Through Synchronized Compensation:

In Stage 2, the reactive power sharing error is compensated by introducing a real-reactive power coupling transient and using an integral voltage magnitude control term. As this compensation is based on the transient coupling power control, it shall be carried out in all DG units in a synchronized manner. Once a compensation starting signal (sent from the central controller) is received by the DG unit local controller, the averaged real power calculation stops updating, and the last calculated PAVE is saved and used as an input of the compensation scheme. Fig. 4 demonstrates the diagram of the proposed control strategy, where *P*0 and *Q*0 are the measured powers before LPF. When the compensation is not enabled, the conventional power sharing method as shown in (1) and (2) is adopted. In Fig. 4, the unity soft compensation gain *G* is adopted for the proposed compensation method, which can avoid the excess power oscillations and current overshoots during the compensation transient. At the beginning of each compensation, the gain *G* will increase slowly to the rated value. After the compensation, *G* will decrease slowly to zero again, meaning that the droop controller is smoothly switched back to the conventional droop control mode.

The proposed method is developed based on the assumption that the real power load demand is constant during the compensation transient in *Stage 2*. For a real power load variation during the compensation stage, the proposed controller may leave some reactive power sharing errors after the compensation. To limit the impacts of small real power demand variations during the compensation transient, a dead band is placed before the integral control of the real power difference (*P*−*P*AVE). To avoid the impacts of large load demand variations or load switching in a micro grid, the compensation period should be properly designed by tuning the integral gain (Kc).

B. Small-Signal Modelling and Analysis:

Small-signal stability is defined as the ability of a power system to maintain its synchronism after being subjected to a small disturbance. The characteristics of a power system can be obtained by small signal analysis [22] using linear techniques.

3.2.1 for reactive power sharing error compensation method

The stability of DG units during the compensation process is investigated by small-signal stability analysis [10], [22]. First, the power flow of the DG unit is obtained as,

$P = (EVY \cos\theta - V^2 Y) \cos\phi - EVY \sin\phi \sin\theta$ (10)

$Q = (V^2 Y - EVY \cos\theta) \sin\phi - EVY \cos\phi \cos\theta$ (11)

where Y and Φ are the magnitude and angle of DG feeder admittance; E and V are the voltage magnitude at the DG unit output and the installation point, respectively. Θ is the power angle.

Accordingly, real and reactive power variations according to DG voltage disturbances are obtained in (12) and (13) as,

$\Delta P_0 = K_{P\Theta} \Delta\Theta + K_{PE} \Delta E$ (12)

$\Delta Q_0 = K_{Q\Theta} \Delta\Theta + K_{QE} \Delta E$ (13)

where P0 and Q0 are the instantaneous output powers of the DG unit, the operator Δ means small-signal disturbance around the DG system equilibrium point, KPΘ, KPE, KQΘ, and KQE represent the power flow sensitivity to voltage angle and magnitude regulation.

When there are some power fluctuations during the compensation, by expanding the proposed compensation method in (9) and (10), the small-signal response of the DG voltage is expressed from (15) to (18) as

$$\Delta\omega = -D_P \cdot \Delta P - D_Q \cdot \Delta Q \quad (15)$$

$$\Delta E = -D_Q \cdot \Delta Q + \left(\frac{K_C}{s}\right) \cdot \Delta P \quad (16)$$

$$\Delta P = \frac{1}{(\tau s + 1)} \cdot \Delta P_o \quad (17)$$

$$\Delta Q = \frac{1}{(\tau s + 1)} \cdot \Delta Q_o \quad (18)$$

where τ is the time constant of LPFs used in the power calculation. Considering that$\Delta\theta = (1/s) \cdot \Delta\omega$, by a simple manipulation on (13) to (18), the dynamic performance of the DG unit during the compensation yields the following matrix equation as

$$(A\,[2\times 2] - B\,[2\times 2]\cdot C[2\times 2])\cdot[\Delta\theta, \quad \Delta E]^T = 0 \quad (19)$$

where

$$A\,[2\times 2] = \begin{bmatrix} s(\tau s+1) & 0 \\ 0 & s(\tau s+1) \end{bmatrix}$$

$$B\,[2\times 2] = \begin{bmatrix} -D_P & -D_Q \\ K_C & -D_Q\cdot s \end{bmatrix}$$

$$C\,[2\times 2] = \begin{bmatrix} k_{P\theta} & k_{PE} \\ k_{Q\theta} & k_{QE} \end{bmatrix}.$$

