

# Software Development for Induction Motors – Performance and High Efficiency Motor

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**Abstract—** This paper presents the software development of induction motor to determine its performance and comparison of standard efficiency motor and high efficiency motor. An interactive tool to obtain the approximate equivalent circuit and performing economic analysis has been developed using Microsoft Visual Basic 6.0. Microsoft Access is used to upload the data for each motor into the software database.

**Index terms –** Induction motor, high efficiency motor, energy efficiency

## I. INTRODUCTION

The bulk of electricity consumption in the industrial and commercial sectors is by electric motor. They are the prime movers for the industrial sector. Activities and processes in the industry and commercial sector depend heavily on electric motors including for compacting, cutting, grinding, mixing, fans, water pumping, materials conveying, air compressing, ventilation, lifts and refrigeration.

In Malaysia, the rising costs of energy make every company in every sector think of ways to lower their electricity bills. Indeed, controlling energy consumption is critical to maintain competitiveness and profitability. Electric motors typically account for 70% of the electricity usage in an industrial facility [1]. They contribute too much of the electrical energy losses. Thus, it is vital to determine the motor's performance.

Motors convert electrical energy into mechanical energy to drive machinery. During this conversion, some energy are lost and make conventional motors inefficient. To solve the problem High Efficiency Motors (HEM) are implemented. HEM produces the same shaft output power but consumes less electrical input power than a standard efficiency motor [2]. It is designed to minimize inherent losses and classified as 'EFF1' by CEMEP (the European Committee of Manufacturers of Electrical Machines and Power Electronics).

By observing the induction motors in the market nowadays, most of the motors are inefficient. The inefficient motors cause energy waste and also increase the operating cost. The High Efficiency Motor (HEM) is implemented to reduce the conventional motor energy losses. The objectives in developing the software are; to understand the performance of the induction motor, to assist managers and engineers to manage their electrical energy consumption, to

increase awareness among the public and to address the importance of energy saving.

## II. SOFTWARE DEVELOPMENT

With the achievements in computer hardware and software, it is now possible to develop an interactive desktop visualization computer aided tools. This computer aided tool with Graphical User Interface (GUI) capabilities will be developed using Microsoft Visual Basic 6.0.

### A. Software Features

The features of this software can be divided into two parts. First is determination of the induction motor performance and second is the HEM analysis. There are two menu bars in the software which are the pop-up menu bar and vertical menu bar. The appearance of these bars allow the user to select and enter the desired function. The structure of the program was divided into the following menu functions; an introduction, theory of induction motor, determination of motor performance, analysis of standard motor and HEM and help function which consist of useful information for the user.

#### A.1. Induction Motor Tool

The "Induction Motor Tool" functions as a calculator which models the induction motor in approximate equivalent circuit and thus provides attractive graphical display of its performance.

Figure 1.0 shows a flow chart of the induction motor performance tools.

In the induction performance tool, the user is required to key in the motor details and data from the DC resistance test, no-load test and locked rotor test to determine the parameter of the equivalent circuit. The function of this tool is to determine the performance of an induction motor.

#### A.2 High Efficiency Motor Analysis

The HEM analysis is based on the specifications of Standard Efficiency Motors and High Efficiency Motors. This software has its programmer's model which consists of the energy savings calculation equation. The software is developed to meet the user requirements of electric motors.

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Figure 2.0 shows the flowchart for the High Efficiency Motor analysis.

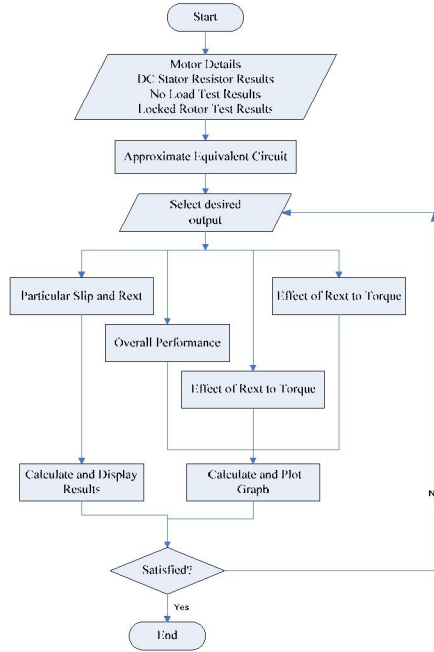


Figure 1.0 Induction Motor Performance Tool

In the HEM analysis, a comparison, is made between EFF1 (High efficiency motors), EFF2 (Improved-efficiency motors) and EFF3 (Standard efficiency motors), where the user needs to select the motor size and speed. The program will automatically calculate the results using the data from the database in the software.

