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A fuzzy logic-based droop control for simultaneous voltage and frequency regulation in an AC microgrid

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ABSTRACT

Modern power systems require increasing intelligence and flexibility in the control and optimization to ensure the capability of maintaining balance between generation and load under violent disturbances. There are several inverter interfaced distributed generations (IIDGs) with local and global control loops in a microgrid (MG). Voltage and frequency of MGs are strongly impressionable from the active and reactive load fluctuations. A change in load leads to imbalance between generation and consumption. The output voltage and frequency of the IIDGs are primarily controlled by the droop characteristics. But, in case of severe changes in load, the IIDGs may be failed and the MG is collapsed. In this paper, for optimally tuning of a generalized droop control (GDC) structure and also secondary voltage and frequency controllers, the fuzzy logic technique is utilized. It is shown that the proposed fuzzy logic controller exhibits high performance and desirable response for different scenarios of change in load.

Introduction

Challenges such as increasing demand for energy, environment problems and increasing reliability in the power systems have caused the entrance of distributed generations (DGs) and Microgrids (MGs) to the power systems. These new units increase the complexity and uncertainty in the system. The main reason of the MGs entrance into the power systems is based on the increasing reliability of the conventional power systems, and also improvement of economic and environmental issues. Presence of renewable energy sources (RESs) in the MGs helps to reduce global warming and to increase speed of entering the power industry in the deregulated environments. MGs are located in the distribution networks of low/middle voltage (LV/MV) levels [1,2].

Typical DGs are diesel engine generators (DEGs), single shaft micro turbines (SSMT), photovoltaic (PV) panels, wind turbines (WTs), solid oxide fuel cells (SOFCs), and reciprocating engines. Todays, as for increasing participation of MGs in power systems, research projects throughout world such as the consortium for electric reliability technology solutions (CERTS) project in the United States [3], MG project in Senegal [4], and some projects in Japan [1] are underway. Some new challenges on the MGs operation and control such as voltage and frequency control in both connected and islanded modes are presented in [2]. The impacts of energy storage devices on MG's dynamic are studied in [5]. In the connected mode, in order to regulate voltage and frequency of the MG, the direct-quadrature-current control method is used [6,7]. Several conventional and intelligent techniques are used to stabilize the voltage and frequency of MGs [8–15]. In this case, voltage and frequency of the MG are controlled through local control loops. To avoid circulating currents between parallel inverters, usually control strategies based on droop characteristics are applied.

The present paper addresses the simultaneous impacts of active and reactive power fluctuations on the MGs' voltage and frequency. Then, a generalized droop control (GDC) is developed to minimize the active and reactive power impacts on the voltage and frequency. Finally, a fuzzy technique is utilized to tune the GDC and secondary control parameters. Simulation results show the effectiveness of the proposed intelligent control scheme.

Generalized droop control

Consider an inverter interfaced DG (IIDG) connected to the load L, with line impedance Z shown in Fig. 1. At point A, active and reactive powers can be expressed as [16]:

$$P = \frac{V_A^2}{Z}\cos\theta - \frac{V_A V_L}{Z}\cos(\theta + \delta) \quad (1)$$

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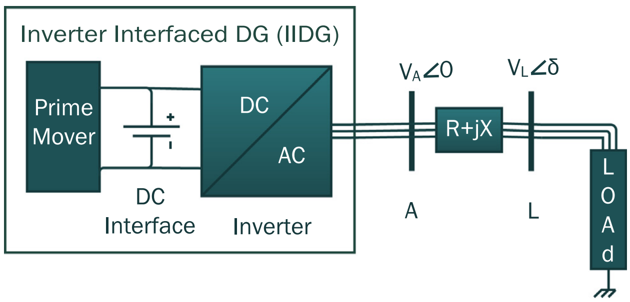

Fig. 1. DG connected with an interfaced inverter system and load.

$$Q = \frac{V_A^2}{Z}\sin\theta - \frac{V_A V_L}{Z}\sin(\theta+\delta) \quad (2)$$

where θ is the angle of line impedance $Z = R + jX$.

