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DESIGN OF INDUCTION GENERATOR FOR WIND TURBINE

M.Sc. Thesis by

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DESIGN OF INDUCTION GENERATOR FOR WIND TURBINE

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by

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"DESIGN OF INDUCTION GENERATOR FOR WIND TURBINE"** completed by **EMAD ELNAGE ELFRITES** under supervision of **Prof. Dr. ABDULLAH YILDIZ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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2019, 18 January **Emad Elnage ELFRITES**

DESIGN OF INDUCTION GENERATOR FOR WIND TURBINE

ABSTRACT

The electromagnetic induction method is usually used for this purpose. Electromagnetic induction is carried out by moving a wire file around a fixed rod with an electric field, either by a magnet or an electric magnet. The induction generator depends on the principle of electromagnetic induction. This phenomenon was discovered by Michael Faraday, and it is reported that the current is produced in the conductor when it is moved through the magnetic field. The resulting output voltage is called the electromotive force (emf). This process can also be reversed. In other words if the electric charge is moving, it will generate a magnetic field. The Faraday-Maxwell induction code determines the relationship in which the value of emf versus the number of cycles (for a file) indicates the rate of change in the magnetic flow. The reason for the minus sign is that the direction of the wattage direction is opposed to the change in flow that produces the voltage. Electromagnetic induction has many applications. For example, in credit cards (magnetic strips on the back of the card) or in order to generate voltage in the motor. Another one is very important because the generator is an "inverted" engine. The objective of this study is to design a small wind turbine which is optimized for the constraints that have residential use. The design process includes the selection of the wind turbine type and the determination of the blade airfoil pitch angle and chord length distribution along the radius. The pitch angle and chord length distributions are optimized based on conservation of angular momentum and theory of aerodynamic forces on an airfoil. Blade Element Momentum (BEM) theory is first derived and then used to conduct a parametric study that will determine if the optimized values of blade pitch and chord length create the most efficient blade geometry. Finally, two different airfoils are analyzed to determine which one creates the most efficient wind turbine blade. The study includes a discussion of the most important parameters in wind turbine blade designed to maximize the efficiency.

Keywords: Wind, energy, pools, slot, rotor, stator.

DESIGN OF INDUCTION GENERATOR FOR WIND TURBINE

ÖZ

Jeneratör, mekanik enerji ile elektrik üreten bir cihazdır. Elektromanyetik indüksiyon yöntemi genellikle bu amaç için kullanılır. Elektromanyetik endüksiyon, bir tel dosyasının sabit bir çubuk etrafına bir elektrik alanı olan bir mıknatıs veya bir elektrik mıknatısı ile taşınması yoluyla gerçekleştirilir. Faraday kanununa göre, bu, bobin içinde makineleri çalıştırmak veya bataryaları şarj etmek için kullanılabilecek bir elektrik akımı yaratır. Mekanik enerji kaynaklarından biri buhar motorları, içten yanmalı motorlara ek olarak türbinlerde veya külçelerde akan su, el krankı, rüzgar türbinleri, basınçlı hava, güneş enerjisi ve diğerleridir. Elektrik jeneratörü, modern elektrik toplumunun temelidir ve eğer jeneratörler çalışmayı keserse, ekonominin önemli ölçüde bozulmasına yol açacaktır.

İndüksiyon üreteci, elektromanyetik indüksiyon prensibine bağlıdır. Bu fenomen Michael Faraday tarafından keşfedildi ve akımın manyetik alanda hareket ettirildiğinde iletkende üretildiği bildirildi. Ortaya çıkan çıkış gerilimine itici güç (emf) denir. Bu işlem tersine çevrilebilir, başka bir deyişle, eğer elektrik yükü hareket ediyorsa, manyetik bir alan meydana getirecektir.

Anahtar Kelimeler: Rüzgar, enerji, havuzlar, yarık, rotor, stator

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NOMENCLATURE

Roman Letter Symbols

EMF	Electromagnetic Field
RPM	Revolution per Minute
ρ	Air Density
Cp	Power Coefficient
λ	Tip Speed Ratio of a Wind Turbine
SRC	Specified Rate Capacity
TSR	Tip Speed Ratio
DFIG	Doubly Fed Induction Generator
IGBT	Insulated Gate Bipolar Transistor
SLT	Slot Liner Thicknes
DE	End of Drive
NDE	Non-End of Drive

CHAPTER 1

WIND ENERGY

1.1 Introduction

The developing utilization and unfaltering increment in the cost of non-inexhaustible sources has constrained individuals to search for alternative fuels that are accessible economically and can take care of their developing demand for energy. Among the options accessible is wind energy, it is one of the alternatives options of energy that has been used since 2000 BC. Wind control has enormous possibilities and has been developing quickly.



Figure 1.1 Old wind turbine

Wind energy is a renewable alternative energy and cheap cost compared to other sources of energy. Wind power is the process of converting wind power to other forms of energy - turning wind energy into physical energy - and can be useful, often using turbines to generate electricity. Wind is not the modern source of energy, was the beginning of the use of this energy is due to the civilization of Egypt Paranoiac, where the Pharaohs used wind to run ships, and that was in about 3000 BC. The mills were also used in the ancient Babylonian grain mill, which was built on a vertical axis with sails or blades moving around the Middle East. The windmill arrived in Europe in the 12th century. The European mills were built on a horizontal axis. High towers with wooden blades became a symbol for the Dutchmen, who pumped water to the reclaimed land for agriculture. The first to use wind to generate electricity is Charles Brush, where he built the "Brush Mill" in Cleveland, Ohio. It looked like a huge fan with a tail, and the mill produced about 12 kW and had worked for 20 years. In 1920 the turbines were developed in a prophetic style, and then the attention of the wind card ceased during the second vernacular war. Then, interest returned to this type of energy in 1940, when Denmark became the center of the study of air turbines. However, the real development of the energy industry was only after the increase in oil prices in 1970. In 1980, real thought was given to how to develop turbines into their present modern form, as well as the term wind farms and the specifications they should have. This column is anchored by the huge helicopter blades. The reason for the fact that the turbines are too high is their possibility of reaching the upper atmosphere and capturing the fast wind currents.

The electricity generation from wind turbines is very simple. It starts with a very long tower, which can be up to 67 meters long, a height of 21 floors. At the top, there is a specific chassis that connects the helicopter blades to the tower by a horizontal axis. It also contains a generator and a handle. The strong wind movement causes the movement of the blades, which in turn moves the handle that connects to the generator, which produces electricity.

The installation of large groups of turbines in areas called wind farms, these turbines and wind farms have the capacity to produce and generate energy in different types as needed from electric power. The large-scale wind farms at the strategic level have

more than 200 turbines, each with more than 100 kilowatts of power to produce about megawatt.

The specifications of wind farms, and this farm has several specifications, there are many vast land, but there must be specific specifications for the use of these lands in the generation of wind energy and one of the most important of specifications is that site should have strong winds to obtain energy regularly where the wind speed should be about 5.5 meters per second. Also, the area of the land should be very large and exposed, not obstructed by high buildings or trees that obstruct the movement of the wind, and be enough to create a large number of turbines, so that each turbine from each other enough distance. Also, the land should be as flat as possible and that means that the wind speed will be more, and it should be high and far away from the Population areas.

It is preferable to set up these air farms on the coast because the winds above the water have constant speeds and at higher rates than the others. There are no obstacles that reduce the speed of the wind on surface of the water, as well as a solution for countries that have a high population density and do not have enough land to establish these farms. Also, the bases of these turbines can be built at a lower cost on the coast.

Global Wind Atlas is an electronic mapping showing the distribution of wind on the surface of the earth and can help users to identify areas that have been recorded the highest level of wind. These maps provide complete and comprehensive information for the assessment of renewable energy available in the countries of the world and the possibility of use. Where the Atlas will support future plans on the possibility of using renewable or alternative energy as an alternative to traditional energy sources that are close to finish.

The most important questions that Wınd Atlas can answer are: What is the share of renewable energy from the state's energy needs? Where is this kind of energy concentrated? What techniques should be used to get the highest profit when using these capabilities? What size of investments can be created? Is there enough market to accommodate?

Wind Atlas is a database for renewable energy that is mainly focused on basic information, whether it is physical information such as wind speed and solar radiation in a particular area. It also provides economic and legal information such as the policies of a particular country on renewable energy. Or what mechanisms of renewable energy are supported in a country?

The World Wind Atlas provides all the information and data you may need on energy sources and the amount of energy available. It also includes information on infrastructure, as well as providing information that enables users to identify areas where there is an opportunity to develop renewable energy projects.

An Electric Generator can be defined as a mechanical device that converts energy into electrical energy, as well as the magnetic field. It works on the principle of electromagnetic induction. This is the basis of generating the inductive current. The generator industry has evolved considerably in terms of generating a very high rated current. The electric current is channeled through the external circuit. The generator has multiple sources including the AC motor, turbines that use the steam engine in operation or through the turbine water cycle So-called hydropower (wind turbines), or through compressed air and others.

The coil is a coil that consists of a twisted metal wire to generate electric magnetization, which makes the current travel large distances in a small space and produces a strong magnetic field around the magnetic field, which produces electrical energy (electromagnetic induction) and through the rotation of the file using mechanical energy For example, a bicycle lamp, which depends on the wheel's rotation to produce electricity to light the lamp, and the power plants are using renewable energy such as air or water through the rotation of turbines that turn the flow of water to electricity. This means that when the rotor is moved by a rotary column connected to the primary mover, an electromagnetic field is generated from the rotor, which travels to the stator, which receives the electromagnetic field and turns it into a current of electricity Spread over three faces and the angle between each face and another (120) degree and then turn into a stream of electricity on a regular basis.

This examination tries to demonstrate how to get the energy out of the wind, the parts of the turbine and how to design the generator (the induction generator) which is utilized as a part of the turbine.



Figure 1.2 Wind farm

1.2 Why We Need Wind Energy?

The most using of power is created by consuming coal, instead of eco-friendly sources like hydroelectric power. This utilization of coal causes untold natural harms through CO2 and other dangerous emanations.

