Ain Shams University
Faculty of Engineering
Engineering Physics and Mathematics Department

Enhancement of Renewable Energy Operation by Optimization Techniques

By

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B.Sc. Electrical Engineering, Ain Shams University, 2014

A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science in Engineering Mathematics

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STATEMENT

This thesis is submitted as partial fulfillment of M.Sc. degree in Engineering Mathematics, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

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Thesis Summary

Meta-heuristic optimization techniques are now used to solve many electrical engineering optimization problems but there is no mathematical proof for their convergence towards the optimal point. In this thesis, three different optimization techniques are used. The used techniques, two of them are Meta- heuristic optimization techniques and the third is classical optimization technique. In the beginning, two different Meta-heuristic techniques (Harmony search algorithm and Invasive weed optimization) are used to find optimal base wind speed at which a doubly fed wind turbine can generate its maximum energy under different wind speed profiles in MATLAB/SIMULINK. Then to check convergence of the two Meta- heuristic techniques, a classical optimization technique is used to solve the same problem. A mathematical curve fitting is used to enhance the performance of the classical optimization technique. The results for the Meta-heuristic techniques and classical technique are compared. From the results, the two Meta-heuristic techniques gave good solutions for the optimal base wind speed and proved their convergence through the classical technique. Therefore the same two techniques are used for another two models. In the first model, the two Meta-heuristic techniques are used to optimal tuning of controllers to enhance dynamic performance of voltage and power. These controllers are pitch angle controller and the Static VAR Compensator voltage regulator controller. The second model is on grid photovoltaic model. In this model, the energy generated from the panels is maximized by optimal tuning of the Incremental Conductance MPPT technique with new adaptive controller using the same two meta-heuristic techniques. Results showed how optimization techniques solve the system problem and gave better system response. Mathematical curve fitting tool is also presented in the thesis to overcome some of difficulties against using of classical optimization techniques in engineering applications.

Keywords: Renewable Energy, Variable and Fixed Speed Wind Turbines, Photovoltaic Systems, Incremental conductance MPPT, Optimization Techniques, Optimal-Controllers-Tuning.

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Renewable energy resources are the future sponsors to electrical power generation with no harmful environmental emissions. Enhancement of these resources operation will enhance the overall electrical power system. Most common used renewable energy resources are wind energy and solar energy which are fast growing with time. The main problems prevent making the best use of this resources in electrical power generation are high variability, unpredictability which prevent solving economic dispatch problem for these resources when be used with other non-renewable energy resources such as fuel and natural gas.

1.2 Wind Energy Systems

Electrical power is generated from wind energy using different methods. Wind turbines are used as prime mover to electrical generators to transfer energy carried by wind into electrical energy. Figure 1.1 shows the operation curve of the wind turbines and generated electrical power corresponding to certain wind speed. Each wind turbine has Cut-in speed (which is the minimum speed to start generating electrical energy), Rated speed (at which the turbine can generated its rated output power) and Cut-out speed (at which wind turbine control circuit will switch it off to prevent turbine from damage) Equation (1.1) represents the electrical power generated form wind turbine which is a function of air density ($\rho = 1.23\ \mathrm{kg/m^3}$), swept area of the turbine blades (A) in ($\mathrm{m^2}$) , wind speed (V) in ($\mathrm{m/s}$) and turbine efficiency (C_p).

