Applied Energy 87 (2010) 3051–3064

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Dynamic behavior of a stand-alone hybrid power generation system of wind turbine, microturbine, solar array and battery storage

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ARTICLE INFO

Article history:
Received 14 April 2009
Received in revised form 8 January 2010
Accepted 23 February 2010
Available online 8 April 2010

Keywords:
Wind turbine
Solar array
Microturbine
Adaptive control
Supervisory control
Indirect space vector control

ABSTRACT

This paper presents dynamic behavior and simulation results in a stand-alone hybrid power generation system of wind turbine, microturbine, solar array and battery storage. The hybrid system consists of a 195 kW wind turbine, an 85 kW solar array; a 230 kW microturbine and a 2.14 kAh lead acid battery pack optimized based on economic analysis using genetic algorithm (GA). At first, a developed Lyapunov model reference adaptive feedback linearization method accompanied by an indirect space vector control is applied for extraction of maximum energy from a variable speed wind power generation system. Then, a fuzzy logic controller is designed for the mentioned purpose and its performance is compared with the proposed adaptive controller. For meeting more load demands, the solar array is integrated with the wind turbine. In addition, the microturbine and the battery storage are combined with the wind and solar power generation system as a backup to satisfy the load demand under all conditions.

A supervisory controller is designed in order to manage energy between the maximum energy captured from the wind turbine/solar arrays, and consumed energies of the load, dump load, battery state of charge (SOC), and generated energy by the microturbine. Dynamic modeling and simulation are accomplished using MATLAB Simulink™ 7.2.

1. Introduction

Renewable energy resources, called sustainable or alternative energy, are energies generated from natural resources such as wind, sunlight, tide, hydro, biomass and geothermal which are naturally replenished. Energy crisis, climate changes such as atmosphere temperature rise due to the increase of greenhouse gases emission and the Kyoto Protocol restrictions in generation of these gases, coupled with high oil prices, limitation and depletion of fossil fuels reserves make renewable energies more noticeable. Moreover, since many remote rural areas in all over the world are not electrified, for example about 72 million households in rural India do not have access to electricity [1], one of the interesting utilization of the renewable energies is to electrify many remote villages and rural areas or rugged terrain located so far from power stations and distribution networks or utility lines which are uneconomical to install. Vulnerability to unpredictable climatic changes and dependency of renewable energy systems on weather conditions remain among their drawbacks.

2. Literature review

Among the renewable energy resources, wind power has had the fastest growth in the world (at the rate of 30% annually) in many developed and developing countries over the last 20 years [2]. For example, installed capacity in Germany is more than 20 GW with an annual output of about 40 TWh in 2007 [3]. In order to convert the wind energy to electrical energy, two types of wind turbines are employed; fixed speed and variable speed wind turbines installed onshore or offshore [4]. In the fixed speed wind turbine, electrical generator is connected directly to the power grid. Therefore, the generator runs at constant frequency and speed. Active and reactive power control of these turbines is described in [5,6]. The variable speed wind turbine (VSWT) is used for more attraction of energy from the wind. The VSWT, which attracts 10–15% more energy, has lower mechanical stress and less power fluctuation in comparison with the fixed speed ones. Furthermore, the wind turbine is divided into two large categories: horizontal and vertical axis wind turbines. Savonius and Sherbious are the most famous vertical axis wind turbines (VAWT). The aerodynamic efficiency of the VAWT is lower than the horizontal type but complexity and price of these types are lower [7].

One of the most important studies in the VSWT is the application of various control schemes for several purposes in the plant.

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doi:10.1016/j.apenergy.2010.02.019