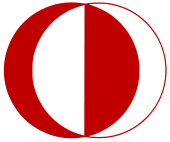
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**MIDDLE EAST TECHNICAL UNIVERSITY**

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

**EE 564** Project #3

***WIND TURBINE GENERATOR DESIGN***

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# Introduction

Renewable energy sources will have importance in our future. Wind energy is a type of renewable energy and today most of developed countries are building wind turbines. We see different types of generators are used in this wind turbines as generator. In this report, an induction generator for wind turbine application will be studied. This will be a squirrel cage induction generator with shorted bars in the rotor. The specifications of the wind turbine are as follows.

Table 1: Wind turbine specifications

|  |  |
| --- | --- |
| Property | Value |
| Rated power | 250 kW |
| Number of poles | 8 |
| Line to line voltage | 400 V |
| Frequency | 50 Hz |
| Rated speed | 758 rpm |
| Insulation class | F |

With the following specifications above, in the first part of the report, an analytical design will be created with pen and paper. Main generator dimensions, flux densities, loadings or other generator parameters will be studied in this first part.

In the second part of the report, finite element analysis will be conducted on RMxprt tool of Ansys Maxwell. Here, generator characteristics will be analyzed such as torque speed characteristics, power factor or efficiency. Comparison of analytical and simulation results will be presented in details.

# Analytical Design

In this part, analytical design of the generator will be studied. First of all, to simplify design procedure, we will consider our generator working as motor with the same slip, but positive slip. To make clear this, let’s consider following torque speed characteristics of an induction motor.



Figure 1: Torque speed characteristics

In above figure, we see desired torque speed characteristics of our induction motor. As generator, induction motor will work in B point as generator as wind turbine. Here, generator supplies power to grid. In A point, our machine works as motor. The two operation points have the same slip; with different signs. Since they have the same slip, we can consider our design problem as follows: induction machine will work as motor at 742 rpm. All other parameters will be the same. With this assumption, we can continue easier in design process. Nothing will differ.

To give information, squirrel cage rotors does not create an induced emf at armature terminals itself because no excitation is placed in the rotor. In the rotor, we have shorted conductor bars and there is nothing that can create MMF in the air gap. To work as generator, our induction machine should connect to the voltage source such as grid, and then our machine can work as generator if required external mover is supplied. Therefore, in following part of the report, we will consider our design problem as **motor design with rated speed of 742 rpm.**

## Main Dimensions

In this first part, we will determine bore diameter, axial length of the motor, and air gap distance. To start with main motor dimensions, we should first determine some motor parameters such as electrical and magnetic loading. Magnetic loading represents average air gap flux density and it is safe to have magnetic loading of **0.45 – 0. 6 T for induction motors**. Electrical loading represents rms ampere turns per unit length of the air gap and it is safe to have **30 – 65 kA/m for induction machines**. We will proceed with following loadings.

Table 2: Loadings of machine

|  |  |
| --- | --- |
| Property | Value |
| Magnetic loading | 0.5 T |
| Electrical loading | 49 kA/m |

Secondly, we will define aspect ratio of our machine. It is defined as ratio of axial length to bore diameter in any machine. It has following relation as a rule of thumb.

Where is the effective axial length of motor, is bore diameter, and is pole number and it is 8. With this equation, we get a relation between bore diameter and axial length. We need another one and we will proceed with tangential stress of the motor. Here, we will use torque relation as follows.

Where is generated torque, is the tangential stress, is the rotor volume and and are peak values of electrical and magnetic loadings respectively, and lastly is the power factor. Here, we can write rotor volume in terms of bore diameter and aspect ratio. At the end, solving these two equations, we get following dimensions.

Lastly, air gap distance will be determined. Air gap distance is an important parameter of the motor. It is determined by production clearances. As a rule of thumb, it should be larger than 0.3 mm. With the increasing size of the machine, air gap clearance also increases. As air gap becomes smaller, reluctance decreases and inductance increases as a result. This leads higher power factor and better utilization of the motor. However, mechanical constraints limit this. As a rule of thumb, following relation can be used.

Where is the power of the machine. To make it straight, let’s choose **air gap distance as 1 mm.**

## Stator Design

In this part, stator parameters will be determined such as stator slot number, slot dimensions, and stator yoke depth. First of all, let’s determine stator number of slots.