Research Article
Comparative Study of Power Sharing Performance in Micro-grid under Two Different Platforms-PSCAD/EMTDC and MATLAB/SIMULINK Simpower System

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Abstract: This study compares the performance of the power sharing method for a microgrid by considering control modes under 2 different simulation platforms: PSCAD/EMTDC and MATLAB/SIMULINKSIM power system. The Consortium for Electric Reliability Technology Solutions (CERTS) microgrid test model that contains 3 DGs with voltage ratings of 4.14 kV is presented as a case study. Simulation studies are carried out under two cases. In case 1, the system is simulated when all DGs operate in UPC mode. In case 2, all DGs operate in FFC-UPC-FFC mode. The performance comparison of PSCAD and MATLAB is evaluated under different simulation time period: grid connected mode from 0-2 sec and island mode from 2-4 sec. load variation under grid connected and island mode is also analysed.

Keywords: Active power, Distributed Generation (DG), feeder flow, frequency deviation, microgrid

INTRODUCTION

In the existing scenario, the foremost challenge faced by the power system are ambiguity of increasing load, non-availability of fuel source, frequent load shedding, reliability and major part of power is exhausted as T and D losses. These criteria make the power system more complex (Mohamed and El-Saadany, 2008). The inclusion of DG units becomes more favorable because the fuel constraint of the centralized power generation. Switching to an integration of DG renewable sources gaining the attraction rapidly, as the present centralized power generation scheme has a constraint of increasing fuel cost. These interactions results in economic operation and enhanced reliability through mutual assistance (Nguyen et al., 2012).

The attractive feature of DG is that they are close to customer location. They are inexpensive than the central station power generation and its allied T and D system. Hence DG can afford enhanced service at lower cost. DG has changed the way of power system operators in order to satisfy the power supply demand by means of permitting local level power generation services (Del Monaco, 2001). The DG unit only initiates the trend of bidirectional flow of power. This results in undesirable effects of usual power flow and voltage control equipment in the present power system (Maurhoff and Wood, 2000). A network of interconnection of power system at a local level with various DG units is called as microgrid. The microgrid approach is targeted on designing for small scale power delivery that satisfies the demands of the constituents. At the local level, microgrid assimilates the end user and buildings with power generation and distribution (Jiayi et al., 2008). Microgrid permits the end user to generate electric power in real-time at appreciably lesser cost. The ability of microgrid to employ small scale power generation and also the utilization of waste heat is the most considerable ecological reimbursement (Marnay and Venkataramanan, 2006).

The most recent novelty like Photovoltaic (PV) cells, solar cells and Fuel Cells (FC) are hinged on inverter in order to link up by means of the distribution system (Liang et al., 2012). Therefore, VSC (Voltage Source Converter) coupled with microgrid in parallel to meet a common load (Sao and Lehn, 2008).

Essentially, a microgrid performs in two operating conditions. Once the microgrid is make contact with the power grid at the intersection of PCC (Point of

Common Coupling), then the microgrid operates in grid-tied mode (Piagi and Lasseter, 2004). Once the microgrid is standing apart from the power grid, then it operates in island mode. If there exists some break down occurs in microgrid, it will switch over to island mode automatically. This exhibits that there is no possibility of power supply interruption to the end users (Griffiths and Colin, 2006).

The microgrid poses two power control modes viz, Unit Power output Control (UPC) and Feeder Flow Control (FFC). These control mode gains its importance in the view of appropriate power sharing among DG units (Katiraei and Iravani, 2006). UPC is projected for active power sharing among manifold DGs. In this mode the DG output power is maintained constant in accordance with the power reference. While in FFC mode, the DG power output is controlled in order to maintain the feeder flow constant (Lasseter, 2006).

METHODOLOGY

The power-control modes description: This segment explores the key point of two power control modes viz., UPC mode and FFC mode.

Unit output Power Control (UPC) mode: The main role of this mode is to control over the power which is injected by the DGs at the required value (P_{ref}). This can be achieved by measuring Voltage (V) at the point of interconnection of microgrid and the current (I) through the DG units as shown in Fig. 1. From this measured value of voltage and current, power injection (P_{DG}) is computed. Finally, thus obtained P_{DG} is fed to the Direct Controller (DC).

