

**ANALIZING INDUCTION MOTOR VARIABLES (VOLTAGE  
ANGULAR VELOCITY, AND EFFICIENCY) TO COMPARE  
BETWEEN NELDER-MEAD METHOD AND POWELL'S  
METHOD OF OPTIMIZATION**

**Adi Adli Bin Bahtiar Affandi**

**Bachelor of Electrical Engineering  
(Control, Instrumentation and Automation)  
June 2012**

**ANALIZING INDUCTION MOTOR VARIABLES (VOLTAGE ANGULAR  
VELOCITY, AND EFFICIENCY) TO COMPARE BETWEEN NELDER-MEAD  
METHOD AND POWELL'S METHOD OF OPTIMIZATION**

**ADI ADLI BIN BAHTIAR AFFANDI**

**FINAL YEAR PROJECT REPORT**

**Faculty of electrical engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**JUNE 2012**

“I hereby declare that I have read through this report entitle “Analyzing AC Induction Motor variables (Voltage, Angular Velocity, And 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)”

Signature : .....

Supervisor’s Name : Mr. Moses Alfian Simanjuntak

Date : .....

I declare that this report entitle “Analyzing AC Induction Motor variables(Voltage, Angular Velocity, And 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.

Signature : .....

Name : Adi Adli B. Bahtiar Affandi

Date : .....

## ACKNOWLEDGEMENT

In the name of The Almighty God who gave me the strength, health and patience to successfully implement and complete a final report. All the praise and selawat is upon to the prophet Muhammad S.A.W.

I would like to special thank my research supervisor, Mr. Moses Alfian Simanjuntak, because his support, encouragement and professional assistance.

I would also like to extend my gratitude, to my beloved parents for the moral, emotional and financial support. In addition, to my entire classmate at 4BEKC, Universiti Teknikal Malaysia Melaka who have been involved directly or indirectly in providing support and guidance during the making of this report.

I have gained a lot of help and support from friends and staff in the faculty of electrical engineering. I want to take this opportunity to say thank you to them for their advice and idea that help in my research.

Your sincere help will be remembered for life.

Thank you.

## ABSTRAK

Projek ini bertujuan mengoptimumkan nilai kecekapan sebagai pemboleh ubah tetap dengan menggunakan voltan dan halaju sebagai pemboleh ubah boleh ubah ke atas motor arus ulang-alik dengan menggunakan proses pengoptimuman. Motor arus ulang-alik digunakan secara meluas dalam aplikasi domestik, komersial dan industri. Malahan peratusan kecil peningkatan kecekapan akan memberikan kesan yang besar kepada penjimatan tenaga dan impak ekonomi. Untuk projek ini, saya akan menggunakan dua kaedah iaitu kaedah Nelder-Mead dan kaedah Powell's untuk mendapatkan kecekapan optimum. Akhir sekali, saya akan membandingkan antara dua kaedah untuk mendapatkan kaedah anggaran terbaik di dalam mencapai kecekapan optimum. Berdasarkan keputusan yang diperolehi menunjukkan kedua-dua kaedah Nelder-Mead dan Powell's mempunyai kaedah yang berbeza di dalam mendapatkan nilai kecekapan yang paling optimum. Kedua-dua kaedah menggunakan kaedah, metodologi dan pengulangan atau lelaran yang berbeza. Hasil kecekapan minimum kaedah Nelder-Mead adalah 0.01193 dengan nilai-nilai halaju voltan 328.8V dan sudut ( $\omega$ ) 299.6rd/s. Kecekapan kaedah Powell 0.01213 dengan nilai-nilai halaju voltan 344V dan sudut ( $\omega$ ), 305.6rd/s yang membuatkan kaedah-Mead Nelder adalah lebih baik. Walau bagaimanapun, keputusan yang diperolehi menunjukkan kedua-dua kaedah memperoleh nilai berhampiran.

## ABSTRACT

This project aims to optimize the efficiency as independent variable with the voltage and speed as the independent variables of induction motor by using optimization process. Induction motors are widely used in domestic, commercial and industrial applications. Even a small percentage of efficiency increase will result in a significant energy conservation and economic impact. Furthermore, I will use two method which are Nelder-Mead Method and Powell's Method to get the optimum efficiency. Finally, I compare the methods to obtain which one as the best estimation of the optimum efficiency. As a result, both of Powell's and Nelder-Mead's method are very different in finding the results. Both of this method use different methodology, algorithm and iteration. The minimum efficiency result of Nelder-Mead method is 0.01193 with the values of voltage 328.8V and angular velocity ( $\omega$ ) 299.6rd/s. Powell's method efficiency is 0.01213 with the values of voltage 344V and angular velocity ( $\omega$ ), 305.6rd/s which makes it the Nelder-Mead method is better. The outcomes of both these methods are closely and approximately. However the value of voltages and angular velocity are different based on the position on the contour.

