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A New Strategic Design and Control of MV Microgrid under Unbalanced Condition Including PV&FC

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Abstract:

This paper design a new control strategy for the islanded operation of a medium voltage (MV) microgrid. The microgrid consists of several distributed generation (DG) units such as photovoltaic (PV) and fuel cell (FC) power generation systems. Each distribution generation unit supplies a local loads and nonlocal loads which can be unbalanced due to the inclusion of single phase loads. The proposed new control strategy of each distributed generation unit constitutes a proportional resonance (PR) controller, a droop control strategy, a negative sequence impedance controller (NSIC). The PR controller is used to adaptively modulate the load voltage, a droop controller is share the average power components between the DG units and the NISC is used to effectively compensate the negative sequence currents of the unbalanced loads. Thus, the power quality of the overall MV microgrid will be improved. The performance of the propped control strategy is conducted in MATLAB/SIMULINK. The simulation result shows that the control strategy is rich in load disturbances and effectively deals with unbalanced condition.

Index Terms- Microgrid, Distributed Generation (DGs), Photovoltaic system, Fuel cell, Voltage control, negative sequence current.

1. INTRODUCTION

Around the world today recognizing both the environmental and climate hazards to be faced in coming decades and the gradual depletion of conventional power sources. These problems have led to a new trend of generating power locally at distribution by using non-conventional energy sources such as solar photo voltaic system, fuel cells, and wind energy. The distributed generation (DG) unit is a rising as a new standard to produce on-site highly reliable and good quality electrical power. DG unit is well suitable when non conventional energy sources are available. These resources can be connected to a LV and/or MV networks are termed as a microgrid [1].

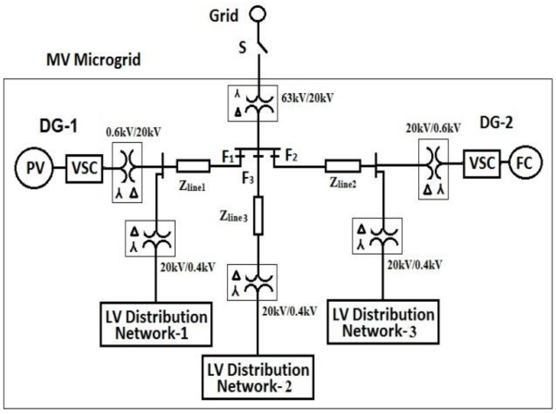


Fig. 1. MV microgrid consisting of two DG units Photo voltaic system and Fuel cells. F_1

Medium voltage (MV) microgrid will act as a major role in active management & control of distribution networks and it is capable of operated in both islanded and grid-connected mode. A medium voltage (MV) microgrid may inherently be subjected to significant degrees of unbalance due more commonly rise in individual customer load buses due to phase load imbalance, especially where large and single-phase loads are used.

However, a MV microgrid should be able to operate under unbalanced conditions without any performance changes. According to the IEEE standards, it is required that the voltage imbalance should be maintained less than 2% for sensitive devices [2], [3]. Each DG unit must inject some part of the negative-sequence current to balance the load voltage when unbalanced loads are presence. Various methods have been proposed in literature for control of microgrid. An *abc*-frame reference control strategy which is robust to the unmodeled load dynamics, the G-H and Q^- - G droop controls are used to share unbalanced currents among DGs.

These methods are show good performance when the exact values of the line impedance is available. Even so , the effectiveness of the proposed method is not used in the multi-bus MV microgrid[4], [5].

This paper designs a new control strategy for an islanded mode multi-bus MV microgrid consisting of various dispatchable three-wire DG units which are solar photovoltaic source and fuel cells. The overall microgrid is controlled according to the de –centralized control strategy so each DG unit solar photovoltaic (PV) and fuel cells (FC) consider as a subsystem equipped with the proposed new control strategy.