In grid-tied mode, the DG units are capable of regulating a constant output power irrespective of varying loads. This is due to the reason the power mismatches are satisfied by the power grid. On the other side, in the case of autonomous mode, the DG units are in need of satisfying the load demand appropriately (Piagi and Lasseter, 2006). So for power sharing droop control method have been adopted. This method is employed by using microgrid frequency as a common signal to equalize the active power generation among the DGs. This state of droop control is noted as a P-F droop control. This type of droop control is more widely adopted for fluctuating operating conditions in power system like frequency or/and voltage based loads and also concerned with system losses (Guerrero *et al.*, 2004). The following equation represents the correlation between the microgrid frequency (f) and DG output Power (P):

$$f' = f^0 - K^U(P' - P^0) \qquad (1)$$

where,
K^U = UPC droop constant
$\acute{f}$ and P' = New operating points of frequency and DG output power
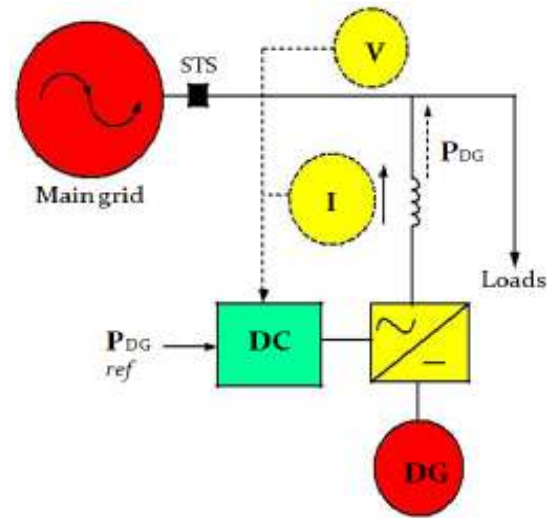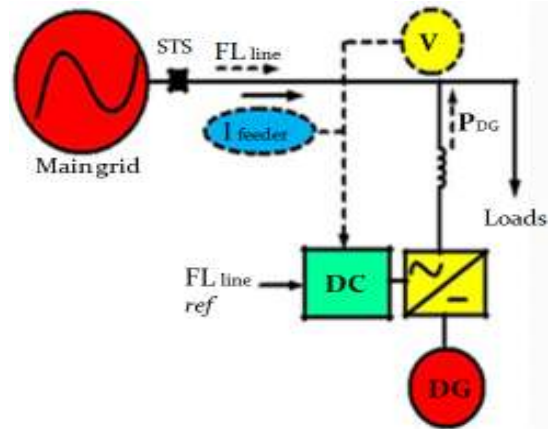

Fig. 1: Unit output Power Control mode (UPC)

Fig. 2: Feeder Flow Control (FFC)

f^0 and P^0 = Nominal values of frequency and voltage

As per this equation, in island mode for a increase in load, output power of the DG unit increases while the frequency of the microgrid tends to decrease (Guerrero *et al.*, 2007).

Feeder Flow Control (FFC) mode: The concept of this mode is that it controls the DG power output by keeping the active power flow in the Feeder (FL_{ref}) left as constant. In grid-tied mode, when the load tends to increase, the DG units will enhance their power output in order to keep the feeder flow constant. So that the power supply from the power grid is maintain unaltered irrespective of load variation among the DGs (Pogaku *et al.*, 2007). The power flow through the Feeder (FL_{line}) is computed by the measured values of the Voltage (V) at the point of interconnection and the current through feeder (I_{FEEDER}) as shown in Fig. 2.

