MODELING OF WIND POWER PLANT

František Rajský

ABSTRACT

This work describes the procedure of modeling single parameters of general loads from which I chose induction motor and, of course, generator electrical energy – wind turbine.

I used the program Matlab for the simulation of the connection between wind power plant and electrical network. I simulated startup of wind turbine and changes of wind flowing. I draw graphs of harmonic frequency of current and voltage based on these changes.

KEY WORD

Wind turbine, modeling of wind power plant, harmonic frequency.

INTRODUCTION

Human has used wind as a source of energy for thousands of years. It was one of the most utilized sources of energy together with hydro power during the seventeenth and eighteenth centuries. By the end of the nineteenth century the first experiments were carried out on the use of windmills for generating electricity. Thereafter, there was a long period of a low interest in the use of wind power. The international oil crisis in 1972 initiated a restart of the utilization of renewable resources on a large scale, wind power, among others. Currently, wind power is a fully established branch on the electricity market and it is treated accordingly. Energy production is not the only criterion to be considered when installing new wind turbines; cost efficiency, the impact on the environment and the impact on the electric grid are some of important issues of significant interest when making decisions about new wind turbine installations. [07]

MODELING OF WIND TURBINEA AND SHORT ELECTRICAL NETWORK

Modeling wind turbines for predicting of their power quality impact is reported in the literature. Models of wind turbines of varying complexity are presented. Electrical engineers, for example, tend to simplify the aerodynamic and mechanic parts of the system and usually stress generator description. In contrast, mechanical engineers often overlook generator performance details. Some reported models seem to be over-parameterized, which obstructs their implementation because the parameters for the detailed description are not generally available.

The complexity of the reported drive-train models varies considerably, however, rather simplified descriptions that often incorporate a soft shaft representation dominate completely in the literature. The soft shaft representation is presented, for example, in [08].

Verifications of models with practical measurements on wind turbines are rarely reported in the literature. A comparison of simulations and measurements of wind turbine responses to grid disturbances have not been found at all by the author. A published comparison between measured and simulated impact of wind turbines during normal operation, namely the comparison of flicker impact, has been found in [07]. Good agreement is reported there, however, only a single result for one wind speed is presented.

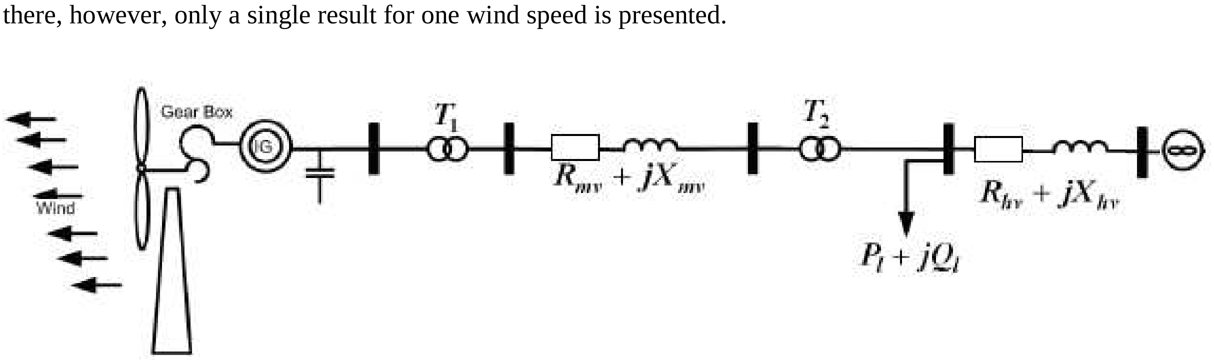

Fig. I. Wind turbine and short electrical network

The result of the decomposition is the amplitude and the phase to be imparted to each frequency in the reconstruction. It is therefore also a frequency, whose value can be represented as a complex number, in either polar or rectangular coordinates. And it is referred to as the frequency domain representation of the original function.

THE WIND POWER

Wind power is the conversion of wind energy into useful form, such as electricity, using wind turbines. In windmills, wind energy is directly used to crush grain or to pump water. At the end of 2007, worldwide capacity of wind-powered generators was 94,1 GW. Although wind currently produces about 1% of world-wide electricity use,[02] it accounts for approximately 19% of electricity production in Denmark, 9% in Spain and Portugal, and 6% in Germany.

