ijiTECH International Journal of Innovative Technologies

WWW.IJITECH.ORG

ISSN 2321-8665
Volume.06, Issue.01,
January-June, 2018,
Pages:0418-0422

# A New Control Strategy to Mitigate the Fault in a Distribution System

K. VINOD KUMAR[1], S. FAHMEEDA PARVEEN[2], G. V. SURESH BABU[3]

**Abstract:** Microgrids have attracted attention in recent years for their role in the integration of distributed-energy resources (DER), delaying transmission investments by adding generation near load centers, and providing islanded operation during outages. Three main value propositions have been identified for microgrids in this work: improving reliability through islanded operation during outages; providing revenue in grid connected operation; and improving power quality by rapidly islanding during utility disturbances and outages. Inverter interfaced distributed generators (DGs) in microgrids have different characteristics and models that are not available in the existing conventional power flow analysis tools. This paper presents a static modeling approach for inverter interfaced DGs that can be applied for time spread load flow analysis and fault analysis of microgrids, including droop-based voltage controlled DGs. Providing improved power quality through seamless islanding is challenging and costly when trying to compete with existing power-quality solutions. The static models have been derived from the common control schemes applied to inverter interfaced DGs, including the constraints emerging from droop control and reflect steady-state behaviors of inverters accurately. In addition to simplification of analysis procedure, the static models can provide a base for the analysis of microgrids with conventional numeric analysis tools. The presented static modeling approach has been validated comparatively with the dynamic modeling matlab/simulink simulation results of a test microgrid.

**Keywords:** Droop Control, Fault Analysis, Inverter, Load Flow, Microgrid, Static Modeling.

## I. INTRODUCTION

Conventional analysis methods to Current Controlled (CC) DGs with limited fault current. Although the approaches seem appropriate for CC DGs in grid connected operation, they do not address Voltage Controlled (VC) DGs in the islanded operation of the microgrids. The fault models of DG inverters under voltage control scheme can be applicable to single-master operation of microgrids. Multi-master operation of microgrids based on droop control requires more comprehensive models of DGs for the analysis of islanded microgrids. Proposes a static modelling approach, which is implemented with phasor simulation method, for inverter interfaced DGs to be applied in load flow analysis of microgrids including faults. The analysis method can be applied for both grid connected and island mode of operation as shown in Fig.1. The limitations are applied to DG currents instead of powers and the effects of the output filter capacitors are also included in the developed analysis method.

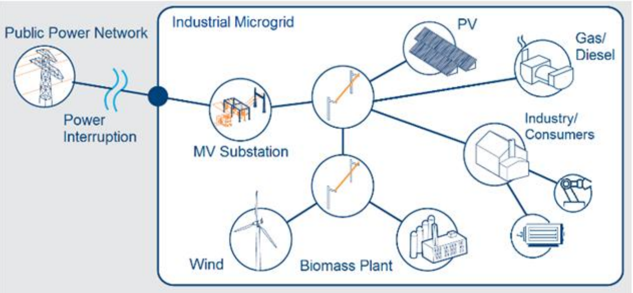

**Fig.1. A typical MG connected to the public power grid.**

To simplify the application procedure especially for time spread load flow analysis, the analysis method has been implemented with the phasor simulation method of Matlab/Simulink using a generic source model. The objective of this research is to mitigate inverter overloads caused by poor transient load sharing between inverters and synchronous generators in islanded microgrids. The cause of the poor transient load sharing characteristics are investigated, and the use of virtual impedance and transient droop are proposed to control the transient load sharing characteristics. Inverter current-limiting in the presence of synchronous generators is investigated and virtual impedance current limiting is proposed to provide stable current limiting during overloads. Finally, current limiting during three-phase faults is investigated. Fault contribution from DG may be sufficient to allow satisfactory operation of protection systems. DG may be able to regulate the voltage and frequency within the islanded system as shown in Fig.2. The parallel operation of DG units within the island may not be cause problems. Unsynchronized, out-of-phase reclosing may not be occur when the islanded distribution is reconnected to the distribution system.