In autonomous operation, FL-F type of droop control method is employed. As the frequency is kept as
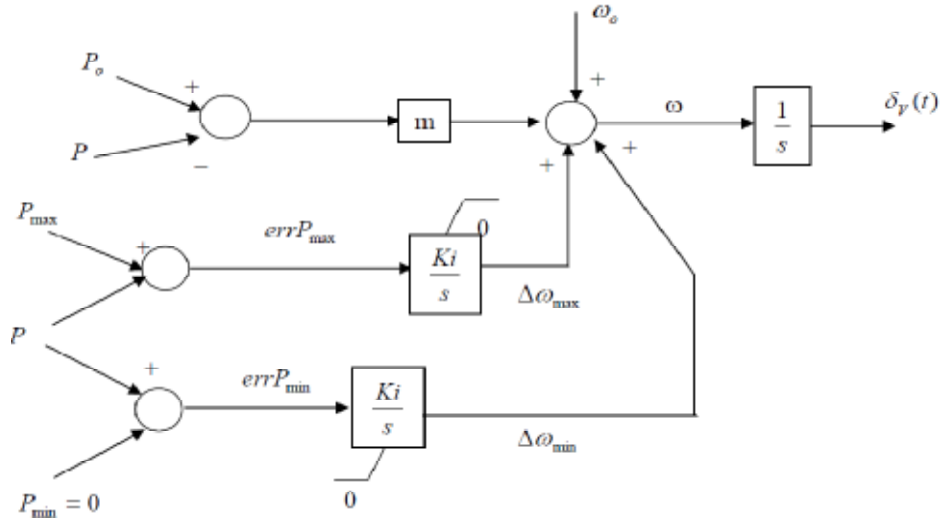
Fig. 3: Control-diagram to enforce limits with Unit output Power Control (UPC)
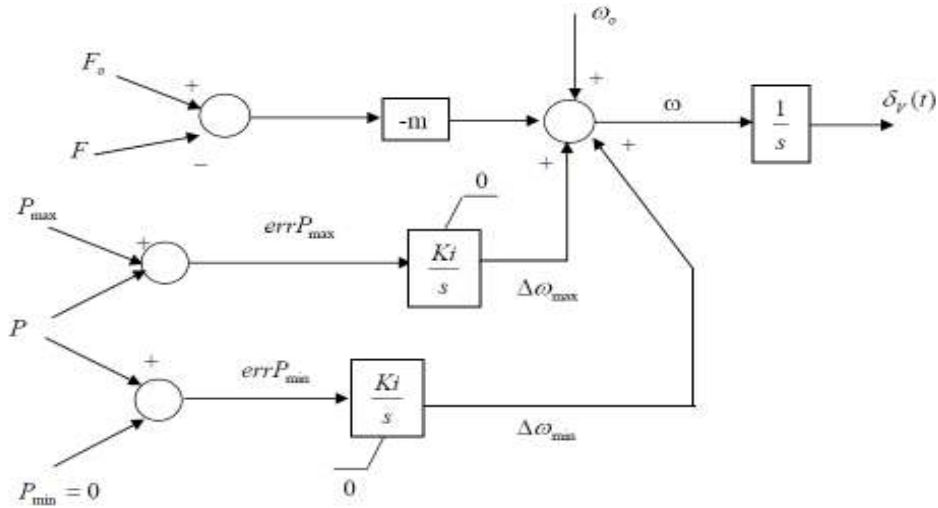

Fig. 4: Control-diagram to enforce limits with Feeder Flow Control (FFC)

a reference signal the power through the feeder flow is balanced. The following equation represents the correlation between the microgrid frequency (f) and Feeder Flow (FL):

$$f' = f^0 - K^F(FL' - FL^0) \qquad (2)$$

where,
K^F = FFC droop constant

As the summation of the Feeder flow (FL_{Line}) to the DG Power output (P_{DG}) is equal to the load i.e.:

$$FL_{Line} + P_{DG} = Loads$$

The value of FFC droop constant (K^F) is chosen in the way that it have the same magnitude and opposite sign of UPC mode (K^U) i.e.:

$$K^F = -K^U$$

DG active power controller: The block diagram that illustrates the active power control to impose limits with UPC and FFC is shown in Fig. 3 and 4 respectively. Here the central controller determines the set points and the input are the frequency (f) and Feeder flow (FL) or Power output (P) which are measured locally. The output is the axis current reference signal for the current controller or the angle of the desired voltage (Moreira *et al.*, 2007). In addition to these, the control block also functioned as:

• Frequency droop control
• Output limit control

As the frequency of the microgrid is more or less equal as that of rated frequency, the active Power (P) and the Feeder flow (FL) is maintained to a fixed value

in grid-tied operation. But in autonomous operation of microgrid, it is the burden of the droop control to satisfy the power mismatches. So that the system will achieve a new steady state values of P and f as per the Eq. (1) and (2).

The steady state P_{DG} is maintained within limits by the output limit control. The output limit must be imposed, as the DG source poses a predetermined capacity for power generation and storage (Lopes *et al.*, 2006).

When the output power surpasses the limits, the output limit control function is triggered and it imposes the limits efficiently.

RESULTS AND DISCUSSION

A single-line diagram modeled with DG controller is shown in Fig. 5 which is simulated using PSCAD in paper 1 at 60 Hz and MATLAB/SIMULINK in MATLAB/SIMULINK at 50 Hz.

The parameters of test model are same in both papers. The test system contains 3 DGs with voltage ratings of 4.14 kV, having maximum power generation limits (arbitrarily chosen to be 2.5, 3.0 and 2.0 MW, respectively). The droop constants were chosen as 1.2, 1 and 1.5, respectively, which mean that 0.05 p.u. frequency deviation leads to 1.0 p.u. changes in the power output of each DG. In order to analysis the performance of the droop control strategy, the simulation results are carried out under two cases.