The proposed new control strategy of each DG unit constitutes a proportional resonance (PR) controller is used to effectively regulate the load voltage, a droop controller is share the average power among the DG units and a negative sequence impedance controller is effectively compensate the negative sequence currents between the DG units under unbalanced condition. Thus, the power quality of the overall MV microgrid will improved. The performance of the proposed control strategy has been test in MATLAB/SIMULINK. The simulation results show that the new control method is robust to load disturbance and effectively deals with under unbalanced condition.

2. STRUCTURE OF MV MICROGRID

Single line diagram of multi-bus medium voltage (MV) microgrid shown in Fig.1 it is composed of a 20-kV three feeder distribution system and two dispatchable three-wire DG units solar photovoltaic (PV) system and fuel cells (FCs). The DG units are connected to feeders, F1 and F_2 through step-up transformers. A Combination of balanced and unbalanced loads are connected supplied through three radial feeders, F_1, F_2, and F3. Thus, the each DG unit can supply any amount of the real/reactive power within the pre-specified limits. In this paper the MV microgrid system operates in the islanded mode. So each DG must control its own power in a decentralized control strategy. Therefore, the photovoltaic system and fuel cells are responsible for compensating the negative-sequence current of the unbalanced loads. The loads are connected to the feeders through star-delta transformers, therefore the loads do not absorb any zero-sequence current from feeders.

3. DYNAMIC MODEL OF A THREE-PHASE, THREE-WIRE DG UNIT

The circuit diagram of a three-phase, three- wire DG unit is shown in Fig. 2.

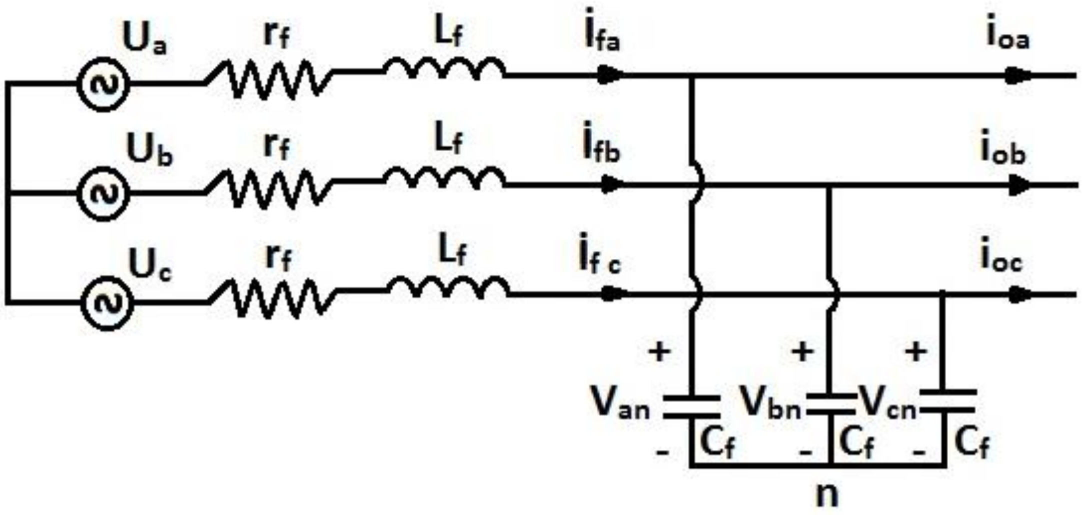


Fig. 2. Circuit diagram a 3-ɸ , three-wire DG unit.

Each DG units can be considered as a subsystem of the medium voltage (MV) microgrid. In this paper photovoltaic (PV) system and fuel cells are assumed as a DG-1 & DG-2 respectively. The main objective is to design a control strategy to regulate the load voltages in the presence of disturbance occurred under unbalanced condition. It should be noted that since the microgrid system is a three-phase three-wire system, the zero-sequence currents became zero. Thus, using the Clarke transformation, the state space equation of the system in the stationary reference αβ-frame is calculated as follows [6].

