Ain Shams University

Faculty of Engineering

Electrical Power & Machines Department

Optimum Sizing and Operation of Energy Storage System for a Grid Connected Wind Energy System

M.Sc. Thesis

By

Eng. Mahmoud Samir Mahmoud Hassan

Submitted in partial fulfillment of the requirements for the M.Sc. degree in Electrical Engineering

Supervised By

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Cairo 2016

Supervisors Committee

For the Thesis

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Statement

This Thesis is submitted to Ain Shams University in partial fulfillment of the requirements of M.Sc. degree in Electrical Engineering.

The included work in this thesis has been carried out by the author at the department of electrical power and machines, Ain Shams University. No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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Abstract

The installation of wind energy systems has gained a rapid development due to their positive environmental impacts. Over the past decades, the global installed capacity of wind energy systems has increased from 7.5 GW in 1997 to 369.5 GW in 2014.

One of the main shortcoming of wind energy systems is the intermittency of their output power that lead to power fluctuations over short periods of time. These fluctuations are considered the main barrier from dealing with these systems as dispatchable power sources. Moreover, they might lead to several technical issues, including voltage fluctuations at the point of common coupling and frequency deviations in microgrids operating in the islanded mode.

A possible solution to overcome the issue of power fluctuations from wind energy systems is the installation of Battery Energy Storage System (BESS). The proper operation of the BESS can lead to achieving the required dispatchability from the wind energy system over a specific period of time. However, the BESS contributes to a significant portion of the total cost of the system, and thus, a careful choice of its size is a must.

In this thesis, a new methodology is proposed to obtain the optimum size of a BESS that can limit the power fluctuations from a wind energy system. The main target of the methodology is to identify the size of the BESS that corresponds to the lowest cost. The function of this BESS is to allow the generation of a constant power from the wind-BESS energy system during a minimum specified period. Moreover, the methodology attempts to extend the lifetime of the BESS by fully charging and discharging the battery during each cycle. In addition, the methodology is used to investigate the impact of the Depth of Discharge (DoD_{max}) on the cost, lifetime and operation of the BESS.

The proposed methodology is based on utilizing the historical wind speed data at the location of the wind energy system. The wind speed data is then converted to the corresponding electric output power using the wind turbine power curve. The optimum size is then identified by an iterative method which is based on choosing the generated power during the charging and discharging periods of the BESS. During the charging periods, the generated power from the system is chosen as the minimum value electrical power from the wind turbine during the charging period. On the other hand, during discharging periods, the generated power from the system is chosen to be the maximum value of the power from the wind turbine during the discharging period. To avoid the rapid changes in the output power and to improve the dispatchability of the system, the charging and discharging periods are not allowed to be less than a specified value (e.g., 30 minutes).

The proposed methodology is also implemented using the Genetic Algorithms technique and the results are compared to the iterative method. In addition, a multi-objective Genetic Algorithm is also used to find the optimum size of the BESS while minimizing the cost and maximizing the charging and discharging times at the same time.

The modeling and simulation of the system is performed in the MATLAB environment and the sensitivity analysis is carried out by investigating the impact of different data patterns on the results.

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Mahmoud Samir

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