Linear Quadratic Integral Controller Based MPPT Design for Proton Exchange Membrane Fuel Cell

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ABSTRACT

In this paper, in order to keep the system running at an efficient power point, the maximum power point tracking (MPPT) based on the linear quadratic integral (LQI) control is used to drive the boost converter for proton exchange membrane fuel cell (PEMFC). LQI controller is used to control the duty cycle of the chopper in order to achieve MPPT. The characteristics of the approach are its good transition response, low tracking error, very fast system reaction against set point, fuel cell temperature and membrane water content, robustness as well as low complexity. The simulation results show the applicability and effectiveness of the used control for PEMFC.

Keywords: LQI control, Fuel cells, MPPT

1 Introduction

Limited to space applications in the last century, fuel cells (FC) are now invading all sectors of activity: transport with on-board batteries, businesses and housing with stationary batteries, daily life with miniaturized batteries. The fuel cell is an electrochemical generator that converts the energy stored in the chemical bonds of compounds (called oxidant: able to receive electrons by reducing, and reductant: able to lose electrons by oxidizing) into electrical energy and in heat. Nowadays, FC's are considered as promising alternative solution for electrical energy generations in the future for mobile and stationary applications. This is due to their high efficiency and environmental friendliness. The problem of extracting the maximum power in renewable energy was first done for processes like photovoltaic panels or wind turbines. Despite the relatively high efficiency of the fuel cell, the power extracted from the fuel cell is not always optimal because of the ever-changing internal variables. MPPT algorithm is required via the power electronics interface to ensure maximum power extraction [1]. A Maximum power point tracking (MPPT) controller traces the MPP of FC using a MPPT algorithm. The MPPT controls the DC-DC boost converter by changing its duty cycle to extract from the FC the output voltage and current, which corresponds to MPP [2]. Recently, many control algorithms have been designed for PEMFC power systems. In this paper, MPPT based linear quadratic integral controller (LQI) is designed. The proposed MPPT control modulates the DC-DC boost converter to extract the maximum power from the system and guarantee optimal resource usage. The various advantages of this type of control is, a good transition response, low tracking error, very fast system reaction against set point and their easy design.

2 LQI control design for PEMFC

In order to apply the LQI control, the system must be linearized. The full boost converter modeling is more detailed in [3]. LQI is an extension of the linear quadratic regulator (LQR) for tracking problems. In LQI, an integral compensator, i.e., the integral of the tracking error, is introduced to guarantee robust tracking [4]– [6], as represented in figure 1.

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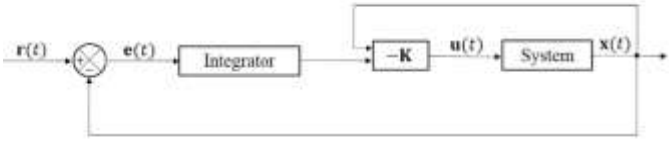

Figure 1: *The LQI control loop*

The objective of the LQI control is to find the optimal feedback law of the form:

$$U(t) = -K.x(t) \quad (1)$$

After finding the solution to the Riccati equation, the optimal gain K, and hence the optimal control input u(t), can be determined using equation (1). The control signal U(t) represents the duty cycle.

The synoptic diagram of the control of PEMFC by LQI is given in the figure (2).

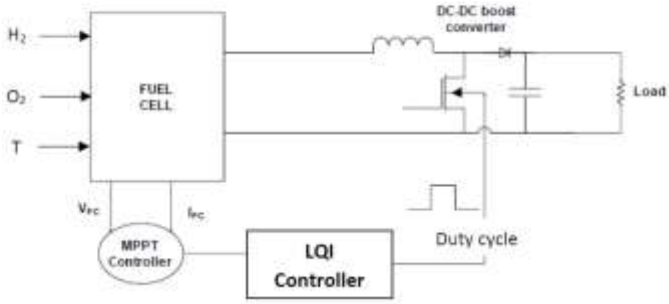

Figure 2: *Synoptic diagram of the PEMFC control.*

3 Results and Discussion

In order to study the application of the LQI control to the ¨PEMFC system, the matlab/simulink environment is used with the following values: the temperature varies from 293K to 343K with steps of 10K, the pressure values of H_2 and O_2 are 0.3, 0.5, 0.7, 0.8, 0.9 and 1 applied at times 0, 0.3, 0.4, 0.5, 0.6 and 0.8s.

In this simulation, the application of the LQI control to drive the converter boosts according to the variations in temperature, in the pressure of H_2 and O_2 and/or the values of the resistance R is made. The figures in this paper illustrate the fast change of the instantaneous FC power and the duty cycle. These results show the applicability and effectiveness of the LQI control for PEMFC system.

4 Conclusion

In this work, a linear quadratic integral controller based maximum power point tracking approach for PEM fuel cell is presented and its characteristics, accuracy and performance is investigated via simulations. The analyses and simulations are performed on a system including of a PEMFC, boost DC/DC" converter and a load for Fuel cell temperature and membrane water content operating conditions.

How to Cite

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