The energy sector is by a long shot the greatest wellspring of these discharges, both in of worldwide, and unmistakably there is a need to handle the environmental change by utilizing and relying upon practical and inexhaustible wellsprings of energy rather than burning fossil fuel reserves. And talk about the mechanism of work wind turbines, there are so-called windmills, which are traditional wind fans or wooden sails or metal blades, but not practical because it does not pick up enough wind to produce electricity. There is also the so-called wind turbine, which is longer than traditional windmills, which are shaped like huge fans on a high column. This column is anchored by the huge helicopter blades. The reason for the fact that the

turbines are too high is their possibility of reaching the upper atmosphere and capturing the fast wind currents.

1.3 The Main Factors Affecting Wind Energy

The energy of the wind corresponds to three basic factors:

1- Winds Speed: In fact, the energy of the wind is not proportional to its speed, but it is directly proportional to the speed cube of this wind, in a simple way, we can find that the potential energy of a wind speed at a site is twice as fast at another location. The potential energy will be eight times the energy of the slowest site. For this reason, it is important to know which sites have the fastest winds to use in order to produce the largest amount of electricity and to use the speeds of those winds.

2- Air Density: The energy of the wind is directly proportional to the air density of the wind. It simply means that the area with low temperatures increases the density of the air and thus increases the energy contained in the passing wind, and vice versa.

3- This is the area of rotation of the blades of the turbine itself, and this area is directly proportional to the square length of the feather for the turban. It represents the radius of the circular area. This explains the manufacture of turbines in large sizes and increase the length of feathers, thereby increasing the diameters of feather rotation.

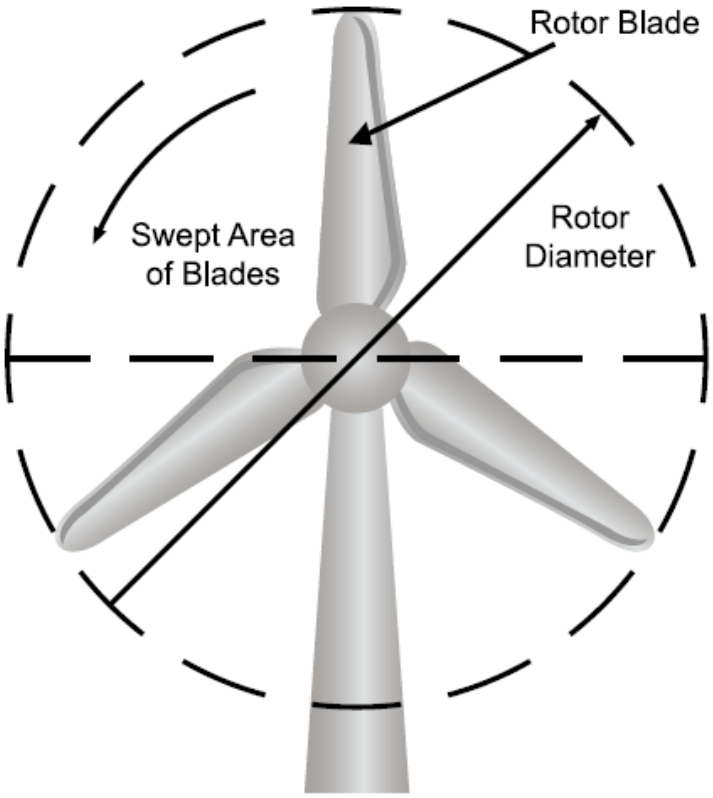


Figure 1.3 Feather Rotation

1.4 Advantages Of Wind Power

Wind energy offers many points of interest, which clarifies why it's one of the quickest developing sources on the earth. The most important benefits are as follows:

1. The wind is free and powered efficiently by modern technology.
2. Once the wind turbine is built, the energy produced does not cause greenhouse gases or other pollutants.
3. Although wind turbines are very high in length, each one only occupies a small plot of land. This means that there is an area which can still be used, this is especially the case in agricultural areas as farming operations still continue.
4. Most people considers wind farms as a distinguished feature of the landscape.

5. Remote regions that are not associated with the power control lattice can utilize wind turbines to create their own particular supply.

6. Wind turbines have an important role in both the developed and the third world.

7. Wind turbines are available in multiple sizes which means that a wide number of people and businesses can use them, single households in small towns and villages can also make good use of a variety of wind turbines available at the present.

1.5 Disadvantages Of Wind Power

1. The power of the wind isn't consistent and it changes from zero to storm force. This implies wind turbines don't deliver a similar measure of power constantly. There will be times without power created by any means.

2. Many individuals feel that the field ought to be left untouched, without these extensive structures being manufactured. İt is preferred here that the landscape is enjoyed by everyone.

3. Much noise is emanated from wind turbines. Everyone can create an indistinguishable level of commotion from a family auto going at 70 mph.

4. Many people see large wind turbines as unsightly structures to be seen. They disfigure the countryside and are generally ugly.

5. When wind turbines are manufactured, they cause some pollution. Therefore wind power does produce some pollution.

6. Enough power is expected to be generated from Expansive wind ranches, For instance, the biggest single turbine accessible today can just give enough power to 475 homes, when running at full limit. How many turbines are needed for a town of 100 000 people?

1.6 Wind Energy-Turkian Scenario

As Turkey nearly gets its energy supply from fossil energy sources, it depends on outer sources to acquire energy required for its economy and distinctive segments. On a similar way, Turkey created 83 pct of the general power in 2008 out of fossil energy sources. Future projectors show that the energy supply of the nation would enlarge and external reliance in energy would increase likewise. The on-going examinations indicate that hydraulic power and wind energy potential, as a feature of the sustainable power wellsprings of Turkey, are profoundly imperative and each of these two sources has the specialized potential to cover the generation of electricity in 2008. The current increment in the quantity of wind energy power stations is connected with the planning of Turkish Wind Atlas and the availability of legal courses to help private business entrepreneurs and the rise in oil prices. Wind energy power stations are working properly in Marmara, Aegean and the Mediterranean areas witness a high average of winds and are expected to be established in other topographical areas.

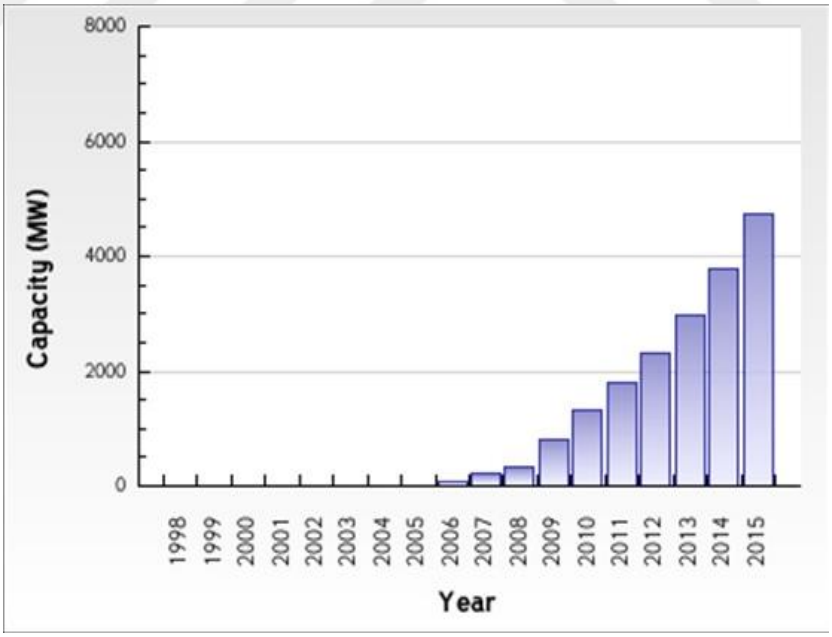


Figure 1.4. Turkey's gross electrical energy production for the years 1998–2015.

1.7 Wind Energy – Arab Countries Scenario

In the Arab world, wind energy is concentrated in specific areas. Despite the large Arab land area, it is not available everywhere. However, existing power grids and expansion plans can transfer this energy from their generation to where they need it.

There are also a large number of countries in the region (Wind Atlas) or Khorayat showing the wind speeds in different regions. It is clear from these maps that these areas have wind in which there are wonderful properties in terms of the possibility of exploitation in the production of electric power.

Countries such as Egypt, Morocco and Oman have average annual wind speeds ranging from 9 to 11 meters per second, with capacity exceeding 30 per cent annually, compared with a global average of between 20% and 25% .

There are also many sites with average annual wind speeds ranging between 7 and 8 meters per second .. They are also suitable for the production of electricity.

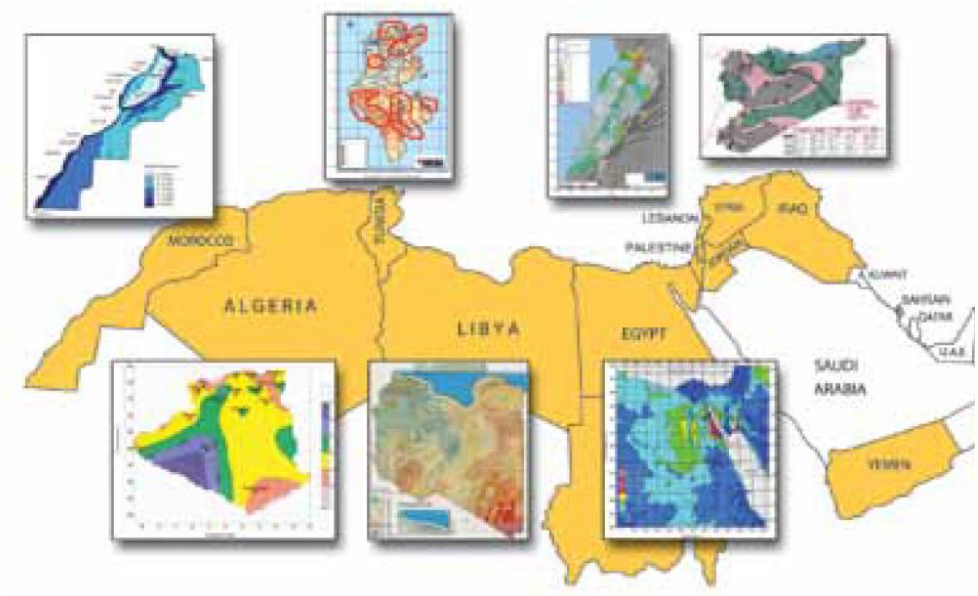


Figure 1.5 Models of wind Atlas and maps available in some Arab countries.

