UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Induction Motor Project

EEE 3091F

Project Outline:

- You are required to work in groups of **two**.
- One project report is required per group. The names and student numbers of all group members must appear on the front page of the project report. The project report must be accompanied by a **PLAGIARISM DECLARATION FORM**. Project reports submitted without accompanying declaration forms will not be marked.
- The deadline for submission of the project reports is:
  16h00 on Monday, 3rd April 2023.
- Answer the questions as concisely as possible. Long-winded explanations will not be read.
- The use of Matlab is recommended. However, other computational software packages may be used. Append your Matlab code (in PDF format) to your project report.
- Use the matrix manipulation capability of Matlab to its full extent. Thus, avoid the use of nested "for" loops.
- You may assume that your machine is connected in a star configuration to a balanced three-phase supply (380V at 50Hz). Moreover, you may restrict your analysis to the motor mode of operation.
- Plot the speed of the machine in rpm on the x-axis of all performance curves for your machine.

Part A- Matlab Code

Given in the appendix are the parameters for an energy-efficient motor and a standard motor.

1. Write a Matlab program to calculate the Thevenin equivalent circuit parameters of the two three-phase induction machines given in the Appendix. Provide answers.

2. Extend your Matlab program to generate the torque-speed characteristics of these machines on the same graph. Answer the following questions concerning the machines:

   a) Calculate the starting torques of the machines. How could you alter this value?

   b) Calculate the maximum (breakdown) torques. How could you alter this value?

   c) Calculate the speed (in rpm) at which maximum torque occurs for both motors. How could you alter this value?

3. Extend your Matlab program to generate the stator current vs. speed characteristics of the machines when it is started direct-on-line. Answer the following questions concerning each machine:

   a) Calculate the stator current at start-up. Is your result as expected? Comment on the differences between standard and energy-efficient motors.

   b) Explain how the stator current at start-up would change when the machine is started under no-load and full-load conditions? Please explain.

   c) Determine the stator currents when the machines develop maximum torque.

   d) Calculate the stator current when the machines are operating under no-load conditions.

4. Extend your Matlab program to generate the power factor vs speed characteristic of this machine. Answer the following questions concerning the machines:

   a) Calculate the power factors at start-up.

   b) Determine the power factors when the machines develop maximum torque.

   c) Calculate the power factor when the machines are operating under no-load conditions. Are your results as expected?

   d) Determine the best power factors that these machines can operate at.

   e) Determine the speeds (in rpm) at which the best power factors occur.

5. If the rotational losses of your machines are negligible, extend your Matlab program to plot the total input power, stator copper losses, air gap power, rotor copper losses and shaft power vs speed, on the same set of axes. Plot the losses for each machine separately. Answer the following questions concerning the machines:

   a) Calculate the stator and rotor copper losses at start-up.

   b) Calculate the stator and rotor copper losses under no-load conditions.

6. If the rotational losses of your machines are negligible, extend your Matlab program to generate the efficiency vs. speed characteristics of the machines on the same plot. Answer the following questions concerning your machine:

   a) Determine the efficiencies of the machines when it develops maximum torque.

   b) Determine the maximum efficiency that these machines can operate at.

   c) Determine the speeds (in rpm) at which the machine will be most efficient.

7. In general, the torque-speed characteristic of a centrifugal pump load can be represented as:

$$T_{Lo} = k\omega^2$$

   Where $k = 946.88 \times 10^{-6}$, is a factor dependant on the mechanical design specifications of the pump and ω is its shaft speed in rad/sec.

   Extend your Matlab program to include this load torque characteristic on the same graph as the nominal torque-speed characteristic of the machines. Assuming that the machines are driving this centrifugal pump load in turn (**not at the same time**), determine the following:

   a) The speeds at which both the machines will operate when driving this centrifugal pump load.

   b) The current that the machines will draw from the supply.

   c) The efficiencies of the machines, assuming that the rotational losses are negligible.

   d) What is the power delivered to the pump for both machines?

   e) What is the power drawn from the supply for both machines?

   f) Is this input power difference between the two machines more or less than what you've expected with reference to the efficiencies of the two machines? Explain.

Part B - Theoretical Questions

In recent years the worldwide energy crisis has highlighted the importance of energy efficient induction motors in comparison to standard efficiency induction motors.

Energy efficient motors are designed in such a way that losses within the motor are minimized.

Increasing the diameter of the stator and rotor winding conductors, thereby reducing the resistance and hence the losses is one of many ways of improving motor efficiency.

