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RESEARCH FOR REALIZE THE CONFIGURATION OF WIND ENERGY TURBINE

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ABSTRACT

For already quite some time, the word energy has received a somewhat negative connotation. Some circles want to make us believe that energy is something that one should have disgust for; a necessary evil that should be avoided at any price. With such unqualified negative thinking that omits recognition of the positive contributions, and that focuses only on the side effects and shadow sides, without paying attention to the technological solutions that can "neutralize" the disadvantages, mankind will not be served well. Such attitudes will have a rather lethargic effect on a healthy development of society.

KEYWORDS: energy source, wind power, global warming

1. Introduction

For the next 20-40 years, there is an ample physical availability of primary energy sources. The current estimations for oil and gas reserves are about 40 and 60 years, respectively. For coal, the estimations are 200 to 300 years, whereas for uranium it depends whether one opts for reprocessing and breeding or not: these reserves vary between 50 and 3000 years depending on the option chosen. If one takes into account the non-conventional fossil sources such as tar sand and oil shale, if one counts on the availability of the massive resources of methane hydrates in the deep ocean, on the uranium concentration in the seas or on the thorium cycle, or even on nuclear fusion from deuterium and tritium, it is obvious that the physical presence of primary energy is not really a concern. In any case, we could still continue to use it for quite a while, at least from the point of view availability. [1]

Today there are many investments made in research on new and cheaper ways of producing electricity in which wind power systems and solar panels play an important role. A great concern is raised over the environmental aspects of how electric energy is being produced varying from pollution by gases or toxic waste up to the visual aspect. However, next to the environmental issues mentioned above, there is one major problem for which there is no easy and cheap solution: the greenhouse effect.

This problem is indeed of a global nature. It has such far reaching consequences, that it is appropriate to spend some time on it.

At first sight, it is simple. The presence of gasses such as water vapour and carbon-dioxide (CO_2) in the atmosphere, guarantees that we know mild temperatures on the earth. Without these gasses, the temperature on earth would be about 30^{0}C lower. An increase of those gasses would therefore lead to a global temperature increase on earth (figure 1). This effect is called the greenhouse effect (IPCC, 1996; Houghton, 1997)

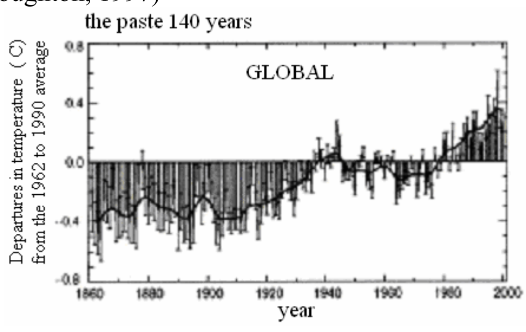

***Fig. 1.** The Earth's surface temperature increases*

The lack of fossil fuel, that thermo plants use, is predicted to end in the near future. A bigger problem when using fossil fuel are the nooses resulted from combustion. This can be solved by developing filters for the nooses and to find cheaper ways to get rid of nuclear waste. Therefore the industry reoriented its interest to more environmentally friendly solutions.

[2]. The most common used alternatives, to provide energy for home use purposes, are residential micro-grid built using both wind power system and solar panels.

The direct proportionality between energy (power) produced by a solar panel and the area exposed to the sun has a great influence over the price of this type of equipment. The technology of fabrication for photovoltaic cell system has been under development for quite a while now but still expensive reciprocal of its power production. [3]

Denmark was the first country to use wind for generation of electricity. The history of wind turbines goes back to the 19th century. In 1890 there was already a fully operational working wind turbine to generate electricity. At the beginning of the 20th century, several hundred units with capacities up to 25 kW were in operation in Denmark [1]. In America, commercial types of wind-electric plants started to appear in the interbelic period.

2. What is and how does the wind power generation system work

Wind power generation consists of electric energy creation, usually at grid parameters, by using different types of rotary systems which harness the power of the wind. These rotary systems may have the main shaft horizontally or vertically. The horizontal position of the shaft is found in the most wind turbines when the vertical position of the shaft can be located only in a few applications and they are usually of low power (under 5 kW).

