

**ANALYZING INDUCTION MOTOR VARIABLES (VOLTAGE, TORQUE &
EFFICIENCY) TO COMPARE BETWEEN NELDER-MEAD METHOD AND
POWELL'S METHOD OF OPTIMIZATION**

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“I hereby declare that I have read through this report entitle “**Analyzing Induction Motor Variables (Voltage, Torque & Efficiency) To Compare Between Nelder-Mead Method and Powell’s Method of Optimization**” and found that is has comply that fulfillment for awarding the degree of bachelor of electrical engineering (control, instrumentation and automation)”

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I declare that this report entitle “**Analyzing Induction Motor Variables (Voltage, Torque & Efficiency) To Compare Between Nelder-Mead Method and Powell’s Method of Optimization**” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This research aims to the efficiency as dependent variable with torque and current as the independent variables of induction motor by using optimization process. The optimal design of induction motor is crucial because of the energy or power consumption. The normal design of induction motor consumes more electricity and energy than the optimal design of induction motor. The application of induction motor is worldwide; therefore minimizing energy consumption of induction motor is one of the important sources for energy savings. Small proportion of the increase in efficiency will be significant energy savings and economic impact. Induction motor efficiency can be raised in various ways. One of them is believed to be optimized for the most economical approach. Therefore, it is very important to choose the best optimization techniques available for three-phase induction motor design. In this research, the optimum efficiency of induction motor will be obtained by using two methods which are Nelder-Mead method and Powell's method. After the calculation of optimization by these two methods, I will compare the methods in order to determine which one as the best estimation of the optimum efficiency.

For the conclusion, both of Powell's and Nelder-Mead's method are very different in finding the results. Both of these methods use different methodology, algorithm and iterations. The outcomes both methods are closely. Both of methods have the same purpose to find the minimum points and as the final results of the minimum efficiency value for both methods are closely and approximately. The minimum efficiency result of Powell's method, 0.0032129 with the values of voltage 241.8V and torque 0.2Nm is lower than Nelder-Mead's method (0.003313) with the range of voltage 265V and torque -0.4Nm which makes it better.

ABSTRAK

Kajian ini memfokus kepada kecekapan sebagai pembolehubah bersandar dengan tork (daya tujah motor) dan arus sebagai pembolehubah bebas motor induksi dengan menggunakan proses pengoptimuman. Reka bentuk optimum motor aruhan adalah penting kerana penggunaan tenaga atau kuasa, reka bentuk yang biasa motor induksi menggunakan elektrik dan tenaga yang lebih daripada reka bentuk optimum motor induksi. Aplikasi penggunaan motor induksi adalah merangkumi seluruh dunia, oleh itu meminimumkan penggunaan tenaga motor induksi adalah salah satu sumber penting bagi penjimatan tenaga. Sebahagian kecil daripada peningkatan dalam kecekapan akan menjimatkan tenaga dan kesan ekonomi. Kecekapan motor induksi boleh dinaikkan dengan pelbagai cara. Salah satu adalah dengan mengoptimumkan rekaan motor induksi untuk pendekatan yang paling ekonomi. Oleh itu, adalah sangat penting untuk memilih teknik pengoptimuman terbaik.

Dalam kajian ini, kecekapan optimum motor induksi akan di kira dengan menggunakan dua kaedah iaitu kaedah Nelder-Mead dan kaedah Powell. Selepas pengiraan pengoptimuman oleh kedua-dua kaedah ini, saya akan membandingkan kedua-dua kaedah untuk menentukan mana satu sebagai anggaran terbaik kecekapan optimum bagi rekaan motor induksi. Kesimpulannya, kedua-dua Powell dan kaedah Nelder-Mead adalah sangat berbeza dalam hasil carian. Kedua-dua kaedah ini menggunakan kaedah dan algoritma yang berbeza. Keputusan kedua-dua kaedah adalah hampir. Kedua-dua kaedah mempunyai matlamat yang sama untuk mencari titik minimum dan nilai akhir kecekapan minimum kedua-dua kaedah adalah rapat dan hampir. Nilai kecekapan minimum bagi kaedah Powell adalah 0.0032129 dimana nilai voltan 241.8V dan daya kilas 0.2Nm adalah lebih rendah daripada kaedah Nelder-Mead dengan nilai minimum kecekapan 0.003313 dengan voltan 265V dan 0.4Nm bagi daya kilas yang membuatnya kaedah Powell lebih baik.