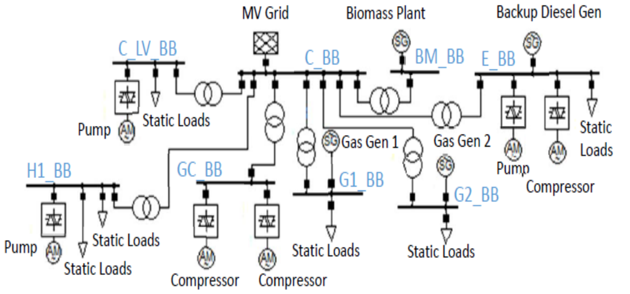

**Fig.2. Schematic of the modelled microgrid with 20/0.4 kV network and various DG units and loads.**

The operating DG units to detect grid problems and to subsequently disconnect the DG units from the grid within a maximum of 2 seconds. Microgrids can be regarded as special applications of active distribution networks. In distribution networks high sub transient fault current components that are seen in the fault currents of transmission systems are not observed. Therefore, fault currents of the microgrids can be approximated by their steady-state values. Based on this consideration, this paper proposes a static modelling approach, which is implemented with phasor simulation method, for inverter interfaced DGs to be applied in load flow analysis of microgrids including faults. The analysis method can be applied for both grid connected and island mode of operation. The limitations are applied to DG currents instead of powers and the effect of the output filter capacitors is also included in the developed analysis method.

## II. DISTRIBUTED ENERGY RESOURCES AND MICROGRIDS

DG technologies typically include wind turbines, solar photovoltaic (PV) systems, fuel cells, small hydro, microturbines and other cogeneration plants. These DGs along with distributed storage systems such as batteries, super capacitors have formed the concept of distributed energy resources (DERs) which are usually connected to the medium voltage (MV) or low voltage (LV) grid within the distribution system. DERs are being increasingly integrated as a means of power supply into the distribution system as opposed to reliance on bulk supply points from traditional centralised power plants. Environmental factors such as limiting the greenhouse gas (GHG) emissions and avoiding the investments of new transmission networks and large generating plants have been the primary motives behind the growth of DERs. DERs have begun to feature active characteristics in the distribution networks with bidirectional power flows, converting the passive networks into active distribution networks. DERs can be divided into two groups in terms of their interfacing mechanism with the microgrid. One group includes rotating machines that are directly coupled to the microgrid, while others are coupled through power electronic interfaces.

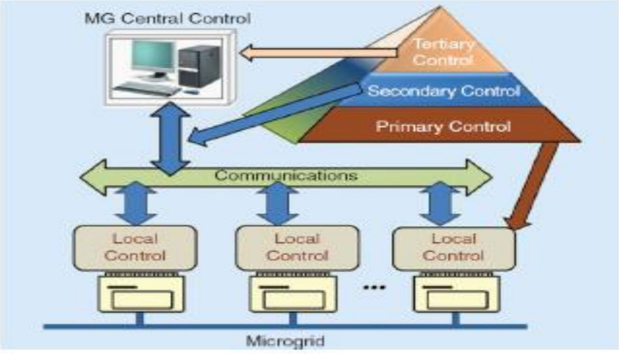

**Fig.3. Microgrid control levels.**

Therefore, the control concepts and power management strategies used in a microgrid comprising both inverter and non-inverter interfaced DERs are significantly different from those of a conventional power system. Different hierarchical control strategies are adopted at different network levels in order to achieve better coordination among the DERs and the local loads. The control strategies must allow the microgrids to operate in islanded mode due to faults or any other large disturbances in the external grid. In grid connected mode, microgrids may export/import active and reactive power to/from the utility grid depending on their primary objective. A hierarchical control of microgrids have been proposed recently to standardize microgrid operation. As illustrated in Fig.3, at the bottom level, a primary controller is responsible for protection functions, local voltage control and power sharing management among multiple DERs to ensure system reliability. At the next level, the secondary controller restores microgrid frequency and voltage either by communicating with the MCC in a centralised manner or by using multi-agent systems in a decentralised manner. The tertiary controller at the top level carries out the economic optimisation based on the energy prices and market operation. Furthermore, the tertiary controller can communicate with the DNSP in order to optimise microgrid operation with the utility grid. In order to carry out successful operation of microgrids, it is vital to have a proper communication methodology. Communication in microgrids is being carried out based on radio communication, through telephone lines, power-line carrier or using a wireless medium (internet and global system for mobile communication).

## III. SYSTEM MODELING

A microgrid, which has a generic schematic diagram as shown in Fig. 4, has two main operational mode; grid connected and island. In each mode microgrid DGs have corresponding control implementations. In grid connected mode all DGs are controlled with current control scheme. Depending on the type of the source in terms of being intermittent (PV, wind) or non-intermittent, DC link voltage regulation or PQ based current control schemes are the accepted common current control approaches respectively, applied to the microgrid DGs in grid connected mode. Note that, DC link voltage based current control regulates the DC link voltage at maximum power point with a very low control bandwidth (1 Hz). Therefore, it can also be termed as PQ control where P set value (P*) corresponds to the available instant renewable source power. In island mode, non-intermittent type DGs return to a droop based voltage control while intermittent DGs (and storage units if exist) continue to operate with current control scheme to extract the maximum available power.