CHAPTER 2

THE WİND TURBİNE COMPONENTS

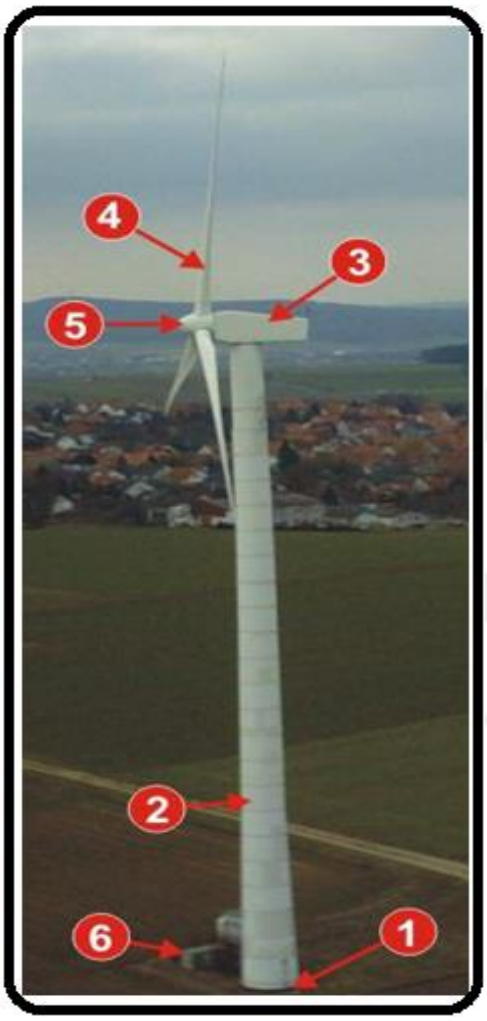


Figure 2.1 The wind turbine components

1. Foundation
2. Tower
3. Nacelle
4. Rotor blade
5. Hub
6. Transformer (this is not a part of the Wind Turbine)

2.1 Tower and Foundation

It is essential here to ensure the security of a wind turbine, thus, a flat foundation is utilized, contingent upon the consistency of the basic ground

The tower development doesn't simply convey the heaviness of the nacelle and the rotor blades, but should likewise retain the gigantic static burdens caused by the fluctuating energy of the wind. In general, a tubular construction of cement or steel is utilized. Another option to this is the lattice tower form.

2.2 Rotor and Rotor Blades

The rotor is the part which, with the assistance of the rotor blades, changes the energy in the wind into rotational mechanical movement.

At present, the three blade, horizontal axis rotor overwhelms. The rotor blades are mostly made of glass-fiber or carbon-fiber reinforced plastics (GRP, CFRP). The sharp edge profile is like that of a plane wing. They utilize a similar rule of lift: on the lower side of the wing the passing air creates higher weight while the upper side produces a force. These powers make the advancement of the rotor i.e. to turn.

2.3 Nacelle With Drive Train

The nacelle holds all the turbine machinery. Since it must have the capacity to pivot to follow the wind course, it is associated with the pinnacle via bearings. The development of the nacelle indicates how the maker has chosen to position the drive train components (rotor shaft with beadings, transmission, generator, coupling and brake) over this machine bearing.



Figure 2.2 The wind turbine components (head)

2.3.1 Gearbox

The gearbox changes the rotor movement of 18-50 rpm into the approx. 1,500 rpm which the generator requires.

The gearbox, therefore, takes up the assignment of coordinating between the pivot rates of the moderate moving of the rotor and the quick moving generator, and for the most part has a few errands to cover for different conditions of the wind.

In case that an extraordinary multi-post ring generator is used, the gearbox is never required again (best-known maker of direct drive turbines: ENERCON).

2.3.2 Generator

For high power wind turbines, doubly-bolstered no concurrent generators are the most ones regularly utilized. Here, the operating rotation speed may be not different like when utilizing regular asynchronous generators. Synchronous generators represents another idea adapted with this regard. A lattice association of synchronous generators is just conceivable by means of transformers, due to the settled turn execution. The impediment of required convoluted control frameworks is countered by the general proficiency and better grid compatibility. The mechanical energy in a wind turbine is changed by the generator into electrical energy.

Generally, a comparison is made between asynchronous and synchronous generators. Asynchronous generators are frequently utilized, they take into account synchronization with the grid and are very powerful and low-maintained in addition, synchronous generators are likewise utilized as they work more effectively. Synchronous generators can be straight associated with the grid, and there is a chance to adapt an inverter, but that may require an extra tool for synchronization with the grid.

All generators must be cooled, and a ventilator is generally utilized for air cooling. Once a water cooling is likewise utilized, moderate running multi-post ring generators work without a gearbox as specified previously.

2.3.3 Coupling And Brake

As a result of the huge number of torque, there is inflexibility in the coupling between the primary shaft and the transmission. The control mechanism of the blades specifies and shapes the form of the brake.

2.4. Electronic Equipment

The electronic equipment of a wind turbine is made out of the generator (as shown above), the arrangement of the matrix indeed of the power, and different sensors.

The sensors for measuring temperature, wind heading, wind speed and numerous different things can be found around the nacelle, and give the support for controling and monitoring the turbine (see chapter "Operation and Maintenance").

2.5. Other Components

As a conclusion, the main job of the components inbuilt in the turbine is to follow the direction of the wind, for cooling, fire extinguishing, warming and lightning assurance, in addition to lifting gear (e.g. winches for extra parts).

2.6. Wind Farms

The term Wind Farm or wind power plant is released when a set of wind turbines are available, and these turbines are connected together to generate electricity that travels through transmission and distribution lines to consumers.

The location of the turbines is determined on the project land based on studies carried out using special computer programs that depend on the characteristics of the topographic location, the obstacles, the nature of the land, the speed and direction of the wind and the extent of its change so that the farm is able to generate as much electricity as possible annually.

In order to distribute and connect these turbines, we are trapped in rows facing vertically in the direction of the prevailing winds throughout the year.

The distance between each turbine and the distance between 30 meters and five times the diameter of the turbine.

The distance between the first turbines row and the parallel row that follows is seven times the diameter of the turbine.

The space around the turbines is meant to give the wind a chance to offset the decline in speed due to collisions with the turbines and to minimize the turbulent damage caused by turbine rotation.

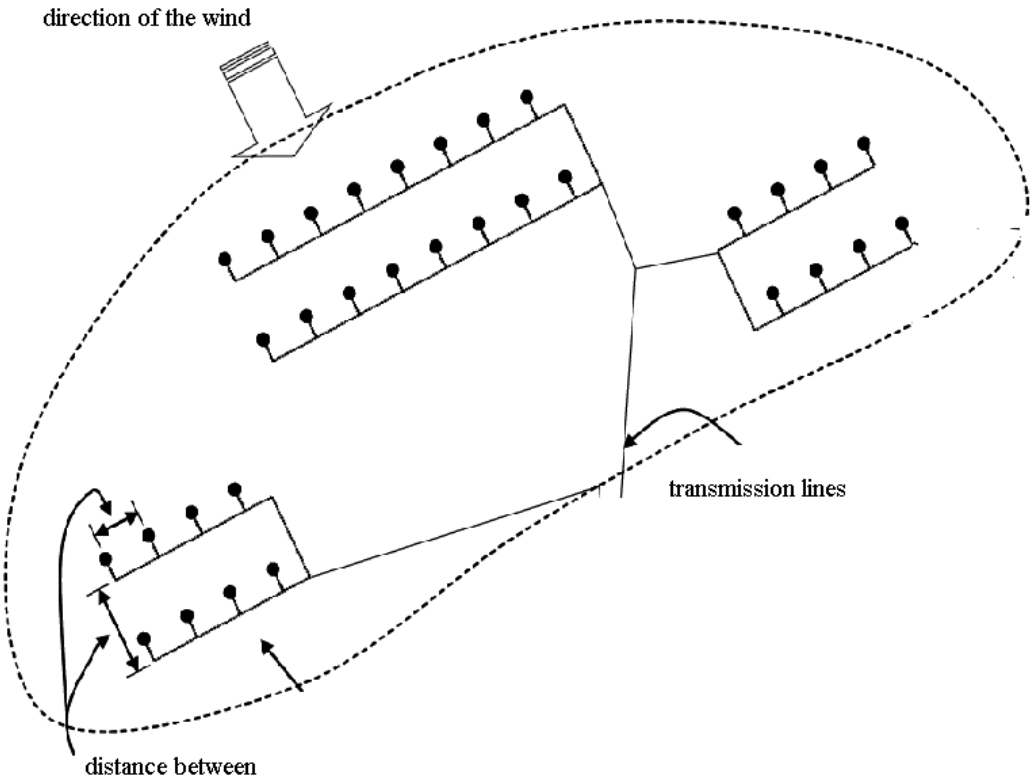


Figure 2.3 Wind farms

CHAPTER 3

WIND ENERGY, THE SYSTEMS OF GENERATING

3.1 Wind Turbines

Wind turbines generate energy using wind energy to drive an electric generator. The wind produces the crane and applies a rotation force by passing over the blades. The axial blades are turned into a column inside the cabin, which is inserted into the gearbox. The gear speed is changed by the gearbox to suit the generator, which uses the magnetic fields to change the circulating energy to electrical energy. The power output goes to the transformer, which changes the power of the alternator at about 700V to the appropriate voltage of the power supply system which is usually 33 kV.

A wind turbine separates dynamic energy from the cleared zone of the blades. The energy of the wind is given by the active energy of the streaming air mass per unit time. That is:

$$P_{air} = 0.5\rho A V_{\infty}^{3} \quad \textbf{(3.1)}$$

Where P_{air} is the power of the wind (in watts), ρ is the air density (1.225 kg/m3 at 15°C and normal pressure), A is the cleared zone in (square meter), and V_{∞} is the wind speed without rotor interference, i.e.: ideally at interminable separation from the rotor (in meter per second).

In spite of the fact that the above condition gives the power accessible in the wind, the power transferred to the wind turbine rotor is decreased by the power coefficient, C

$$C_P = \frac{P_{Wind\ turbine}}{P_{air}}$$

$$P_{wind\ turbine} = 0.5\rho C_P A V_{\infty}^{3} \quad \textbf{(3.2)}$$

The Betz limit defines the Maximum value of Cp which indicates that a turbine can never extricate over 59.3% of the power from an air stream. Basically, wind turbine rotors have an extreme Cp esteem in the scope of a 25-45%.

