Available online at www.sciencedirect.com

Journal of Applied Research and Technology

Journal of Applied Research and Technology xxx (2017) xxx–xxx

www.jart.ccadet.unam.mx

Original

Analysis of droop control method in an autonomous microgrid

Amir Khaledian *, Masoud Aliakbar Golkar

Department of Electrical Engineering, K. N. Toosi University of Technology, Tehran, Iran

Received 20 August 2015; accepted 9 March 2017

Abstract

In this paper an analytical approach is conducted to evaluate the droop control method in an islanding microgrid. Droop control is the key solution for sharing the demand power between generators in autonomous microgrids where there is no support from the electricity distribution grid. In the paper, three important load types are investigated to verify the droop control performance. First, coupling of active power and reactive power is considered in the microgrid and a new method is proposed to facilitate separate control of powers. In the proposed method the effects of droop gains on decoupling of active power and reactive power control, voltage regulation, power oscillation and system stability are studied. In the second load type study, by applying the different types of faults, induction motor characteristics are observed. By simulation results it is shown that the fault intensity and duration will determine how the microgrid attains to fast frequency convergence and how fast protection system operation can improve system stability. In the third case, imbalanced nonlinear load is studied in the microgrid and the influences of embedded controllers on harmonic distortion, system balance and voltage regulation are observed.

Keywords: Distributed generator; Droop control; Electrical load and microgrid

1. Introduction

The interconnection of small generation systems like solar photovoltaics, micro turbines, fuel cells, wind turbines and energy storage devices to low voltage distribution network will lead to a dynamic power system. These power sources give the capability of decentralized generation and are known as distributed generators (DGs) (Chowdhury & Crossley, 2009; Sumithira & Nirmal Kumar, 2013).

A microgrid which includes local DGs and loads, can operate in two different modes of operation. In interconnected mode it is connected to the main upstream grid, being supplied from or injecting power into it. Other mode is autonomous mode of operation and the microgrid is disconnected from distribution network (Balaguer, Lei, Yang, Supatti, & Peng, 2011; Majumder, Ghosh, Ledwich, & Zare, 2009).

DGs improve the service reliability and decrease the need for future generation expansion planning. Moreover, in concept of islanding microgrid it extends up the possibility of making sources responsible for local power quality factors in a way that is not conceivable with conventional centralized power generation (Fu et al., 2012; Marwali & Keyhani, 2004; Zhengbo, Linchuan, & Tuo, 2011).

Unlike conventional generators which almost exclusively produce 50 or 60 Hz electricity, the majority of DGs are connected to the grid via voltage source inverters (Strzelecki & Benysek, 2008). The basic control objective for DGs in a microgrid is to achieve accurate power sharing while regulating of the microgrid voltage magnitude and frequency. Centralized control of a microgrid based on communication infrastructure is also proposed. However, in remote areas with long distance between inverters, it is impractical and costly to use communication link.

Decentralized controllers are investigated to eliminate communication links. Thereby power sharing for microgrid generators is achieved by means of droop controllers. In some studies a static droop compensator is reported for power sharing (Chandorkar, Divan, & Adapa,1993; Katiraei & Iravani, 2006).

* Corresponding author.
E-mail address: akhaledian@mail.kntu.ac.ir (A. Khaledian).
Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.1016/j.jart.2017.03.004

Please cite this article in press as: Khaledian, A., & Aliakbar Golkar, M. Analysis of droop control method in an autonomous microgrid. *Journal of Applied Research and Technology* (2017), http://dx.doi.org/10.1016/j.jart.2017.03.004

Droop control is enhanced featuring the transient response performance (Guerrero, De Vicuna, Matas, Castilla, & Miret, 2004). To decrease the active power (P) and reactive power (Q) dependency, droop controllers with virtual frequency–voltage frame (Li & Li, 2011) and virtual output impedance (Chiang, Yen, & Chang, 2001) are also discussed. For nonlinear loads, harmonic based droop controllers are proposed (Borup, Blaabjerg, & Enjeti, 2001; Lee, & Cheng, 2007; Marwali, Jung, & Keyhani, 2004). Although these control methods can improve the overall power quality factors, but they have complexities in adjusting control parameters.

As it can be seen in literature review, there is no comprehensive study of microgrid in presence of important load types and only one kind of load is considered in each article. In this paper microgrid with droop control is analyzed in presence of different kind of loads. Step change in active demand power, dynamic loads such as induction motors in fault condition, and imbalanced harmonic distorted loads are three types of loads considered in this paper. Load characteristics effects on power quality factors are observed in simulation results. These studies can properly comprise the most important loads being utilized in a sample microgrid.