Wind energy is various, renewable, widely distributed, cleans, and reduces greenhouse gas emissions when it displaces fossil-fuel-derived electricity. The intermittency of wind seldom creates insurmountable problems when using wind power to supply a low proportion of total demand, but it presents extra costs when wind is to be used for a large fraction of demand. Wind power also needs less service.

Induction generators often used for wind power projects require reactive power for start up, so substations used in wind-power collection systems include substantial capacitor banks for power factor correction. Different types of wind turbine generators behave differently during transmission network disturbances, so extensive modeling of the dynamic electromechanical characteristics of a new wind farm is required by transmission system operators to make safe predictable stable behaviour during system faults.

In particular, induction generators cannot support the system voltage during faults, unlike steam or hydro turbine-driven synchronous generators (however properly matched power factor correction capacitors along with electronic control of resonance can support induction generation without electrical network). Transmission systems operators will supply a wind farm developer with a grid code to specify the requirements for interconnection to the transmission grid. This will include power factor, constancy of frequency and dynamic behaviour of the wind farm turbines during a system fault.

Electricity generated from wind power can be highly variable at several different timescales: from hour to hour, daily, and seasonally. This will be shown in practical part of this thesis. The following tab. shows installed wind power capacity in world.

Installed wind power capacity (MW)				
Rank	Nation	2005	2006	2007
1	Germany	18 415	20 622	22 247
2	United States	9 149	11 603	16 818
3	Spain	10 028	11 615	15 145
27	Turkey	20	51	146
28	Czech Republic	28	50	116

Tab. I Installed wind power capacity

THE WIND TURBINE

A wind turbine is a rotating machine that converts the kinetic energy in wind into mechanical energy. If the mechanical energy is then converted to electricity, the machine is called a wind generator or wind turbine.

The article on wind power describes turbine placement, economics, public concerns, and controversy. The wind energy section of that article describes the distribution of wind energy over time, and how that affects wind-turbine design. See environmental concerns with electricity generation for discussion of environmental problems with wind-energy production.

POTENTIAL TURBINE POWER

The amount of power transferred to a wind turbine is directly proportional to the density of the air, the area swept out by the rotor, and the cube of the wind speed.

The usable power P available in the wind is given by:

$$P = \frac{1}{2} \cdot \alpha \cdot \rho \cdot \pi \cdot r^2 \cdot v^3 \qquad [W] \tag{1.1}$$

Where α … an efficiency factor determined by the design of the turbine

ρ … mass density of air in kilograms per cubic meter

r … radius of the wind turbine in meters

v … velocity of the air in meters per second

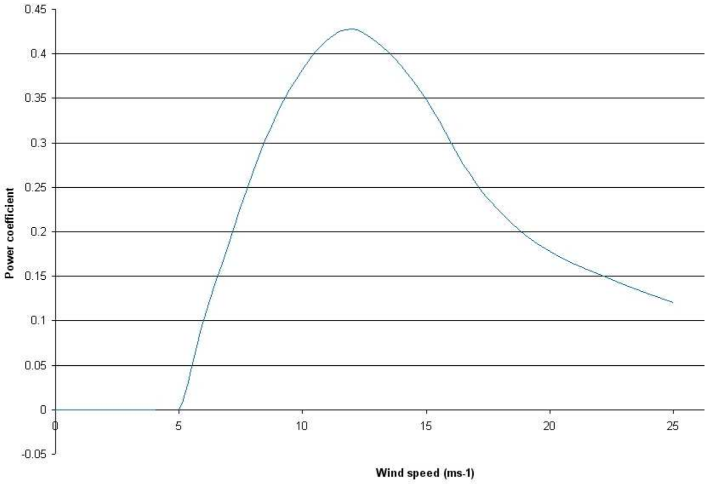

Fig. II. An approximation of the power coefficient for a typical 1 MW horizontal axis wind turbine. The power coefficient represents a non-linear dynamic system.

In order to calculate the maximum theoretical efficiency of a thin rotor (a wind turbine) one imagines it to be replaced by a disc that withdraws energy from the wind passing through it.