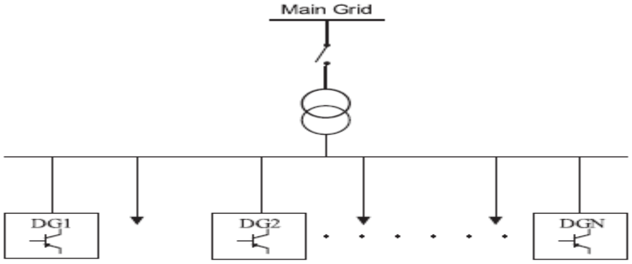

**Fig. 4. Schematic diagram of a generic microgrid.**

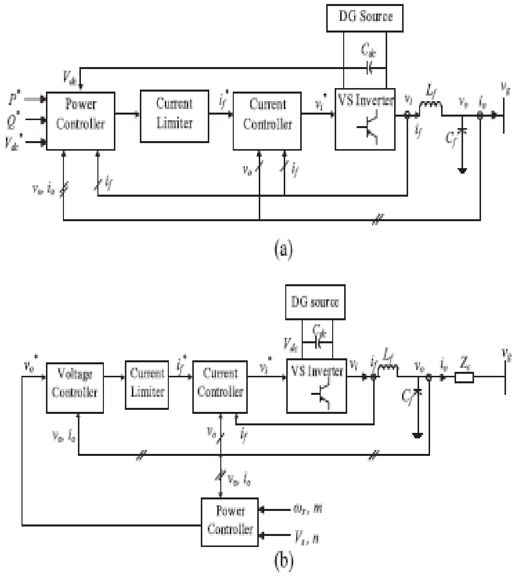

**Fig. 5. Microgrid DGs control implementations. (a) Block diagram of current control scheme. (b) Block diagram of voltage control scheme.**

In Fig. 5(a) and (b), control block diagrams of the current control and voltage control schemes together with single line electrical diagram of the inverters are presented, respectively. There exists an LC filter at the output of DG inverters. It needs to be pointed out that transition between the operational modes of the microgrids requires switching between the aforementioned control schemes for the relevant DGs. In case of an unintentional islanding, fast islanding detection plays a critical role for proper operation of the microgrid. It is also to be noted that the modified droop control schemes proposed for soft transition like those in have the same respective steady-state behavior in each mode and can be handled in the same content as the control schemes presented here. In both current control and voltage control schemes, current controller and current limiter are the common blocks with similar implementations. Current limiter is one of the critical control implementations that effects the fault response of DGs. Some possible current limiting strategies for CC DGs are described. It should be noted that in static modeling the matter of interest is the steady-state behavior of the current limiting strategy applied. For VC DGs the same current limiting strategies can be applied. In this case, however, since the current references are produced by the voltage controller in a closed loop (see Fig 5 (b)), anti wind-up and latch-up strategies should be taken into consideration.

The voltage controller in voltage control scheme and the current controllers in both schemes can be implemented in either synchronous dq frame, stationary αβ or natural abc frame. The common approach is use of PI controllers with additional feed-forward compensation, implemented in synchronous dq frame. The coupling impedance Zc shown in the block diagram of the voltage control scheme in Fig. 5(b), is required for stability of islanded microgrids and intentionally placed to provide enough stability margin for LV microgrids that have negligible line impedances. It can be implemented either physically or virtually by proper control implementations. Power controllers, on the other hand, dictate the main characteristics of steady-state behaviors of VC and CC DGs. They are dealt separately in the following parts in connection with corresponding steady-state behaviors of DGs for both control schemes.

## IV. SIMULATION RESULTS

### Case-1: Fault Analysis Of Islanded Microgrid

In this case, the microgrid is islanded and two equivalent droop controlled inverters (DG1 and DG2) are also added to the microgrid, located at distribution transformer substation. In addition, there exists a consumer PV inverter connected to Bus 3. Note that, location of islanding switch at the high voltage side of the distribution transformer is advantageous for safety reasons. Inverters have a nominal power of 5 kVA with a peak current limit of 40 A (twice the rated current), and are operating at rated power before the fault is applied. The fault is three-phase to ground fault with a ground resistance of 1Ω, applied at t=0.6s at Bus 6 as shown. The threshold fault voltage level for VC DGs to switch to the current limiting mode has been set as Vf = 160 V. Under these conditions, static modeling analysis results for droop controlled inverters and PV inverter output currents before and after the fault have been obtained as follows(table-1). The current values obtained above indicate that the droop controlled inverters have been subjected to current limiting after the fault whereas current level of PV inverter has not reached limit level. Dynamic simulation results, on the other hand, for the droop controlled inverters and PV inverter is presented in Figs. 6 and 7, respectively. For comparison, static analysis results for PV inverter current before and after the fault is superimposed on the dynamic analysis result in Fig. 6. As seen, the static analysis model determines the steady-state values of dynamical elements quite successfully. Since PV inverter reference current is low pass filtered, output current settles down with a delay and performs some oscillations after the fault, but finally reaches the expected steady-state value.