The main function in this analysis is to calculate the demand savings, annual energy savings, annual cost savings and payback period when comparing standard efficiency motor with HEM. The analysis ranges from a 1hp to 100hp induction motor available in the market.

### B. Formulas for Calculating Induction Motor Performance Tools

The performance of an induction motor may be characterized by the following major factors [3]:

- i. Efficiency
- ii. Power Factor
- iii. Torque
- iv. Starting Current

The following equations are used to determine its performance :

$$P_{out} = 3I_2'^2 R_{2t} \frac{(1-s)}{s} \quad (1)$$

$$P_{in} = \sqrt{3} V I_1 \cos \phi \quad (2)$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (3)$$

$$T = \frac{3(I_2')^2 R_{2t} / s}{2\pi \times N_s} \quad (4)$$

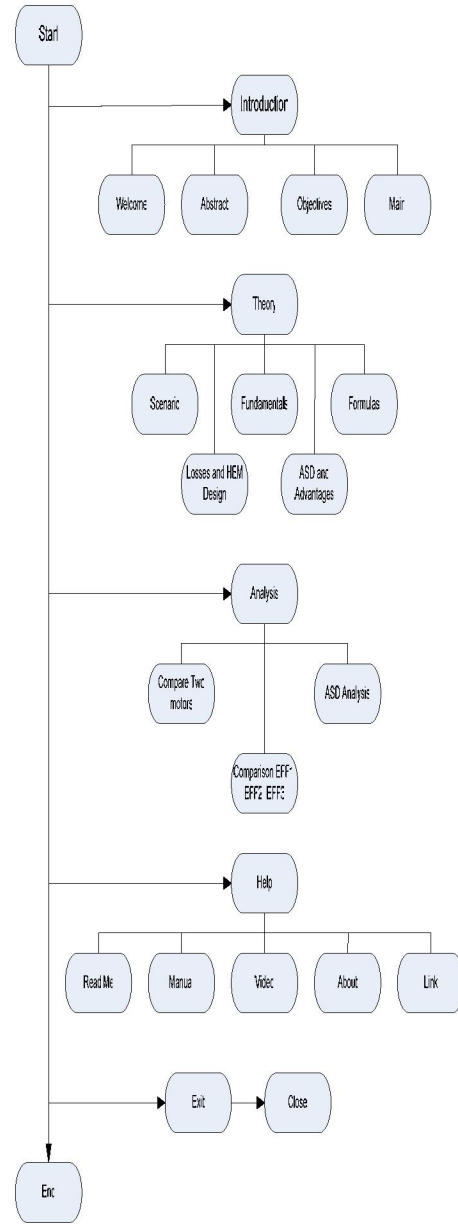


Figure 2.0 High Efficiency Motor Analysis

### C. Formulas for Calculating Energy Savings

The efficiency of a motor is the ratio of the mechanical power output to the electrical power input. The following equations are used to calculate the total annual cost savings.

$$i. \text{ Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Input} - \text{Losses}}{\text{Input}} = \frac{\text{Output}}{\text{Output} + \text{Losses}}$$

$$ii. \text{ Motor Power Output, kW} = \text{Motor Loading}(\%) \times \text{Motor Nameplate kW}$$

$$iii. \text{ Motor Power Input, kW} = \frac{\text{Motor Power Output}}{\text{Efficiency}(\%)}$$

$$iv. \text{ Demand Saving, kW} = \text{Motor Power Output} \times \left( \frac{1}{\eta_{Std}} - \frac{1}{\eta_{HEM}} \right)$$

v. Annual Energy Savings = Demand Savings  $\times$  Operating Hours

vi. Total Annual Cost Savings = Annual Energy Savings  $\times$  Tariff Rate

$$= \text{Hrs} \times \text{kW} \times \% \text{FL} \times \text{RM/kWh} \times \left( \frac{1}{\eta_{\text{Std}}} - \frac{1}{\eta_{\text{HEM}}} \right)$$

Where: Hrs – annual running time in hours  
 kW – motor rating in kilowatt  
 %FL – Fraction of full load power  
 RM/kWh – Electricity cost in RM/kWh  
 $\eta_{\text{Std}}$  – Efficiency of standard motor  
 $\eta_{\text{HEM}}$  – Efficiency of High efficiency motor.

vii. Simple payback (years) =  $\frac{\text{Price premium}}{\text{Total annual cost savings}}$

\*Price premium = Cost of High Efficiency Motor – Cost of Standard Efficiency Motor

