PERFORMANCE ANALYSIS OF AUTONOMOUS MICROGRID SUBSEQUENT TO LINE - GROUND FAULT TRIGGERED CONDITION

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Abstract

With the emergent expansion of micro grid, the performances of microgrid subsequent to the various fault conditions have become an attractive area to be examined. This paper investigates the dynamic performance of the microgrid during (i) addition of non-linear load and (ii) fault triggered events. The microgrid consists of two DGs which are interfaced through a PE converter. The interface converters are equipped with P-F and Q-V droop control. The impacts of the droop control on the microgrid stability has been analysed in this work. The performance of the controllers in MATLAB/SIMULINK platform is also presented.

Keywords*— Distributed Generation, Droop control, L-G Fault, Microgrid, Non-linear load*

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1. INTRODUCTION

WITH the Growing importance of clean energy technology and the interactions of power electronic devices with the renewable energy sources, the distribution network adapted a new concept of “microgrids.” Distributed generation (DG), micro sources, controllers, loads and storage devices are composed together to form a microgrid structure [1]. Microsources like diesel generator, fuel cells, solar cells, and wind turbine generator are used in microgrid [2]. DGs are commonly paired with the power electronic devices like inverters to make in contact with the microgrid. It supports the main grid by providing the reliable power supply independently without the requirement of generation expansion [1].

A microgrid system can function in two sorts based on the static transfer switch (STS) position namely, grid tied mode and autonomous mode. When a fault or any disturbances occurs, the microgrid automatically shifts to the isolated mode i.e., island mode. It is necessary for a microgrid to function even in isolated mode in order to maintain the load demand, power supply reliability and power quality [3]. Therefore, the problem related with enhancing the microgrid dynamic response to the unplanned events gathers attention [4].

In the existing scenario, the power companies face a tough competition in order to enhance the quality and reliability of never-ending power supply. Therefore it is more imperative to tackle the DG disconnection due to intentional or accidental events. In course of island function of microgrid, the DG has to sense instantly and switch over to the control modes, so that voltage is supplied uninterruptedly to the sensitive loads. [5]

In current scenario, the custom of the utility do not authorise the microgrid to function in an island mode. But it will permit in exceptional circumstances, which desperately need all the DGs to be detached when scheduled and accidental switching transients exist. The above mentioned criterion is applied on the basis of safety purpose and also to satisfy the present protection constraints in the distribution system. [6]

During transition from grid connected mode to island mode, there is a possibility of microgrid to experience transient stability problem. This situation particularly occurs when the microgrid is unable to satisfy the load demand due to system’s rotating kinetic energy reduces.

Even though the micro sources are interfaced with power electronic devices, but it is highly vulnerable to the transient overloads. So it is obligatory to spot the transient instability and small signal instability [2].

Typically the microgrid is functioned parallel to the main grid but at the event of fault conditions it gets detached from the main grid and functioned independently. The most challenging subject in the microgrid is protection against the fault events [7]. The protection of microgrid relates with the issues of control and operation of a microgrid.Among various control schemes, this paper highlight on droop control techniques like P-F droop control & Q-V droop control.

The primary focus of droop control is to retain the fundamental frequency & the voltage magnitude of microgrid with manifold DGs in autonomous mode so that the appropriate powers are shared [8]. Frequently used droop control technique to enhance power sharing and the voltage/ frequency synchronization are real power–frequency (P–F) droop control and reactive power–voltage magnitude (Q–V) droop control. Consequently its implementation is simple and it empowers decentralized control of manifold distributed generations (DGs)

It has been shown that inverter interfaced DG can damp frequency oscillations through it has fast control action. For the inverter-based DG, a control scheme based on the real/reactive power control concept is considered. This paper analyses the impact of different control approaches and schemes of an inverter-based DG on microgrid stability during and subsequent to fault-forced islanding conditions. Further, the microgrid stability performance is examined with different load types, IM loads.

The significant contributions of this work include:
1) Cataloguing of the stability constraints for an inverter based generators and inverter coupled DG interface control schemes.
2) Investigation of the interface constraint of induction motor loads and DG on a microgrid subsequent to fault activated islanding incidents.