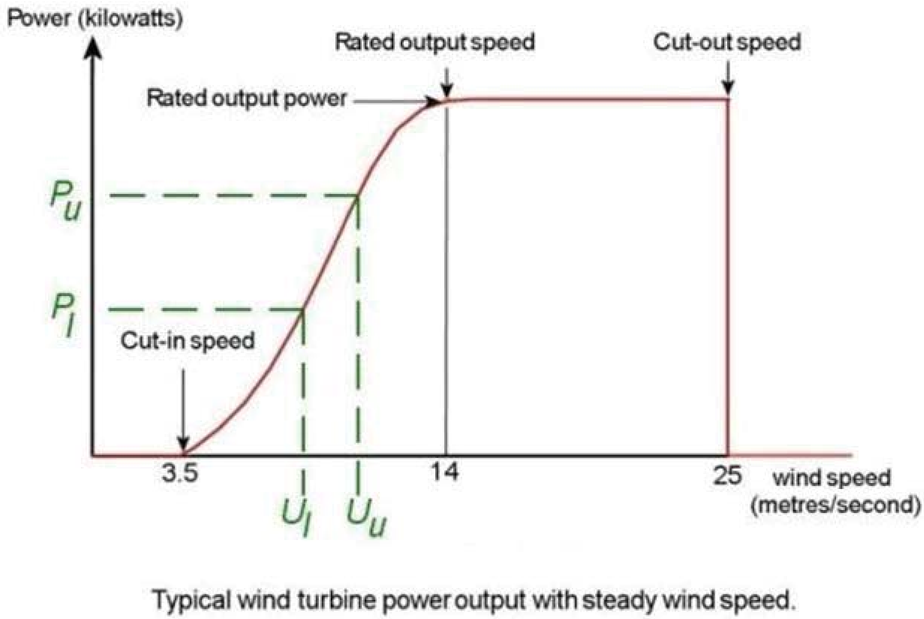
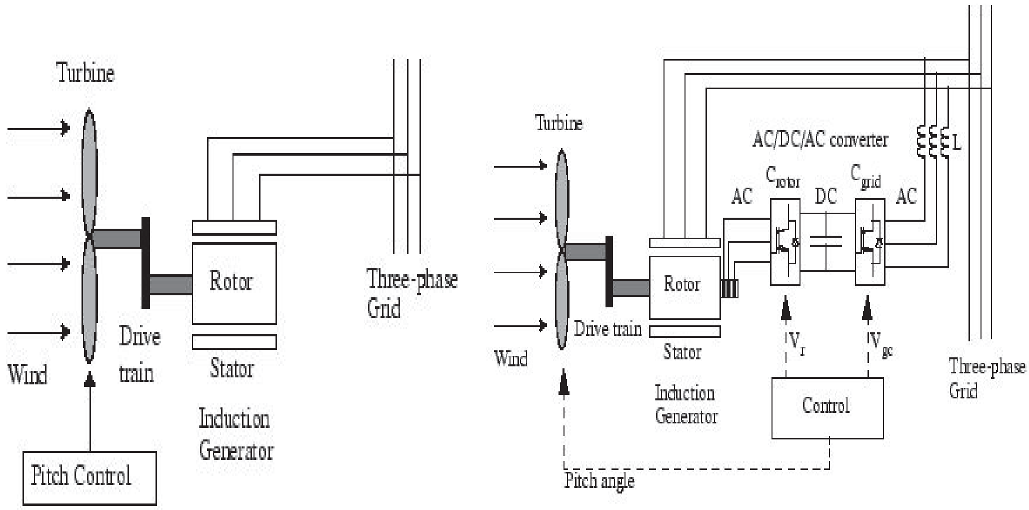


Figure 1.1–Wind Turbine Operation Curve

$$P = \frac{1}{2}\rho A V^3 C_p \qquad \text{watt} \qquad (1.1)$$

The main two types of wind turbines are fixed speed wind turbines and variable speed wind turbines. The main construction difference between these two types is the control circuit. Fixed speed wind turbines rotates with fixed rated speed slightly higher than rated speed and has only a blade pitch angle control to control the turbine output power to be very near to rated power at wind speeds higher than rated turbine speed. The variable speed wind turbine can rotate under wider range of speeds and the output power is also controlled using blade pitch angle control and turbine output voltage is controlled using (AC/DC/AC) converter circuit. Figure 1.2 shows the main difference between the two types of wind turbines.



a) Fixed Speed Wind Turbine Model

b) Variable Speed Wind Turbine Model

Figure1.2– Difference between Fixed and Variable Speed Wind Turbines

Permanent magnet synchronous generator wind turbine [1] and squirrel cage induction generator wind turbine [2] are examples of fixed speed wind turbines. Doubly fed induction generator [3] is an example of variable speed wind turbines.

Fixed wind turbines' have high variations in their terminal voltage under variations of wind speed higher than variable speed wind turbines. Flexible Alternating Current Transmition systems (FACTs) can be used to improve fixed speed wind turbines' terminal voltage. Static VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM) are examples of FACTs devices used with fixed speed wind turbines [4]. These devices can inject reactive power to the wind turbine bus to minimize the wind turbine terminal voltage variations and decrease the voltage regulation.

1.3 Solar Energy Systems

Several forms can be used to generate electrical power by solar energy; one of these forms is Photo Voltaic panel (PV). The PV panels are many types which all change the sun irradiance into electrical power