### III. RESULTS

#### Example 1

Performance Calculations of Induction motor

$$P.F = \cos B = \cos 23.1^\circ = 0.92 \text{ lagging}$$

$$P_{\text{out}} = 3I_2' R_{2l}' \frac{(1-s)}{s} = 3(5.128)^2 \times 4.31(1-0.1)/0.1 = 3060.1 \text{ W}$$

$$P_{\text{in}} = 3V I_1 \cos B = \sqrt{3} \times 400 \times 7.10 \times \cos 23.1^\circ = 4524.62 \text{ W}$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\% = \frac{3060.11}{4524.62} \times 100\% = 67.63\%$$

$$T = \frac{3(I_2')^2 R_{2l}' / s}{2\pi \times N_s} = \frac{3 \times (5.128)^2 \times 4.31}{(2\pi \times 25)0.01} = 21.65 \text{ Nm}$$

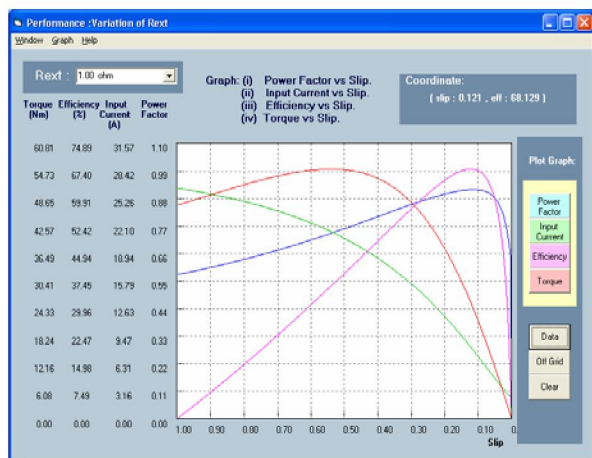


Figure 3.0: Motor Overall Performance

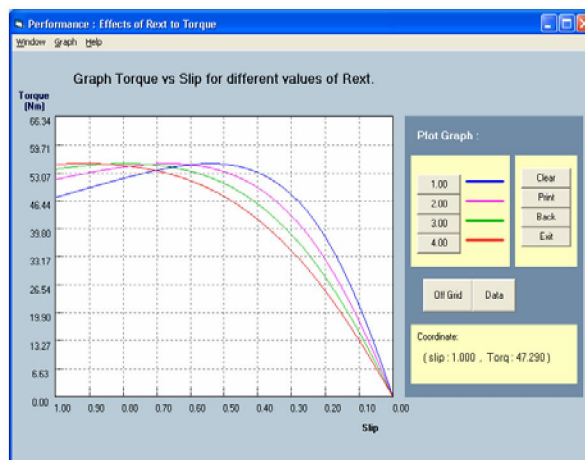


Figure 4.0 Effect of External Resistance to Torque

#### Example 2 (simple comparison):

##### User's Specification:

Energy Cost per Kilowatt-Hour (RM/Kwh) : RM 0.21  
 Motor Size : 60 kW  
 Motor Loading : 80%  
 Operating Hour per Year (Hrs) : 7000 Hours  
 Standard Efficiency Motor Efficiency : 92%  
 High Efficiency Motor Efficiency : 95%  
 Cost of High Efficiency Motor : RM 9000  
 Cost of Standard Efficiency Motor : RM 6000

##### Result:

Demand Savings = 1.64 kW  
 Annual Energy Savings = 11480 kW  
 Annual Cost Savings = RM 2411  
 Payback Period = 1.24 Years

TABLE 1.0 DEMAND SAVINGS, ANNUAL ENERGY SAVINGS, ANNUAL COST SAVINGS AND PAYBACK PERIOD FOR DIFFERENT OPERATING HOURS

Operating Hours	Demand Savings (kW)	Annual Energy Savings (kW)	Annual Cost Savings (RM)	Payback Period (Year)
1000	1.64	1640	344.4	8.711
2000	1.64	3280	688.8	4.355
3000	1.64	4920	1033.2	2.904
4000	1.64	6560	1377.6	2.178
5000	1.64	8200	1722.0	1.742
6000	1.64	9840	2066.4	1.452
7000	1.64	11480	2410.8	1.244
8000	1.64	13120	2755.2	1.089