2. CONTROL STRATEGIES

The frequency and the active power are merely interrelated foe a generators. As the load increases, the load torque increase correspondingly which earns that the rotational speed and the system frequency to decrease [8]. The decreasing frequency with increasing load is maintained by the concept of droop control. The control strategy used in this work is conventional droop control i.e., real power- frequency droop control (P-F) and reactive power – voltage droop control (Q-V).

The frequency and voltage are being controlled respectively by the active and reactive power output of the DG sources. Thus the distributed power sharing in microgrid is based on maintaining the power output proportionally according to the DGs rating and power sharing among DGs [9].

2.1 P-F Droop Control Method

In a P-F droop control method, all DG in the system utilise its real power output and fix the frequency at its point of connection (PC). So in order to share real power accurately, the frequency will perform as the common communication signal among all the DGs [8]. When the microgrid is switched to island mode, each inverter experiences an error in the frequency generation. To resolve this, operating points of the power is altered to match the load. P-F droop functions at each microsource can effectually resolve these difficulties without a communication linkage.

During grid attached mode, the loads acquire power from the grid and the main power supply as per the utility requirement the microgrids safely switch over to the isolate mode in case of non-availability of main power supply due to fault, voltage transient, black outs, etc [9],[10]. During isolated mode, phase angle of the voltage at each DG will alter which results in notable frequency reduction. In addition to this frequency reduction, the increase in power permits accurate power sharing at each DG.

2.2 Q-V Droop Control

The output voltage magnitude of a DG can be controlled to change the reactive power supplied to a system. However, in the presence of a number of DGs, maintaining a voltage to a pre-defined value can cause the reactive power circulation amongst these DGs. This becomes more prevalent when the microgrid has short line segments. This problem can be minimized by implementing voltage droop control in all the DGs [11]. Also, the voltage droop control results in reactive load power sharing in the microgrid. The conventional voltage droop characteristic.

Voltage control must also insure that there are no large circulating reactive currents between sources. With small errors in voltage set points, the circulating current can exceed the ratings of the microsources.

This situation requires a voltage vs. reactive power droop controller so that, as the reactive power generated by the microsource becomes more capacitive, the local voltage set point is reduced. Conversely, as Q becomes more inductive, the voltage set point is increased [12].

The relationship between P-f & Q-V droop control is

$$f = f_0 - K_p (P - P_0)$$

$$V = V_0 - K_q (Q - Q_0)$$

Where,
f, V = The frequency and Voltage at a new operating point
P, Q = Active and reactive power at a new operating point
f_0 , V_0 = Base frequency and voltage
P_0 , Q_0 = temporary set points for the real and reactive power.
K_p , K_q = UPC droop constant

3. STABILITY ANALYSIS

Recently in the stream of microgrid, the stability analysis gains more importance on the researchers' perception. The system planners and operators are primarily focusing on the reclamation of the power system when exposed to a severe disturbance. Classically the system must be planned and operated by concerning the uninterruptable power supply to the loads. Transient stability exploration can also be used for the dynamic analysis over time duration of few seconds toward few minutes based on the time constants of dynamic modeled[13],[14].

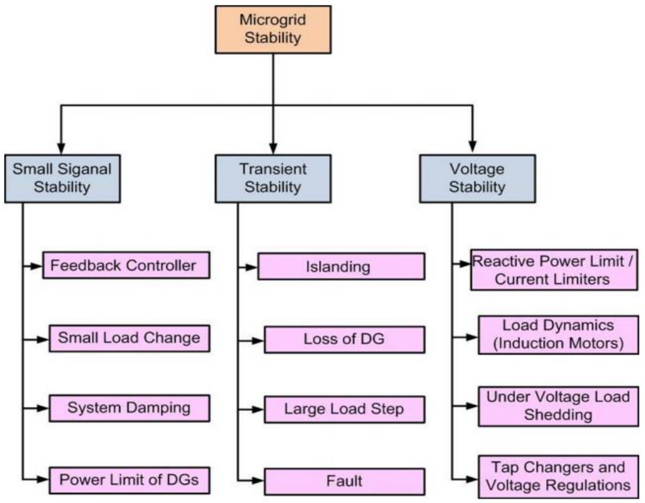

Fig 3.1 Different stability issues in microgrid

3.1 Transient Stability

The microgrid is capable of functioning even after large disturbances, which is the system will shift its functioning mode to island mode. The large disturbance occurs because of the switching of heavy loads suddenly, faults that occur on the transmission line, generating units tripping. This sudden disturbance makes the system to lose its synchronism. This sort of stability is designated as transient stability. The system stability issues have been explored by the many researchers recently [15]. Various stability issues and the stability improvement methods are shown in Fig 3.1 and Fig 3.2. The stability aspect includes the types of microgrid, micro sources, its parameters and control strategies. Since most of the micro sources are inter coupled with the power electronic devices i.e. voltage source inverter (VSI), the stability aspects of the microgrid mainly based on the control methods of the VSI [16],[17].

