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Robust control of an isolated hybrid wind–diesel power system using Linear Quadratic Gaussian approach

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ABSTRACT

This paper presents the application of the Linear Quadratic Gaussian (LQG) controller for voltage and frequency regulation of an isolated hybrid wind–diesel scheme. The scheme essentially consists of a vertical axis wind turbine driving a self-excited induction generator connected via an asynchronous (AC–DC–AC) link to a synchronous generator driven by a diesel engine. The synchronous generator is equipped with a voltage regulator and a static exciter. The wind generator and the synchronous generator together cater for the local load and power requirement. However, the load bus voltage and frequency are governed by the synchronous generator. The control objective aims to regulate the load voltage and frequency. This is accomplished via controlling the field voltage and rotational speed of the synchronous generator. The complete nonlinear dynamic model of the system has been described and linearized around an operating point. The standard Kalman filter technique has been employed to estimate the full states of the system. The computational burden has been minimized to a great extent by computing the optimal state feedback gains and the Kalman state space model off-line. The proposed controller has the advantages of robustness, fast response and good performance. The hybrid wind diesel energy scheme with the proposed controller has been tested through a step change in both wind speed and load impedance. Simulation results show that accurate tracking performance of the proposed hybrid wind diesel energy system has been achieved.

1. Introduction

During last three decades, the assessment of potential of the sustainable eco-friendly alternative sources and refinement in technology has taken place to a stage so that economical and reliable power can be produced. Different renewable sources are available at different geographical locations close to loads, therefore, the latest trend is to have distributed or dispersed power system. Example of such systems is wind–diesel. This system is known as hybrid power systems.

The advantage of hybrid power systems is the combination of the continuously available diesel power and locally available, pollution-free wind energy. With the hybrid power system, the annual diesel fuel consumption can be reduced and, at the same time, the level of pollution can be minimized. A proper control strategy has to be developed to take full advantage of the wind energy during the periods of time it is available and to minimize diesel fuel consumption. Therefore, a proper control system has to be designed, subject to the specific constraints for a particular application. It has to maintain power quality, measured by the quality of electrical performance, i.e., both the voltage and the frequency have to be properly controlled [1]. These results in a need for a simulation study of each new system to confirm that a control strategy results in desired system performance.

The wind–diesel systems are normally equipped with a control system, which functions to reduce the system frequency oscillations, when the system is subjected to wind/load disturbances [2].

Various control strategies have concerned with the voltage and/or frequency control of the hybrid wind–diesel power system and achieving optimal out of the turbine. In some schemes, the hybrid wind–diesel power system uses compressed air energy storage with the wind–diesel hybrid system [3]. Other control schemes use static VAR compensators for reactive power control [4]. Mathematical modeling of a typical hybrid system with PI controllers and system dynamic studies on it has been reported by Scott [5]. However, it is well known that the performance of the systems with fixed gain controllers designed on the fixed parameter model of the system does not stay optimal as the system parameters undergo a change.

Recently, advanced control techniques, which were applied successfully on the machine drives, have been proposed for regulating the wind power in a grid connected wind energy conversion scheme. They include Artificial neural networks [6–8], fuzzy

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