Furthermore, the closed-loop characteristic equation of the matrix equation can be obtained in

$s4\Delta\theta + As3\Delta\theta + Bs2\Delta\theta + Cs\Delta\theta + D = 0$ (20)

where *A, B, C,* and *D*, as shown in the equation at the bottom of the next page. The eigenvalues of (19) and (20) indicate the small-signals response of the DG unit during the compensation. Note that when the nondiagonal elements of $B[2\times 2]$ are zero as

$$B\,[2\times 2] = \begin{bmatrix} -D_P & 0 \\ 0 & -D_Q\cdot s \end{bmatrix}$$

the corresponding matrix (19) essentially describes the behavior of the DG unit using the conventional droop control in (1) and(2).

Fuzzy logic

Considering that the variation of microgrid load demand, such as that in the residential area microgrids, is normally slow, a compensation time of a few seconds in Phase 2 is considered in this study

A compensation dynamic of a few seconds also ensures that the compensation performance is not very sensitive to the "compensation flag" synchronization accuracy. So, the requirements on the communication link bandwidth and the response time of DG unit local controllers can be quite low. This project is again designed by replacing droop controller with fuzzy logic controller. FLC generates the required small change for amplitude modulation index to control the magnitude of the injected voltage. The centred defuzzyfication technique was used in this fuzzy controller

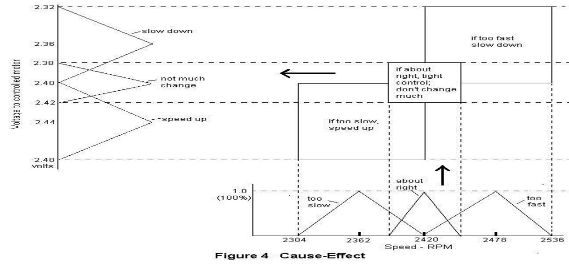

Figure 5. Membership Functions

The rules for fuzzy logic controller are:

Δe \ e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NM	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PM	PB
PB	ZE	PS	PS	PM	PB	PB	PB

Fig 6.

IV. RESULTS AND DISCUSSION

A networked microgrid model has been established using MATLAB/Simulink. As shown in Fig. 7, the simulated microgridis composed of three identical DG units and two linear loads. With the same power rating, three DG units shall share the load equally. The detailed configuration of the DG unit is presented in Fig. 8, where an *LC* filter is placed between the IGBT bridge outputs and the DG feeders. The DG line current and filter capacitor voltage are measured to calculate the real and reactive powers. In addition, the well known multiloop voltage controller is employed to track the reference voltage [7], [8] [14]. The circuit and control parameters of the DG unit are listed in Table I.