Strength: Wind force is the ratio of the projected blade area to the wind-resistant area. The expected blade range is the blade area offset by the wind or projected to the wind.

Power has an immediate correlation with torque and speed. High-speed rotors are characterized by high torque and low speed, and are used for pumping water. Murphur, low power rotors, enjoys fast and low torque, and is usually suitable for generating electricity.

Tip Speed Ratio

Tip speed ratio of a wind turbine (λ) is defined as:

$$\lambda = \frac{\omega R}{V_{\infty}} \tag{3.3}$$

Where ω is rotational speed of rotor (in rpm), R is the radius of the swept area (in meter).The tip speed ratio λ and the power coefficient Cp are dimensionless and is adapted as a tool to describe the performance of the size of wind turbine rotor.

Specified Rated Capacity

Specified Rate capacity (SRC) is an essential index which is used to put a variety of wind turbine designs under comparison.

$$SRC = \frac{Power\ Rating\ Of\ The\ Generator}{Rotor\ Swept\ Area} \tag{3.4}$$

It varies between 0.2 (for small rotors) and 0.6 (large rotors)

3.2 Characteristics of Wind Turbine

Different Characteristics of wind turbine are plotted to have a superior comprehension.

Power-Speed Characteristics

Mechanical Power transmitted to the shaft is:

$$P_m = 0.5\rho C_P A V_\infty{}^3 \quad \textbf{(3.5)}$$

Where:

Cp is a function of tip speed ratio (TSR) and pitch angle "α" for wind turbine with radius

The associated curves show the relationship between the mechanical energy extracted from the wind and the rotor speed at different wind speeds. For each wind speed, the optimum turbine speed is output at maximum power.

Such a gathering of wind turbine bends is represented to by a solitary dimensionless bend, explicitly: the Cp – λ curve as shown in figure 2.2

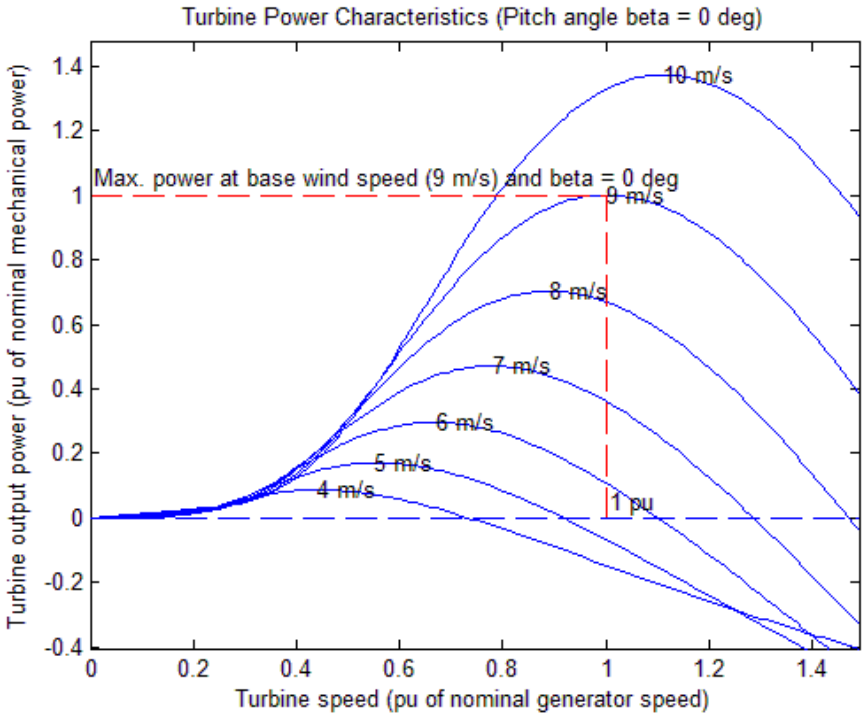


Figure 3.1 Typical Power versus speed characteristics of a wind turbine

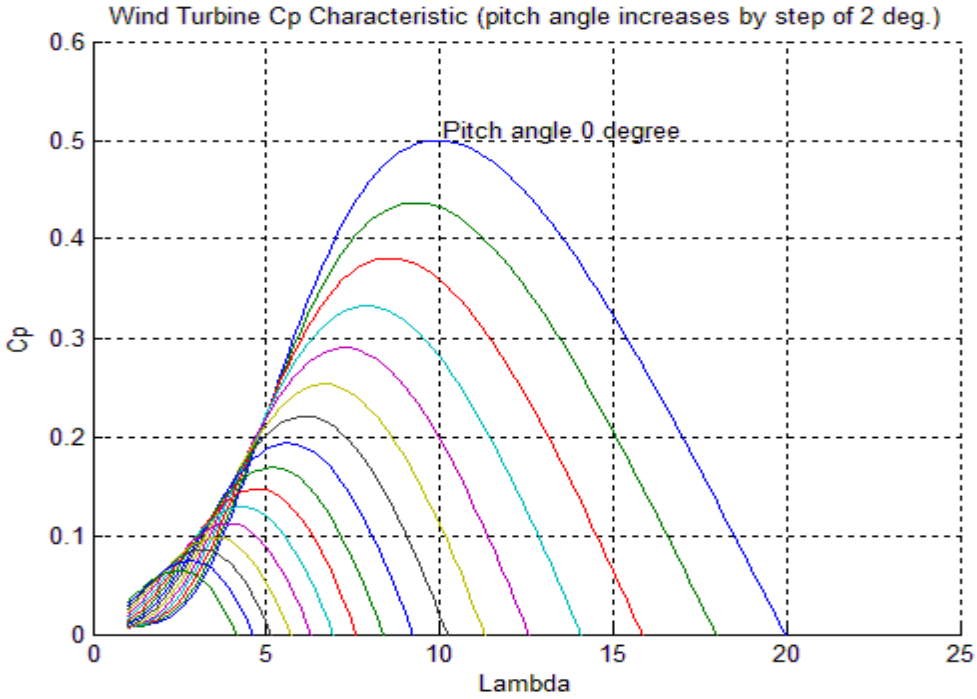


Figure 3.2 Typical curves of power coefficient (C_p)
Versus Tip speed ratio (λ) for various angles of pitch angle

Torque–Speed Characteristics:

The typical torque versus speed characteristics of horizontal axis (two blade propeller type) wind turbine is shown in Fig 3.3:

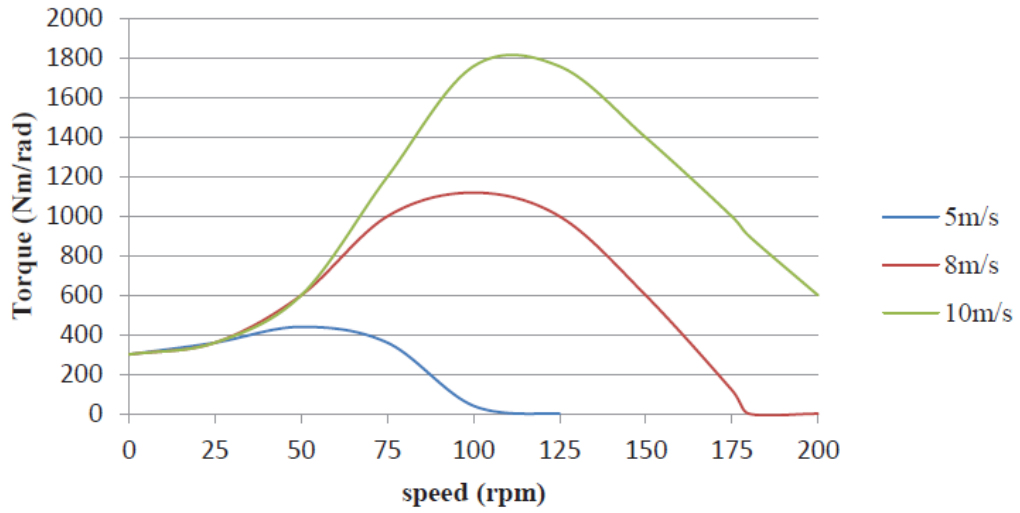


Figure 3.3 Torque versus speed characteristics

The direct relationship between Torque and Power is:

$$T_m = \frac{P_m}{\omega} \tag{3.6}$$

Using the optimum values of C_p and λ, the maximum value of aerodynamic torque is:

$$T_{max} = 0.5\rho C_{P-opt}\pi\left(\frac{R^5}{\lambda_{opt}^3}\right)\omega^2 \tag{3.7}$$

The turn shows that the torque achieves any higher value at any wind speed at an unambiguous rotational speed, and this torque is very different in terms of the order of the rotation speed box. Torque is mostly dependent on the electric load and can be changed as a box for speed of rotation by picking up the load properly.

Diverse control systems, for example, pitch edge control, Stall control (dynamic and uninvolved), Power electronic control and Yaw control are utilized to control the wind turbines.

CHAPTER 4

INDUCTION GENERATOR

Inductive generator or asynchronous generator is a type of AC generator that uses standard induction motors to achieve control. Induction generators work by mechanically turning their generators into generators, giving a negative spin. In most cases, a non-renewable DC motor is used as a generator, without any internal modifications.

4.1 Principle Of Operation

Generators and inductive motors produce electrical energy when the spindle rotates faster than the synchronous frequency. For a typical column drive (two pairs of poles on a fixed part) running on an electrical grid of 60 Hz, the synchronous speed is 1800 rpm. A comparable four-column engine running on a 50 Hz network will have a synchronized speed of up to 1500 rpm. In typical engine operation, the static motion revolution is faster than the engine. This begins with the constant transition of the induction on the rotary currents, making the rotor motion with the attractive tip inverse to the fixed part. In this way, the rotor is dragged to beyond the flow of the fixed part, by an estimate equal to the slide. In the generator operation, the main motor (the turbine and the engine) runs the rotor at the synchronized speed. The movement of the engine continues to incite currents in the rotor, but since the rotor restriction currently cuts off the fixed part files, an active current is generated in the hard drive files, the engine acts as a generator, and sends the power back to the electrical grid.

Grid and Stand-Alone Connections

Polarization is generated by a capacitor connected to the machine in the case of a stand-alone system. In the case of a network connection, it attracts the magnetic current from the grid.

- The frequency and voltage of the machine on the grid connected system will be managed by the electric network, since it is very small compared with the entire system.