Considering linear approximation for dependency of the system frequency (f) and the voltage amplitude (V_A) to the active power (P) and reactive power (Q), also assuming being inductive of line ($X \gg R$), two typical equations can be defined as follows:

$$f - f_0 = -k_p(P - P_0) \quad (3)$$

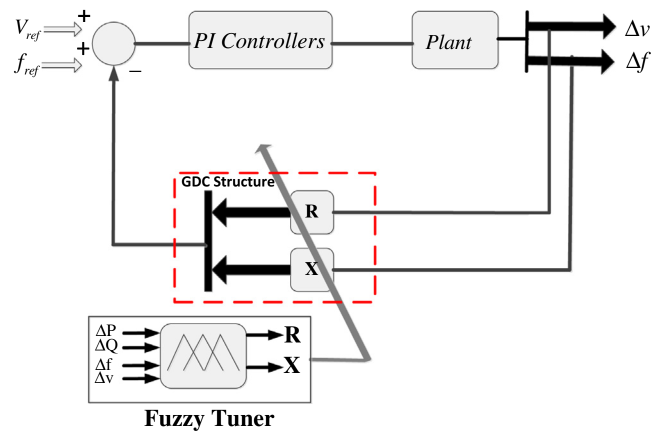

Fig. 4. GDC based on fuzzy logic.

$$V_A - V_{A0} = -k_q(Q - Q_0) \quad (4)$$

where, f_0 and V_{A0} are the rated frequency and voltage of the MG. Hence, k_q and k_p are droop control coefficients. According to (3)

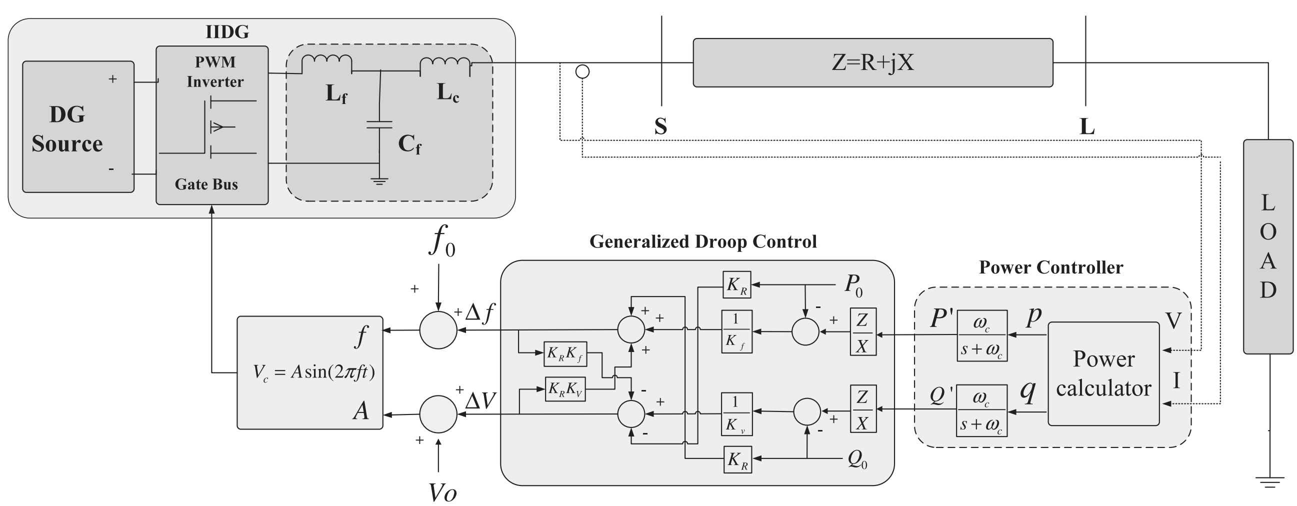

Fig. 2. Block diagram of an IIDG controlled by GDC.

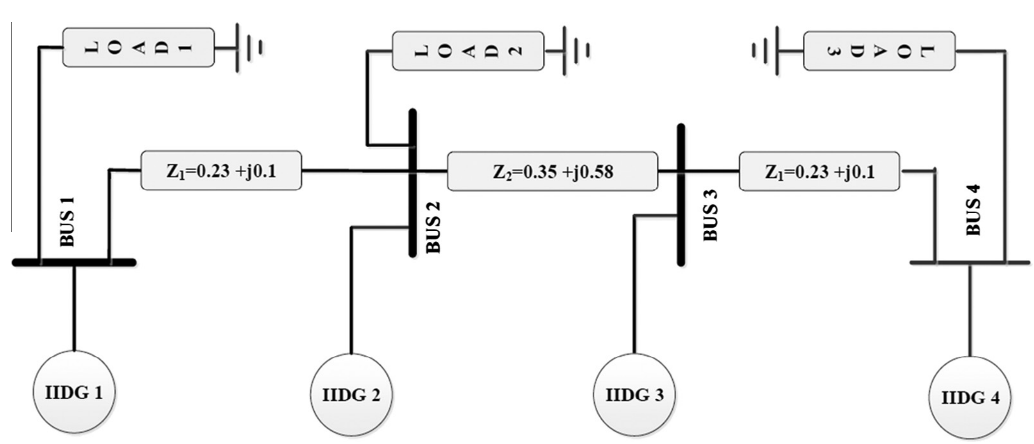

Fig. 3. An MG with four DGs and three load banks.