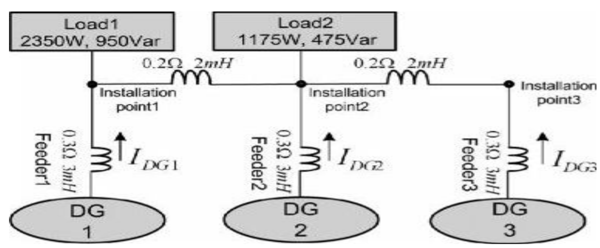

Fig 7: Networked microgrid in the simulation

TABLE I

DG SYSTEM PARAMETERS

Parameter		Values
Interfaced Inverter **(Simulation& Experiment)**	Filter Inductor (L_f/R_f)	L:5*mH*/R:0.2Ω
	Filter Capacitor (C_f)	40*uF*
	Sampling-switching frequency	9kHz-4.5kHz
Microgrid Parameter **(Simulation)**	Rated RMS voltage (Line-Line)	208V (60Hz)
	Total Loads	3525W-1425Var
Droop coefficients **(Simulation)**	Frequency droop D_P	0.00125 Rad / (Sec • W)
	Voltage droop D_Q	0.00143 V/Var
	Integration dead-band	6 W
	Integral gain *Kc*	0.0286 V/ (Sec • W)
	LPF time constant τ	0.0159 Sec
Microgrid Parameter **(Experiment)**	Rated RMS voltage (Line-Line)	104V/60Hz
	Total Loads	540W/280Var
Droop coefficients **(Experiment)**	Frequency droop D_P	0.00143 Rad/(Sec • W)
	Voltage droop D_Q	0.00167 V/Var
	Integration dead-band	6 W
	Integral gain	0.0286 V/ (Sec • W)
	LPF time constant τ	0.0159 Sec

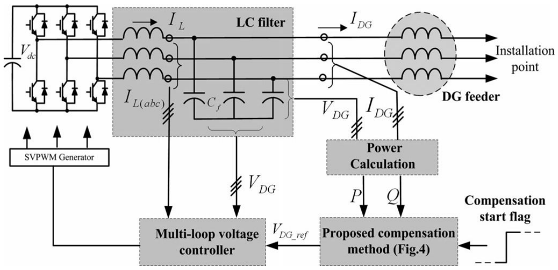

Fig. 8. Configuration of the DG unit

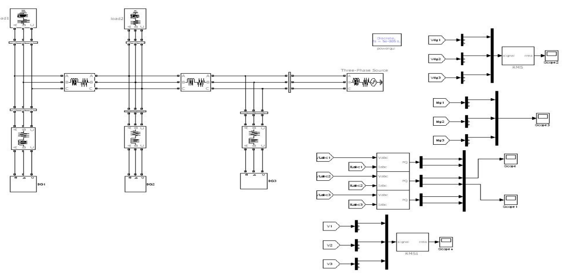

Fig 9. Simulink Micro Grid Circuit

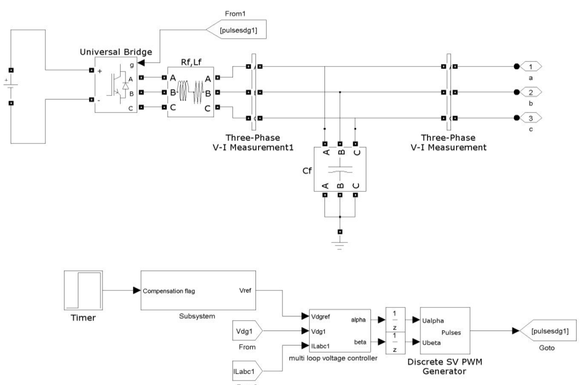

Fig 10. Configuration of the DG unit

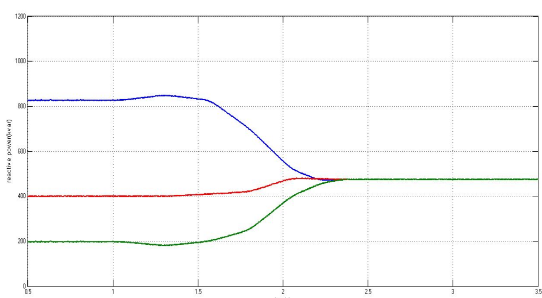

Fig.11.Simulated reactive power sharing performance in a networkmicrogrid (compensated is activated at 1 s).

