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WIND ENERGY CONVERSION SYSTEM: THEORETICAL STUDY AND DESIGN USING SIMULATION TOOLS

ALBERT JOHN VARGHESE and REJO ROY

Department of Electrical Engineering
Rungta College of Engineering and Technology
Bhilai, Chattisgarh, India
E-mail: ajvberty@gmail.com
rejoroy@gmail.com

Abstract

The Study of Wind Energy Conversion Systems is a complex area in which many different components like Wind Turbines, Generators, Power Electronic Converters, Controllers for Maximum Power Point Tracking, Load and Filters etc has to be implemented. The cost of implementing all these systems and to install it and monitor the power generation capacity is a tedious and cost intensive task. Moreover the wind itself is prone to changes based on location, season, altitude etc. The researchers are forced to adopt various mechanisms to incorporate all these variations so that they can find the most optimized solution for final implementation of Wind Energy Conversion System, considering all these factors. This paper discusses about the various tools and techniques adopted by the electrical engineering researchers in the field of wind energy power generation.

1. Introduction

The increasing energy demands of the nation and due to adverse effects of global warming there is a rapid transition from fossil fuel-based energy generation to renewable energy is happening quickly. Wind energy plays a very vital role in it. As of 2020, India ranks 4th in terms of installed wind power capacity in the world. Almost 10% of total power production comes from wind in India based on the reports of Central Electricity Authority, India. 70% of the annual wind generation is during the months of May to September.

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Renewable Sources like Solar, Wind, Biomass, Hydro etc can play a very wide role to fulfil the energy demands of India and can aid in the nation's economic growth. Dependency on renewable energy has multiple benefits like help in climatic variations, development of rural areas and moreover will help achieve sustainable development. As wind energy is plentiful, widely distributed, renewable, clean and it uses a smaller land area it is one of the best alternative for fossil fuels and has lower environmental impacts it can prove to be a major contender for alternative energy source in India.

2. Basic Wind Energy Conversion System

The Wind Energy Conversion System transfers kinetic energy from wind movement into mechanical energy with the help of a wind turbine. The generator shaft is connected to the wind turbine, and while the wind turbine rotates, the generator shaft rotates as well producing electrical energy.

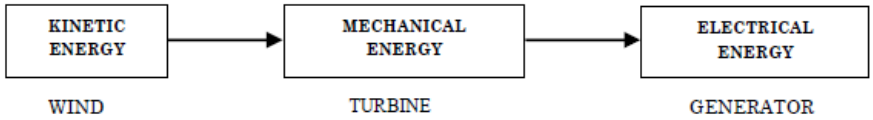

Figure 1. Stages of Wind Energy Conversion.

The power in wind is given as:

$$P = \frac{1}{2}\rho A V^3 \tag{1}$$

Where P is the Power in Wind in Watts, ρ is the air density in kg/m3, A is the Swept Area in m^2 and V is the Wind Velocity in m/s. All designed Wind Conversion system can only extract a maximum of 59.3% of the kinetic energy in flowing air (i.e., wind) as determined by Betz Limit.

Wind Turbines (Horizontal axis Turbines [6] [8] [13] [17] or Vertical axis Turbines [21] [22] [25] [26]) are directly connected or with a gear drive mechanism to Generator (Squirrel Cage Induction Generators, [21] [24] Doubly Fed Induction Generators [6] [23] or Permanent Magnet Synchronous Generators [most of the reference papers]), the electrical energy generated is given to an AC-DC rectifier based on power electronics and is connected to a DC Link and further connected to a power electronic DC-AC converter [19]

[27] and given to a filter to remove harmonics and via transformer the energy is supplied to the grid or to the battery storage for standalone applications. The MPPT Controller is responsible for adjusting the turbine for maximum power extraction and deciding the duty cycle for the power electronic switches so that maximum output can be received. [4] [8] [11]

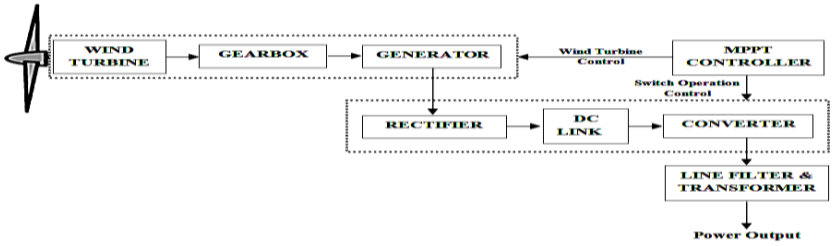

Figure 2. Basic Block Diagram for Wind Energy Conversion System.