Due to lower loss, the energy efficient motor is able to provide the same amount of output power for a decreased amount of input power in comparison to the standard motor. In this way less power is drawn from the supply and an electrical and monetary saving is possible.

At present, energy efficiency motors are more expensive than standard motors, however this price difference can be made back with time due to reduced running costs.

Refer to figure 1&2 in the appendix to answer the following questions.

1. An industrial company is considering replacing all of their currently installed standard motors with energy-efficient motors due to the current energy crisis. The owner also wishes to decrease the monthly electricity bill. Assume that the electricity price charged by Eskom is 28.288c/kWh. The following motors are currently installed on the plant:

   - 150, 3kW motors
   - 110, 7.5kW motors
   - 60, 15kW motors
   - 40, 55kW motors

   a) Explain briefly why bigger motors are generally more efficient than smaller motors?

   b) State the reason why it is not a good idea to underload motors (i.e. below 50% load)?

2. If all motors on the plant run for 12 hours a day at full load, and then for an additional 4 hours a day the 55kW motors run at 75% load, what is the monthly kWh usage and monthly electricity bill if:

   a) Standard motors are installed?

   b) Energy efficient motors are installed?

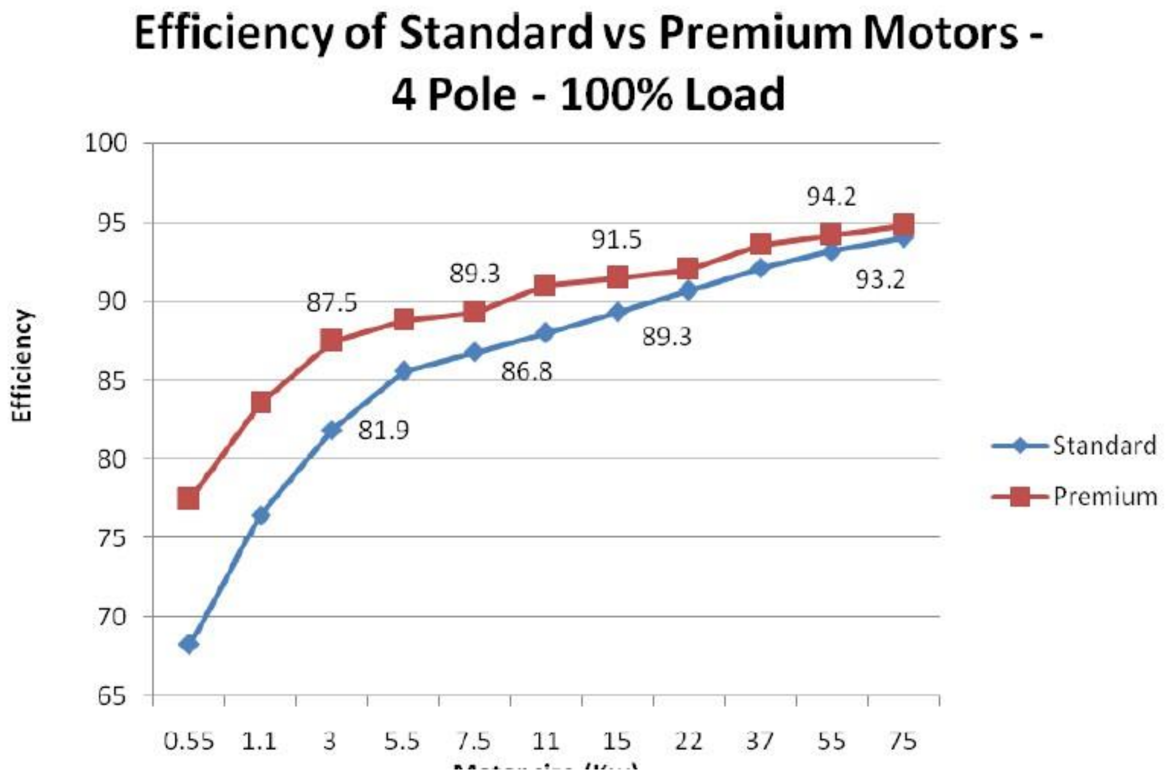
   c) Hence, the monthly saving?

3. If one of the 15kW motors fails, the owner has a choice of replacing it with another standard motor or purchasing an energy-efficient motor for R4000 more than a standard motor would cost. How long would it take the owner to retrieve this money assuming that he buys the energy-efficient motor and it runs for 24 hours a day at full load?