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CHAPTER 1

1 INTRODUCTION

Optimization techniques for induction motor have been developed to solve problems involving variables such as motor torque, motor current and etc. It is also can be defined as when operating within a set of constraints, it can search for the best result. In other words, it was described as the process of solution search that is more useful than several others[16].

Most studies on the design of induction motors using optimization techniques are concerned about minimizing the cost of the motor and also concern about describing the optimization technique that was employed in order to get best results of a single optimal design. As the induction motor that in their optimal design that concerns with the cost of the motor and also includes efficiency, power factor and other effects.

There are two different optimization approaches of the induction motor optimization that are "theoretical method" and "technical method". The optimized design parameters of the theoretical optimization approach might appear to satisfy any positive value of the motor performance. On the other hand, in the technical optimization approach, several design parameters, when viewed from the reference is limited by the dimensional limits that are determined by policy makers.

For optimization approach, looking from the basic differences that are resulting from motor optimally designed for both approaches as well as its design parameters, they have different performance characteristics. It is very clear that the theoretical method leads better design than the technical method of optimization. In general, the results of the theoretical method can be valued as the best possible values according to the given set of parameters and problem definition, while the results of the technical optimization method can approach the results of the theoretical optimization. However, due to the complex structure of most engineering problems, numerical techniques are estimated, and used as standard unconstrained optimization techniques, such as the Nelder-Mead simplex method[1].

Optimization of induction motor for maximum efficiency using a mathematical optimization method is a good approach for the design of the motor. In this approach, the manufacturer, any requirement from any consumer can easily be expressed in the formulation of the optimization problem. The optimal design parameters known as “the general nonlinear programming problem,” are the families of constrained optimization problem[2].

Minimizing energy consumption of three-phase induction motor is one of the important sources for energy savings. It is because the large number of three-phase induction motor of the service. Today, the U.S Power system capacity is about 700 gig watts. About 60% of its capacity has been used to power single-phase induction motor. Small proportion of the increase in efficiency will be significant energy savings and economic impact. Induction motor efficiency can be raised in various ways. One of them is believed to be optimized for the most economical approach. Therefore, it is very important to choose the best optimization techniques available for three-phase induction motor design[5]. The energy saving in electric motors can be achieved by either designing an energy-efficient motor or driving the Conventional motor under high-efficiency conditions[4].

The need to conserve energy of the industry has attracted by the attention of the motor losses and efficiency. The focused on improving and optimizing material design strategies for major efforts more efficient. However, it can be improved by intervening in the operation principle of the motor efficiency. Simple and effective method of control for some motor, in order to improve the dynamic response has been proposed in order to minimize losses and improve efficiency[8].

In general, the motor efficiency can be improved by two different methods. One possible improvement will be basically achieved by the addition of materials to be used and more expensive technologies. Another possibility is the motor efficiency by optimizing the design point for the optimization method. The difference between the two approaches is in the later case, where as a completely new design that is derived, improving the former case is done by changing the existing design[1].

In order to gain the efficiency optimization calculation, it will use the MATLAB simulation tools. The two tools that I will use are the Nelder-Mead and Powell's method. The Nelder-Mead method has been used extensively for the optimization of simulation models for over twenty five years. There have over 2,000 citations to the original papers, with 200 citations in 1989 alone. The Nelder-Mead rescaling and shrinking steps make it sensitive to random variations in the response function values, and introduce risks of false convergence on stochastic functions[8],[11]. It gives analytical and empirical evidence that characterizes false convergence on stochastic functions, and discuss several modifications to reduce the likelihood of false convergence. It describes a computational comparison of several modifications when used to optimize simple stochastic functions of two and ten variables. Nelder-Mead was intended for deterministic function.