Case 1: All DGs operate in UPC mode.
Case 2: All DGs operate in FFC-UPC-FFC mode.

The simulation results for active output power, feeder flow and system frequency simulated using PSCAD and MATLAB for case 1 are shown in Fig. 6 and 7, respectively.
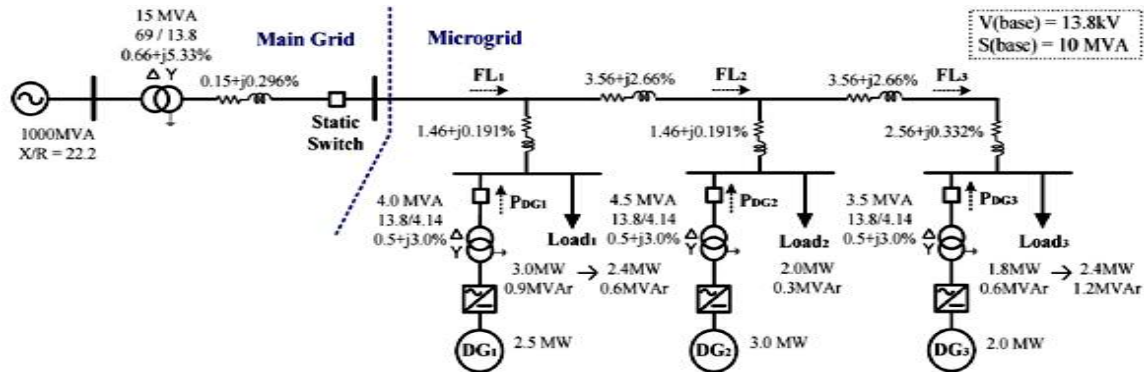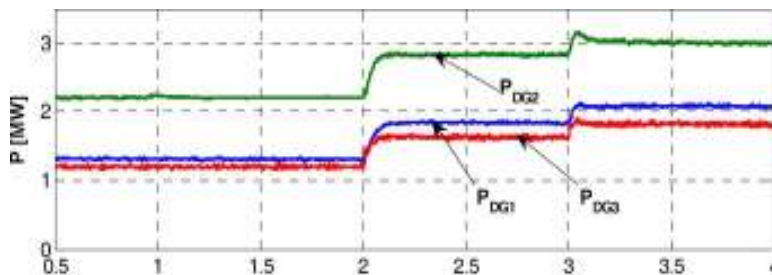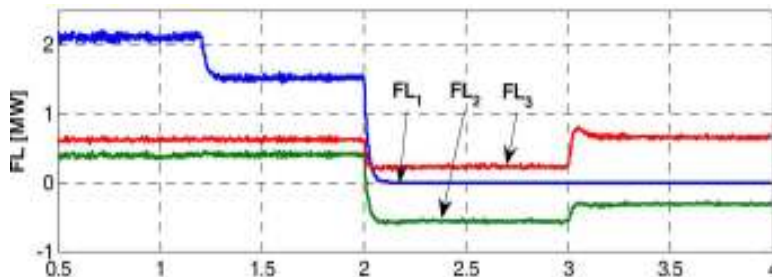

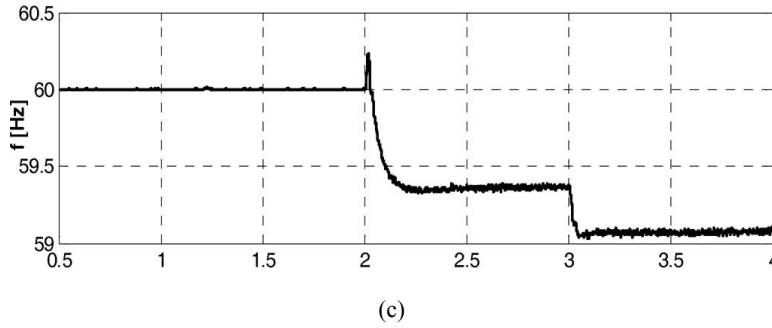Fig. 5: Single line diagram of microgrid arrangement

(a)

(b)

(c)