3. Simulation Tools used for study of Wind Energy Conversion Systems

There are a variety of techniques used for simulating and determine a wind energy conversion system's efficiency, and to study its performance or other characteristics.

Hardware Based Approach

Some of the techniques using hardware used for study and design of wind energy conversion systems are as classified below

1. Wind tunnels are used for studying the operation of wind turbines and connected systems in different speed and pressure conditions. Wind Tunnels are large tubes with air blowing through them on both the ends of the tube, fans are connected. A powerful fan on one end to blast wind onto the object and the other to move air out of the tunnel. [17]

2. Another approach is to connect the generator with a motor and run the motor according to the required speed and study the performance of generator and the connected power electronic devices. [2][12][22][26]

Software Based Approach

Some of the software tools used for study and design of wind energy conversion systems are as classified below.

1. Blade Design

a. QBlade - It is an open-source simulation tool. It is also a cross-platform wind turbine simulation software and can be used for wind turbine rotor blade design. [13] [14]

2. Wind Energy Conversion System Design

a. Simulink is a graphical environment in MATLAB. Simulink can be used for designing, simulating and evaluation of multi-domain system dynamics. [1] [3] [4] [6] [8] [10] [15] [19] [24] [25], MATLAB can be used in combination with PSIM [5], MATLAB can be used in combination with RTLab [12], MATLAB can be used in combination with PLECS. [21]

b. Power System Simulator for Engineering is a software tool which allows power system designers to model and simulate electricity transmission systems in steady-state and over periods ranging from a few seconds to tens of seconds. [23]

c. PSCAD (Power Systems Computer Aided Design) is time domain simulation tool used to assess electrical network transients. It's a group of programs that offer electromagnetic transients a graphical Unix-based graphical interface (EMTP). PSCAD/EMTDC is yet another title for it. [27][28]

d. Plexim developed PLECS, a software tool for process modelling of circuitry. It was created with power electronics in mind, but it may be used with any electrical power circuit. [21]

e. PSIM is an electronic circuit modelling computer software that was developed for power electronics and motor drive system simulations but could be used to simulate any circuit design. [5]

f. Control Desk is dSPACE's laboratory software for building seamless ECUs (Electronic Control Units). From the start of the process until the end, it executes all of the necessary tasks and provides users with an unified workplace environment. [11]

3. Components Design

a. FLUX 2D captures the complexity of electromagnetic and thermal phenomena to predict the behaviour of future products with precision. [18]

b. JMAG is electrical device design and development tool using computer simulation. JMAG was first developed in the 1980s as a design tool for devices like actuators, motors, circuit elements, and receiver/transmitters. [18]

c. Pro/ENGINEER CAD is a software package as well as it is the most reliable and flexible parametric solid modelling alternative for Computer Aided Design. [16]

d. Adams assists engineers in researching the dynamic behavior of moving components and the propagation of loads and forces in mechanical systems. [16]

4. Hybrid System Analysis

a. HOMER is one of the free software made by the United States, National Renewable Energy Laboratory. This software program is used to develop and analyse off-grid and on-grid power sources for isolated, stand-alone, and distributed power generation systems from a technical and economic perspective. [9][20]

5. For Measurements of Parameters

a. LabVIEW is systems engineering software tool. It is used for applications that demand rapid access to systems hardware and data insights for testing, measuring, and controlling. [7]

6. Hardware Specific Software

a. Used in Conjunction with Yasakawa based Motor Driver, DriveWorksEZ (DWEZ) is a software application that allows users to programme customized logical and mathematic algorithms into the GA800, GA500, A1000, V1000, and U1000 drives. This simply arranges function block symbols in a graphical flow diagram to develop application programmes. Only a few mouse button presses separates users from complete drive and machine control. [11]

4. Conclusion

It is quite evident that research in the field of Wind Energy Conversion Systems is simple to carry out on the basis of the above discussed tools and techniques. Some of the merits of using these are

(1) The researcher need not shell out large amount of money by using some of the already existing low cost techniques and tools.

(2) Using these tools and techniques a number of systems with different specifications can be designed and easily compared.

Optimized hardware based on the results achieved using the techniques described can be found out before going for the purchase of the components.

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