- Frequency and voltage on the stand-alone systems, are complex function of machine parameters, capacitance is adapted for excitation, sort and load esteem.

4.2 Grid Connected Induction Generator

Hinted generators connected to the network build their induction from the network of facilities. The current generated for the supply system is maintained when the IG is running above the synchronized speed. The rotary cuff machines only work through the fixed part and often operate at low negative sliding. On the contrary, wound rotation machines can maintain control through the fixed part as well as the rotor to the bus through a wide system known as the Doubly Fed.

Fixed Speed Grid Connected Wind Turbine Generator

The fixed-speed wind turbines has a structure and performance "as shown in Fig3" which depends on the features of mechanical sub-circuits, e.g., pitch control time constants etc.

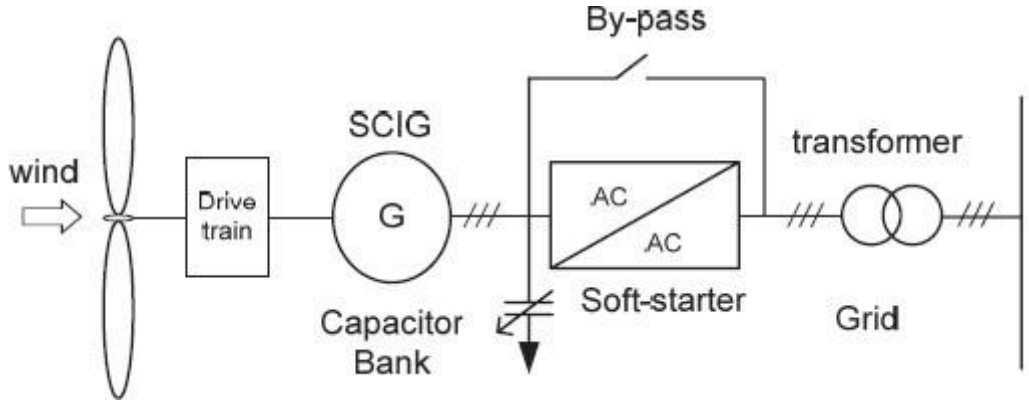


Figure 4.1 Fixed speed wind turbine with directly grid connected squirrel-cage induction generator

The response time of these mechanical circuits may lie in the range of many seconds from the millisecond. Accordingly, a rapid change in the output voltage can be observed every time a wind wave hits the turbine.

A well-assembled mechanical plan to ingest high mechanical stress "and not only required firm power grid" is generated as a result of these variations in electric power to enable stable operation which leads to an expensive mechanical structure, especially at high-rated power.

4.3 Variable Speed Wind Turbine Generator

There is another way to make turbines more suitable by adapting variable speed turbines, since they are the most frequently used wind turbines because they store a part of the electrical oscillation due to turbulence by expanding the rotor speed and rotor blades. In this case, Power output by these turbines at any given speed.

Fig.4.2 shows a variable speed turbine connected to a Squirrel-Cage Induction Generator SCIG. Although these direct-online systems have been built up to1.5MW, there are many disadvantages created due to the presence of power such as:

a) This power converter, which must be appraised at 1p.u.of aggregate system power, is costly.

Converter proficiency assumes an essential part in absolute productivity system over the whole operating grange.

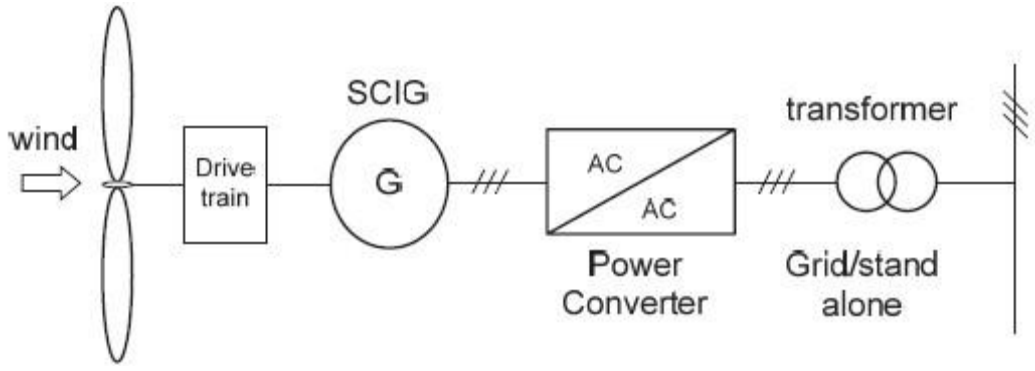


Figure 4.2 Variable speed wind turbine with the squirrel-cage induction generator

Another way- we can do- is using Doubly Fed Induction Generator (DFIG) as shown in Fig.4.3. It is composed of a stator connected directly to a grid and rotor– via slip rings associated with grid through four-quadrant ac-to-ac converter based

on insulated gate bipolar transistors (IGBTs). There are some advantages offered by this system as follows:

1. The cost of inverter is not high as its rating is typically 30% of the entire system power.
2. The efficiency of the system improves.
3. The Power-factor control is achieved at a low price.
4. There is a complete control of active and reactive power.

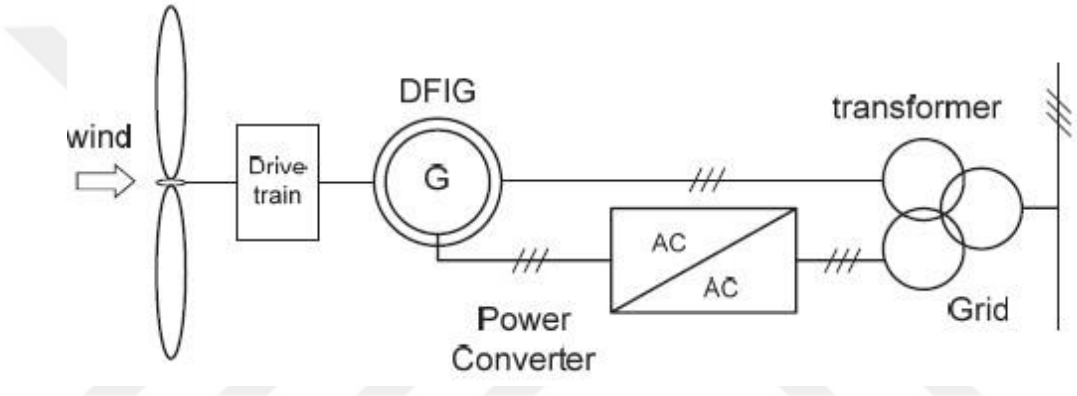


Figure 4.3 Variable speed wind turbine with doubly-fed induction generator

The dual feeder generator with the power adapter shown in Fig. 4 is an efficient and a controllable method for obtaining the mechanical energy transferred from the variable-speed rotor to the fixed-frequency electrical grid. The basic explanation behind the induction of dual-feed induction generators associated with national systems is their ability to provide a continuous voltage control and a frequency while rotor speed changes.

4.4 The Insulation System In Wind Turbine Generator

The magnetic field inside a motor or generator is not completely uniform. Thus as the rotor turns, a voltage is developed on the shaft longitudinally (directly along the shaft). This voltage would cause micro-currents to flow through the lubricant film on the bearings. These currents, in turn, would cause minor arcing, heating, and eventual bearing failure. The larger the machine is, the worse the problem becomes.

To avoid this problem, the rotor side of the bearing body is often insulated from the stator side. In most instances, at least one bearing will be insulated, usually the one farthest from the prime mover for generators and farthest from the load for motors. Sometimes, both bearings are insulated.

Important developments have taken place in the insulating materials available for motor production. In early years of electric motors organic materials were commonly used (cotton, paper etc.). However, synthetic materials, plastics are now more common. These are durable materials and can withstand much higher temperatures than organic materials. The impact of this has been a considerable reduction in the size of electrical machines.

The insulation of a machine is probably the weakest component in it and, therefore, one of the most important parts. It largely determines the maximum rating of the machine since it decides the maximum temperature rise permissible for a given line in service. All insulation deteriorates with time due to several causes.

i) Drying out which results in cracking and distortion and a decreasing ability to withstand mechanical shock, vibration continual thermal expansion and contraction.

ii) Chemical changes in composition which result in material with a substantially different dielectric strength which is almost always lower than the original.

According to B.S. a suitable insulation is one which will satisfactorily withstand the electrical stresses imposed on it over the life time of the apparatus. The life time depends on the application and may be a few seconds for military purposes, a few

thousand hours for aircraft use, but is usually between 10 and 30 years for industrial machines. It is, therefore, most important not to allow the operating temperature of the insulation at the hottest place to exceed that which will restrict the life to less than the required length.

Most insulation, particularly organic ones, have a life, dependent exponentially on the absolute temperature, and this relationship gives a rule that the time of failure of organic insulation is halved for every 9° or 10° rise in the operating temperature. In the evaluation or life expectancy tests; insulation is taken round a typical cycle of operation many times more rapidly than in practice and exposed to moisture, mechanical shock and vibration. Where an exponential relationship exists information from tests at high temperatures can be extrapolated to obtain an indication of the whole curve.

4.5 Class Of Insulations

Insulation materials are divided into seven classes according to the maximum temperature at which they can be operated while giving life of 10 to 30 years. These are given in detail in T.S. 3067, 1978, as follows.

Insulation Class	Y	A	E	B	F	H	C	Over 180
Maximum Temp. °C		90	105	120	130	155	180	

For many years' classes A, B, and C were associated with the appropriate temperature ranges but many new materials recently introduced have required the inclusion of the new intermediate classes. The important materials in the various classes are.

Class Y: mostly organic materials including cotton, silk, paper, wood cellulose and other organic fibers but impregnated.

Class A: the materials of class Y but impregnated with natural organic raisins such as shellac.

Class E: mostly the materials of class Y but impregnated with synthetic resins and varnishes; wires coated with synthetic enamels; cotton, paper used as laminates bonded with synthetic bonding agents.

Class B: very stable organic materials and inorganic materials including, mica-tapes glass-fiber and asbestos tapes with or without synthetic impregnation.

Class F: materials of class B with more stable bonding agents and impregnation, also nylon and ethylene tapes.

Class H: Mechanize, glass-fiber and asbestos laminates, silicone elastomers bonded and impregnated with the latest synthetic and silicone resins.