Fig. 6: Simulation results for case 1- all DGs in UPC mode (simulated using PSCAD), (a) active power output of each DG, (b) power flow in the feeders, (c) system frequency
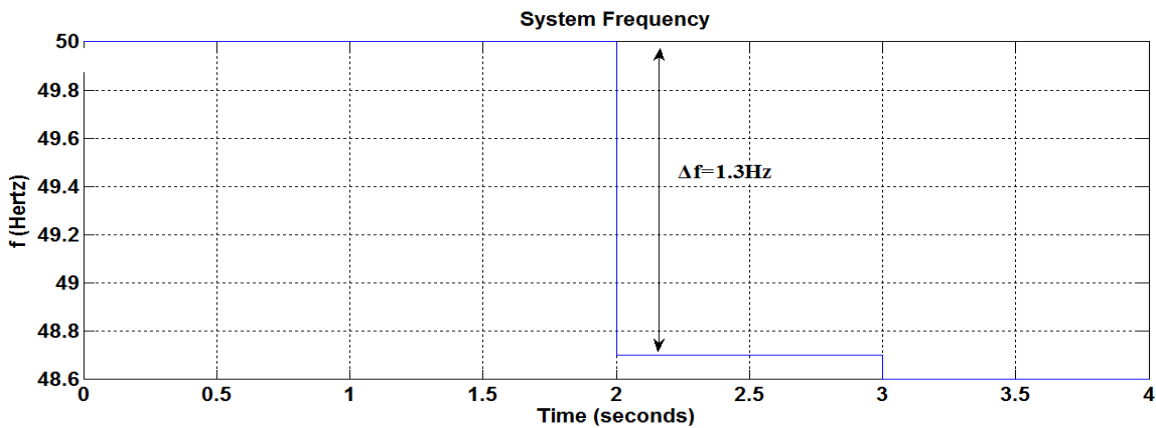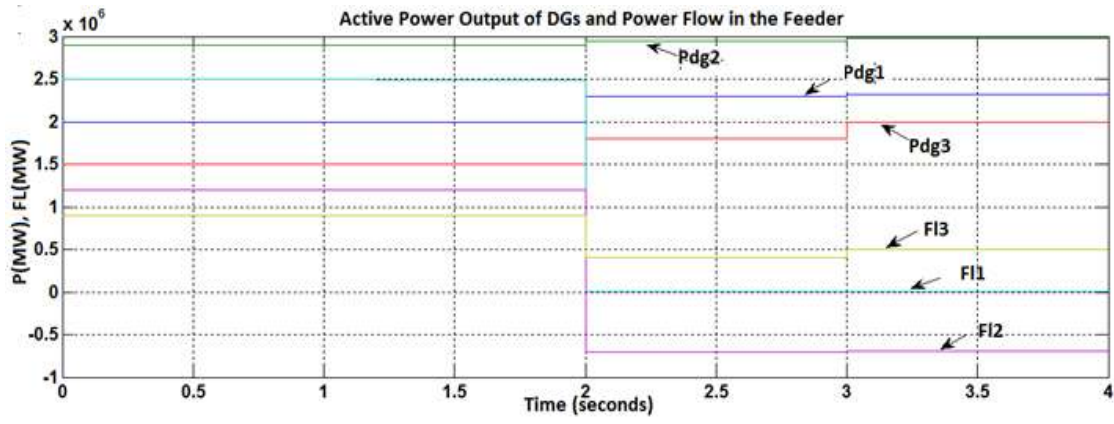

(a)

(b)

Fig. 7: Simulation results for case 1-all DGs in UPC mode (simulated using MATLAB/SIMULINK), (a) active power output of each DG and power flow in the feeders, (b) system frequency

From the simulation results Fig. 6 and 7, a comparison is made between MATLAB and PSCAD when all DGs operate in UPC mode is shown in Table 1.

With an aid of data available from tabulation, a comparison graph (Fig. 8 and 9) is made to visualize the power balance and frequency deviation for case 1.

From the Fig. 8 it is clear that the total power of the microgrid in MATLAB platform is more than the total power under PSCAC. Once the operating mode changes to island mode at 2 sec, the simulation result of PSCAC indicates that the active power generation is not picking up to the level of 6.4 MW. It takes a few seconds of duration to match the load demand of 6.8 MW, whereas MATLAB can able to meet the load demand

immediately. In addition to load demand, MATLAB has excess power generation than PSCAC which can be stored with the help of any storage device.

Similarly from Fig. 9, during grid connected mode, the operating frequency was able to maintain at a nominal frequency because any change in frequency deviation was compensated by the main grid. During the island mode, the deviation in frequency is less under PSCAC/EMTDC than MATLAB/SIMULINK.