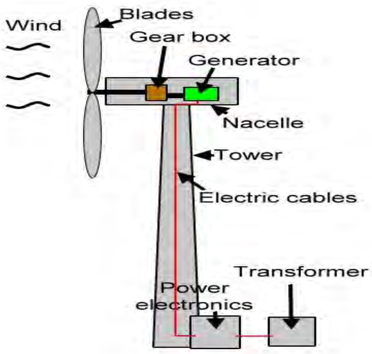

Fig. 2. *Wind turbine – Basic configuration*

A wind turbine uses the horizontal moving of air because this movement is the most powerful type of air current that can be used to rotate a propeller (a rotor in our case). The ascendant, or vertical, flow of air is found only in small regions and it is rarely detected nor it presents any powerful force. [4] The basic idea of how a wind turbine works can be seen in Figure 2 and described in the following paragraphs.

The horizontal flow of air blows over the rotary system on the wind turbine causing it to rotate in a certain direction. Because the rotor is a big component it needs a certain wind speed to put it on motion (usually above 5 m/s). Some wind turbines allow adjustments to be made to the blades attack angle. In this case the blades can be adjusted to a maximum efficiency level. By doing this, it allows the rotor to turn at an optimum level. Not all the time the blades adjustment can give an optimum performance, to reach it, the nacelle must also turn.

The maximum efficiency is reached when wind direction is parallel with the nacelle and the blades are configured for the actual wind speed.

If the wind turbine needs to be shut down, for various reasons including maintenance, it uses both a mechanical and electrical breaking system to turn the rotor off.

The mechanical breaking system can be mounted on the main shaft before or after the gear box. The electrical breaking system is made by turning the generator into a motor. This type of breaking cannot stop the rotor completely. Therefore there is also a mechanical breaking system.

The mechanical breaking system uses hydraulic or air pressure for locking the rotor in a fixed position.

The propeller, in our case is named a rotor because it converts mechanical energy into torque rather than torque into mechanical energy as a propeller is doing in cases of airplanes, ships or other machines. The rotor received its mechanical energy from the wind and converts the horizontal flow of air into torque at its main shaft. This torque is then converted into electric energy by the generator itself.

The generator mounted in the nacelle needs to turn at certain speeds much higher than the rotor speed. For this purpose many wind generators are using a gear box to amplify the movement of the rotor (eg. 20 rpm) up to the speed needed by generator (eg. 1500 rpm).

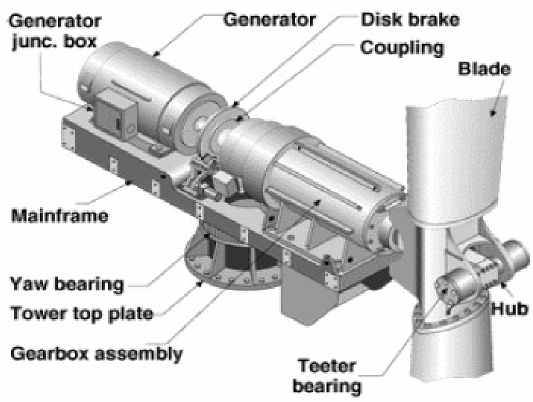

Fig. 3*. Wind turbine – Main components*

The main component of every wind generator system, figure 3, is the generator itself.

It is an important element because it generates electric energy by converting the mechanical energy received from the rotor.

The power, that a wind turbine generates, needs to have the appropriate parameters so it could be used successfully. To create a sinusoidal wave, that has the frequency and the voltage level compatible to the grid, a power converter is needed. This power converter will convert the energy received from the generator either DC or AC into an AC wave shape with the correct frequency and voltage level. To do that, it uses some commutation devices IGBTs or MOSFETs that need to be commanded by a DSP or other device so that the output voltage will meet its requirements.

After the AC voltage was created, it can be used in homes or if it is connected to power grid it needs to be prepared for transport, this being done by a transformer which raises the voltage to some high levels (20 kV or more).

3. Configuration of wind system

Currently, there are several main wind turbine (WT) configurations: fixed speed and directly grid connected wind turbine, variable speed WT with squirrel cage induction generator, variable-speed WT with double fed induction generator or variable speed, direct-driven synchronous generator. For every configuration presented bellow there could be several variations.

3.1 Configuration 1

The first configuration, figure 4, consists of several components connected in series to one another. In this configuration the rotor is connected directly to the synchronous generator. The power transfer from the generator to the grid is made by using a bidirectional converter. This converter allows full control to both active and reactive power. Because of using a synchronous generator the power converter should be designed to handle full power. The full power zone is reached when the wind has the potential of turning the rotor at generator nominal speed.

