WIND ENERGY

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Summary

This Article reviews both historical and modern technical development of wind turbines all over the world for obtaining electrical and mechanical energy and the trends and prospects of the wind power application for the propulsion of vessels. Aspects of modern wind turbine technology, are briefly described also as fundamental theory of the transformation of energy of moving air into mechanical or electrical energy, wind turbine generator system classes, control systems tower types and offshore installation, stand-alone and hybrid systems, turbines for water pumping and heating, batteries,

environmental and legal aspects, economics of wind energy systems, international and national activity and so on. The Article is addressed to a wide audience, including students, engineers and scientists, researchers, manufacturers and anyone else who is interested to acquire basic knowledge about wind energy technology.

1. History of Wind Power Application

Man began to use the wind power alongside with solar energy, heat of fire and power of animal's millennia ago. The exact historical date when and where the first wind mills or first sails, have appeared is unknown. It is possible to consider, that certain wind mills for grains grinding and water pumping or sails for sea navigation have appeared in most developed at those times countries (Egypt, China, Persia a. o.).
Within centuries the sails were constantly perfecting, that resulting in development of floating transportation means, increasing the sizes of vessels, their carrying capacity and buoyancy. The modern changes of sails will be considered below.

Within the passage of time there was perfection of the originally primitive aerodynamics of wind mills, that increased their reliability, strength and productivity. Originally in the wind mills the wind wheel was installed on a fixed frame of a cylindrical or polygonal plane shape made from bricks or wood, and the wind wheel was set in that direction, whence the wind blows more often. Then to increase operating time and accordingly productivity of the device the miller started to turn the whole frame together with the wind wheel installed on it. Such turn was made manually with help of a driving rod, by means of which the miller could put the frame and hence the wind wheel in the wind direction. Protection from high winds was accomplished by turning the rotor out of the wind or by removal the canvas, which covered the rotor latticework.

With increase of power the sizes of wind wheels and grindstones have grown, the mills became bulky and so heavy, that the turn of the frame with a wind wheel, fixed on it, became rather inconvenient. Therefore the following stage of the development was turning only the upper part of the installation, in which the main shaft with wind wheel, transmission, rotary circle and drive rod were located. The mills of this type were supposed to use wind wheels of large diameters and the power up to 3-5 kW were reached. Further in all countries the mills only of this type (with turn of a top of a mill) were under construction. The design of the mills of this type has served as prototype for modern fast rotating wind turbines.

Technological development, for example, necessity to supply air for smelting furnaces, operation blacksmith bellows and heavy blacksmith hammers, sawmills etc. constantly put before power engineering new tasks of increase of power, reliability of power supply systems, both convenience of maintenance and servicing of the equipment. Therefore alongside with development of wind engines, further development and perfection have received water wheels, their history by its roots retreating also deep in the past of mankind.

The significance of water wheels and wind engines began to reduce after the invention of the steam machines in the middle of the 18th century, which were quickly improved and were distributed in all areas of human activity.

The steam engine in comparison with water and wind engines had that advantage that could produce large power in a period of time, convenient for a consumer. Its operation did not depend on the weather conditions that is on the presence of wind, or water in the river.

Therefore application of wind mills and water engines became restricted to limited areas of production activity as, for example, in agriculture, where a great many wind and water engines for pumping water for livestock and watering of vegetable cultures are still used even now.

In the mid of the 19th century the need of creation of wind engines for water pumping became evident. In that period the development of the American West begun on large areas of fertile soils however with water supply strata located rather deep under the ground surface. Development of railways in western direction also promoted development and design of advanced wind engines called the American Multiblade wind turbine.

Wind engines of this type had a high torque and adequate efficiency and suited very well for pumping water from small depths. At the end of the 19th and beginning of the 20th century several millions of such wind engines were constructed in different countries. Wind engines of this type are successfully used till now in a number of countries for water pumping.

At the end of the 19th century a significant breakthrough in power production was achieved - the invention of an internal-combustion engine working on petroleum or products of it’s processing. It can be said that the invention and use of the internal-combustion engines literally lashed the rates of development and advance of the human society. The internal-combustion engine - compact, powerful, mobile, reliable, easy to maintain, has pushed aside on a background the steam machine, as well as the wind and water engines. It is possible to say, that from the invention of an internal-combustion engine a new era began in the history of the mankind – era of struggle for petroleum markets.

Despite of the prevailing significance of internal-combustion engine the conventional activities on perfecting the wind and water engines were constantly conducted in some countries such as Germany, USA and Russia. This was promoted by a number of factors and, first of all by the very large industrial experience of designing of wind mills and wind engines for water pumping which was accumulated in the world, and also by the fact that for some kinds of activities, especially in agriculture, in some countries application of the wind engines was economically more expedient than use of other power sources. Generally speaking, at the beginning of the 20th century wind power was used all over the world to produce mechanical work by means of hundreds of thousands of multiblade wind engines.

2. Wind Energy for Electrical Power Production

At that time in Denmark a wind engine for electricity production was constructed with of a rotor diameter of 24 m. These activities in Denmark were continued and rather soon there were several hundreds wind power stations with capacities of 5 to 25 kW.