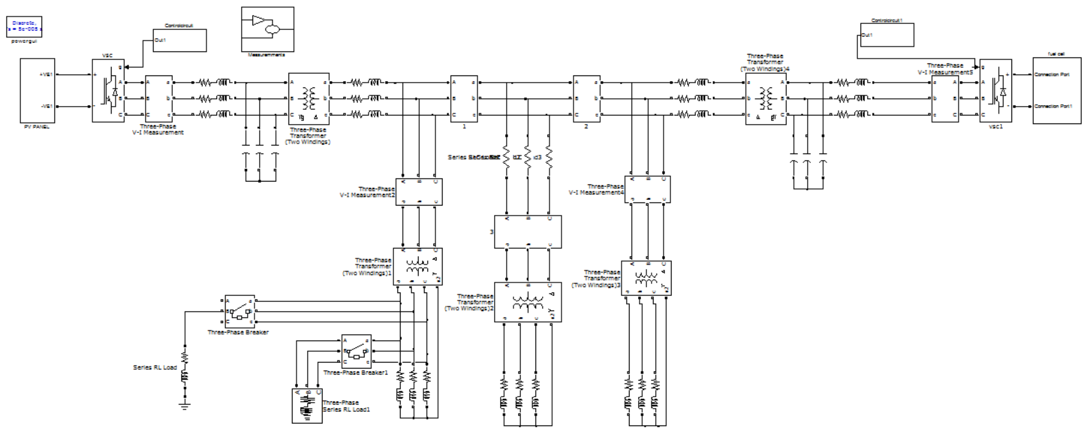
$$\mathbf{X} = \mathbf{AX} + \mathbf{BU} + \mathbf{EW}, \quad \mathbf{Y} = \mathbf{CX} \qquad \textbf{(1)}$$

Where
X = $[v_\alpha, v_\beta, i_{f\alpha}, i_{f\beta}]^T$ **,**
U = $[U_\alpha, U_\beta]^T$,
W = $[\, i_{O\alpha}, i_{O\beta}]^T$ **,**
Y = $[v_\alpha, v_\beta]^T$ and

$$A = \begin{bmatrix} 0 & 0 & -1/C_f & 0 \\ 0 & 0 & 0 & 1/C_f \\ -1/L_f & 0 & -r_f/L_f & 0 \\ 0 & -1/L_f & 0 & -r_f/L_f \end{bmatrix}, \quad B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1/L_f & 0 \\ 0 & 1/L_f \end{bmatrix}$$

$$E = \begin{bmatrix} -1/C_f & 0 \\ 0 & -1/C_f \\ 0 & 0 \\ 0 & 0 \end{bmatrix}, \quad C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \tag{2}$$

4.SIMULATION DIAGRAMS



Case.1 simulink model of (MV) microgrid under balanced and unbalanced load through feeder F_1

5.SIMULATION STUDIES

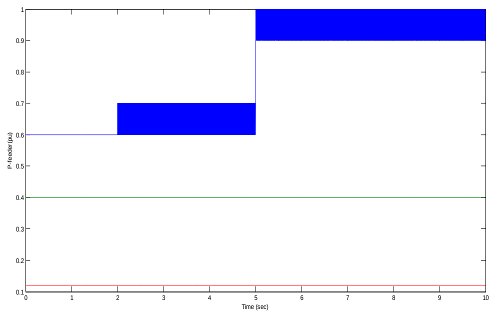
In order to verify the performance of the proposed control strategy, the medium voltage (MV) microgrid of case 1& 2 has been simulated in MATLAB/SIMULINK software. All DG units photovoltaic (PV) system and fuel cells (FCs) are equipped with the proportional resonance (PR) controller, droop controller and negative sequence impedance controller (NISC). F_1 & F_2 which is connected to a local load and F_3 is connected to a non local load is supplied by the DGs Case 1 & 2 simulation studies are accomplished as detailed in the below following segment.