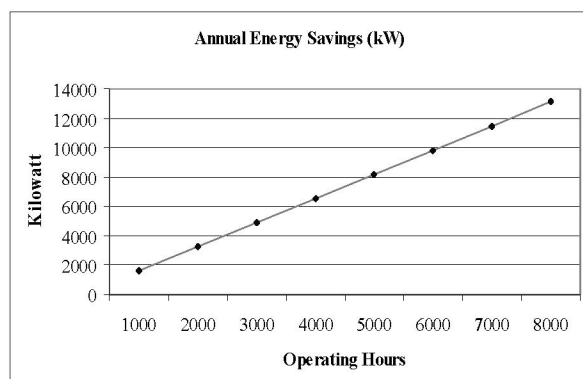


Figure 5.0: Graph for Annual Energy Savings

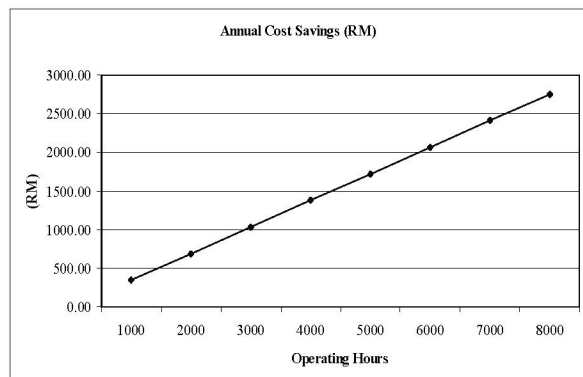


Figure 6.0: Graph for Annual Cost Savings

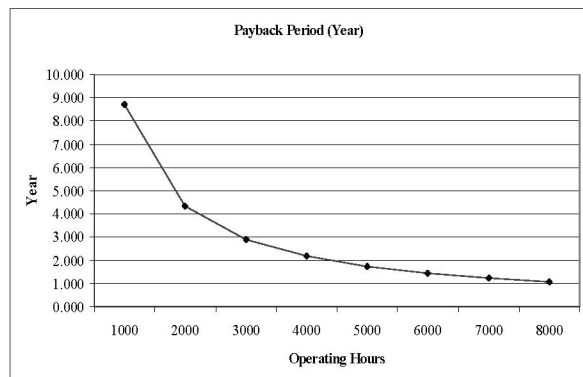


Figure 7.0: Graph for Payback Period

### Example 32 (comparison between EFF1, EFF2 and EFF3):

#### User's Specification:

Energy Cost per Kilowatt-Hour (RM/Kwh)	: RM 0.21
Motor Size	: 2 HP
Motor Loading	: 100%
Operating Hour per Year (Hrs)	: 8760 Hours
EFF1 Efficiency	: 86%
EFF2 efficiency	: 79%
EFF3 efficiency	: 78%
Cost of EFF1	: RM 600
Cost of EFF2	: RM 350
Cost of EFF3	: RM 280

#### Result:

Demand Savings for EFF1 = 0.18 kW

Demand Savings for EFF2	= 0.02421kW
Annual Energy Savings for EFF1	= 1558.728 kW
Annual Energy Savings for EFF2	= 212.11 kW
Annual Cost Savings for EFF1	= RM 327.33
Annual Cost Savings for EFF2	= RM 44.54
Payback Period for EFF1	= 0.98 Years
Payback Period for EFF2	= 1.57 Years

## IV. ANALYSIS

The software is able to evaluate or determine the performance and efficiency of each motor and the most suitable motor for an application. The guidelines being provided to save the energy and cost consumption for the industrial area by identifying the most cost-effective choice when replace low efficiency motors. The software includes wide range (from 1hp to 100hp) of the three types of induction motors that will allow the user to select which motor they want to compare. The software can easily calculate the demand savings, annual energy savings, annual cost savings and payback period compared to standard efficiency motor with High Efficiency Motor. At the same time, it will display the summary results and graphs that are related to the calculation.

Figure 3.0 and 4.0 show the overall performance and effect of variations in the external resistance of the induction motor respectively. For the HEM analysis, Figure 5.0-7.0 show that more energy could be save and early return in investment if the operating hours of the motor increases. Example 3 shows that EFF1 motor is better then EFF2 and EFF3. The payback period for EFF1 is 0.98 years compared to EFF2 which is 1.57 years.

## V. CONCLUSIONS

Software with user-friendly GUI features besides attractive graphical display has been developed.. This software is to assist user to attain the performance of induction motor as well as obtaining economic analysis of High Efficiency Motors. This software has the ability to display the performance of an induction motor by having some of the motor details and also test result of No Load Test, Locked Rotor Test and DC Stator Resistance Test inserted. From these inputs, user may see the approximate equivalent circuit and from this circuit, the performance of induction motor will be plotted.

## VI. REFERENCES

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## VIII. BIOGRAPHIES

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