Let v_1 be the speed of the wind in front of the rotor and v_2 that of the wind back flow from it. The mean flow velocity through the disc representing the rotor is v_{avg}, where

$$v_{avg} = \frac{1}{2} \cdot (v_1 + v_2) \tag{1.2}$$

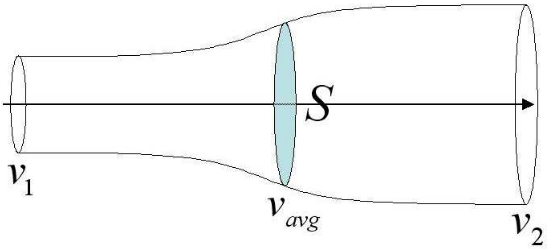

Fig. III. Schematic of wind flow through a disk-shaped actuator.

With the area of the disc equal to S, and with ρ = wind density, the mass flow rate (the mass of wind flowing per unit time) is given by:

$$\overline{m} = \rho \cdot S \cdot v_{avg} = \frac{1}{2} \cdot \rho \cdot S \cdot (v_1 + v_2) \tag{1.3}$$

The power delivered is the difference between the kinetic energies of the flows approaching and leaving the rotor in unit time:

$$\overline{E} = \frac{1}{2} \cdot \overline{m} \cdot \left(v_1^2 - v_2^2\right) = \frac{1}{4} \cdot \rho \cdot S \cdot (v_1 + v_2) \cdot \left(v_1^2 - v_2^2\right) \tag{1.4}$$

The work rate obtainable from a cylinder of wind with area S and velocity v_1 is:

$$P_{Ewin} = \frac{1}{2} \cdot \rho \cdot S \cdot v_1^3 \qquad [W] \tag{1.5}$$

AERODINAMIC MODEL OF THE TURBINE ROTOR

The wind turbine continuously extracts kinetic energy from the wind by decelerating the air mass, and feeds it to the generator as mechanical power. The aerodynamic model of the wind turbine is necessary because it gives a coupling between the wind speed and the mechanical torque produced by the wind turbine. The mechanical power P_M , produced by the wind turbine rotor can be defined as:

$$P_M = C_P \cdot P_{Ewin} \tag{1.6}$$

where: C_P performance coefficient of the wind turbine;

The C_P characteristics, for different values of the intensity angle β , are illustrated below. The angle β is turning of screw blade.

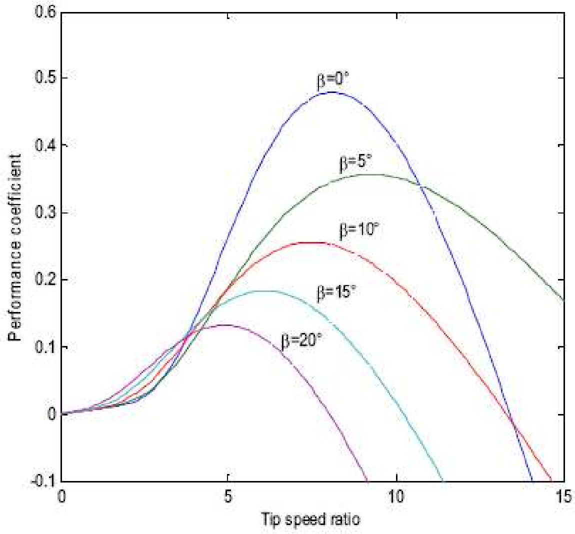

Fig. IV. Performance coefficient versus tip speed ratio characteristics, for different values of the pitch angle.

CONSLUSION

Electrical power output of a wind turbine is a mainly function of the wind speed. Typically, power transmission network occurs between the power plant and a substation near a populated area. Electricity is then distributed from the substation to the consumers. Electric power transmission allows distant energy sources to be connected to consumers in population centres. A good electrical network design calls for the knowledge of the currents, which flow in the lines either in an operating or under a design state. The network progresses depend of these currents that mean corresponding with power outputs. It is analysis in the case of the operating network, current calculation, voltage drop, power losses, frequency analysis, flickers, over voltage, time behaviour of the short circuit.

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