Table 1: Comparison between MATLAB and PSCAD when all DGs operate in UPC mode

Case (1) -all DGs operate in the UPC mode

| System parameters/ time (sec)	Paper 1 (PSCAD at 60 Hz)				Paper 2 (MATLAB/SIMULINK at 50 Hz)			
	Grid connected		Autonomous		Grid connected		Autonomous	
	0-1.5	1.5-2.0	2.0-3.0	3.0-4.0	0-1.5	1.5-2.0	2.0-3.0	3.0-4.0
PG1	1.3	1.3	1.80	2.05	2.0	2.0	2.30	2.32
PG2	2.2	2.2	2.75	3.00	2.9	2.9	2.98	3.00
PG3	1.2	1.2	1.60	1.80	1.5	1.5	1.80	2.00
FL1	2.0	1.5	0.00	0.00	2.5	2.5	0.00	0.00
FL2	0.4	0.4	-0.60	-0.40	1.2	1.2	-0.70	-0.70
FL3	0.6	0.6	0.30	0.60	0.9	0.9	0.40	0.50
Frequency	60	60	59.40	59.10	50	50	48.70	48.60
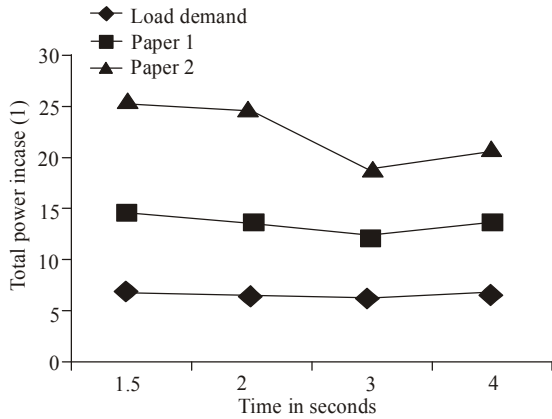
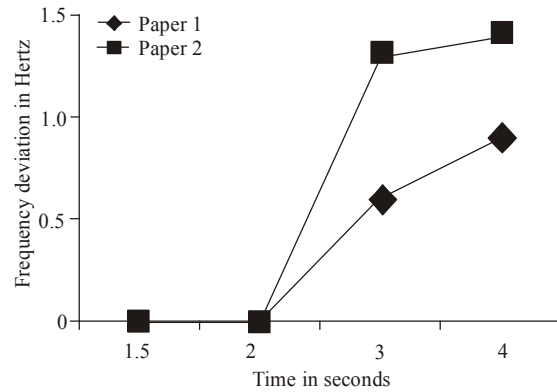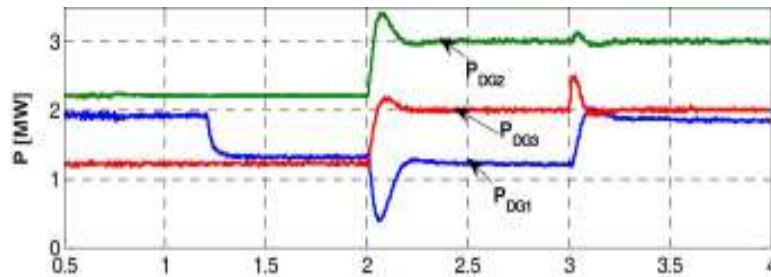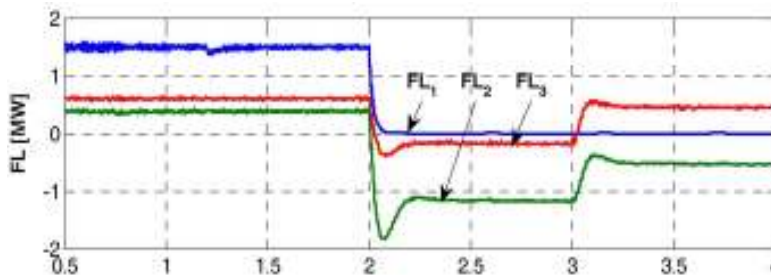Fig. 8: Comparison chart for total power and load demand-case 1

Fig. 9: Comparison chart for frequency deviation-case 1
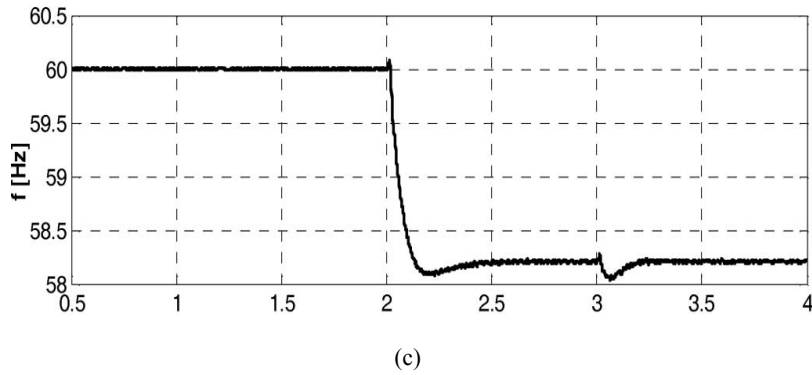