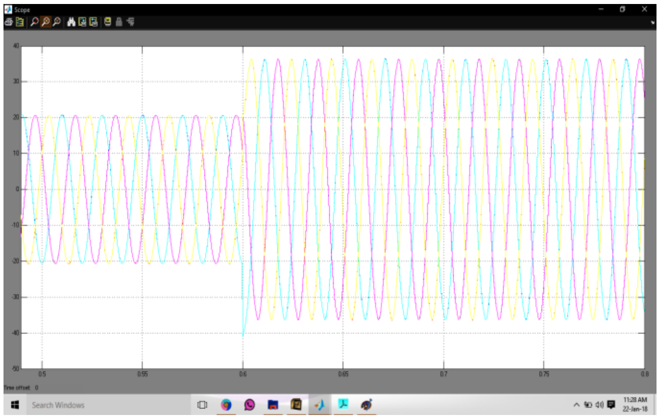

**Fig.6. Dynamic simulation results for droop controlled inverter currents.**

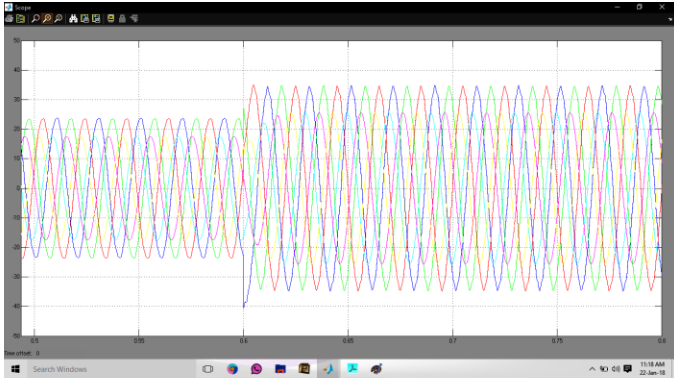

**Fig.7. Dynamic simulation results for PV inverter current.**

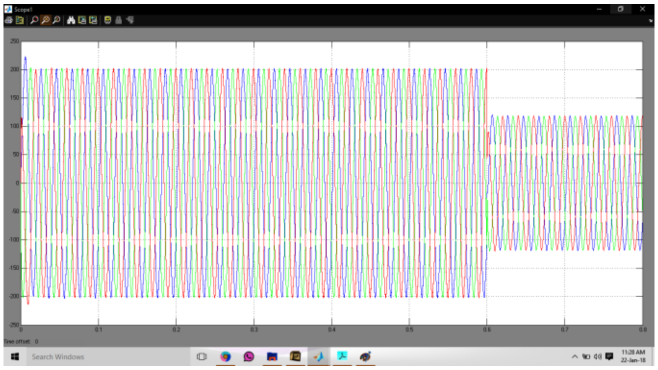

**Fig.8. Grid voltage (Bus 1) when current limiting is not applied to the inverters.**

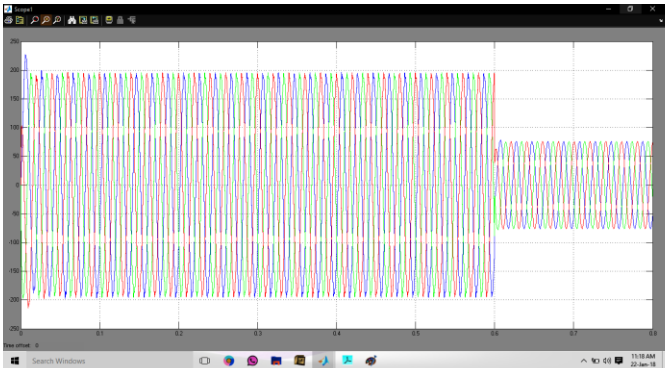

**Fig.9. Grid voltage (Bus 1) when current limiting is applied to the inverters.**

Figs. 8 and 9 present dynamic simulation results of the Bus 1 voltage for the cases with and without current limiting applied to the inverters, respectively. Note that, Bus 1 node is the point beyond the coupling impedances of droop controlled inverters whose voltage is used to detect fault condition and corresponding current control mode in static models of voltage controlled inverters. Without current limiting, grid voltage reduces from 200 V peak to 125 V peak with an inverter output current of 75 A peak. Note that the threshold voltage must be high enough to detect current limiting mode accurately (it needs to be higher than 125 V in this case) but low enough to distinguish the normal operation condition from the faulty condition. The accurate threshold voltage value can be determined with a two-step solution. In the first step, VC DGs are included to the system without current limiting. If currents of VC DGs exceed their limit values then in the second step they are included with current limiting with a threshold voltage determined according to the output voltages of the first step. It should be noted that if droop coefficients are arranged so as to provide proportional power sharing between the VC DGs, then all droop controlled DGs are expected to switch to current limiting mode simultaneously. Current limiting, on the other hand, dramatically reduces the fault voltage levels in the microgrid. Note that, this extra voltage reduction emerging from current limiting can be used for fault detection in microgrid protection systems as an alternative to the conventional over-current based fault detection methods.

## V. CONCLUSION

Microgrid inverters present specific steady-state behaviors due to their specific control features such as droop control and current limiting that cannot be processed with the conventional power flow analysis tools. Analyzing the network with dynamic models, on the other hand, is quite compulsive and takes too long time due to computational burden and complexity as the network enlarges. In this study, it has been shown that static equations of an islanded microgrid, including droop based DG inverters, has enough constraints to be solved by numeric methods. Then, by using phasor simulation method it has been shown that developed static models for DG inverters, based on the constraints of droop control and current limiting, can be used to perform power flow analysis of