Class C: glass, pure mica, ceramics, quartz, asbestos and silicone rubber, epoxy resins in the included form, and other exotic materials.

Class Y is rarely used as a practical insulation for machines because of the hydroscopic nature of the untreated materials and the fact that even a minute proportion of moisture has a very large effect in decreasing the dielectric strength of the insulation.

The materials of class C are inconvenient to use apart from exceptional cases of extreme operating conditions because of their brittle nature and the difficulty of forming them. They have, however, been successfully used for machines operating at over 200°C. Silicone rubber, though expensive, is extremely promising because of its outstanding electrical and mechanical properties, and because even after breakdown it decomposes to silica which is a good insulation unlike carbon. With the latest epoxy resins machines can be even operated in water without the danger of breakdown.

The breakdown voltage of the various materials depends very largely on the moisture content for dry material measured with small sphere gaps across which is applied a variable d.c. voltage, typical figures are:

i) Air - 3,000 volts per mm.

ii) Materials of Classes Y, A and E - 10-12 kV/mm but impregnation, particularly with oil, will considerably increase this figure.

iii) Materials of Classes B, F and H -30-40 kV/mm

iv) Varnished tapes and cloths in the region of 20 kV/mm but extremely susceptible to moisture.

Mica is the most universal, high grade insulation material but, in the pure form, is stiff and difficult to use. It is normally used in 'splits' and bonded to synthetic tapes.

As already mentioned, the insulation in machine is subjected to non-uniform stresses and must resist against vibration, chafing and mechanical shock. The more normal values of voltage gradient used would, therefore, be in the order of 1000 to 1500 volts/mm, and for low and medium voltage machines an empirical expression for thickness of slot-liner is:

$$\text{Slot liner thickness} = 0.4 + \frac{\hat{E}}{1000} mm \qquad \textbf{(4.1)}$$

Where, $\hat{E}$ is the peak voltage to earth. When a machine is completed, the insulation is tested at a voltage equal to 1000 volts plus twice the rated voltage ($1000+2\hat{E}$) for one minute and there must be no change in the resistance of the insulation. The test is carried out at a frequency of between 25 and 100 Hz.

The temperature rises in values in table 4 are estimated on the basis of 40°C ambient temperature for an insulation life of 20 years under average operating conditions. The working life of the material is closely related to the 'hot spot' temperature within the winding.

The next Table. Insulation classes and allowable temperature rise for 3 phase motors of core length less than 1 m.

CHAPTER 5

DESIGN AND CALCULATION OF THE GENERATOR

Inductive alternator (asynchronous generator) is a type of alternating current (AC) generator that adapts to the principles of induction motors to provide supply. Induction generators work by rotating their rotors mechanically faster than synchronized speed.

An asynchronous AC motor can be used regularly as a generator, without any internal changes. Inductive generators play an important role in applications such as small hydropower plants or wind turbines, or in the reduction of low pressure high pressure gas streams, as they can offset energy with moderate baseline controls.

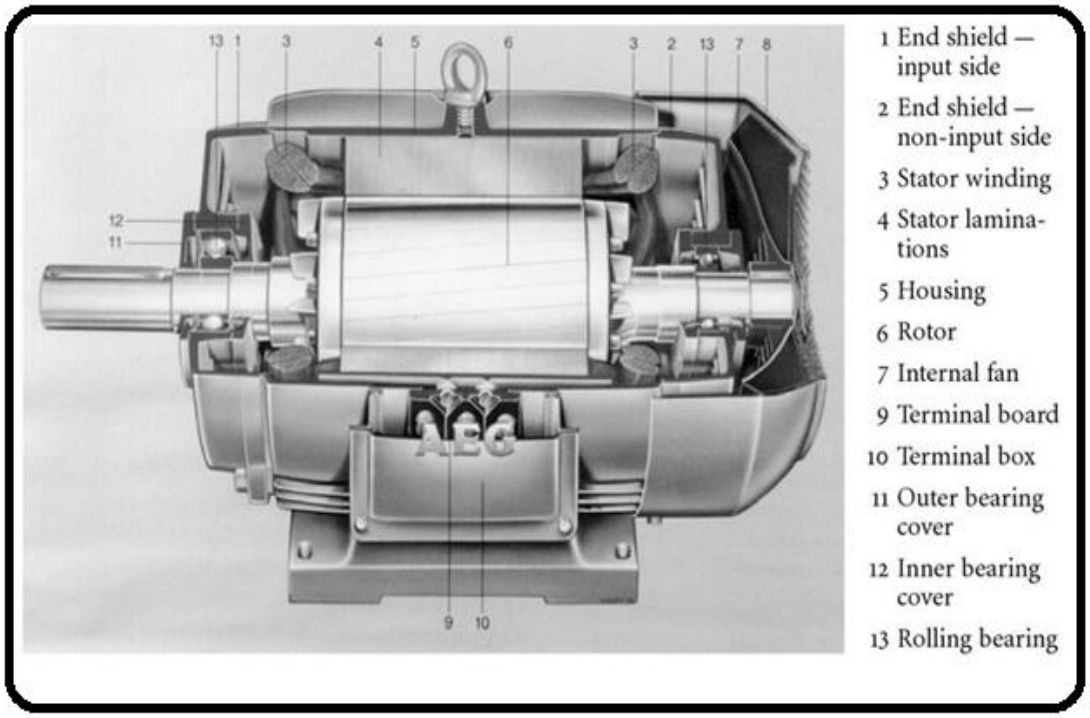


Figure 5.1 Induction generatoe

5.1 Principles Of Operations

It is possible that the rotor rotates faster than the synchronous speed produced by the induction generator. In the case of a four-pole model motor (a pair of electrodes on the fixed part) operates on a 60 Hz electrical network, the synchronization speed is equivalent to 1800 rpm, while the synchronized speed is 1500 rpm. The polar motor operates on a 50 Hz network, the engine operates slower than the synchronized speed, and the term "slip" is used to express the difference between synchronized speed and operating speed and is usually averaged. Percentage of synchronized speed. For example, the 1450 rpm engine works at a speed of 1500 rpm + 3.3%.

The rotor rotation works faster than rotor rotation in the normal operation of the motor. As a result, the rotor rotates the spin of the rotor, which produces a magnetic pole opposite the fixed part. Currents in the rotor at the frequency of the slide.

It is clear that the main engine (turbine or engine) in the alternator operation rotates above the synchronized speed (negative slide). If the flow of the corresponding rotor intersects the fixed part files, it produces an active current, the motor acts as generator and the current is returned to the power grid.

Induction generators, often used for wind power projects in the 1980s and 1990s, require interactive energy to make substations used in wind power systems, including large, intensive banks to correct the problem. Power factor. Different types of wind turbine generators operate separately. It is therefore necessary for operators of the transmission systems to adapt the costly modeling of the dynamic electromechanical characteristics of a new aerodynamic farm to ensure consistent, predictable performance when there are errors in the general system. In particular, steam turbines or synchronous hydraulic generators can withstand system voltage in the event of fault, unlike inductors.

These generators are no longer used in modern turbines. Instead, most turbines use variable speed generators combined with a partial or total power adapter between the turbine amplifier and the assembly system, which generally has more desirable characteristics for interconnection and transit capabilities. Low voltage. Modern

concepts use dual feeders with partial scale transformers, squirrel induction generators or synchronous generators (permanently energized and electric) with full-scale transformers.

Transmission system operators will provide a wind farm developer with a network code to determine the interconnection requirements of the transmission system. The power factor is included in this system, in addition to the constant frequency and dynamic performance of wind turbines through system failure.

5.2 Parts Of Generator

5.2.1 The Stator

The stator is the external stationary piece of the motor, which comprises of:

- The external barrel shaped the motor edge, which is made of both welded sheet steel, cast iron and cast aluminum combination. This may incorporate feet or a spine for mounting.

- The magnetic path, which includes a set of double rust plates in the cylindrical area. The magnetic strip is coated to reduce currents and reduce more losses and heating.

- A series of well-insulated electrical twists, placed inside the slots of the magnetic path, is necessary. The zone to be visualized for a three-phase motor requires three sets of twists, one for each floor.

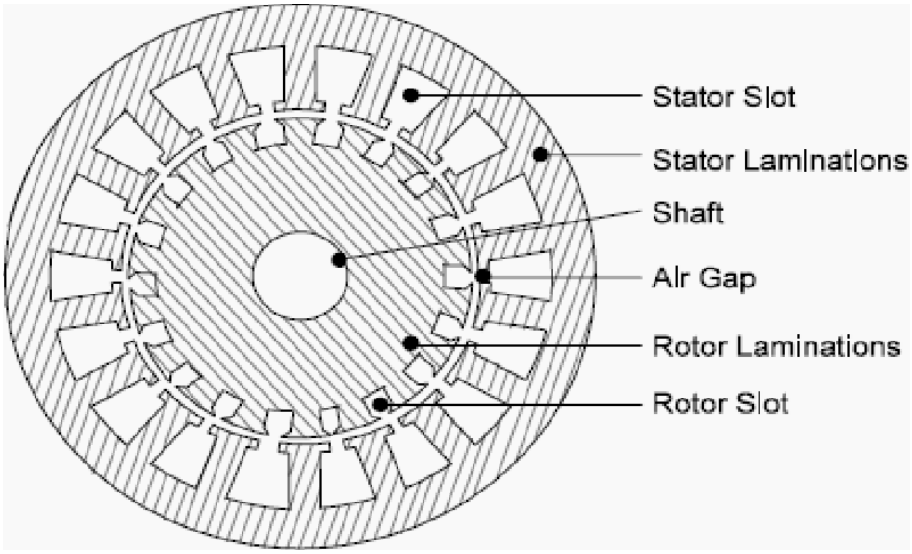


Figure 5.2 Stator and rotor laminations

5.2.2 The Rotor

This is the motor rotating. As explained above, the rotor consists of a group of slotted steel plates which are compressed in the form of a cylindrical magnetic path and an electrical circuit. The electrical circuit of the rotor is either:

- **The type of Wound rotor**: This section consists of 3 sets of insulated rolls with links divided into 3 sliding rings mounted on the column. The outer seals of the rotor part of the brushes are also attached to the sliding rings. This type of engine is often called sliding ring motor.

