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REVIEW ARTICLE

Investigating the Foundation Used in the Wind Turbines

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ABSTRACT
Today, we build the most land-based wind turbines on strong and stiff soils, but probably in the future wind turbines will have to be built also on soils with less good properties. The ordinary and fairly simple foundation method with a concrete slab with large area may be abandoned since it can give too large differential settlement. In this article the foundations for onshore wind turbines where both the more conventional method with a large concrete slab are investigated, but also alternative foundation methods are studied, mainly piled foundations . A case study of an 80 meter high wind turbine with realistic loads is presented. The study includes geotechnical and structural design for three different soil profiles, in which three different foundation methods are used. The financial aspect and properties of the three foundations are also discussed and compared in this article, among which a pile foundation is highly focused and recommended with a 10% financial deduction compared to conventional foundation types.
Keywords: *Wind turbine, blade, foundation, Concrete Slab, Pile*

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INTRODUCTION

The extents of human demand on energy resources are always one of the fundamental issues in human everyday life and the endeavor to achieve a never-ending source of energy has been mankind's oldest dreams.

From the designs carved on the walls of caves can be found that early humans were able to well-known the muscular power as a source of mechanical energy and use it. But since this power is very limited and weak, human are always search for endless power in their imagination which is always available at any time and place. This issue can be well received in different stories which have been built in the imagination of the human mind. Little by little, by the progress of human civilization, wood and then coal, oil and gas entered the energy market. But due to the increasing energy demand and limitation of fossil resources on the one hand, the increase in environmental pollution caused by burning these sources, and on the other hand it made the use of renewable energy day-to-day more important and more widespread. Wind energy is one of the main types of renewable energy that the human mind has long been concerned so that he is always thinking about the use of energy in industry. Human have been used wind energy to drive the boat and Sailing ships and windmills. In the current situation with respect to the listed items and economic feasibility of wind compared to other new energy sources, wind energy seems to be vital and necessary. In our country, there are proper capabilities and suitable potential for the installation of wind turbines, which according to its feasibility and studies and investigation, the investment has been conducted in this area, the development and application of this technology has put clear vision beyond energy policy in this area.

WIND SOURCE

When sunlight reaches to the uneven surfaces of the earth unequally leads to changes in temperature and pressure and due to these changes, the wind occurs. The Earth's atmosphere also due to the earth's rotation, transfers heat from the tropics to the polar regions that it also creates the wind. Ocean currents also would act in a similar way and it is the cause of 30% of overall heat transfer in the world. In the

global scale, these atmospheric circulation act as a strong factor for heat transfer. Earth's rotation can also provide additional energy in the establishing of semi-permanent patterns of atmospheric circulation of the planet. Then as it was mentioned, the wind is as one of the various forms of solar thermal energy, which is a semi-continuous pattern. Changes in wind speed are hourly, daily and seasonal and affected by the weather and topography of the Earth. More wind energy resources are located in coastal areas and mountainous.

Global Distribution of Wind

Generally, the wind in the world has two types of distribution:

A) Hadley Rotational Flow:

Between the latitudes of 30 ° north and 30 ° south, the warm air which is rising in equator would go up and cooler air from the north and south will be replaced with it, this process called Hadley flow.

This flow in the Earth's surface means that the cold winds blow toward the equator and on the other hand, the air that comes down at 30 ° North and 30 ° South is very dry because the rotational speed of the earth's latitudes is far less than the rotation of the earth at the equator, it is moving to the East. Usually in these latitudes, there are desert areas like the Sahara.

B) Deposited Rotational Flow:

Between the latitudes of 30 ° N (south) and 70 ° N (South), predominantly westerly winds are under way.

These winds would make a spin wave, and transfer cold air southward and warm air to north,this pattern called deposited flow.

Measuring the Potential of Wind Energy

The potential of wind energy has been studied as a power source in various areas on the basis of available information, in the available wind resources in each area.

Potential related to the wind resources are generally divided into five categories:

1. Meteorological potential: this potential represents the available source of wind energy.

2. The local potential: this potential is conducted based on meteorological potential but it is limited geographically to areas that are available for energy production.

3. The technical potential: this potential with regard to the type of available technology (efficiency, turbine size, etc.) is calculated upon the local potential.

4. The economic potential: this potential is technical potential that economically and based on economic policies and performance can be achieved.

5. The performance potential: this potential is considered by taking into account the constraints and incentives factors in order to determine the applicable capacity of wind turbines at a specific time limit, such as incentive tariff that assigned in accordance with the policies of various governments to the suppliers of wind power energy which is resulted from wind turbines.

