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Operation and control of a hybrid microgrid containing unbalanced and nonlinear loads

Farhad Shahnia, Ritwik Majumder*, Arindam Ghosh, Gerard Ledwich, Firuz Zare

School of Engineering, Queensland University of Technology, 2 George Street, Brisbane, Queensland 4001, Australia

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ABSTRACT

This paper shows how the power quality can be improved in a microgrid that is supplying a nonlinear and unbalanced load. The microgrid contains a hybrid combination of inertial and converter interfaced distributed generation units where a decentralized power sharing algorithm is used to control its power management. One of the distributed generators in the microgrid is used as a power quality compensator for the unbalanced and harmonic load. The current reference generation for power quality improvement takes into account the active and reactive power to be supplied by the micro-source which is connected to the compensator. Depending on the power requirement of the nonlinear load, the proposed control scheme can change modes of operation without any external communication interfaces. The compensator can operate in two modes depending on the entire power demand of the unbalanced nonlinear load. The proposed control scheme can even compensate system unbalance caused by the single-phase micro-sources and load changes. The efficacy of the proposed power quality improvement control and method in such a microgrid is validated through extensive simulation studies using PSCAD/EMTDC software with detailed dynamic models of the micro-sources and power electronic converters.

1. Introduction

The ever increasing energy demand, along with the necessity of cost reduction and higher reliability requirements, are driving the modern power systems towards distributed generation (DG) as an alternative to the expansion of the current energy distribution systems [1]. In particular, small DG systems, typically with power levels ranging from 1 kW to 10 MW, located near the loads are gaining popularity due to their higher operating efficiencies. Fuel cells (FCs), photovoltaic cells (PVs), batteries, micro-turbines, etc. are nowadays the most available DGs for generation of power mostly in peak times or in rural areas [2].

A diesel generator set (genset) consists of an internal combustion engine, exciter and a synchronous generator coupled on the same shaft. Such systems are widely used as backup or emergency power in commercial as well as industrial installations. Diesel gensets are also extensively used in remote locations where no utility supply exists [3]. Over the last few decades, there is a growing interest in FC system for power generation and it has been identified as a suitable solution for distributed generation [4]. Other than FC, the use of new efficient PVs has emerged as an alternative measure of renewable green power, energy conservation and demand side management [5].

Microgrids are systems with clusters of loads and micro-sources. To deliver high quality and reliable power, the microgrid should appear as a single controllable unit that responds to changes in the system [6]. The high penetration of DGs, along with different types of loads, always raises concern about coordinated control and power quality issues. In microgrid, parallel DGs are controlled to deliver the desired active and reactive power to the system while local signals are used as feedback to control the converters. The power sharing among the DGs can be achieved by controlling two independent quantities—frequency and fundamental voltage magnitude [7–9].

General introduction on microgrid basics, including the architecture, protection and power management is given in [10]. A review of on going research projects on microgrid in US, Canada, Europe and Japan is presented in [11]. Different power management strategies and controlling algorithms for a microgrid is proposed in [12]. Refs. [13–16] have evaluated the feasibility for the operation of the microgrids during islanding and synchronisation. An algorithm was proposed in [17] and used for evaluation of dynamic analysis for grid connected and autonomous modes of the microgrid. In [18], it is shown that a proper control method of distributed resources can improve the power quality of the network. There are still many issues which are needed to be addressed to improve the power quality in a microgrid.

The power quality issues are important as the power electronic converters increase the harmonic levels in the network voltage and current. Unbalance loads can cause the current and hence

* Corresponding author. Tel.: +61 423049353.
E-mail address: ritwik.majumder@student.qut.edu.au (R. Majumder).

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