(i). Load changes in feeder F_1

In this case, while the MV microgrid is initially operating under balanced conditions, a single phase RL load with 240 kVA and PF=0.98 is connected to the LV side of the feeder F_1 at time t = 2 s. After at time t = 5 s, an unbalanced three-phase RL load with 560 kVA and PF = 0.9 is connected to the same feeder F_1. The changes occurred in an instantaneous real and reactive power of the three feeders are shown in Fig. 11. Since feeder F_1 becomes unbalanced double-frequency ripple is appeared in the instantaneous power components of this feeder. As it is observed, the doubled frequency ripple is increased at time t = 5s due to the inclusion of unbalanced three-phase load. The positive and negative sequence components of the currents of all the three feeders are shown Fig. 12. It is observed that the positive and negative-sequence currents conduct at t = 2s and t = 5s.

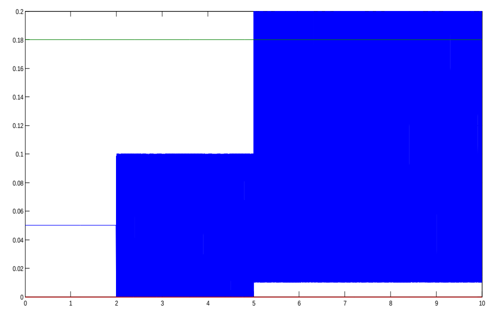
An instantaneous voltages of the DGs terminals prior and subsequent to the connection of unbalanced load at t = 5s as shown in Fig. 13. The voltage controller of each DG unit photovoltaic- (PV) and fuel cells offers a set of regulated balanced voltages as its terminals. The frequency of microgrid system under unbalanced load is shown in Fig. 14. An instant of changes in frequency is imposed to the PR controller by the droop controller based on the p-f characteristic.Instantaneous real and reactive power components of the DG units PV and FC during load switching are shown in Fig. 15. The average power of the DG units shows low frequency oscillations.

(a)



P_{F1}, ______ P_{F2}, ______ P_{F2}

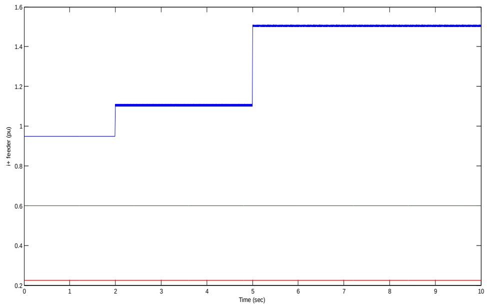
(b)



Q_{F1}, ______ Q_{F2}, ______ Q_{F2}

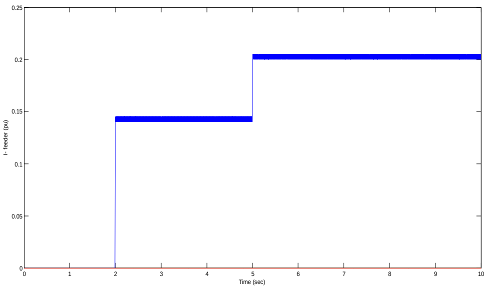
Fig. 11. Load changes in feeder F_1 (a) real, and (b) reactive power components.