## Contents

ACKNOWLEDGEMENT .....	iv
ABSTRAK .....	v
ABSTRACT .....	vi
Contents .....	vii
LIST OF TABLE .....	ix
LIST OF FIGURES .....	x
LIST OF APPENDICES .....	xii
INTRODUCTION .....	1
1.1 Project Background .....	1
1.2 Problem statement .....	3
1.3 Objective .....	3
1.4 Scope .....	4
2 Literature Review .....	5
2.1 Introduction .....	5
2.2 Induction Motor .....	5
2.3 Voltage and Speed (Angular velocity) .....	6
2.4 Efficiency .....	7
2.5 Optimization .....	8
2.6 Nelder-Mead method .....	8
2.7 Powell's method .....	8
3 METHODOLOGY .....	10
3.1 Introduction .....	10
3.2 Methodology Project .....	10
3.2.1 Flow chart explanation .....	13
3.2.2 Concept and theory study .....	13
3.2.3 Problem in modeling .....	13
3.2.4 Modeling analysis .....	14
3.2.5 Computation .....	14



3.2.6	Analysis and result.....	14
3.3	Nelder- Mead method.....	15
3.3.1	Initial Triangle $BGW$ .....	16
3.3.2	Midpoint of the Good Side .....	16
3.3.3	Expansion Using the Point $E$ .....	17
3.3.4	Contraction Using the Point $C$ .....	17
3.3.5	Shrink toward $B$ .....	18
3.3.6	Logical Decisions for Each Step.....	19
3.4	Powell's method.....	20
4	RESULT .....	22
4.1	Introduction .....	22
4.2	Result.....	22
4.2.1	Nelder-Mead method result .....	23
4.2.2	Powell's method result.....	25
4.2.3	The result of combination Nelder-Mead and Powell's method .....	32
CHAPTER 5	.....	34
5	ANALYSIS AND DISCUSSION .....	34
5.1	Introduction .....	34
5.2	Analysis and Discussion.....	34
5.2.1	Nelder-Mead method .....	37
5.2.2	Powell's method.....	47
6	CONCLUSION AND RECOMMENDATION .....	57
6.1	Introduction .....	57
6.2	Conclusion.....	57
6.3	Recommendation.....	58
7	PROJECT POTENTIAL .....	59
7.1	Introduction .....	59
7.2	Project potential.....	59
References	.....	61
APPENDICES A	.....	63

## LIST OF TABLE

TABLE	TITLE	PAGE
4.0	Logical decision of Nelder-Mead algorithm	19
4.1	Process and result of 10 iterations Nelder-Mead method	24
4.2	The first iteration of Powell's method	26/47
4.3	The second iteration of Powell's method	28/49
4.4	The third iteration of Powell's method	30/52
4.5	The result between Nelder-Mead method and Powell's method	33
5.1	Value for Best (G), Good (G) and Worst (W)	37
5.2	Process and result of 1 <sup>st</sup> and 3 <sup>rd</sup> iteration Nelder-Mead method	40
5.3	Process and result of 2 <sup>nd</sup> , 4 <sup>th</sup> and 9 <sup>th</sup> iteration Nelder-Mead method	41
5.4	Process and result of 5 <sup>th</sup> iteration of Nelder-Mead method	42
5.5	Process and result of 6 <sup>th</sup> , 7 <sup>th</sup> and 8 <sup>th</sup> iteration of Nelder-Mead method	43
5.6	Geometric movement of Nelder-Mead method	46

## LIST OF FIGURES

FIGURE	TITLE	PAGE
3.0	Flow chart of methodology	12
3.1	The flow chart of Nelder-Mead algorithm	15
3.2	Reflected point $R$ for Nelder-Mead method	16
3.3	Point of $R$ an extended point of $E$	17
3.4	Contraction point for Nelder-Mead method	18
3.5	Shrinking the triangle toward $B$	18/41
3.6	The flow chart of Powell's algorithm	20
4.0	3D plot of Nelder-Mead method result	23
4.1	3D plot of Powell's method result	25
4.2	3D plot of Nelder-Mead method and Powell's method	32
5.1	Experiment circuit of Three Phase Induction motor	35
5.2	Example of 3D optimization graph and contour	36
5.4	The reflection for 1 <sup>st</sup> and 3 <sup>rd</sup> iteration point	39
5.5	The expansion for 1 <sup>st</sup> and 3 <sup>rd</sup> iteration point	39
5.6	The contraction for 2 <sup>nd</sup> , 4 <sup>th</sup> and 9 <sup>th</sup> iteration point	41
5.8	The reflection for 5 <sup>th</sup> iteration point	42

5.9	The contraction for 6 <sup>nd</sup> , 7 <sup>th</sup> and 8 <sup>th</sup> iteration point	43
5.10	Nelder-Mead step	44
5.11	Nelder-Mead movement to find minimum point	45

**LIST OF APPENDICES**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	The result from experiment AC induction motor	49
B	3D plotting result coding	50
C	3D plotting result combination method coding	51

## CHAPTER 1

### INTRODUCTION

#### 1.1 Project Background

Three-phase induction motors are widely used in domestic, commercial and industrial applications. On an average, the energy consumed by an induction motor during its life cycle is 60–100 times the initial cost of the motor. Even a small percentage of efficiency increase will result in a significant energy conservation and economic impact. Therefore, efficiency of the motor is of vital importance both during selection and operation. According to the massive usage of three-phase induction motors, its manufacturing and operating cost have to be minimized.