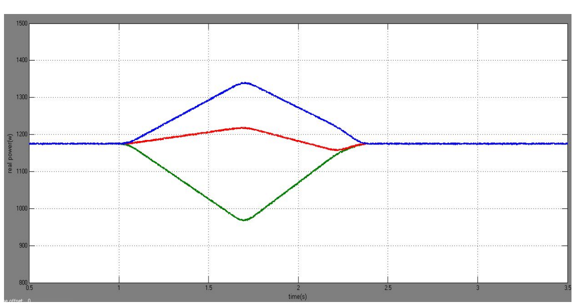

Fig 12.Simulated real power allocation presentation in a complex micro grid Using PI Controller (Compensation is activated at 1 s).

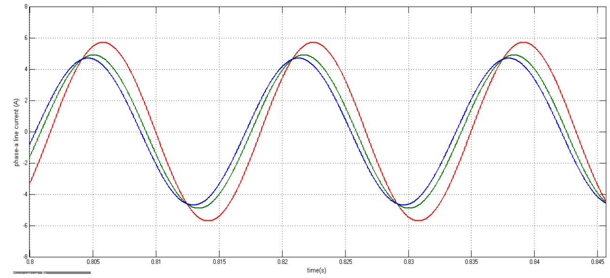

Fig 13.Simulated DG currents before compensation Using PI Controller

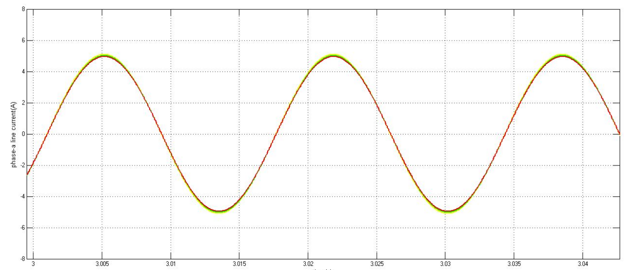

Fig 14.Simulated DG currents after compensation Using PI Controller.

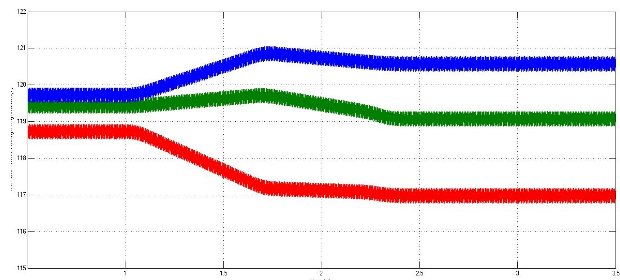

Fig 15 Simulated DG voltage magnitudes Using PI Controller.

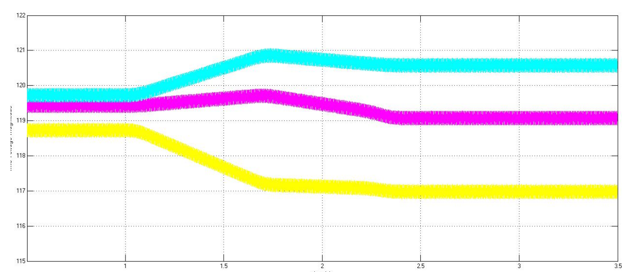

Fig 16.Simulated installation points voltage magnitudes Using PI Controller.

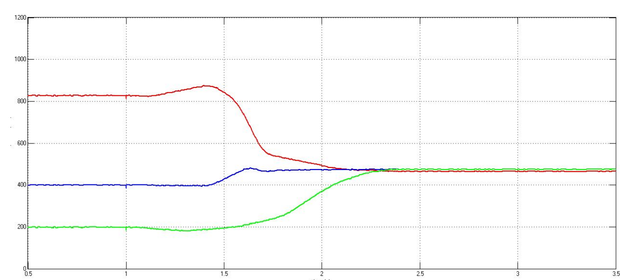

Fig 17 Simulated reactive power distribution performance in a network micro grid Using PI Controller (0.1 s synchronization flag delay in DG unit1)