At the same time manufacturing of wind engines for electric power generation well existed in some other countries, in particular, in USA. The wind engines had rotors with 2 or 3 blades. Such wind engines have been manufactured by firms Windcharger (200 W to 1.2 kW) and Jacobs (1.5 to 3 kW). These wind engines belong to a class of chargers and were intended to charge electric storage batteries. In turn the effective load of the battery could be bulbs, wireless, refrigerators, low consumption electric tools etc., for which operation direct current of 12 or 110 V was used. The success in elaboration of electric generators, which could be coupled with the wind engines, provided for creation of the wind power plants. However, the cost of the electric power delivered by centrally powered systems was much lower than the cost of the electric power produced by wind engines. This has hampered the development of wind engines and in a number of cases led to termination of their manufacturing.

This was also the time of rapid development of military and civil aviation. Many problems of aerodynamics, dynamics and strength of flying vehicles have been solved. The achievements of aircraft aerodynamics have allowed the scientists to consider from the new scientific positions the theory of an air wing and operation of wind engines in a ram airflow and to create fundamentals of the theory of fast-rotating wind turbines with low number of blades.

Between the years 1920 and 1925 the Russian Professor Nickolai Zhoukovski has elaborated the theory of a wind engine, which further was wide spread to practical use. At the same time in Germany the theory of wind engines was developed and experimental research carried out by Ludvig Prandtl and Albert Betz. In the USA research of wind engines aerodynamics was conducted by Professor Karman.

In the 30th and 40th years of the 20th century in Germany, Russia, Denmark and Netherlands development of wind power plants with improved aerodynamics began, totaling to some thousands kW. However the world was not yet ready by technical, economic and ecological reasons for large-scale deployment of such installations and was compelled to go on a path of development of fossil fuel power systems.

The large fuel and energy monopolies consistently expanded electrical networks, using conventional techniques of electric power production based upon petroleum, coal, hydro resources of large rivers and rather jealously reacted to the attempts of use of non-conventional power resources such as the wind, sun, biomass, tidal energy etc.

Nevertheless at that time development of wind engines and the appropriate research work did not stop in some countries. So, in 1933, in the USSR in Crimea near Sevastopol city on the Black Sea coast a wind power system of 100 kW capacity was installed. For that time it was the most powerful wind power plant in the world supplying power to the electrical grid.

In 1941 on Grandpa's Knob, near Rutland, Vermont, USA a grid connected wind mill with output power of 1250 kW was constructed (Palmer Coslett Putnam was head of the team). The machine had a 34 m high tower and two stainless steel blades, which spanned 53 m. This wind mill worked in parallel with a hydroelectric power station. When the wind speed was sufficient the necessary power was produced by the wind power plant thus decreasing consumption of water by the hydro plant. In case of absence of the wind the consumers were provided with electricity from the hydroelectric power station. This wind generator worked through 1941 to 1945 and then was disassembled for economic and technical reasons (bearing and blade failures). In spite of this the whole project was determined as successful.

Similar research activities were conducted also in Denmark and Germany. In Denmark the grid connected Gedser wind turbine was constructed in 1957. This machine produced 200 kW at 15 m s^{-1} wind speed. The wind turbine had a 26 m high tower and a 24 m in diameter wind wheel.

In 1957 in Germany a wind turbine was constructed (Ulrich Hutter was head of the team) with power of 100 kW at 8 m s^{-1} wind speed. The wind turbine had a 35 m rotor diameter and was in successful experimental operation for about 11 years.

The above mentioned isolated successes in development of wind power had not show much progress prior to the advent of the global energy crisis in the 70th and 80th. The world came to the conclusion that the era of cheap oil is over and that time had come to boost intensive search for and development of other power sources besides oil and gas.

An obvious solution to manage the new situation could be augmented use of coal and nuclear power. However environmental concerns hamper increase of coal utilization. There are also strong public objections against nuclear power, which emerged at that time.

Therefore the energy crisis has resulted in a new stage in development of renewable energy sources and in particular wind power.

The work on creation of large wind turbines was initiated in the USA at the beginning of the 80th. In 1974 the MOD-O downwind horizontal-shaft machine with a two-blade rotor of 38 m diameter and rated power of 100 kW has entered in experimental operation.

The rotor and the nacelle were placed at top of four-legged steel truss tower about 30 m high. The next machine was named MOD-OA and had a rated power of 200 kW. The machines MOD-1 and MOD-2 had respectively 200 and 300 kW power.

In the same period of time an extensive development program for wind turbines was initiated in Denmark, Sweden, Germany, Netherlands and the United Kingdom. The rated power of planned wind mill units was in the range of some hundreds to several thousands kW.

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Biographical Sketch

Professor Vladimir A. Dobrovolski, Ph.D. was born in Moscow, Russia in 1936. He graduated from Moscow Aviation Institute in 1960 and Ph. D. Degree in 1968.

1960-1963 - test engineer, the USSR Civil Aviation

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