WIND POWER

The kinetic energy of wind is always proportional to the square of the wind speed when the wind hits a level, its kinetic energy becomes to a level of pressure (force) on its surface level. The product of wind power upon wind speed is equal to the wind power. Wind power is proportional to the square of wind speed, then wind power will be proportional to the cube of wind speed. So the higher the wind speed, the greater the power will be, for example, if wind speed doubles its power eight times and if the wind speed increases three times, the wind power will be increased twenty-seven times.

Wind Energy Technology Developments in Recent Years.

The world's largest wind turbine manufacturers are now Vestas, Enercon and NAJM a icon companies that respectively have the 23.3% and 14.6% and 12.4% of the world market at their disposal. The information that is obtained from the technology market research of wind in Germany which is as the leading country in the wind industry of the world, reflects the trend of the industry in recent years and therefore, according to these data in the predictions about the future of the energy, itwill be beneficial. The average capacity of wind turbines installed in Germany is almost 900 KW, but if only we take the installed turbines in the first half of 2003, the average capacity of new turbines is1,560 KW. So a clear trend of increasing size of modern wind turbines is visible. In the wind turbines market, there are 58 turbine that from these 58 turbine models only 4 models are gearless that have been tested on medium and large sizes. But 54 other models (including the medium, large and extra-large sizes) still use the gearbox. So the gearless turbines are still in its infancy, and their situation will be clear after years of experience and operation. In the past, wind turbines worked with a constant rotational speed (the rotor), but today's models are almost abandoned speed system and turned into a two-speed or variable speed. From the 58 models in the market, can be seen that just 2 models are a one-speed and 34model speed with variable speed and 22 model with a two-speed. [2]

As well as the use of wind power for energy production, the Swedish government pursues a goal that by 2020 wind energy production in the country amounted to 30 trillion watt-hours in a year. Explaining that now the energy production level is 2.5 trillion watt-hours for a year. To achieve this goal, several thousand new wind turbines must be built. [3]

The purpose of this paper is to examine how to build models for wind turbine foundation design. The study included weight foundations and Pile foundations, the conducted designs must get received the standards of Europe. Based on the foundation of economy, performance and function are studied. The design should be about mechanical engineering, geology and structural design, finite element design and materials science (mainly concrete and steel) are required. Before dealing with the various foundations and their properties we are going to have a brief description of wind turbines and their described components.

The Benefits of the Exploitation of Wind Energy

Wind energy, like other renewable energy sources have the better features and benefits than to other energy sources that these benefits are including of:

1. Lack of need of wind turbines to fuel, which in turn reduces the consumption of fossil fuels
2. Free wind energy
3. The ability to supply some parts of the electricity demand
4. The lower relative amount of energy power of the wind upon the fossil fuels
5. Thelower operating costs and capital costs of wind energy in the long term
6. Diversifying the energy sources and creating a sustainable energy system
7. The high maneuverability, for operation in any capacity and size (from a few watts to several MW)
8. There is no need for water
9. There is no need for ground for mounting
10. Lack of environmental pollution than fossil fuels

Wind Turbines: [4]

In this type of turbines generally used from wind energy to produce electricity. Nowadays, there are generally two kinds of turbines that their functions are completely different. The most common turbines are the ones that their blades rotate around a horizontal axis, the other turbines that rotate around the vertical axis of earth, Figure 1.

Figure 1: Wind turbine with vertical axis on the right and wind turbine with horizontal axis and on the left [4]

In both mentioned turbine, the rotating movement of rotor blades is around a vertical or horizontal axis that leads to the production of electricity. In this article, we only examined the horizontal axis of turbine. Components of such turbines are described in Figure 2.

Figure 2: The components of the wind turbine (1 Foundations 2. Rig, 3. System handlers, 4. Rotating screen, 5.Foot of turbine, 6. Converter) [5]

Foundation design should be in a way that have both sufficient strength as well as long life. This is done by spreading the force to the foundation. Vertical forces transmitted to the foundation, including the dead load towers, blades, drive systems as well as wind power, wind in addition to increase the force on the foundations of a relatively large bending moments are imported to the foundation.

Mast height varies between 40 m to 130 m, which the higher the rotation speed, the higher the blades will be.

Operator system is the shielding parts of accrued turbine and converts the rotational energy into electricity. The system generally includes: gearbox (which adjusts the speed of rotation), a generator that produces electricity and a braking system. The braking system is conducted by this target that reduces the speed if the blade speed gets more than the usual or stops it in the necessary conditions of rotation. Furthermore, the system is capable of putting blinds in the proper wind direction.