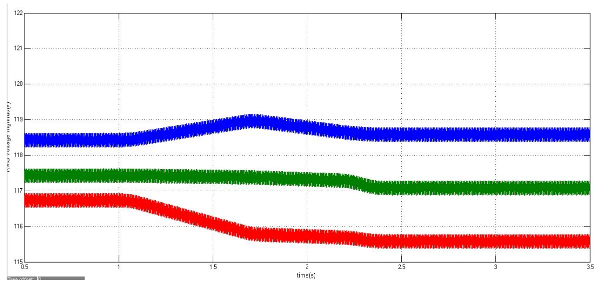

Fig. 18. Simulated installation points voltage magnitudes.

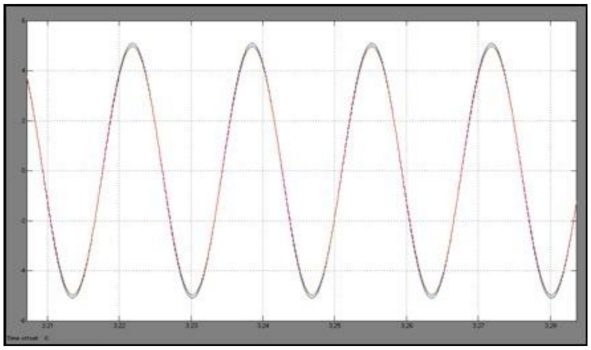

Fig.19.Simulated DG currents after compensation Using FLC.

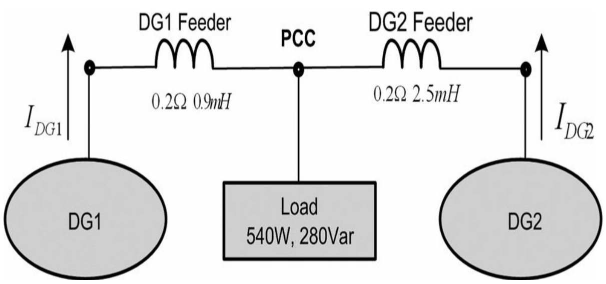

Fig. 20. Hardware microgrid in the experiment.

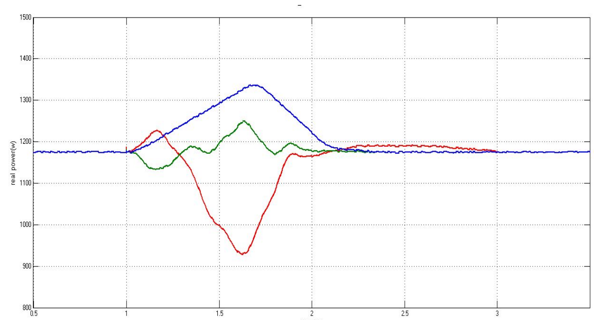

Fig. 21. Simulated real power sharing performance (bypass DG1 feeder impedance).

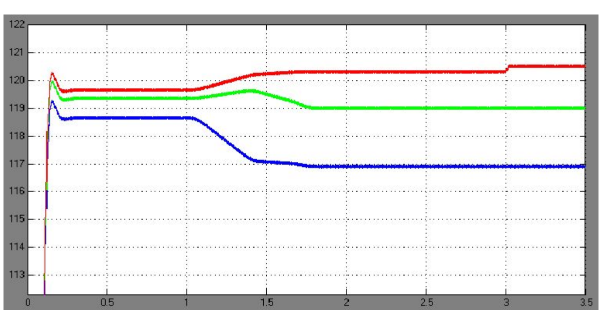

Fig 22. Simulated DG voltage magnitudes Using FLC.