3.2 L-G Fault

The L-G faults are detected by the zero sequence current which is manipulated from the three phase current.In a fault, the system may lose stability very rapidly before the loads are cut off [18]. In a microgrid, storage plays an important role during islanding.

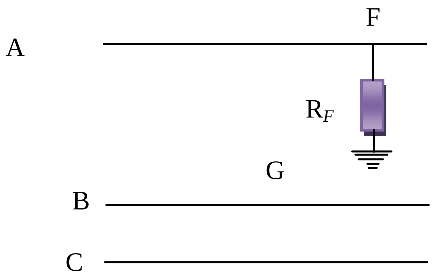

Fig 2 Single Line to Ground fault

Single line to ground fault is explored in this work. The fault is occurring at the phase A to ground as shown in the Fig 2.

4. SIMULATION MODEL

The microgrid is modelled with two micro sources which have a DC source as input and the P-F and Q-V droop control have been employed. At the time of starting, RL load is connected to the system as shown in Fig 3. In order to highlight the performance difference of microgrid when connected with normal load and nonlinear load, induction motor is connected at 0.75sec and disconnected at 2.5 sec. As a next, study about the activity of microgrid with RL load during fault triggered incident for a period of analysed. To perform this activity, a LG fault was introduced for a period of 1 to 1.5 secs. This microgrid system has been simulated under the Matlab/Simulink software environs.

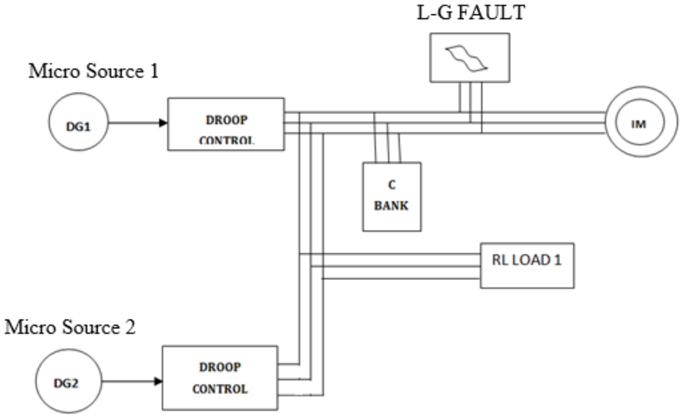

Fig 3 Single line layout of the utility and microgrid systems

5. SIMULATION RESULTS

The simulation result includes real and reactive power of DG1 and DG2 respectively. Fault voltage, fault current and rotor speed of induction motor load is also analysed during the disturbance period.

5.1 Real and Reactive Power

5.1.1 Microsource 1

The simulation starts with RL load at 0.75 sec induction motor load is added so that the real power of source 1 increases from 100KW to 110KW whereas the reactive power of source 1 decreases from -180KW to -240KW as cited in Fig 5.1 and Fig 5.2.

At 2.5 sec the induction motor load is disconnected from the grid. So that the real and reactive power regains its original power output.

As it is on the source side, the real and reactive power of the microsources does not affect because of the L-G fault.

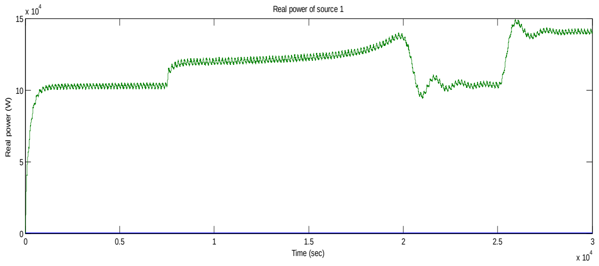

Fig 5.1 Real power of source 1

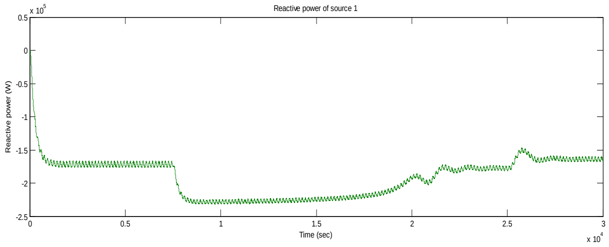

Fig 5.2 Reactive power of source 1

5.1.2 Microsource 2

In course of normal operating condition the real power output from the source 2 is 80 KW. When the induction motor load is added at 0.75 sec, the real power output drops instantly to 70KW but it regains its original power output when the induction motor load is disconnected as presented in Fig 5.3

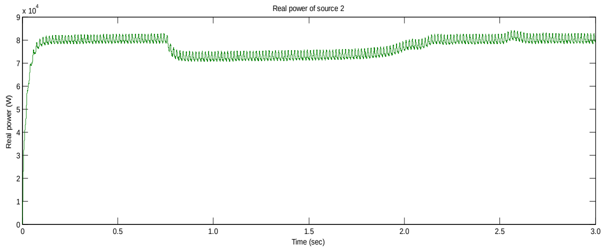

Fig 5.3 Real power of source 2

Similarly the reactive power output of micro sources 2 is initially -110 KW it decreases further at 0.75 to 1.5 sec to the value of -120 KW.

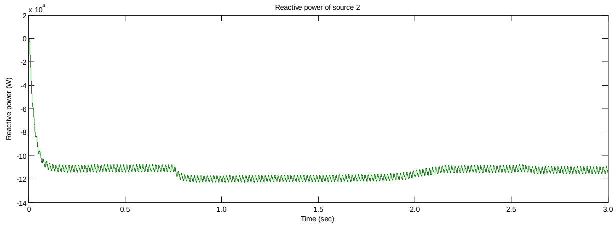

Fig 5.4 Reactive power of source 2

5.2 Fault Voltage and Current Analysis

5.2.1 Fault Voltage

Initially the voltage on the induction motor load side is zero as the IM load is included only at 0.75 sec. the IM load voltage is at 440 V as soon as the motor starts but its instantly drops to zero when the L-G fault occurs i.e., at 1 sec. So the load voltage remains at zero until the L-G fault is recovered i.e., till 1.5 sec. after 1.5 sec the load voltage increases to 440 V.

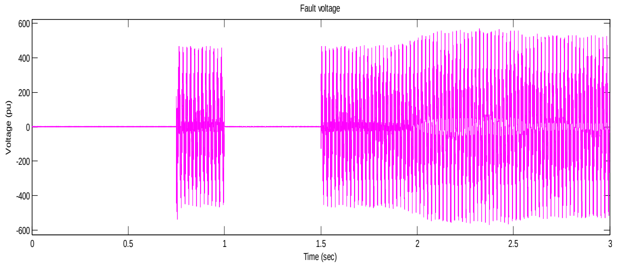

Fig 5.5 Fault voltage

5.2.2 Fault Current

During fault event the fault current will increase to its maximum value of 1.5 mA from 1 sec to 1.5 sec. It will remain zero throughout the operating period.

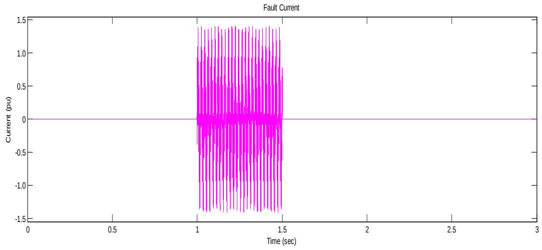

Fig 5.6 Fault current

5.3 Rotor Speed of the IM Load

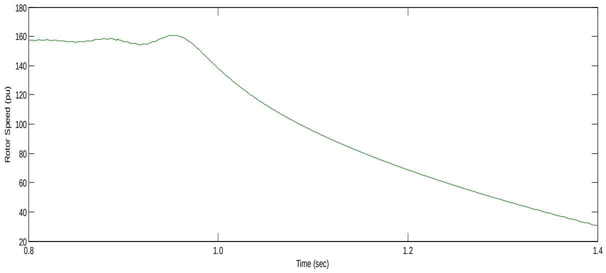

Fig 5.7 Rotor speed of induction motor load during disturbance

Before fault, the rotor rotates at a rated speed. During L-G fault event, it is observable that the rotor speed drops to zero from its rated speed. So from 1 sec to 1.5 sec the IM load will starts to shut down. The rotor speed response of the IM load to the disturbance is exposed in Fig 5.7. During disturbance period the torque imbalance will occur so that the rotor speed suddenly reduces.