Besides that, the other method is Powell's method. It is an extension of the basic pattern search method. It is the most widely used direct search method and can be proved to be a method of conjugate directions. A conjugate direction method will minimize a quadratic function in a finite number of steps. Since a general nonlinear function can be approximated reasonably well by quadratic function near its minimum, a conjugate directions method is expected to speed up the convergence of even general nonlinear objective functions. The definition, a method of generation of conjugate directions and the property of quadratic convergence are presented in this section[15].

If there are only one zero-order method that must be programmed, the overwhelming choice would be the Powell's method. The principle reason for the decision would be that it has the property of quadratic convergence. This property can be simplified to be, "For a quadratic problem with n -variables convergence will be achieved in less than or equal to n Powell cycles". A quadratic problem is an unconstrained minimization of a function that is expressed as a quadratic polynomial. Engineering design optimization problems are rarely described by a quadratic polynomial. This does not imply that you cannot use the Powell's method. What this means is that the solution should not be expected to converge quadratically. In practice, as the solution is approached iteratively, the objective can be approximated very well by quadratic function, so that quadratic convergence property is realized in the computations in the neighborhood[16].

1.1 Problem statement

The problem statement for my project is the complication on how to get the maximum output power value, P_{out} close to the input power of the motor, P_{in} with τ and V as independent variables.

1.2 Project Objectives

- To determine the maximum induction motor efficiency.
- To compare the 2 methods which were used to obtain the maximum efficiency
- To obtain the most optimum state of the induction motor in terms of the maximum efficiency conditions that it have gain through data collection and calculation by using MATLAB.

1.3 Project Scope

This project focuses on the involvement of the calculation of induction motor efficiency using independent variables to gain the optimum state of the motor by using MATLAB. The optimization calculation methods are Nelder-Mead and Powell's method.

CHAPTER 2

2 LITERATURE REVIEW

2.1 Introduction

Induction motors are mainly employed in industrial processes as actuators and final elements. Hardware implementation of induction motor control and drive systems is an important issue of industrial motor application[6]. In many applications, efficiency optimization of induction motor presents an important factor of control[7].

This is the research that deals with the efficiency optimization of induction motor using calculation of Nelder-Mead and Powell's method in MATLAB.

2.2 Raw Data Collection of Induction Motor

In order to run the calculation, it requires raw data from the induction motor that will include the dependent and independent variables. To obtain the data, it requires running an experiment in terms of the usage of the induction motor.

Based on the research objectives, the induction motor's variation in torque and current will be studied as independent variables to gain the efficiency. For the best result of optimization calculation using MATLAB, the input data must be at least 70 to 100 variables. According to the Nelder-Mead and Powell's method of calculation, the result of the optimization will be more accurate when the input data is high. The larger number of input will be more accurate in the results.

The variables that are used in this research include:

- Dependant variable, $\frac{1}{\eta}$
- Independent variables,
 - Torque, τ
 - Current, I

According to the variables above, we know that the formula of efficiency is:

$$\eta = \frac{P_o}{P_i} \tag{2.1}$$

$$P_o = \frac{2\pi \cdot \tau \cdot n_r}{60} \tag{2.2}$$

$$P_i = V_L \cdot I_L \tag{2.3}$$

where:

- τ_{out} , Output torque (Nm)
- 60, rotation per minutes
- P_{out} , Output power (W)
- η , Efficiency (%)
- V_L , Input voltage (V)
- n_r , Rotor speed (rpm)
- I_L , Output current (A)