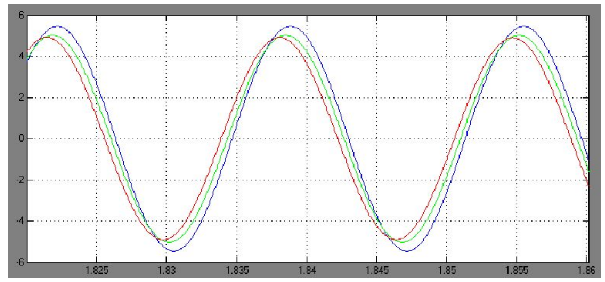

Fig 23.Simulated DG currents before compensation Using FLC.

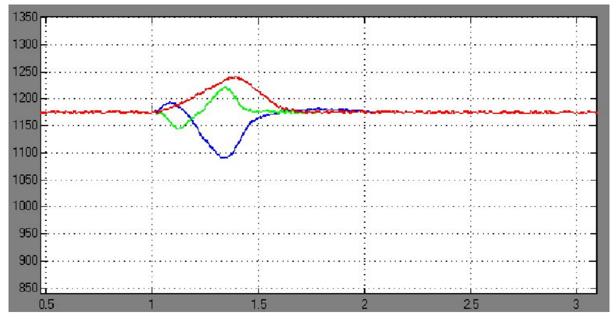

Fig 24.Simulated real power allocation presentation in a complex micro grid Using FLC (Compensation is activated at 1 s).

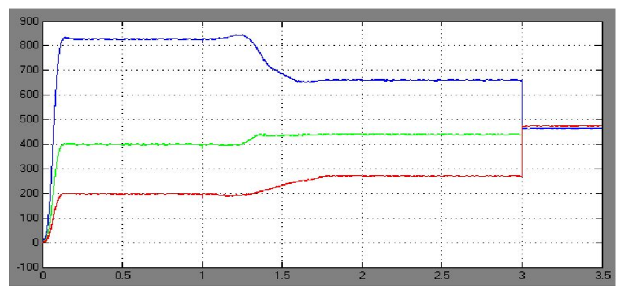

Fig 25.Simulated reactive power sharing performance in a network micro grid Using FLC (compensated is activated at 1 s).

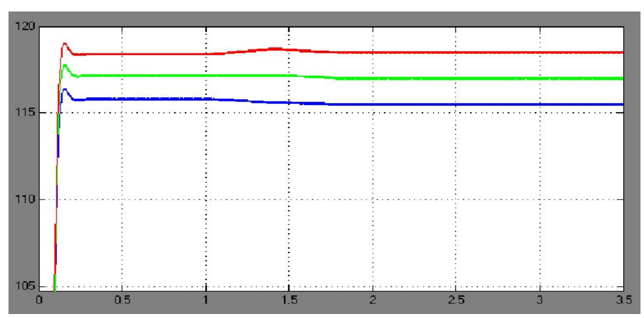

Fig 26. Simulated installation points voltage magnitudes Using FLC.

CONCLUSION

In this project, an improved microgrid reactive power sharing strategy was proposed. The strategy injects a real-reactive power transient coupling term to identify the errors of reactive power sharing and then compensates the errors using a slow integral term for the DG voltage magnitude control. The compensation strategy also uses a low-bandwidth flag signal from the microgrid central controller to activate the compensation of all DG units in a synchronized manner. So, accurate power sharing can be achieved while without any physical communications among DG units. In addition, the proposed strategy is not sensitive to microgrid configurations, which is especially suitable for a complex mesh or networked microgrid. The droop controller is replaced by FUZZY logic controller for the better performance of the proposed system. Simulation results validate the feasibility of the proposed strategy and by using FUZZY logic controller