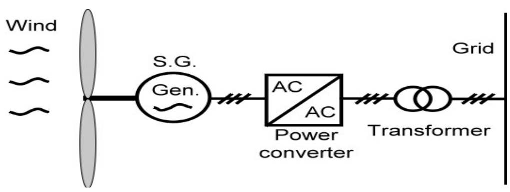

Fig. 4. Wind turbine – configuration 1

This could be considered as an advantage, because it assures that sometimes it could function at nominal parameters.

This configuration also has its disadvantage by using a big and heavy generator. Also, because the generator has permanent magnets (PM), it is an expensive apparatus.

Because it doesn't use a gear box it could be considered a simple wind turbine from a mechanical point of view but the power converter control system is a little bit more complicated than the other configurations.

3.2 Configuration 2

As seen in Figure 5, the configuration involves using a gear box for transferring the power from the rotor to the generator. This allows a smooth control of the power that is produced. The generator is not so expensive in this case because it doesn't have PM or other components that are expensive. The gear box and the induction machine generator allow the system to work at variable speed.

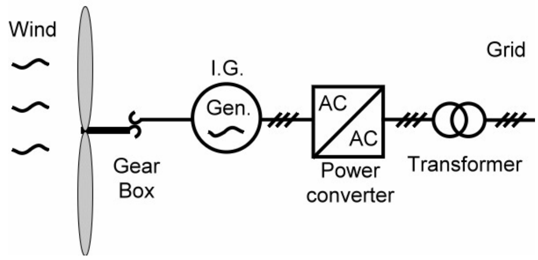

Fig. 5. *Wind turbine – configuration 2*

The squirrel cage induction generator must receive a certain amount of power from the grid to generate electric current. This is done by using a bidirectional converter between the generator and the grid.

The converter allows a flow of current in both directions through controlling both active and reactive power. It has to be designed to withstand full load because there are cases where the generator could generate power at nominal ratings. This configuration can be used for both grid-connected or standalone applications because of the flexibility allowed in its control. Also a big advantage is the variable speed that it can operate though not depending on the wind speed.

3.3 Configuration 3

The 3rd configuration differs from the other 2 because of the design and the components that it uses. In this case the power converter is only designed to withstand 25 % of nominal power.

The transformer has tertiary windings.

The generator, figure 6, is constructed to allow access to both rotor and stator windings. The stator windings are used for grid connection and the rotor windings are connected to the power converter.

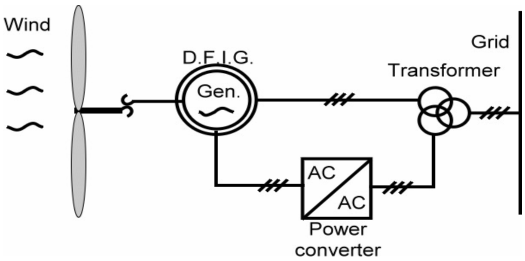

Fig. 6. *Wind turbine – configuration 3*

As in the above two cases, the power converter is also bidirectional. The bidirectional power converter is used especially because it allows a smooth control of active and reactive power.

For all power converters that are bidirectional, a great care should be taken to assure correct firing of the IGBTs or MOSFETs used in the high power section of the converter. The command part for this type of power converter is a little more complicated like the one used for 2 quadrant converter because it must check the power flow and control 2 inverters instead of one.

3.4 Configuration 4

This configuration is different from the other configurations because it uses a softstarter to allow the generator to start slowly (softly). This type of configuration is a more robust solution.

The soft-starter is not such an expensive component but the mechanical construction raises some difficulties because it has to support a certain amount of stress. Its major disadvantage is that it operates at constant speed with only 1-2% speed variation.

Also the system is very sensitive to the wind and, because of this, it gives certain power pulsations.

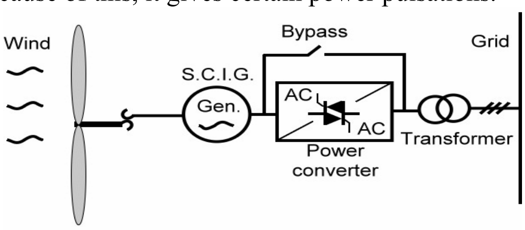

Fig. 7. *Wind turbine – configuration 4*

3.5 Chosen Configuration

Taking into consideration the above possible configurations, number 2 has been selected. In this configuration the gear box has been eliminated. The bidirectional converter will have to control the generator energy flow more rigorously as a normal converter will do because it has to provide power to and from the generator in the same time. Also the cost for the induction generator is very small compared with a synchronous machine or other type of machine for that matter. We consider this configuration to be easier to implement from a mechanical point of view. Also, for this system, the components are not so expensive and can be easily found. The only problem will be the power converter where the control system is a little more complex then the one used for a simple inverter.

4. Influence of wind speed over electricity generation

The amount of wind at a certain site is critical as it determines the amount of energy the turbine will produce. The best site for a wind turbine is where the wind speeds exceeds 5 m/s as higher the average wind speed for a region is, the better is for a wind turbine farm to be constructed. For example, a 10 kW turbine with an average annual wind speed of 4.47 meters per second produces about 7 700 kWh per year. The same turbine produces about 12500kWh per year at a site with an average annual wind speed of 5.36 meters per second. If the wind exceeds a critical speed limit the turbine is shut down. But in nowadays most of the wind turbines have a braking system, electrical one or mechanical one so most off wind speed problems are solved by mechanical brake or electrical brake. [5]

The wind resource can vary significantly over an area of just a few kilometers because of local terrain influences on the wind flow. There are resources that can be used to help determine the wind resources in your area:

• wind resource maps can be used to estimate the wind resource in your area;

• observation of an area's vegetation is an indicator of the wind resources in an area, for example trees can be permanently deformed by strong winds;

• the most accurate measurement is done through direct monitoring by a wind resource measurement system; however, this can be very expensive

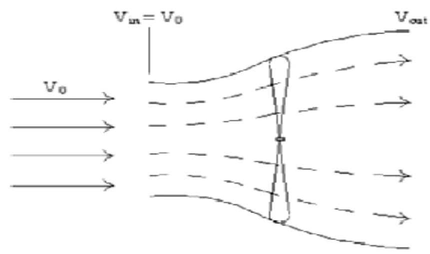

Fig. 8. *Wind Speeds Increase with Height*

Equation 1 formula illustrates factors that are important to the performance of a wind turbine. Notice that the wind speed, V, has an exponent of 3 applied to it. This means that even a small increase in wind speed results in a large increase in power. That is why a taller tower will increase the productivity of any wind turbine by giving it access to higher wind speeds. The formula for calculating the power from a wind turbine is:

$$P = k \cdot C_p \cdot \frac{1}{2} \cdot \rho \cdot A \cdot V^3 \qquad (1)$$

Where: P - Power output, kilowatts;

Cp – Maximum power coefficient, ranging from 0.25 to 0.45, dimension less (theoretical maximum = 0.59)

ρ – Air density, is about 1.25 Kg/m3 in normal conditions of temperature, pressure, see level etc.

A – Rotor swept area, m2 or π D2/4 (D is the rotor diameter in m, π = 3.1416)

V – Wind speed, m/s

k – 0.000133 A constant to yield power in kilowatts. (Multiplying the above kilowatt answer by 1.340 converts it to horsepower – i.e., 1 kW = 1.340 horsepower).

Speed variation take-in consideration the height of the tower as seen in equation 2:

$$\frac{V}{V_0} = \left(\frac{h}{h_0}\right)^{\alpha} \qquad (2)$$

Where: V0 – is wind speed in m/s at the ground level h = 0

a – coefficient characteristic to a location, α=0.1÷0.4

5. Conclusions

The future energy policy should not be based on an attitude "either", "or". Because of the serious challenges that we have to face, and taking into account the dynamics and its consequences due to the liberalization of the markets, we cannot afford that "luxury". The energy policy will have to be based on "this and that". All possible routes must be considered. For the time being, the energy world manages to get by. But, in the long run, one will have to "intervene" drastically. We hope that our current generation will take up its responsibility and that it invests in as many realistic long term options as possible. Only then, we will sufficiently pay back for our "consuming" of the fossil sources.

Wind energy is an ideal renewable energy because:

1. it is a pollution-free, infinitely sustainable form of energy
2. it doesn't require fuel
3. it doesn't create greenhouse gasses
4. it doesn't produce toxic or radioactive waste.

Wind energy is quiet and does not present any significant hazard to birds or other wildlife. When large arrays of wind turbines are installed on farmland, only about 2% of the land area is required for the wind turbines. The rest is available for farming, livestock, and other uses. Landowners often receive payment for the use of their land, which enhances their income and increases the value of the land. Ownership of wind turbine generators by individuals and the community allows people to participate directly in the preservation of our environment. Each megawatt-hour of electricity that is generated by wind energy helps to reduce the 0.8 to 0.9 tones of greenhouse gas emissions that are produced by coal or diesel fuel generation each year.

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