2. Droop control

Droop control for a sample microgrid is considered in direct-quadrature-zero reference frame which facilitates control process by transforming time variant quantities of voltage and current in three phases reference frame to direct current (dc) quantities. Figure 1 illustrates the alternative current (ac) three phases (abc) and direct-quadrature-zero (dq0) coordinate frames.

Reference voltage for pulse width modulation (PWM) signals of inverters is generated by three back to back power, voltage and current controllers (Marwali & Keyhani, 2004; Pogaku, Prodanovic, & Green, 2007). Figure 2 shows a DG unit connected to the microgrid by inverter. Output filter (L_fC_f) and coupling inductance (L_c) are connected before the terminal bus. It is assumed that the input source of inverter is an ideal dc link. Inner controllers are further discussed.

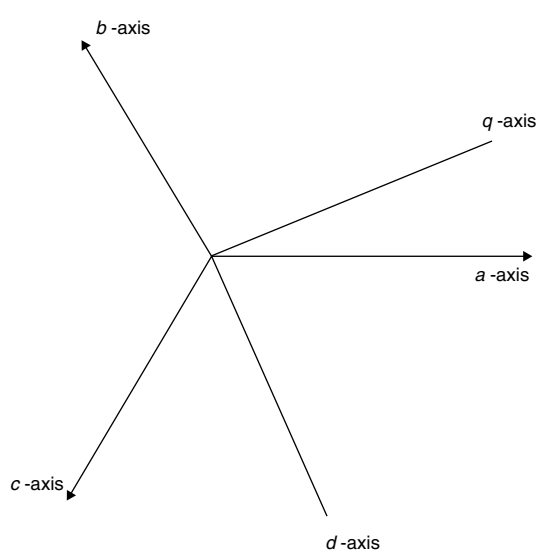

Figure 1. Three phases and direct-quadrature-zero coordinate frames.

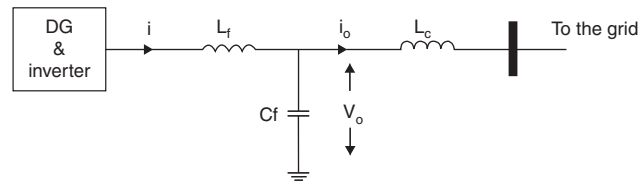

Figure 2. DG connected to the microgrid via inverter.

2.1. Power controller

Droop control scheme mimics the operation of governor and exciter in synchronous generators and determines output frequency and voltage of DGs according to the active and reactive powers derived from their terminals. In order to determine frequency and voltage by droop equations, instantaneous active and reactive powers (p and q) should be calculated from the generator output voltage and current (v_0 and i_0) as they are shown in Figure 2. i is the current of coupling inductance where its values in dq0 reference frame are i_d and i_q, v_{od}, v_{oq}, i_{od} and i_{oq} are the values of output voltage and current variables in dq0 reference frame along d-axis and q-axis respectively.

$$p = v_{od}i_{od} + v_{oq}i_{oq} \tag{1}$$

$$q = v_{od}i_{oq} - v_{oq}i_{od} \tag{2}$$

According to Eqs. (3) and (4) to derive P and Q, above quantities should be passed through low pass filter in which ω_f is the cut-out frequency. Reference voltage (v^*_{od}) and frequency (ω) of power controller can be obtained by Eqs. (5) and (6) respectively.

$$P = \frac{\omega_f}{s + \omega_f} p \tag{3}$$

$$Q = \frac{\omega_f}{s + \omega_f} q \tag{4}$$

$$\omega = \omega_n - k_1 P \tag{5}$$

$$v^*_{od} = V_n - k_2 Q \tag{6}$$

In above equations ω_n and V_n are nominal frequency and voltage of microgrid. K_1 and K_2 are droop gains; these gains relate to economic and technical features of each DG unit. Droop gains are kept the same for all generators in this paper for simplicity. Reference voltage along the q-axis (v^*_{oq}) is set to be zero in order to have positive sequence components in three phase system.

According to droop characteristic, frequency of each DG changes continuously by variation in its active power. When a disturbance occurs, frequency will reach the steady state amount after transition time. DGs have different frequencies in compare to each other during transient time because they face different impedances. As one frequency is possible for generators of a microgrid, active power is divided between DGs in a way

Please cite this article in press as: Khaledian, A., & Aliakbar Golkar, M. Analysis of droop control method in an autonomous microgrid. *Journal of Applied Research and Technology* (2017), http://dx.doi.org/10.1016/j.jart.2017.03.004