REFERENCES

[1] A. Mehrizi-Sani and R. Iravani, "Potential-function based control of amicrogrid in islanded and grid-connected modes," IEEE Trans. PowerSyst., vol. 25, no. 4, pp. 1883– 1891, Nov. 2010.
[2] K. D. Brabandere, B. Bolsens, J. V. D. Keybus, A.Woyte, J. Drisen, andR. Belmans, "A voltage and frequency droop control strategy for parallelinverters," IEEE Trans. Power Electron., vol. 22, no. 4, pp. 1107–1115,Jul. 2007
[3] Y. Li and Y.W. Li, "Powermanagement of inverter interfaced autonomousmicrogrid based on virtual frequencyvoltage frame," IEEE Trans. SmartGrid., vol. 2, no. 1, pp. 30–40, Mar. 2011.
[4] A. Tuladhar, H. Jin, T. Unger, and K.Mauch, "Control of parallel invertersin distributed AC power system with consideration of line impedanceeffect," IEEE Trans. Ind. Appl., vol. 36, no. 1, pp. 131–138, Jan./Feb.2000
[5] C.-T. Lee, C.-C. Chu, and P.-T. Cheng, "A new droop control strategyfor the autonomous operation of distributed energy resource interfaceconverters," in Proc. Conf. Rec. IEEE Energy Convers. Congr. Expo.,Atlanta, GA, 2010, pp. 702–709.
[6] J. M. Guerrero, L. G. Vicuna, J. Matas, M. Castilla, and J. Miret, "Awireless controller to enhance dynamic performance of parallel invertersin distributed generation systems," IEEE Trans. Power Electron., vol. 19,no. 4, pp.1205–1213, Sep. 2004.
[7] Y. W. Li and C.-N. Kao, "An accurate power control strategy for powerelectronics-interfaced distributed generation units operation in a low voltagemultibusmicrogrid," IEEE Trans. Power Electron., vol. 24, no. 12,pp. 2977–2988, Dec. 2009.
[8] J. He and Y. W. Li, "Analysis, design and implementation of virtualimpedance for power electronics interfaced distributed generation," IEEETrans. Ind. Appl., vol. 47, no. 6, pp. 2525–2538, Nov./Dec. 2011.
[9] E. A. A. Coelho, P. C. Cortizo, and P. F. D. Garcia, "Small-signal stability for parallel-connected inverters in stand-alone AC supply systems," *IEEE Trans. Ind. Appl.*, vol. 38, no. 2, pp. 533–542, Mar./Apr. 2002.
[10] N. Pogaku, M. Prodanovic, and T. C. Green, "Modeling, analysis and testing of autonomous operation of an inverter-based microgrid," *IEEE Trans. Power Electron.*, vol. 22, no. 2, pp. 613–625, Mar. 2007.
[11] Y.W. Li, D. M. Vilathgamuwa, and P. C. Loh, "Design, analysis and realtime testing of a controller for multibus microgrid system," *IEEE Trans. Power Electron*, vol. 19, no. 5, pp. 1195–1204, Sep. 2004.
[12] J. A. Jardini, C. M. V. Tahan, M. R. Gouvea, S. U. Ahn, and F. M. Figueiredo, "Daily load profiles for residential, commercial and industrial low voltage consumers," *IEEE Trans. Power Del.*, vol. 15, no. 1, pp. 375–380, Jan. 2000.
[13] D. N. Zmood and D. G. Holmes, "Stationary frame current regulation of PWM inverters with zero steady-state error," *IEEE Trans. Power Electron.*, vol. 18, no. 3, pp. 814–822, May 2003.
[14] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. de Vicuna, and M. Castilla, "Hierarchical control of droop-controlledAC andDCmicrogrids—A general approach toward standardization," *IEEE Trans. Ind. Electron.*, vol. 55, no. 1, pp. 158–172, Jan. 2011.
[15] L. Corradini, P.Mattavelli, M. Corradin, and F. Polo, "Analysis of parallel operation of uninterruptible power supplies though long wiring cables," *IEEE Trans. Power Electron.*, vol. 25, no. 4, pp. 2806–2816, Apr. 2010.
[16] D. De and V. Ramanarayanan, "Decentralized parallel operation of inverters sharing unbalanced and nonlinear loads," *IEEE Trans. Power Electron.*, vol. 25, no. 12, pp. 3015–3025, Dec. 2010.

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