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Control of grid-connected fuel cell plants for enhancement of power system stability

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Abstract

This paper presents a methodology for effective control of fuel cell devices connected to an electric utility distribution network. A controller is developed for a fuel cell power plant to assist the conventional generators to damp out oscillations, which is possible by utilizing the fast response characteristic of fuel cells. It achieves the objective by generating appropriate switching signals to the DC–AC inverters and modulating both active and reactive powers. Computer model of the controller is developed and its effectiveness is proved by a sample test. Fuel cell devices, therefore, can be used to improve power system stability when these are applied to a power distribution system.

Keywords: Fuel cells; Power system control; Power system stability; Rotor oscillation; DC–AC inverter

1. Introduction

As the increase in world population requires definitely more electrical energy, more usage and the resultant less reserve of fossil fuels may stop or delay future development of technology. Nuclear power generation, considered once as an unlimited energy source, is now proved being a technology that is not easily accepted. Renewable energy sources are still of low economy and unrealistic, so the energy problem has worldwide been a difficult issue to solve. The tasks to resolve the energy

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problem include (i) more efficient utilization of fossil fuels, (ii) more secure use of nuclear energy, and (iii) development of new technologies for utilization of renewable energy sources including solar, wind, tidal, and fuel cell power.

In recent years, fuel cell power supply in addition to solar power is spotlighted as a part of environmentally benign technology as the world's environmental concern about global warming and acid deposition grows. A fuel cell is an electrochemical device that directly converts the free-energy change of an electrochemical reaction into electrical energy. Due to its great features such as high efficiency, fast load-response, modular production and fuel flexibility, the fuel cell technology is going to be largely applied to dispersed power plants and transportation vehicles.

The feasibility of a fuel cell system in coordination with a photovoltaic system has been successfully demonstrated for a grid-connected application [1,2]. Owing to its fast ramping capability, the fuel cell system can smooth out the photovoltaic cell's inherent problem of intermittent power generation. Yamaguchi et al. [3] have developed 1-MW phosophoric acid fuel cell plant simulator and load-following and shutdown operation characteristics were examined by comparing the simulation results with the process and control test results. A computer model for simulating a transient operation of a tubular solid oxide fuel cell was proposed [4]. The transient model includes the electrochemical and thermal aspects of cell operation that affect the output power produced, which is achieved by stepping back and forth between the two parts. Lukas et al. [5] have reported a nonlinear mathematical model of an internal reforming molten carbonate fuel cell plant for its control application. The model can be used to evaluate the cell responses to varying load demands and to define transient limitations and control requirements. Another approach to fuel cell modeling is found in Ref. [6] where an electrical equivalent circuit of a fuel cell generation system was developed for system control and the system is tested using a fuzzy logic controller. Several test results for operation of the phosphoric acid fuel cell plant installed in Germany are reported by Hoelzner et al. [8], where the response time for load change from 25% of the rated power to full load is 1 min.

This paper focuses the application of a fuel cell device to power system control. As its utilization in a power system increases, it is quite required to obtain a strategy for efficient control of the fuel cell system. The paper proposes a controller for the fuel cell system to enhance the overall power system stability, which is possible by utilizing the fast response characteristic of fuel cells. It achieves the objective by generating appropriate switching signals to the DC–AC inverters and modulating both active and reactive powers. Computer simulations will prove effectiveness of the models for the fuel cell system and the controller.

2. System description

The configuration of a grid-connected fuel cell power plant is illustrated in Fig. 1. A model for a single cell is described separately in Appendix A. The fuel cell system consists of three major subsystems: