Domestic Wind Turbines and Componets

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Abstract:

The following study introduce the componets and opreration of wind turbines from the physical principles to the electrical and mechanical parts. However this kind of technology has many disadvantages, it is the one of the most popular solution to produce electric current in a cheap and environment friendly way.

Figure 1

The Big Brother (Nordex 2,5 MW)

1 HOWS AND WHYS

Wind is moving air. The engine that drives this movement is the sun. Although modern wind turbines can produce some electricity in light winds, the stronger the breeze the better. Why? The power available in the wind is proportional to the cube of its speed. One easy way to access higher wind speeds is simply to go up. Winds high above the ground are stronger than winds near the ground. On average a five-fold increase in elevation, say raising the height of the wind machine from 10 feet to 50 feet, will result in twice as much available wind power. That's why wind turbines are perched on tall towers and are often located on mountains or hilltops. Given the need for strong winds, finding the best sites for commercial wind farms is critical. The location of power plants fueled by wind must be near existing power lines and in the windiest sites available. To compete head-to-head with fossil fuel generating technologies, wind turbines are best located in areas where wind speeds are 60-70 km/h at 50 m height. Wind farms are located in the most windy areas and close to utility power lines.

1.1 The relation between the energy an wind

$$\text{Kinetic energy} = \frac{1}{2}mv^2 \quad [J]$$

$$\text{Power} = \frac{1}{2} \cdot (\text{mass flow rate per second}) \cdot v^2$$

Power= kinetic energy in the moving air

ρ = the desity of air

A= the surface brushed by the rotor blade

v = the velocity of air

$$P = \frac{1}{2}(\rho A v)v^2 = \frac{1}{2}\rho A v^3 \quad [W]$$

2 THE AERODYNAMICS

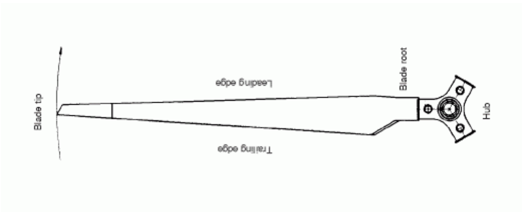


Figure 2

Three bladed rotor

The three bladed rotor is the most important and most visible part of the wind turbine. It is through the rotor that the energy of the wind is transformed into mechanical energy that turns the main shaft of the wind turbine.

2.1 Basic theory

Aerodynamics is the science and study of the physical laws of the behavior of objects in an air flow and the forces that are produced by air flows.

The front and rear sides of a wind turbine rotor blade have a shape roughly similar to that of a long rectangle, with the edges bounded by the leading edge, the trailing edge, the blade tip and the blade root. The blade root is bolted to the hub. The radius of the blade is the distance from the rotor shaft to the outer edge of the blade tip. Some wind turbine blades have moveable blade tips as air brakes,and one can often see the distinct line separating the blade tip component from the blade itself. If a blade were sawn in half, one would see that the cross section has a streamlined asymmetrical shape, with the flattest side facing the oncoming air flow or wind. This shape is called the blade’s aerodynamic profile.

2.1.1 The stall phenomena

A stall is understood as a situation during which an angle of attack becomes so large that the air flow no can longer flow smoothly, or laminar, across the profile. Air looses contact with the rear side of the blade, and strong turbulence occurs.

2.2 Summary

The main points as described in this article can be shortly stated in the following:

- The air flow around a wind turbine blade is completely dominated by the head wind from the rotational movement of the blade through the air.
- The blade aerodynamic profile produces lift because of its streamlined shape. The rear side is more curved than the front side.
- The lift effect on the blade aerodynamic profile causes the forces of the air to point in the correct direction.
- The blade width, thickness, and twist is a compromise between the need for streamlining and the need for strength.
- At constant shaft speed, in step with the grid, the angle of attack increases withincreasing wind speed. The blade stalls when the angle of attack exceeds 15 degrees. In a stall condition the air can no longer flow smoothly or laminar over the rear side of the blade, lift therefore falls and drag increases.

3 THE TRANSMISSION SYSTEM

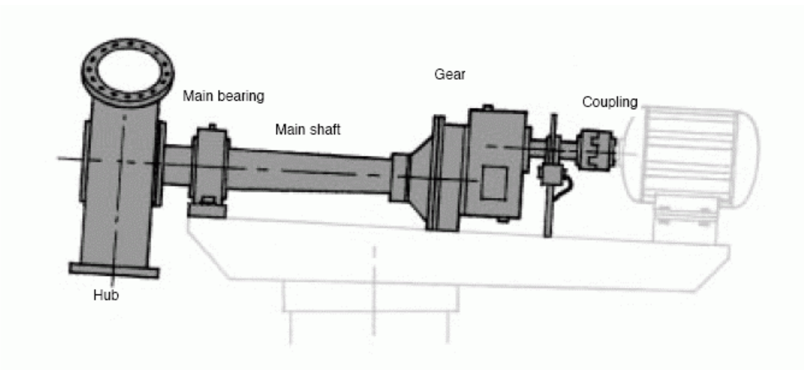


Figure 3

The transmission system

The transmission system is the link between the wind turbine blades and the generator

3.1 The Main Shaft

The main shaft of a wind turbine is usually forged from hardened and tempered steel. Hardening and tempering is a result of forging the axle after it has been heated until it is white-hot at about 1000 degrees centigrade. By hammering or rolling the blank is formed with an integral flange, to which the hub is later bolted. The shaft is reheated a final time to a glowing red, following the forging process, and then plunged into a basin of oil or water. This treatment gives a very hard, but at the same time rather brittle surface. Therefore the axle is once again reheated to about 500 degrees centigrade, tempering the metal and thereby enabling the metal to regain some of its former strength.

3.2 The Gearbox

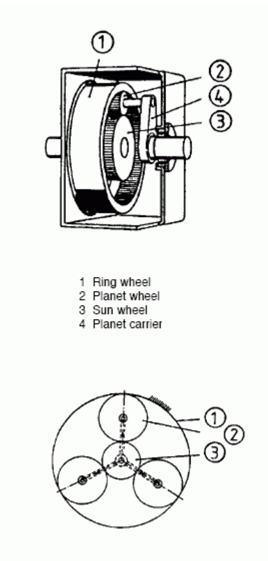


Figure 4

The gearbox

One of the most important main components in the wind turbine is the gearbox. Placed between the main shaft and the generator, its task is to increase the slow rotational speed of the rotorblades to the generator rotation speed of 1000 or 1500 revolutions per minute (rpm). Without much previous experience with wind turbines, one might think that the gearbox could be used to change speed, just like a normal car gearbox.

3.2.1 The Coupling

The coupling is placed between the gearbox and the generator. Once again it is not possible to consider the coupling as the same as a clutch in a normal car. One cannot engage or disengage the transmission between the gearbox and the generator by pressing a pedal, or in some other such way. The transmission is a permanent union, and the expression 'coupling' should be understood as a junction made by a separate machine component. The coupling is always a flexible unit, made from built-in pieces of rubber, normally allowing variations of a few millimeters only. This flexibility allows for some slight differences in alignment between the generator and the gearbox.

4 THE GENERATOR

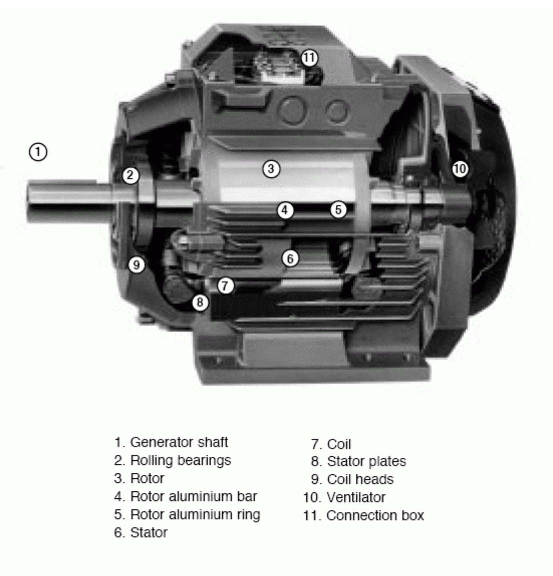


Figure 5

Parts of the generator

The generator is the unit of the wind turbine that transforms mechanical energy into electrical energy. The blades transfer the kinetic energy from the wind into rotational energy in the transmission system, and the generator is the next step in the supply of energy from the wind turbine to the electrical grid.

4.1 Three Phase Alternating Current

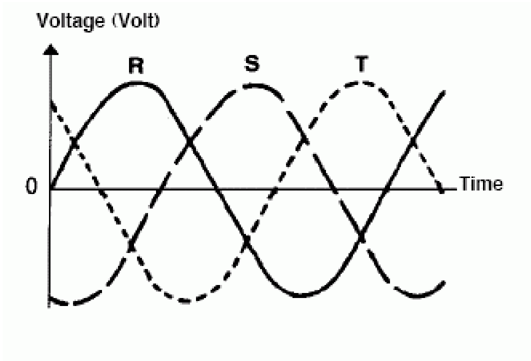


Figure 4

3 phase voltage

Even though the cycles in the alternating current are of no great importance for lamps and other such things, it is impractical for certain other machines that the current is always alternating around zero. Therefore, years ago, it was discovered that AC could be supplied with three phases. The principle of 3 phase electrical power is that the generator at the power station supplies 3 separate alternating currents, whose only difference is that they peak at three different times. The knack with these three separate alternating currents, or phases, is that it is thereby possible to ensure that the sum of the delivered power is always constant, which is not possible with two or four phases. It is perhaps a little impractical with three phase current, because it is necessary to run four different wires out to the consumer, three different phase wires and a neutral wire (zero). However for electric motor use, the advantages of three phase alternating current are many. The voltage difference between two of the phases is greater than that between any one single phase and zero. Where the voltage difference is 230 V between one hase and zero, it is 400 V between two phases. his is often used in high energy consumption equipment such as kitchen vens etc., which normally always are connected to two phase power. In a household installation usually only one on the phases plus the neutral wire is led to an ordinary socket. Normally the istallation has several groups, and one pase will typically cover one part of the house, and another phase will run to the other rooms. Three phase sockets are rather large and are often known as power sockets, mainly because of their use in electrical motor operation. For ease in distinguishing between the different phases, in Hungary the three phases have been named R, S, T (L1,L2,L3).

5 CONTROL AND SAFETY SYSTEMS

Control and safety systems comprise many different components. Common for all of these is that combined together they are part of a more comprehensive system, insuring that the wind turbine is operated satisfactory and preventing possible dangerous situations from arising.

Details in control and safety systems are somewhat different according to different types of wind turbines.

5.1 Problem Description

The first problem is common to all control and safety systems: A wind turbine is without constant supervision, apart from the supervision of the control system itself. The periods between normal qualified maintenance schedules is about every 6 months, and in the intervening 4,000 hours or so the control system must function trouble-free, whether the wind turbine is in an operational condition or not. In almost every other branch of industry there is a much higher degree of supervision by trained and qualified staff. However a wind turbine must be able to look after itself and in addition have the ability to register faults and retrieve this stored information concerning any special occurrence.

The high demands on reliability require systems that are simple enough to be robust, but at the same time give the possibility for necessary supervision. The number of sensors and other active components need to be limited as far as possible, however the necessary components must be of the highest possible quality. The control system has to be constructed so that there is a high degree of internal control, and to a certain degree the system must be able to carry out its own fault finding. The other problem most of all relates to the safety systems. A wind turbine, if not controlled, will spontaneously overspeed during high wind periods. Without prior control it can then be almost impossible to bring to a stop. During high wind, a wind turbine can produce a much higher yield than its rated power. The wind turbine blade rotational speed is therefore restricted, and the wind turbine maintained at the rated power, by the grid-connected generator. If the grid connection is lost, by reason of a power line failure or if the generator for some other reason is disconnected, while the wind turbine is in operation, the wind turbine would immediately start to rapidly accelerate. The faster the speed, the more power it is able to produce. The wind turbine is in a run-away condition.

5.2 The Controller

In one way or another the controller is involved in almost all decision-making processes in the safety systems in a wind turbine. At the same time it must oversee the normal operation of the wind turbine and carry out measurements for statistical

use etc. The controller is based on the use of a micro computer, specially designed for industrial use and therefore not directly comparable with a normal PC. It has a capacity roughly equivalent to that of a 80286 PC system processor. The control program itself is not stored in a hard disk, but is stored in a microchip called

an EPROM. The processor that does the actual calculations is likewise a microchip. Most wind turbine owners are familiar with the normal keyboard and display unit used in wind turbine control. The computer is placed in the control cabinet together with a lot of other types of electro-technical equipment, contactors, switches, fuses, etc. The many and varied demands of the controller result in a complicated construction with a large number of different components. Naturally, the more complicated a construction and the larger the number of individual components that are used in making a unit, the greater the possibilities for errors. This problem must be solved, when developing a control system that should be as fail-safe as possible. To increase security measures against the occurrence of internal errors, one can attempt to construct a system with as few components as possible. It is also possible to build-in an internal automatic self-supervision, allowing the controller to check and control its own systems. Finally, an alternative parallel back-up system can be installed, having more or less the same functions, but assembled with different types of components.

The controller measures the following parameters as analogue signals (where measurements give readings of varying values) :

- Voltage on all three phases
- Current on all three phases
- Frequency on one phase
- Temperature inside the nacelle
- Generator temperature
- Gear oil temperature
- Gear bearing temperature
- Wind speed
- The direction of yawing
- Low-speed shaft rotational speed
- High-speed shaft rotational speed

Other parameters that are obviously interesting are not measured, electrical power for example. The reason being that these parameters can be calculated from those that are in fact measured. Power can thus be calculated from the measured voltage and current The controller also measures the following parameters as digital signals (where the measurements do not give readings of varying values, but a mere an on/off signal) :

- Wind direction
- Over-heating of the generator
- Hydraulic pressure level
- Correct valve function
- Vibration level
- Twisting of the power cable
- Emergency brake circuit
- Overheating of small electric motors for the yawing, hydraulic pumps, etc.
- Brake-caliper adjustment
- Centrifugal-release activation

Even though it is necessary to limit the number of measurements, certain of these are duplicated, for example at the gearbox, the generator and the rotational speed. In these cases we consider that the increased safety provided, is more important than the risk of possible sensory failure. Internal supervision is applied on several levels. First of all the computer is equipped with certain control functions, known as 'watchdogs'. These supervise that the computer does not make obvious calculation errors. In addition the wind turbine software itself has extra control functions. For example in the case of wind speed parameters. A wind turbine is designed to operate at wind speeds up to 25 m/s, and the signal from the anemometer (wind speed indicator) is used in taking the decision to stop the wind turbine, as soon as the wind speed exceeds 25 m/s. As a control function of the anemometer the controller supervises wind speed in relation to power. The controller will stop the wind turbine and indicate a possible wind measurement error, if too much power is produced during a period of low wind, or too little power during a period of high wind. A wind measurement error could be caused by a fault in the electrical wiring, or a defect bearing in the anemometer. A constant functional check of the relationship between wind speed and power production ensures that it is almost impossible for the wind turbine to continue operation with a wind measurement error, and the possibility of a wind turbine being subject to stronger winds than its designed wind speed rating, is therefore more or less eliminated. The third safety principle for the controller lies in duplication of systems. A good example is the mechanical centrifugal release units. These supervise the blade rotational speed and activate the braking systems, even if the speed measurement system of the controller should fail.

A domestic wind turbine has two centrifugal release units. One of these is hydraulic and placed on the wind turbine hub. It is normally called a CU (Centrifugal release Unit). Should the wind turbine operate at too high a rotational speed, a weight will be thrown out and thereby open a hydraulic valve.

Once the valve is open, hydraulic oil will spill out from the hydraulic cylinders that hold the blade tips in place, thereby activating the blade tip air brakes. No matter what actions the controller or the hydraulic system thereafter attempts to carry out, pressure cannot be maintained in the cylinders and the air brakes will continue to remain activated, until a serviceman resets the centrifugal release manually. The advantages of the hydraulic centrifugal release units is that it is completely independent the controller and the hydraulic system. This ensures that a possible fatal software design error, not discovered during design review, will not result in a possible run-away of the wind turbine.

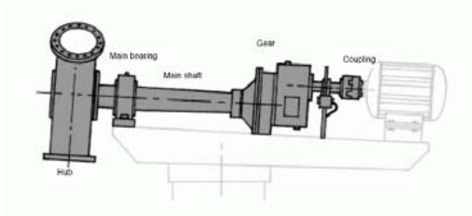
5.3 The Mechanical Brake

The Mechanical brake is a disc brake placed on the gearbox high-speed shaft. The brake disc, made of steel, is fixed to the shaft. The component that does the actual braking is called the brake caliper. Likewise this is also a fail-safe system, hydraulic oil pressure is necessary to prevent the brake unit from braking. Should oil pressure be lacking, a powerful spring presses the brake blocks in against the brake disc.

Braking is a result of friction between the brake block and the disc. Wind turbine brakes experience large stress forces, therefore it is necessary to use special materials for brake blocks on large wind turbines. These are made of a special metal alloy, able to function under high temperatures of up to 700 degrees Centigrade. By comparison, the temperature of the brakes on a car rarely exceed 300 degrees. The mechanical brake function is as described under point 2 of the section dealing with the possible problem situations - to prevent the rotational speed of the blades from increasing above the rated rotational speed.

6 Building a domestic wind turbine

The principles are the same as described above. The domestic version is much more smaller (8-10 m high) than an industrial, but it must produce at least 5 KW energy for an individual house or building. The blade rotor could be placed radially or axially to the main shaft. The controller unit is an indoor device, which is a microcontroller card with a multi line LCD display and utility buttons in a wall mount case.



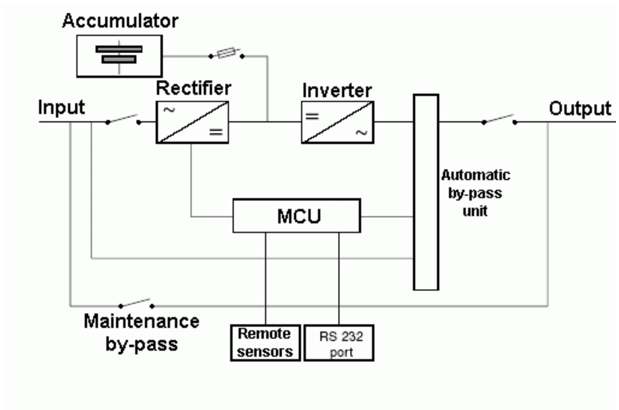


Figure 6

The main parts

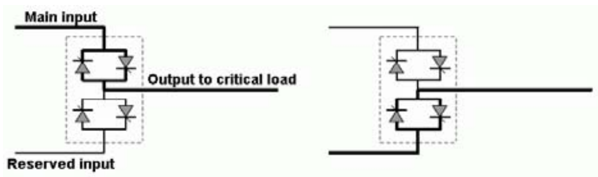


Figure 7

Static switch for UPS

Conclusions

The alternative energy producer systems are much more inportant in the present and this situation will not change in the future. We have to solve energy problems by producing environment friendly technologies. Novadays the law and energy industry is in the opposite side and don’t supprt technologies like this in Hungary.

References

[1] Paul Gipe: Wind energy basics, 1999