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Dynamic reverse droop power sharing in microgrid based on neural networks

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Abstract

This paper presents a dynamic reverse droop power-sharing scheme to control frequency of micro grids based on neural networks. Micro grid is included undispatchable distributed generation (DG) such as wind turbine and dispatchable voltage source converter DG which is considered as auxiliary generation. Power sharing control strategies of distributed generation (DG) units without communication are based on the droop concept; while for the DG units in current control mode that applied in most renewable resources such as the wind, the droop control may not be implemented directly since the output of droop control is voltage amplitude and frequency. Also, the droop coefficients are constant and determined as a function of DG unit capacity. However, the generation capacity of the wind turbine is not constant. Therefore, in the proposed scheme first, the reverse droop method is provided for the wind turbine power sharing as its outputs are active and reactive power reference. Then, the dynamic coefficients are modified as a function of generalized regression neural networks. Finally, the control strategy is presented for coordinate control of wind turbine and auxiliary generator (AG) to ensure frequency stability of micro grid. The proposed control strategy is validated through extensive simulation results using MATLAB/Simulation software.

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Keywords: Microgrids; dynamic droop; neural nework; wind turbine.

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1. Introduction

Power generation from renewable energy (RE) resources such as wind, photovoltaic (PV) are used as distributed generator (DG) technologies. Increasing the penetration level of DG have transformed distribution networks from passive to active networks and has introduced the concept of micro grids. Micro grids consist of multiple parallel connected DG units with coordinated control strategies, which can operate in both grid-connected and islanded modes. Because of the uncertainty of RE resources, other energy sources, such as diesel generators and energy storage systems, are critical part to enable the stand-alone operation of micro grids or to smooth the micro grids power during grid-connected operation Nejabatkhah (2015).

Power sharing control strategies between DG units have been used to ensure voltage and frequency stability of micro grids. These strategies are categorized as communication-based control techniques and droop characteristic based techniques. Power sharing control strategies based on communication are not often recommended because of their high finance costs and low reliability. The control methods based on droop concept include conventional and variants of the droop control, virtual framework structure-based method, constructed and compensated based methods, common variable based control method and the droop-signal injection method Han et al. (2016). The common point in all of the mentioned methods is generating the magnitude and frequency of the fundamental output voltage of the DG according to the droop characteristic for power sharing control. Potential advantages and drawbacks of droop characteristic based control are presented in Han et al.(2016).

These droop control strategies are very effective when applied to the grid following DG units in voltage control mode (VCM).While for the grid forming DG units in current control mode (CCM)applied in most renewable sources such as wind turbine, the droop control may not be implemented directly since the output of droop control is voltage amplitude and frequency. Therefore, the analysis of droop and reverse droop control for both VCM and CCM DG units are carried out in Wu et al. (2014). All of the DG units which are considered in Wu et al. (2014)are dispatchable voltage source converter. In this paper, power sharing control based on dynamic droop and reverse droop control is implemented for micro grids based on renewable resources. The studied micro grid is included dispatchable AG and the wind turbine is driven by doubly fed induction generator (DFIG).

The intermittent nature of wind could be accounted as its most challenging characteristic. Currently, the DFIG is commonly used in type-3 wind turbines which are occupied close to 50% of the wind energy market Liserre et al. (2011). Based on new grid code, as wind power penetration increases, it is essential for wind turbines to participate in frequency regulation in the grid-connected operation of DFIG. According to this, DFIG should not work on maximum power point tracking (MPPT) mode during periods of low loads Luo & Ooi (2006); Banakar et al. (2008); Luo et al. (2007). There are several publications related to the subject of grid frequency support using wind energy systems Morren et al. (2006); Gautam et al. (2011); Margaris et al. (2012); Zhang et al. (2012). Most of the proposed methods use the kinetic energy stored in the wind turbine rotating mass to provide additional power to the system in case of grid frequency variation. Frequency support in islanded micro grid is usually accomplished using inertia emulation Ramtharan et al. (2007);de Almeida et al. (2006) and droop control Shahabi et al. (2009) for the operation of DFIG. It may be worthy to mention that in all of these works, a secondary, usually dispatchable, source of energy was employed to restore the frequency to its nominal value. The application of variable speed wind turbine based on DFIGs for frequency and voltage regulation in micro grids and mini grids has also been discussed in Fazeli et al. (2012). According to this, the magnetizing current supplied from the rotor side converter of DFIG is regulated to control the stator voltage and the stator frequency. An energy storage system (ESS) is used to supply power to the grid or absorb excess power captured from the wind turbine. When the ESS is fully charged, pitch control is required to limit the power transferred to the grid. The approach of Fazeli et al. (2012) is based on direct droop control, and also it is used ESS to regulate the frequency of micro grid. However, the current paper considers micro grid without any battery storage. In Zhang & Ooi (2013), the stand-alone operation of DFIG is presented in the absence of any dispatchable sources. The droop coefficient of power is considered constant in Zhang & Ooi (2013) and it only considers constant wind speed with always excessive generation in compare to load demand. Besides, if the load demand is more than wind generation, using auxiliary generation is inevitable. The objects of this paper are implementing coordinate directdroop and reverse droop power sharing between wind turbine and AG to regulated ac bus voltage and at the same time adjust frequency. Accordingly, the output of reverse droop control is active and reactive power and therefore it is implemented on wind turbine driven by DFIG. Simultaneously, as the output