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High stability adaptive microgrid control method using fuzzy logic

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ABSTRACT

Appropriate control strategies for power sharing between multiple generation units operating in parallel are required to create a stable AC microgrid bus. In this paper, we explore the droop control strategy, implemented by power electronics units, to maintain a stable AC bus voltage without the need for a separate (central) communication layer. In particular, our suggested control method is based on adaptive fuzzy logic control (FLC). Fundamentally in low voltage microgrids, due to the effects of feeder and line impedance, the droop control method is subject to real and reactive power coupling and steady-state reactive power sharing errors, and in particular for complex microgrid configurations, the reactive power sharing poses certain challenges. To improve the reactive power sharing equalization, an enhanced FLC strategy has been utilized to calculate a droop coefficient for reactive power control. A second FLC is implemented in an integrator controller, where the reactive power error has been compensated through the injection of small real power disturbances. Root locus analysis of a representative microgrid with three inverters has been undertaken to confirm that stable solutions are feasible. Implementation of a set of gain values into time domain analysis demonstrates excellent voltage and frequency stability on the main bus, as well as equalized real and reactive power sharing between inverters to within ±5 W and ±10 VAR, respectively.

1. Introduction

During the past decade, the market interest for smart grid applications that employ renewable energy generation technologies has grown rapidly. In comparison to conventional centralized power generation, clean and renewable power generators, such as solar photovoltaic (PV) systems, can be located close to the consumer. Small units may also be connected to the secondary distribution level of the grid, or even implemented in stand-alone (grid-isolated) microgrid configuration – both implementations reduce or even avoid the cost of transmission and distribution infrastructure (Perez, Zweibel, & Hoff, 2011). As most PV systems grid interface through power electronics converters, their flexible digital control may possibly enhance grid power quality. High penetration of such power converter PV systems, however, may also have negative impacts, such as system resonance, protection interference, and harmonic distortion. The microgrid concept, a managed local bus onto which local generation sources and loads are connected, has been proposed to address these challenges, and IEEE standard 1547.4 covers key considerations for their planning and operation (Kroposki, Basso, & DeBlasio, 2008). Compared to a standard PV system, a microgrid can provide more flexible power management and more stable electrical service. Its ability to grid disconnect during times of grid instability offers supply protection for critical loads. In the evolving grids, microgrids may be considered an enabling technology for sustainable cities.

Microgrids are commonly implemented with frequency and voltage magnitude droop control to achieve power sharing between multiple parallel generators in a decentralized manner, where power converters undertake local measurement of frequency and voltage (Liang, Choi, Zhuang, & Shen, 2012; Li, Vilathgamuwa, & Loh, 2004) to autonomously adjust generator outputs in order to maintain these parameters within preset ranges. In comparison to centralized control with its separate communications layer, droop control is arguably the preferred control method for microgrids for multiple reasons: there is no single point of failure due to communications, fast system's response with respect to state variables (i.e., voltage and frequency) can be achieved without explicit latency considerations; and microgrid stability can in

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