- **Squirrel cage rotor type:** This section consists of a set of copper or aluminum rods installed in the openings, which are connected to the end ring at the end of the rotor. The construction of these rotary twists is like a squirrel cage. Circular aluminum rods are usually poured into the rotor openings, resulting in a very solid construction. Although the aluminum circular bars are in direct contact with the steel strips, each rotor current flows practically through the aluminum bars rather than the balloons.

5.2.3 Other parts of Rotor

They are necessary to finish the induction motor are:

- Two end-flanges to support two bearings, one at the end of (DE) and the other is at the non-end of drive (NDE)
- Two bear parts they used to support the rotor rotating shaft, at ends DE and NDE.
- The Steel shaft that for transmitting the force of torque to the given load.
- Cooling fan is located at the end NDE to powerfully impose cooling both for the generator stator and generator rotor.
- A terminal box at the top or on one side to receive external electrical connections.

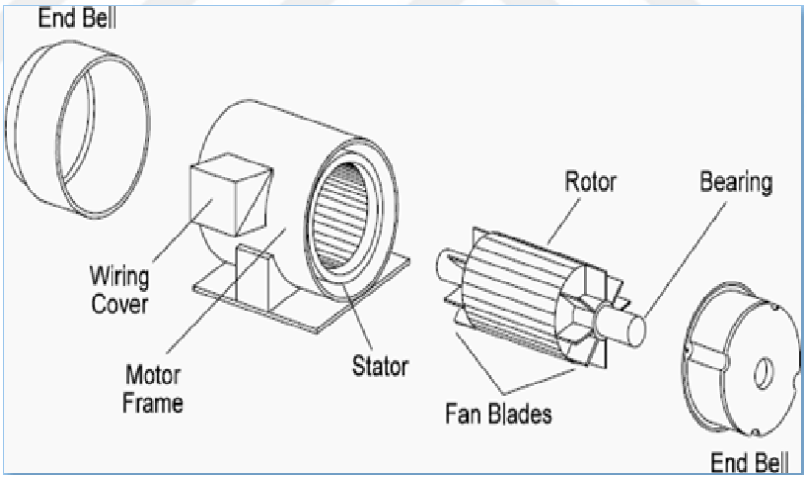


Figure 5.3 Assembly details of a typical AC induction motor

5.3 The Calculations of Design

To design a generator gıves 2000V, 50 Hz with power of shaft 150HP, from 600rpm with Y connection.

From the equatıon

$$n = \frac{120\,f}{P} \quad \textbf{(5.1)}$$

Where n is the shaft rotation per minute, f is the needed frequency and P numbers of poles in the engine.

For low speed rotation 375 rpm, we calculate the numbers of poles as:

$$p = \frac{120\,f}{n} = \frac{120 \times 50}{375} = 16 \ pools \quad \textbf{(5.2)}$$

Using design sheet No.5 - end of this project - to find the power factor PF (cos ϕ) and the efficiency (μ)

$$Pf = 0.87 \quad , \quad \mu = 90\% = 0.9 \quad \textbf{(5.3)}$$

The power S will be as $S = \frac{P}{\mu\, cos\phi} = \frac{150 \times 0.746}{0.9 \times 0.87} \simeq 143\ KVA$

Produced factor $\frac{S}{n} = \frac{143}{0.375} = 381$ KVA\1000 rpm

Form design sheet No.4 we can find the output coefficient G as

$$G = 3.2 \quad \textbf{(5.4)}$$

To find the inner diameter D_i of the stator from the equation:

$$\frac{S}{N} = G\ D_i^2\ L_C \quad \textbf{(5.5)}$$

Where L_c is the core length

$$D_i^2\ L_c = \frac{S}{N} \cdot \frac{1}{G} = 381 \times \frac{1}{3.2} = 119.06 \backslash 1000 = 0.119\ m^3 \quad \textbf{(5.6)}$$

To find D_i from the equation:

$$Di = \sqrt[3]{\frac{PDi\ Lc}{Kr\ .\pi}} \quad \textbf{(5.7)}$$

Where Kr is the ratio of (core length \ pole pitch) and we can find it from the design sheet No.6 as Kr = 1.5

$$Di = \sqrt[3]{\frac{16 \times 0.119}{1.5 \times 3.14}} = 0.739m \times 100 \simeq 75\ cm \quad \textbf{(5.8)}$$

We calculate the length of core from Lc the equation:

$$D_i^2\ L_c = \frac{S}{N} \cdot \frac{1}{G} = 0.119\ m^3 \quad \textbf{(5.9)}$$

$$D_i^2 = 0.5625\ m^2$$

$$L_c = \frac{0.119}{0.5625} = 0.2115m \times 100 \simeq 22\ cm \quad \textbf{(5.10)}$$

To calculate the outer dimension of the stator D_o we can get the ratio of (D_i\D) from the table design No.7 depend on the numbers of poles 16 as :

$$\frac{Di}{Do} = 0.87 \quad \textbf{(5.11)}$$

Then

$$D_o = \frac{Di}{0.87} = \frac{75}{0.87} \simeq 86\ cm \quad \textbf{(5.12)}$$

For Stator winding design we use the equation:

$$E_{phase} = = \frac{Vll}{\sqrt{3}} \ldots \quad \textbf{(5.13)}$$

Where $V_{L.L}$ is the given voltage generator when we use the star mode at the design in our case V=2000 V

$$E_{phase} = = \frac{2000}{\sqrt{3}} = 1154v \simeq 1150\ v \quad \textbf{(5.14)}$$

From the design sheet No.3 we got the magnetic loading β

For Produced factor $\frac{S}{n} = 381$ KVA\1000 rpm

$$\beta = 0.57 \quad T \tag{5.15}$$

To find the flux per pole Φ_{pole} we use the equation:

$$\beta = \frac{P \ \Phi p}{\Pi \ Di \ Lc} \tag{5.16}$$

$$\Phi_p = \frac{\beta \ \Pi \ Di \ Lc}{P} \tag{5.17}$$

$$\Phi_p = \frac{0.57 \times 3.14 \times 0.75 \times 0.22}{16} = 0.0184573 \ \text{wb} \tag{5.18}$$

For constant winding factor Kw = 0.955 we calculate the number of turns per phase of the conductors as:

$$N = \frac{Eph}{\sqrt{2} \ \Pi \ Kw \ \Phi ph \ f} \tag{5.19}$$

$$N = \frac{1150}{\sqrt{2} \times 3.14 \times 0.955 \times 0.0184573 \times 50} = \frac{1150}{3.91368} \tag{5.20}$$

$N \simeq 294$ turns for one conductor (5.21)

To know the total conductors per turn in three phases is:

$$N_{total} = 2 \times 3 \times 294 = 1764 \text{ conductors} \tag{5.22}$$

We consider the number of slot per pole per phase q=3, then the number of slots are:

$$q \times 3 \text{ phases} \times P = 3 \times 3 \times 16 = 144 \text{ slots} \tag{5.23}$$

To calculate the slot pitch λ we use the equation:

$$\lambda = \frac{\Pi \ Di}{No.of \ slots} = \frac{3.14 \times 75}{144} = 1.6 \ cm \tag{5.24}$$

Where $\lambda = S + t$ S, is the slot width.

t, is the tooth width.

From the equation ……

$$P\ \Phi_{pole} = \beta\ A \tag{5.25}$$

Where $A = t \times L_c \times$ total No. of slots

$$P\ \Phi_{pole} = \beta \times t \times L_c \times \text{total No. of slots}(144) \tag{5.26}$$

So we can calculate the tooth width t as:

$$t = \frac{P\ \ \Phi p}{\beta\ Lc \times 144} \tag{5.27}$$

$$t = \frac{16 \times 0.0184573}{0.57 \times\ 0.22 \times 144} \simeq 0.8 \text{ cm}$$

Then the slot width $S = \lambda - t = 1.6 - 0.8 = 0.8$ cm

Now we try to calculate the rated current I_{hp} from the equation:

$$I_{ph} = \frac{S}{\sqrt{2}\, Vll} \tag{5.28}$$

$$I_{ph} = \frac{143000}{\sqrt{2} \times 2000} = 42 \text{ A} \tag{5.29}$$

We can shoes the current density J from 3.5 to 4 A\mm^2 let us consider it as 4

From the low $J = \frac{I}{A}$ we can calculate the wire dimension A

Then $A = \frac{I}{J} = \frac{42}{4} = 10.55 \text{ mm}^2$

The number of conductors per slot can calculated as $\frac{total\ of\ conductors}{total\ number\ of\ slots}$

$$= \frac{1764}{144} = 12.25 \simeq 12 \text{ condctors} \tag{5.30}$$

From this result we can consider the new numbers of turns as:

$$= \frac{12 \times 144}{3\ phase \times 2\ conductor\ per\ turn} = 288\ turns \quad \textbf{(5.31)}$$

The filling factor is the total copper area in a slot \ area of a slot, and we can consider it as f.f. = 0.4

So we can calculate the slot area as:

$$\text{Slot area} = \frac{total\ conductor\ area\ in\ the\ slot}{\text{filling factor f.f.}} = \frac{12 \times 10.55}{0.4} \simeq 320\ \text{mm}^2 \quad \textbf{(5.32)}$$

$$\text{The depth of slot D} = \frac{A\ \text{Slot area}}{\text{slot width}} = \frac{320\ mm2}{0.8\text{cm} \times 10} = 40\ mm \quad \textbf{(5.33)}$$

The peak value of phase voltage $\check{E}_{ph}$ is:

$$\check{E}_{ph} = \sqrt{2}\ Eph = \sqrt{2} \times 1150 = 1640\ \text{V} \quad \textbf{(5.34)}$$

$$\text{slot lıner (thıknes)} = \text{f.f.} + \check{E}_{ph} \backslash 1000 = 0.4 + 1640 \backslash 1000 = 2\ \text{mm} \quad \textbf{(5.35)}$$

Now we can calculate the total thickness of slot as:

Thickness of isolator + (numbers of conductor's × thickness of horn) + sum of constants

$$2 + 12 \times 2.25 + 4 + 3 + 1 = 37\ \text{mm} \quad \textbf{(5.36)}$$

We have to calculate the magnetic loading β at the 1\3 of total high of slot, in this high the diameter will be as:

$$D_i + (\text{h} \backslash 3 \times 2) = 75 + (3.7 \backslash 3 \times 2) \simeq 78\ \text{cm} \quad \textbf{(5.37)}$$