Appendix

Table 1. Motor parameters

Parameter	SE Motor	EE Motor
R_1	2.087Ω	1.500 Ω
X_1	4.274 Ω	3.642 Ω
X_m	66.560 Ω	72.252 Ω
X_2	4.274 Ω	3.642 Ω
R_2	2.122 Ω	1.994 Ω
P_{rot}	134.669W	88.924W



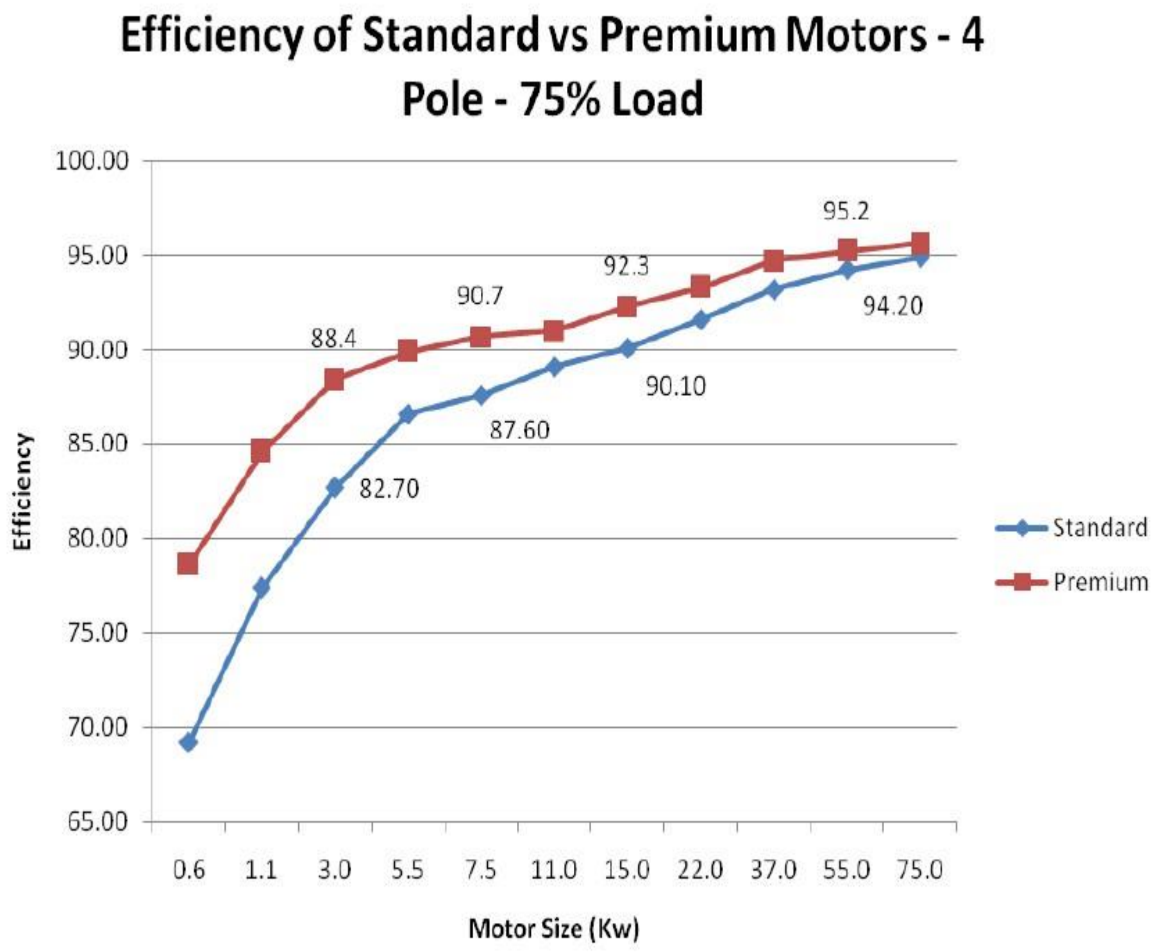


Figure 2

Figures 1 and 2 are summarized in Table 2 below.

Table 2. Efficiency of standard vs premium motors with load

	Motor Efficiency at 100% Load		**Motor Efficiency at 75% Load**	
Motor size (kW)	Standard	Premium	Standard	Premium
3.0	81.90	87.5	82.70	88.40
7.5	86.80	89.3	87.60	90.70
15	89.3	91.5	90.10	92.30
55	93.2	94.2	94.20	95.20