A LINEAR QUADRATIC REGULATOR FOR A PEM FUEL CELL BASED POWER SUPPLY SYSTEM FOR RESIDENTIAL USE

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ABSTRACT

This paper presents a linear quadratic regulator of a stand-alone proton exchange membrane (PEM) fuel cell power plant (FCPP). The controller modifies the inverter signal control and the phase angle of the ac output voltage to control the active and reactive power output from an FCPP to match the terminal load. The control actions are based on feedback signals from the terminal load, output voltage and hydrogen input. Simulation results show that the proposed control strategy operated at low commutation frequency (2khz) offers good performances versus load variations with low total harmonic distortions (THD) even it very useful for high power applications.

Keywords

Modeling of PEM fuel cell, controlling of PEM fuel cell, linear quadratic regulator.

1. INTRODUCTION

The private sectors and utilities are now concentrating on green power technologies with accrued benefits on account of their cleanliness, modularity, high efficiency and reliability. Among the different green power technologies e.g. wind power, photovoltaic, micro turbine, and fuel cells, the fuel cell based distributed generation is considered as one of the most promising technology due to high operating efficiency (40-60%), reliability and higher potential capability [1],[2].

Fuel cells (FC) basically convert chemical energy of hydrocarbon fuels, typically hydrogen directly into dc form of electrical energy. The fuel cell based distributed generation can be placed anywhere in the system to upgrade system integrity, reliability and efficiency. Among the various types of fuel cells, PEMFC are particularly attractive for residential use due to their relatively low operating temperature (~80oC) and good dynamic response [3],[4].

The open circuit voltage of the single cell is in the range of 0.8-1.2V. To get higher operating voltage and power; many such cells are stacked and connected in the form of cascaded series and parallel connection. Normally the fuel cell stack available in the market gives operating voltage in the range of 26V to 50V. These stacks are now widely used in portable devices automotive industry, residential and stationary power needs. A FC based power system mainly consists of a fuel-processing unit (reformer), FC stack and power conditioning unit. The FC uses hydrogen as input fuel and produces DC power at the output of the stack [5].

The performance of the stack is expressed by the polarization curve, which gives the relation between stack terminal voltage and load current, as shown in Figure.1. It is evident from Figure.1 that the cell voltage decreases almost linearly as the load current increases. Therefore the output voltage should be regulated at a desired value [1-4].

To enable the FCPP to conform to the load changes, it is essential to control the active and reactive power output of the power plant. Many schemes of control have been developed in literature. In Ref. [6],[7], the authors introduced a technique to control the active and reactive power output from an FCPP. The proposed technique is based on controlling the inverter modulation index (m) to control the voltage level and the reactive power output from the FCPP. The active power flow from the FCPP to the load is controlled through controlling the phase angle of the ac output voltage (δ). A neural network (NN)-based controller to control the active and reactive power output of the FCPP has been developed in Ref. [8]. This paper introduces a technique based on linear quadratic regulator (LQR) to control the output voltage at the load point versus his variation from a stand-alone fuel cell power plant for residential use.

The FC output voltage is modeled based on the FC load current. Since numerous FC based power system topology can be chosen to meet the required criterion, in this study we selected a commonly used 5 kW (48 V) fuel cell, a single stage voltage source PWM inverter followed by a low-pass filter and a step up transformer to perform voltage and real power control as well as power quality performance evaluation with respect to residential load variations. It is assumed that the FC output voltage ranges from 40V to 70V.

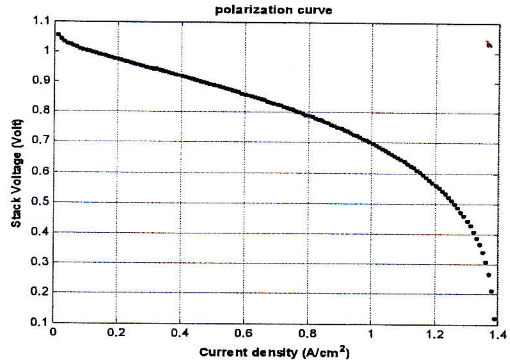

Figure 1. A cell voltage versus current density