6. CONCLUSIONS

In this paper, based on droop control scheme, which includes P-F and Q-V droop control is studied for microgrid stability. The proposed control scheme is demonstrated for a microgrid with two inverter interfaced DG units. This paper evaluates the impact of P-F and Q-V droop control strategies of microgrid under load change and subsequent to the fault incident. The impacts identified are

1. Load power is shared equally for inverter interfaced DG with P-F and Q-V droop control.
2. There is a voltage dip due to the IM load.
3. Due to the occurrence of the L-G fault , the microgrids switch over from grid-tied mode to island mode.

REFERENCES

[1] J.S. Bridle, “Probabilistic Interpretation of Feedforward Classification Network Outputs, with Relationships to Statistical Pattern Recognition,” Neurocomputing—Algorithms, Architectures and Applications, F. Fogelman-Soulie and J. Herault, eds., NATO ASI Series F68, Berlin: Springer-Verlag, pp. 227-236, 1989. (Book style with paper title and editor)

[2] W.-K. Chen, Linear Networks and Systems. Belmont, Calif.: Wadsworth, pp. 123-135, 1993. (Book style)

[3] H. Poor, “A Hypertext History of Multiuser Dimensions,” MUD History, http://www.ccs.neu.edu/home/pb/mud-history.html. 1986. (URL link *include year)

[4] K. Elissa, “An Overview of Decision Theory," unpublished. (Unplublished manuscript)

[5] R. Nicole, "The Last Word on Decision Theory," J. Computer Vision, submitted for publication. (Pending publication)

[6] C. J. Kaufman, Rocky Mountain Research Laboratories, Boulder, Colo., personal communication, 1992. (Personal communication)

[7] D.S. Coming and O.G. Staadt, "Velocity-Aligned Discrete Oriented Polytopes for Dynamic Collision Detection," IEEE Trans. Visualization and Computer Graphics, vol. 14, no. 1, pp. 1-12, Jan/Feb 2008, doi:10.1109/TVCG.2007.70405. (IEEE Transactions)

[8] S.P. Bingulac, “On the Compatibility of Adaptive Controllers,” Proc. Fourth Ann. Allerton Conf. Circuits and Systems Theory, pp. 8-16, 1994. (Conference proceedings)

[9] H. Goto, Y. Hasegawa, and M. Tanaka, “Efficient Scheduling Focusing on the Duality of MPL Representation,” Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS ’07), pp. 57-64, Apr. 2007, doi:10.1109/SCIS.2007.367670. (Conference proceedings)

[10] J. Williams, “Narrow-Band Analyzer,” PhD dissertation, Dept. of Electrical Eng., Harvard Univ., Cambridge, Mass., 1993. (Thesis or dissertation)

[11] E.E. Reber, R.L. Michell, and C.J. Carter, “Oxygen Absorption in the Earth’s Atmosphere,” Technical Report TR-0200 (420-46)-3, Aerospace Corp., Los Angeles, Calif., Nov. 1988. (Technical report with report number)

[12] L. Hubert and P. Arabie, “Comparing Partitions,” J. Classification, vol. 2, no. 4, pp. 193-218, Apr. 1985. (Journal or magazine citation)

[13] R.J. Vidmar, “On the Use of Atmospheric Plasmas as Electromagnetic Reflectors,” IEEE Trans. Plasma Science, vol. 21, no. 3, pp. 876-880, available at http://www.halcyon.com/pub/journals/21ps03-vidmar, Aug. 1992. (URL for Transaction, journal, or magzine)

[14] J.M.P. Martinez, R.B. Llavori, M.J.A. Cabo, and T.B. Pedersen, "Integrating Data Warehouses with Web Data: A Survey," IEEE Trans. Knowledge and Data Eng., preprint, 21 Dec. 2007, doi:10.1109/TKDE.2007.190746.(PrePrint)