(a)

(b)

(c)

Fig. 10: Simulation results for case 2-all DGs in FFC-UPC-FFC mode (simulated using PSCAD/EMTDC), (a) active power output of each DG, (b) power flow in the feeders, (c) system frequency
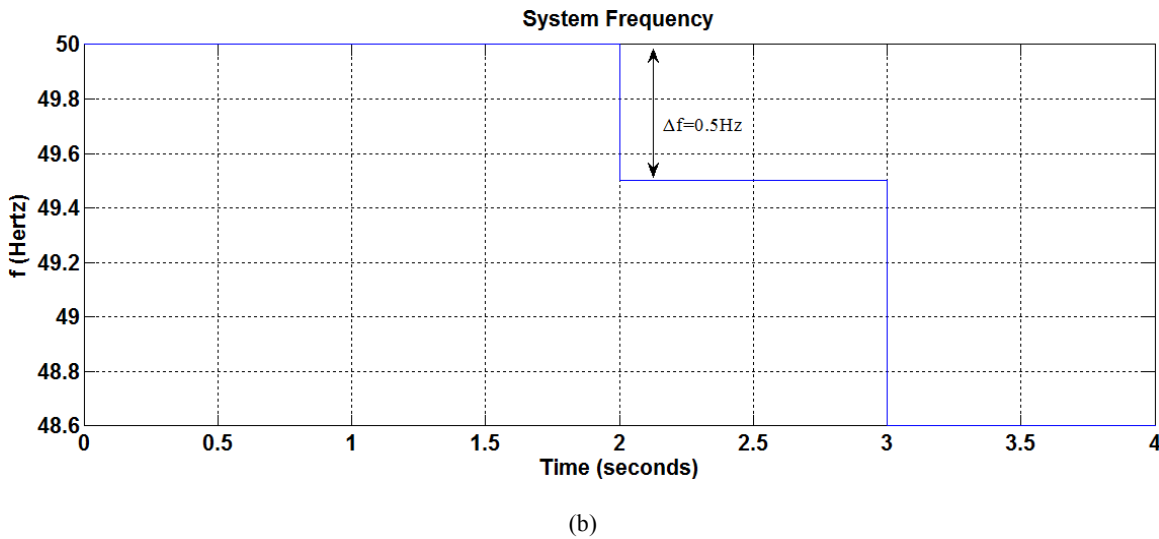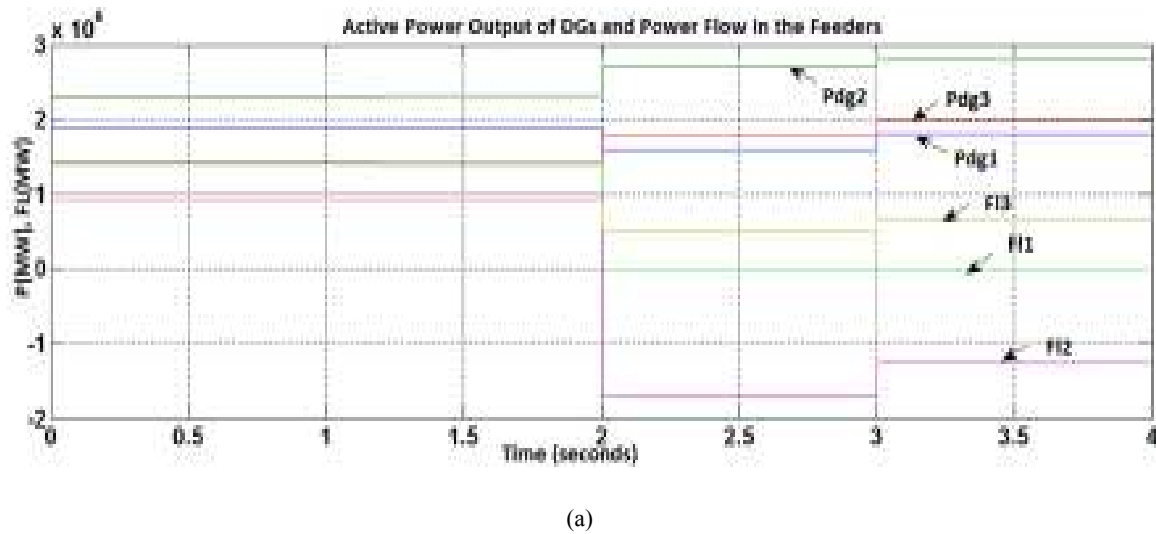