(a)



I^{+}_{F1}, ______ I^{+}_{F2}, ______ I^{+}_{F2}

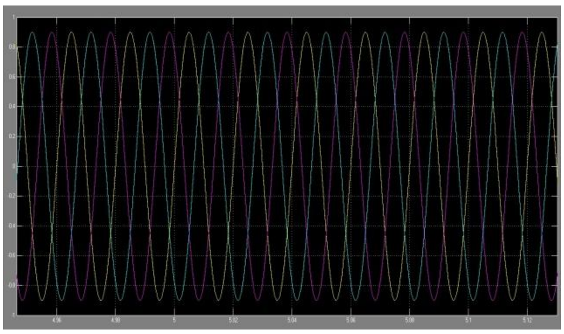
(b)



I^{-}_{F1}, ______ I^{-}_{F2}, ______ I^{-}_{F2}

When the second load switching comes at t = 5s, the negative sequence current of F_1 is increased up to the capacity of the negative sequence current injected by DG_1 is achieved. In this case, based on Fig. 3, the NISC of DG_1 is enabled and the controller starts to increase the negative sequence currents of DG_1 after about 0.85s. The NISC sets the reference signal of the negative sequence currents to $I^{-}_{max\ DG1}$. Hence, the excess of the negative sequence current of the local unbalanced loads is provided by DG_2.

(a)



(b)

Fig. 13. Instantaneous voltages at DG terminals under unbalanced load changes in feeder F_1, (a) DG_1 (PV) and (b) DG_2 (FCs).

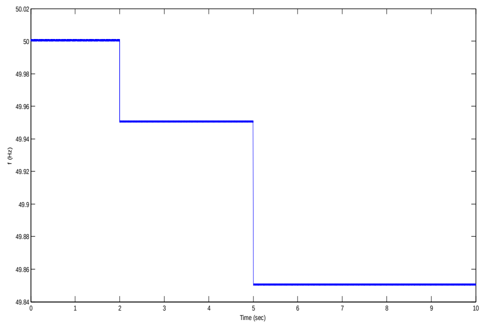
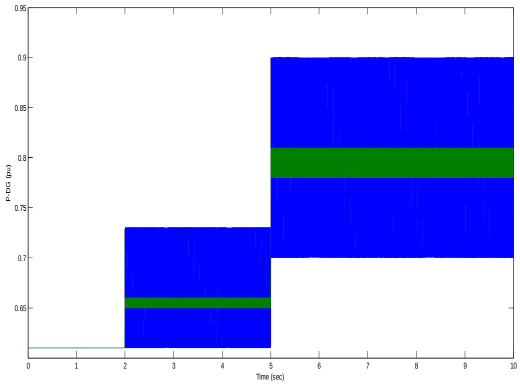
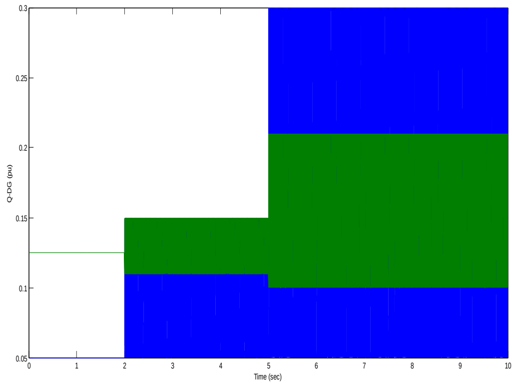


Fig. 14. Frequency of islanded microgrid under un- balanced load changes.

(a)



P_{DG1}, _______ P_{DG2}



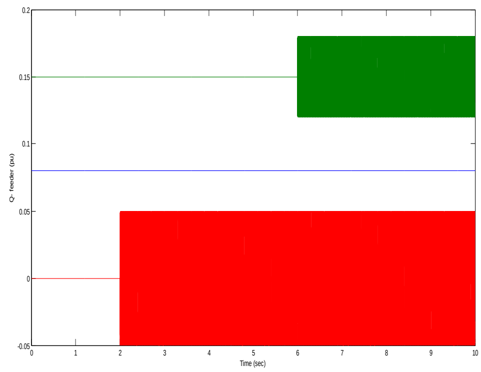
(b)

Q_{DG1}, ______ Q_{DG2}

Fig. 15. Dynamic response of DG units PV and FCs under unbalanced load changes

(ii). Load changes in feeders F_2 and F_3.