In order to obtain the maximum efficiency of the induction motor, the Nelder-Mead and Powell's method will calculate the minimum efficiency. From the formula above, in order to gain the minimum efficiency, the formula of efficiency must be converted to:

$$\frac{P_i}{P_o} = \frac{1}{\eta} = \frac{60 \cdot V_L \cdot I_L}{2\pi \cdot \tau \cdot n_r} \tag{2.4}$$

$$Min = \frac{1}{\eta} = \frac{P_i}{P_o} = \frac{60 \cdot V_L \cdot I_L}{2\pi \cdot \tau \cdot n_r} \tag{2.5}$$

From the formula (2.1) and (2.2), the value of the Output torque (Nm), τ and Output current (A), I_L plays a big role in contributing to the efficiency. The rational of choosing Output torque (Nm), τ and Output current (A), I_L as independent variable because of the formula implication that will directly contribute to changing the value of the efficiency.

2.3 Nelder-Mead and Powell's Method

The MATLAB efficiency optimization calculation tools that will be used in this research are Nelder-Mead and Powell's method. The process of optimization often deals with looking for the maximum and minimum value of a function by depending on variables from a wide variety of data. The ultimate objective is to find the point values from the data that is maximum or minimum according to the function algorithm[3]. The process steps for acquiring a minimum value of a function can be obtained by these methods[12].

2.3.1 Nelder-Mead Method

This method is basically an engine that search for pattern and comparison function values from three points of a triangle. The three points are best, good and worst where the worst point is the largest then will be replaced by a new value in iterations. The new point of worst will form a new triangle and the search will proceed. The search might generate multiple size and shapes of triangles and the value of the three points will get lesser every time. The minimum point can be found once the triangle size is reduced[10].

2.3.1.1 Initial Best, Good and Worst Points

From all of the data collected, 3 points will be selected that are point Best (B), Good (G) and Worst (W). The best value is the minimum value of the 1/efficiency while the value of good is next to the value of best. The worst value is the maximum value of 1/efficiency from the data. The subscripts are then reordered so that $B \leq G \leq W$. It uses the notation of:

B(best) = (x1, y1), **G(good)** = (x2, y2), and **W(worst)** = (x3, y3)

2.3.1.2 The Midpoint of the Good Side (M Point)

M point is the coordinate value of the midpoint where the calculation is by averaging the value of Best and Good.

$$M = \frac{B+G}{2} \quad (2.6)$$

2.3.1.3 The Reflection Point (R point)

By reflecting the triangle that was made from midpoint of B to G then generates a line across W to M where the line segment is called d. The formula of R is:

$$R = M + (M - W) = 2M - W \quad (2.7)$$

2.3.1.4 Expansion Using the Point E

The condition when the value R is less than the value of W then it shows that the algorithm is correct. Next is to generate another line segment between the point M and R to the point E. The point E can be obtained by moving additional distance, d along the line joining M and R. According to the algorithm, the condition when the value of E is less than R so the new and better vertex is found. The formula of E is:

$$E = R + (R - M) = 2R - M \quad (2.8)$$

2.3.1.5 Contraction Using the Point C

When the condition where the point value of R and W are the same, then another point must be generated. Consider the 2 midpoint from before (WM and MR), the smaller point value is called C. The selection between these 2 points is crucial since it is the higher dimensions.

2.3.1.6 Shrink toward B

Another step is when the value at point C is more than W so the point G and W must be shrunk to the point B. The new point for G is replaced with the point M and the point W is replaced with S, which is the average value of the line segment of B and W.

2.3.1.7 Logical Decisions for Each Step

The final step is when each iteration is finished and when starting a new iteration, the minimum value must be set to the best point, good point is next to best and worst is the maximum value[15].