(a)

(b)

Fig. 11: Simulation results for case 2-all DGs in FFC-UPC-FFC mode (simulated using MATLAB/SIMULINK), (a) active power output of each DG and power flow in the feeders, (b) system frequency

In case 2, the simulation results for active output power, feeder flow and system frequency simulated using PSCAD and MATLAB for case 2 are shown in Fig. 10 and 11, respectively.
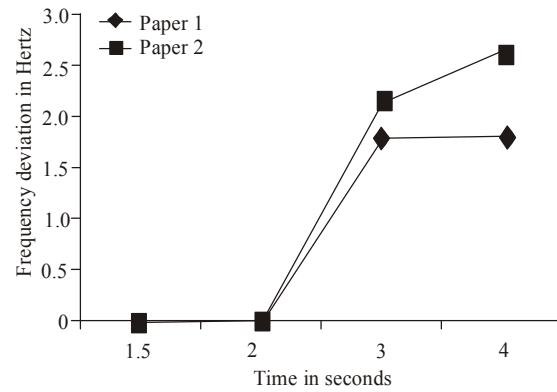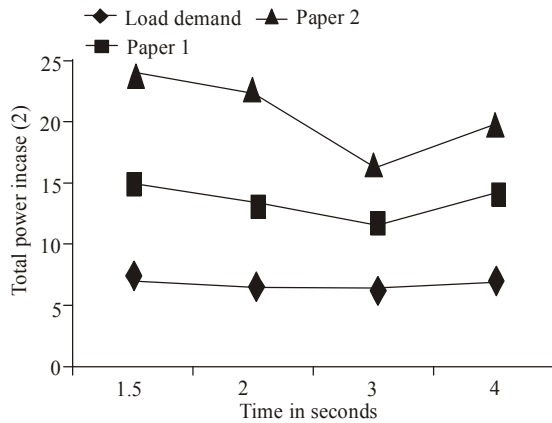
Fig. 12: Comparison chart for total power and load demand-case 2   Fig. 13: Comparison chart for frequency deviation-case 2

Table 2: Comparison between MATLAB and PSCAD when all DGs are operating in FFC-UPC-FFC mode

System parameters/ time (sec)	Case (2) -FFC-UPC-FFC configuration							
	Paper 1 (PSCAD at 60 Hz)				Paper 2 (MATLAB/SIMULINK at 50 Hz)			
	Grid connected		Autonomous		Grid connected		Autonomous	
	0-1.5	1.5-2.0	2.0-3.0	3.0-4.0	0-1.5	1.5-2.0	2.0-3.0	3.0-4.0
PG1	1.99	1.3	1.28	1.9	1.90	1.90	1.70	1.8
PG2	2.20	2.2	3.00	3.0	2.20	2.20	2.70	2.8
PG3	1.20	1.2	2.00	2.0	1.40	1.40	1.80	2.0
FL1	1.50	1.5	0.00	0.0	1.40	1.40	0.00	0.0
FL2	0.40	0.4	-1.20	-0.5	1.00	1.00	-1.70	-1.3
FL3	0.60	0.6	-0.20	0.6	0.98	0.98	0.50	0.6
Frequency	60	60	58.20	58.2	50	50	49.65	49.2

Table 2 shows the comparison of both platforms when all DGs operate in FFC-UPC-FFC mode is shown in Table 2.

From the above available data, the graph is plotted (Fig. 12 and 13) to spot the power balance and frequency deviation for case 2.

As stated in case 1, in case 2 also the power generation simulated under MATLAB is more than the PSCAD platform.

In order to analysis the behavior of microgrid for load variations, operating in island mode, the load is switched over from 6.2 to 6.8 MW at 3 sec. The DGs of PSCAD met the changes in load demand, whereas MATLAB fails. While comparing the frequency deviation in both the platform for grid connected and island mode, the frequency is constant for the grid connected mode of operation. When the operation changes to island mode, the PSCAD exhibits reduced frequency deviation in comparison with MATLAB.

CONCLUSION

This study compares the simulation of microgrid on two different platforms: PSCAD/EMTDC and MATLAB/SIMULINK. This study presents the results on active output power, feeder flow power and system frequency deviation under two cases:

Case 1: All DGs operate in UPC mode
Case 2: All DGs operate in FFC-UPC-FFC mode

In comparing the results, MATLAB/SIMULINK is more flexible in meeting the load demand, whereas PSCAD/EMTDC has more efficient in maintaining the frequency deviation.

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