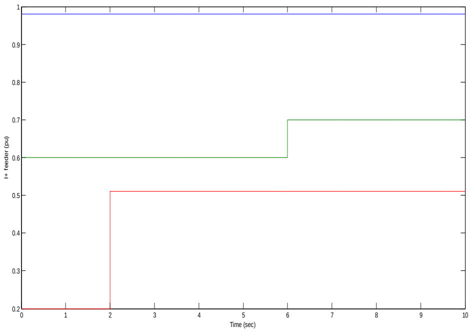
In this case, while the MV microgrid system is operated under balanced condition, the first load switching is applied at t = 2s, where two 140-kW single-phase resistive loads are connected to the phases *b* and *c* at the LV side of the feeder F_3, the second load switching is applied at t = 6s where two 100 kV single-phase resistive loads are connect to the phases *b* and *c* of the feeder F_2. Instantaneous real and reactive power components of feeders F_2 and F_3 under unbalanced loads are shown in Fig.16



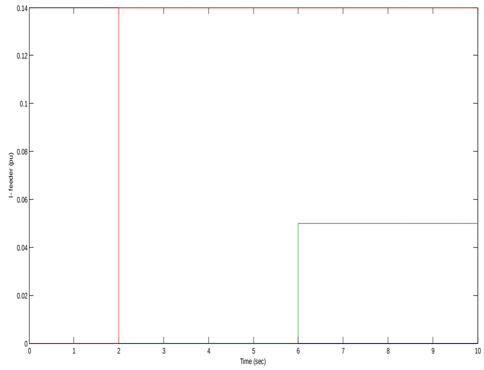
Q_{F1}, ______ Q_{F2}, ______ Q_{F2}

Fig. 17. Instantaneous (a) real and (b) reactive power components of feeders F_2, F_3 under un- balanced load changes.

(a)



I^{+}_{F1}, ______ I^{+}_{F2}, ______ I^{+}_{F2}



(b)

I^{-}_{F1}, ______ I^{-}_{F2}, ______ I^{-}_{F2}

Fig. 18. (a) Positive and (b) negative sequence components of feeders.

CONCLUSION

This paper presents a new control strategy for islanded operation of a multi-bus MV microgrid consisting of two dispatchable electronically coupled distributed generation (DG) unit photovoltaic (PV) generation system, fuel cells (FCs) and unbalanced loads. The proposed control strategy is framed to a PR controller, droop controller and negative-sequence impedance controller (NISC). The PR controller is used to regulate the load voltage, droop controller is used to share the average power among the DG units and the NISC is used to minimize the negative-sequence currents in the MV lines. Moreover, the negative-sequence current of a local load is completely compensated by its dedicated DG and nonlocal loads is shared among the adjacent DGs. Thus the power quality of overall microgrid is improved. The simulation studies are carried out in MATLAB/SIMULINK software. The simulation results conclude that the proposed strategy is robustly regulates voltage and frequency of the microgrid, is able to share the average power among the DGs, effectively compensate the negative- sequence currents of the DGs such that the power quality of the overall microgrid is not degraded.

REFERENCES

[1] N. Hatziargyriou, H. Asano, R. Iravani, and C. Marnay, “MicroGrids,” IEEE Power Energy Mag., vol. 5, pp. 78–94, Jul.–Aug. 2007.

[2] A. G. Madureira and J. A. P. Lopes, “Coordinated voltage support in distribution networks with distributed generation and MicroGrids,” IET Renew. Power Gener., vol. 3, pp. 439–454, Sep. 2009.

[3] M. H. J. Bollen and A. Sannino, “Voltage control with inverter-based distributed generation,” IEEE Trans. Power Del., vol. 20, no. 1, pp. 519–520, Jan. 2005.

[4] M. C. Chandrokar, D. M. Divan and B. Banerjee, “Control of distributed ups systems,” in Proc. 25th Annu. IEEE PESC, 1994, pp. 197–204.