small to medium scale microgrids including faults. The developed static models also include practical aspects of DG inverters such as current based limiting instead of powers and effects of output filter capacitors. Static modeling with phasor simulation method facilitates the time spread load flow analyses considerably. The convergence of the phasor simulation method has pointed out that the proposed droop and limit current constraints provide enough conditions for the analysis of large microgrids using numeric methods, as well. On the other hand, the detection of current limiting requires a special consideration due to the lack of a current reference information in power controller of the voltage controlled DGs. As a solution, a grid voltage based current limiting detection has been proposed, where threshold voltage can be determined with a two-step solution. It has been shown that the proposed method serves the purpose in case of symmetrical faults.

## VI. REFERENCES

[1] A. Arulampalam, M. Barnes, A. Engler, A. Goodwin, and N. Jenkins, “Control of power electronic interfaces in distributed generation microgrids,” Int. J. Electron., vol. 91, no. 9, pp. 503–523, Sep. 2004.

[2] J. M. Guerrero, J. Matas, L. G. de Vicuna, and M. Castilla, “Wirelesscontrol strategy for parallel operation of distributed–generation inverters,” IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1461–1470, Oct. 2006.

[3] J. A. Pec¸as Lopes, C. L. Moreira, and A. G. Madureira, “Defining control strategies for microgrids islanded

operation," IEEE Trans. Power Syst., vol. 21, no. 2, pp. 916–924, May 2006.

[4] F. Katiraei and M. R. Iravani, "Power management strategies for a microgrid with multiple distributed generation units," IEEE Trans. Power Syst., vol. 21, no. 4, pp. 1821–1831, Nov. 2006.

[5] J. M. Guerrero, M. Chandorkar, T.-L. Lee, and P. C. Loh, "Advanced control architectures for intelligent microgrids-Part I: Decentralized and Hierarchical control," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1254–1262, Apr. 2013.

[6] C. A. Canizares et al., "Trends in microgrid control," IEEE Trans. Smart Grid, vol. 5, no. 4, pp. 1905–1919, Jul. 2014.

[7] IEEE Application Guide for IEEE Std. 1547, IEEE Standard for Interconnecting Distributed Resources With Electric Power Systems, IEEE Standard 1547.2-2008, 2009.

[8] J. M. Carrasco et al., "Power-electronic systems for the grid integration of renewable energy sources: A survey," IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1016, Jun. 2006.

[9] C. A. Plet, M. Graovac, T. C. Green, and R. Iravani, "Fault response of grid-connected inverter dominated networks," in Proc. IEEE Power & Energy Soc. General Meeting, Minneapolis, MN, USA, 2010, pp. 1–8.

[10] C. A. Plet andT.C.Green, "Fault response of inverter interfaced distributed generators in grid-connected applications," Elect. Power Syst. Res., vol. 106, pp. 21–28, 2014.