The tooth width at 78 cm of high is:

$$\frac{D1 \backslash 3 \times \Pi}{\text{total No.of slots}} = \frac{78 \times 3.14}{144} = 1.7\ cm \quad \textbf{(5.38)}$$

The tooth pitch at h\3 $\lambda_{h \backslash 3} = 1.7 - 0.8 = 0.9$ cm

Number of teeth per pole $t_{h \backslash 3} = 144 \backslash 16 = 9$ teeth\pole

To calculate the effective length from the core as:

$$L_{c\ effective} = L_c \times s.f \quad \textbf{(5.39)}$$

where s.f is the stacking factor = 0.9

$$L_{c\ effective} = 22 \times 0.9 = 19.8\ cm \quad \textbf{(5.40)}$$

From what we got before we can calculate the pole arc as:

Pole arc = $L_{c\ effective}$ × number of teeth per pole × $t_{h\backslash 3}$

$$\text{Pole arc} = 19.8 \times 9 \times 0.9 = 160.38\ cm^2 \quad \textbf{(5.41)}$$

For new results which we got at 1\3 of high we can get the new flax density as

$$\beta = \frac{\Phi p}{Aarc} = \frac{0.0184573}{0.016038} = 1.15\ T \quad \textbf{(5.42)}$$

Peak flux density $\beta = 1.15 \times \sqrt{2} = 1.62T$ it must be less than 1.8 T

The area behınd teeth $A_c = h_c \times L_c \times 0.9$

$$\text{Where} \quad h_c = \frac{Do-Di-2h}{2} = \frac{86-75-2\times 3.7}{2} = 1.8\ cm \quad \textbf{(5.43)}$$

Then $A_c = 1.8 \times 22 \times 0.9 = 35.64 cm^2 = 3.564 \times 10^{-3}\ m^2$

$$\text{The core flux density} \quad B_c = \frac{\Phi p\backslash 2}{Ac} = \frac{0.0184573\backslash 2}{3.564 \times 10-3} = 2.5\ T \quad \textbf{(5.44)}$$

For this much of Bc it very high we need to decrease it, we need to increase the h_c,

$$hc = hc+1 = 1.8 + 1 = 2.8 \quad \textbf{(5.45)}$$

Then the new $B_c = \frac{hc\ old}{hc\ new} \times Bc\ old = 1.66\ T$ so this value is good.

Now we calculate the air gap g by using this equation:

$$g = 0.2 + 2 \times \sqrt{Di\ \ Lc} \quad \textbf{(5.46)}$$

$$g = 0.2 + 2 \times \sqrt{0.75\ \times o.22} \simeq 1\ \ mm$$

$\bar{I}_2 = i_1 \times \cos\theta$ **(5.47)**

$= 42 \times 0.87 = 36$ A

$i_e = \frac{Qr}{P\,\Pi} \times Ib$ **(5.48)**

$i_b = \frac{2\,N\,Kw\,M(phase)}{Qr} \times i_2$

$i_b = \frac{2 \times 288 \times 0.955 \times 3}{96} \times 36 = 618.84\,A$

$i_e = \frac{96}{16 \times 3.14} \times 483.5 = 1182.49\,A$

Bare area $Ab = \frac{ib}{J}$ we can consider J as 6 because it without insulators

$Ab = \frac{618.84}{6} = 103.14$ mm^2 **(5.49)**

$A_e = \frac{Ie}{J} = \frac{1182.49}{6} = 197.08$ mm^2 **(5.50)**

For the rotor, the diameter can be calculated as:

$D_r = D_i - 2g$ **(5.51)**

$D_r = 75 - 2 \times 0.1 = 74.8$ cm

slot pitch$= \frac{\Pi\,Dr}{Qr} = \frac{3.14 \times 74.8}{96} = 24.4\,mm$ **(5.52)**

For the rotor we can consider the values t = 9.5 and S = 8

Then we can calculate the slot depth as $= \frac{Ab}{s} = \frac{103.14}{8} = 12.89\,mm$

Rotor bars area =103.14 mm^2

Ring area = 197.08 mm^2

By making t_e = 10 mm, so $L_e = \frac{Ae}{te} = \frac{197.08}{10} = 19.7\,mm$

Table 5.1 reslut dimensions of design with used equations

PART NAME	DIM.	USED EQUATION
numbers of poles	16 $pools$	$n = \frac{120\,f}{P}$
The power S	143 KVA	$S = \frac{P}{\mu\, cos\phi}$
inner diameter	75 cm	$Di = \sqrt[3]{\frac{PDi\ Lc}{Kr\ .\pi}}$
length of core	22 cm	$D_i^2\ L_c = \frac{S}{N}\ .\ \frac{1}{G}$
outer dimension of the stator	86 cm	$D_o = \frac{Di}{0.87}$
Produced factor	0.57	$B = \frac{S}{n}$
the flux per pole	0.0184573 wb	$\beta = \frac{P\ \Phi p}{\Pi\ Di\ Lc}$
number of turns per phase	294 turns	$N = \frac{Eph}{\sqrt{2}\ \Pi\ Kw\ \Phi ph\ f}$
conductors per turn in three phases	1764 conductors	$N_{total} = 2\times3\times294$
calculate the slot pitch	1.6 cm	$\lambda = \frac{\Pi\ Di}{No.of\ slots}$
tooth width	0.8 cm	$t = (\frac{P\ \ \Phi p}{\beta\ \ Lc \times 144}$
calculate the rated current I_{hp}	42 A	$I_{ph} = \frac{S}{\sqrt{2}\,Vll}$
conductors per slot	12 condctors	$= \frac{total\ of\ conductors}{total\ number\ of\ slots}$
Slot area	320 mm^2	Slot area $= \frac{total\ conductor\ area\ in\ the\ slot}{\text{filling factor f.f.}}$
The tooth width		$= \frac{D1\backslash3\ \times\ \Pi}{\text{total No.of slots}}$
Number of teeth per pole	9 teeth\pole	$t_{h\backslash3}$
effective length from the core	19.8 cm	$L_{c\ effective} = L_c \times s.f$
flux density	1.66 T	$\beta = \frac{\Phi p}{Aarc}$
air gap g	1 mm	$g = 0.2 + 2 \times \sqrt{Di\ \ Lc}$
dimeter (rotor)	24.4 mm	$D_r = D_i - 2g$

Table 5.2 Comparison between this design with others.

PART NAME	This design dimension	Other design dimensions
numbers of poles	16 $pools$	8 $pools$
Shaft rpm	375	1500
The power S	143 KVA	200 KVA
inner diameter	75 cm	60 cm
length of core	22 cm	18 cm
outer dimension of the stator	86 cm	66 cm
Produced factor	0.57	0.57
the flux per pole	0.0184573 wb	0.0184573 wb
number of turns per phase	294 turns	170 turns
conductors per turn in three phases	1764 conductors	1300 conductors
calculate the slot pitch	1.6 cm	1.6 cm
conductors per slot	12 condctors	10 condctors
Slot area	320 mm^2	300 mm^2
Number of teeth per pole	9 teeth\pole	12 teeth\pole
effective length from the core	19.8 cm	17.8 cm
flux density	1.66 T	1.60 T
air gap g	1 mm	1 mm
dimeter (rotor)	24.4 mm	20.4 mm

Most of use equations were taken from (N.H. Malik and A.A. Mazi, “Capacitance requirements for isolated self-excited induction generators," IEEE Trans. on Energy Conversion, Vol. EC- 2, March 1987) and (Mahariq, I. Electrical Machines Design, not book, Ankara, 2016)

CHAPTER 6

CONCLUSION

- It is known that there are many types of energy sources, including the usual sources of energy, such as oil, coal, gas and nuclear power as well as types of renewable energy sources such as solar energy and water. But as it is clear, the most important, cheapest and the best energy can be obtained continuously and clean is (wind power).

- The generator Is the device that depends on the current reflector to produce a constant current, and depends on the mechanical device on the principle of electromagnetic induction to convert the kinetic energy of electric energy having a magnetic field is dependent on the generation of induction current, and is noted that the generator industry has seen a significant development in terms of generation of inductive current Developer to very high degrees.

- Electrical generator components. The electrical generator consists of two main parts: the mechanical part;

Rotator: It is the part that rotates in the electric machine.

The electrical part: The components include: Stand frame: the power part of the electric machine. The files on the carrier frame generate electricity and can be installed on the fixed member or on the rotor inside the mechanical part.

Domain files: It is the part that assumes the responsibility of generating the magnetic field in the electric machine.

Sliding rings: This is the part that drives the electrical current within the field files. This requires the completion of an electric exchanger located above the axis of the moving part.

How the generator works. The work of the electric generator starts in conjunction with the rotation of the coil around the magnetic field. The electric energy is

produced by the electromagnetic induction. It is indicated that the rotation of the coil is done by a bicycle that depends on the power of the wheel to generate electricity. It ends with lighting the lamp for the bicycle. Electricity is dependent on renewable energies of water and wind to convert the power of water flow to electricity to work turbines. Physically, when moving the rotor using a column of spin connected to the primary engine generates electromagnetic field depending on the files of the rotor, moving this electromagnetic field to the files of the fixed part and the latter in turn receives the electromagnetic field to be converted into an electric current in files distributed to three aspects, The angle between the two sides is 120 degrees, resulting in a regular electrical current that takes the form of sinus waves.

- The advantage of the induction generator in wind power generation is due to the following reasons:

1. There is no electrical connection between the source and the rotor. It works by induction, and is therefore called Induction Motor. And depends on his work on Slip.

2. The current generated in the product (rotor part) is rotated and rotated in closed aluminum conductors.

3. The speed of the rotor (product) is less than the speed of the fixed part (magnetic flux). This speed difference is necessary to generate the slippage and hence the engine's rotation. Where without sliding the engine stops. As a result, we find that the engine writes about 1425 cycles / minutes. While the fixed speed is 1500 rpm.

4. The power factor is always Lagging Power Factor.

5. Used to rotate machines with slow and medium speeds of not more than 3000 cycles / minutes. And the average torque as well.

- For design the induction generator used in wind turbine we need to make numbers of pools more because the motion of wind does not cause high speed,

so low speed of wind causes low flux density, then we need more pools to get high magnetic flux to get enough power.

- We have to consider all the characteristics of the machine when we start to design it, dimensions of machine, the needed power, the speed which we can get it from the wind in the place of wind turbine.

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