The blades are designed in a way that can convert wind power into rotary motion. Profiles and performance of blades are similar to airplane wings that are usually made of fiberglass or pre-stressed plastic zip carbon. The number of blades could be two, three or more, usually three-bladed most commonly used.

Crown of turbine, is the link between the blades and the system operator. The design is very complex and usually made of cast iron and casting alloys after heat treatment used to reach your desired specifications.

Transformer is not the main component of wind turbines as its own, but it needs electricity to transfer power from wind turbines.

The Main Body of the Articles

In this paper, the resistance of different lands, in terms of geology and structural design has been the foundation for implementation.

Types of foundations:

Foundation types which were used depends on the character of the place of foundation that briefly are included in three follow items: [4]

- Lands with quite stiff soils. Most foundations in this land would run as a massive foundation.
- Lands with 20 meters of clay layer that by the cause of pressure have become the bedrock thick. In these cases, the precast concrete piles used that in this case piles are responsible for bearing the whole load.
- Lands with clay soils that are made of rock with considerable height. In these cases, the concrete piles will be used as a consolidation platform. Cups and plates bearing the foundation that has been called integrated candle.

For the three types of foundation design has been said that the thickness of the using concrete foundation is the same. However in the second and third mode of pages can be used with candles and piles.

In the first case, the geological conditions of environment required that the implementation of the foundation should be done inexpensively and easier. The second mode for short pile height of 680 meters is pretty good, while the third is held candles as high as 3720 meters. [4]
Using from large-sized candles for the third mode caused the high cost and difficulty in the design and implementation of the foundation. For the third mode they considered the relatively large localized meeting vertically at a height of 155 mm from the top of the foundation which was significant [4]. In this study, the two-dimensional design of geological factors has been considered with limited elements. Despite the challenges in the design of spark plugs in two dimensions, so their three-dimensional design is highly recommended in the possible condition. Among the other items on the difficulties of long-pile design which is finding noteworthy is the stiffness ratio between piles and pages.
A company called Rocky, which is responsible for the design and manufacture of metal tubes and the foundation. [6] This company studied about special foundation design toward the construction of wind turbines that includes the drill and metal tubes in order for the placement has been done.
As shown in Figure 3, this work by eight steel piles with a diameter of 600 mm which has been put in the holes of the bedrock with the height of 10 meters, then thinner metal tubes inserted into the created cavity. Inside the metal pipe by means of woven reinforcement has been put there and then the total volume of the metal pipe filled with concrete. In order to deploy the rig, the turbine should be created on the surface of the octagonal shape of metal pipes with concrete. This piece of octagon concrete, the distance of each side of it is12 meters and its thickness is 2 meters. In this project because of the existence of the piles the thickness of the ordinary concrete is much thinner than the foundation slabs thickness (about 1/3), for example, if the volume of the concrete page with pile would be 250 cubic meters while the common foundation will be 800 m cube, and in total the foundation pile is 10% cheaper.

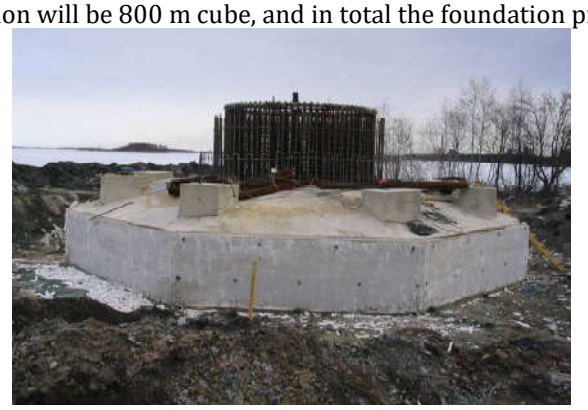

Figure 3: Running the foundation with pile by Rocky Company [6]
The thick metal pipes inside them can be filled with reinforced concrete to be used as candles, A4. [7]

Figure 4: Running the foundation with pile by Rocky Company [6]

RESULTS AND DISCUSSIONS
The results of this study suggest that due to the type of discussed land, all three of these modes can be used for establishing foundations for wind turbines. First, based on the characteristics of available land is economically far more affordable. Second and third modes according to the type of ground floor and the

height of the pile are considered to apply. However, the problems in the design and implementation of foundation in the third mode with the high length piles should also be mentioned during research.
In this paper, the research conducted by the Rocky Company on the implementation of the foundation with piles in order for the wind turbines was mentioned. This method has about a 10% cost savings compared to conventional methods of running the foundation. In this way we can use from the thick metal pipes that inside them is filled with reinforced concrete as piles [6].
This article is solely about the turbines installed on land, but nowadays the design and manufacture of installed wind turbines in sea is also very attractive.

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