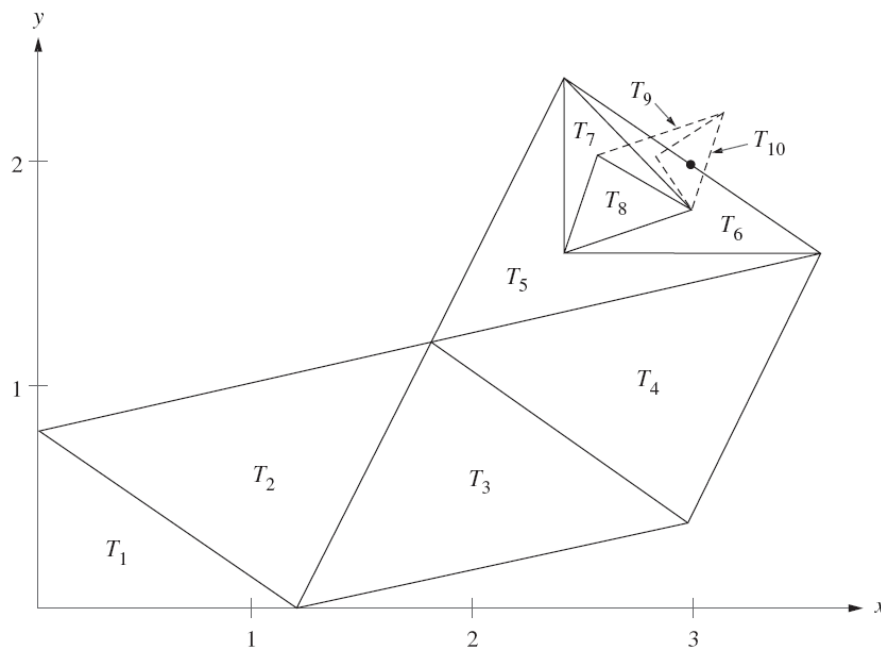


Figure 2.1 : Sequence of Triangle Pattern Search of Nelder-Mead Method[12].

2.3.2 The Powell's method

According to most text books and journal, Powell's method is basically a function algorithm that generates searches for a minimum function of a wide range of data while neglecting the derivatives[16]. In other words, if X_0 is an initial function at a minimum function value. Assuming the derivatives of function X_0 is not available. In order to calculate approximating another minimum function is to calculate the next approximation of X_1 by choosing the next minimum function in the data. The method produces the chain of points and coordinates and will obtain the value of the minimum point[12].

2.4 MATLAB Simulation

After done with the data collection, the efficiency optimization calculation will be run by using simulation on the MATLAB. MATLAB or also known as the Matrix Laboratory is a type of mathematical software simulation produced by MATHWORKS. The basic functions of MATLAB are including the basic mathematical calculations, matrix operations, generating user interface, plotting graph functions and more. Besides that, MATLAB also have a variety of applications such as control system design, testing and measurement, modeling and analysis and others[11].

According to most viewed optimization research ever made, MATLAB is probably the best engine to generate and calculate optimization. The variables wide range of function of the MATLAB comes in handy in the optimization calibration. In this research, the usage of the 3D plotting function is very flexible and the implication to this research is limitless. The 3D plotting functions are such as legend function, axes plotting, arrow text and others. Besides that, MATLAB encourage skilled engineer to learn more by producing design parameters according to basic engineering knowledge with the compliance of smart search algorithms to obtain optimal design for any given data[9].

CHAPTER 3

3 PROJECT METHODOLOGY

3.1 Introduction

Chapter 3 will explain the details of the methodology that will be used to make this research complete and working. Basically, it is an overview of my research that contains several methods.

3.2 Methodology Overview

The purpose of the research is to determine the maximum efficiency of induction motor and to compare the two methods that were use to obtain the maximum efficiency. The variables that will be used are dependent and independent variables. In order to gain the maximum efficiency, there are two independent variables that will be used to calculate the independent variables. The independent variables are torque, T (Nm) and voltage, (V) while the dependent variable is efficiency (η). Some of the methodology that I will use involves calculation and algorithm method of finding the induction motor optimization. There are two calculations algorithm methods which are Nelder-Mead and Powell's method.