In the literature, most of the works are only concerned with reducing the manufacture cost by minimizing its active material costs [1][2][3][4][5]. This is the main objective of the motor producer but may not be beneficial to consumers. Since the manufacture cost is a small portion of the total power loss cost of the motor during its lifetime. Accordingly, the design of induction motor should also put emphasis on minimizing its active power loss cost [4][5][6]. This is the objective of consumers as the power consumption cost is reduced and also leads to admirable goal of global energy conservation.

The design of induction motors is based on universally accepted physical and mathematical principles which have been verified by experimental methods. The knowledge of these principles is often insufficient to produce the "optimal design" due to the fast changing technological developments.

Moreover, with the increasing cost of electrical energy and concurrent development in the material technology, the operating cost and/or some specific items of performance play a significant role in the overall economics as well as in the efficiency of the system. In this case a design optimization allows to achieve better results.

Optimization is an essential part of design activity in all major disciplines. Today, globalization demands that additional dimensions such as location, language, and expertise must also merit consideration as new constraints in the development process. Improved production and design tools coupled with inexpensive computational resources have made optimization an important part of the process. Generally, the use of the word optimization implies the best result under the circumstances. This includes the particular set of constraints on the development resources, current knowledge, market conditions, and so on. The ability to make the best choice is a perpetual desire among us all [7][8][9].

The techniques that are used in optimization are also used for obtaining solutions to nonlinear problems in many disciplines, so the subject has an attraction to a wider audience from many fields. Optimization was described as the process of search for the solution that is more useful than several others. This means that outcome of applying optimization techniques to the problems, design or service must yield number that will define the solution, in other words, number or values that will characterize the particular design or service [10].

The optimization is math work with their product is MATLAB and Simulink. Of specific note is the optimization toolbox, which implements most of the concepts developed in this research. Knowledge of MATLAB is a skill that is in demand from those entering the workspace to work in analytical areas.

MATLAB is introduced by Mathwork as the language for technical computing. Borrowing from the description in an earlier brochure, valid even now, MATLAB integrates computation,

visualization and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation.

MATLAB is a standard tool for introductory and advanced courses in mathematics, engineering and science in many universities around the world. In industry, it is a tool of choice for research, development and analysis. MATLAB basic array element is exploited to manipulated vectors and matrices that are natural to the subject. Its powerful visualization features are used for graphical optimization [9][10].

For my project, I will do a research on how to determine the most optimum state of induction motor by using Nelder-Mead Method and Powell's Method to achieve the maximum efficiency,  $\eta$ . The independent variables that I use in my project is motor voltage and angular velocity. This is based on the efficiency,  $\eta$ , is ratio between  $P_{out}$  and  $P_{in}$ . [10][11][12][13][14].

Nelder-Mead Method is a method pattern search that compares function values at the three vertices of a triangle. Powell's method is a method generates the sequence of point and the coordinates of the minimum point are found.

## 1.2 Problem statement

How to get the maximum output power,  $P_{out}$  close to the input power of induction motor,  $P_{in}$

## 1.3 Objective

The objectives of the research are:

- (a) To determine the maximum induction motor efficiency
- (b) To compare the two method that I use to obtain the maximum efficiency



## 1.4 Scope

To find the most optimum state to achieve the maximum efficiency of induction motor by taking voltage and angular velocity as independent variables by using 2 methods and do the simulation using MATLAB based on data collection in motor electrical lab

## CHAPTER 2

### 2 Literature Review

#### 2.1 Introduction

This background study is a reference and guide for research controlling induction motor variables (voltage angular, velocity, and efficiency) to compare between Nelder-Mead Method and Powell's Method of optimization.

#### 2.2 Induction Motor

AC induction motors are the most common motors used in industrial motion control systems, as well as in main powered home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors.

Various types of AC induction motors are available in the market. Different motors are suitable for different applications. Although AC induction motors are easier to design than DC motors, the speed and the torque control in various types of AC induction motors require a greater understanding of the design and the characteristics of these motors.

Like most motors, an AC induction motor has a fixed outer portion, called the stator and a rotor that spins inside with a carefully engineered air gap between the two.

Virtually all electrical motors use magnetic field rotation to spin their rotors. A three-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator because of the nature of the supply

Two sets of electromagnets are formed inside any motor. In an AC induction motor, one set of electromagnets is formed in the stator because of the AC supply connected to the stator windings. The alternating nature of the supply voltage induces an Electromagnetic Force (EMF) in the stator as per Lenz's law, thus generating another set of electromagnets; hence the name – induction motor. Interaction between the magnetic field of these electromagnets generates twisting force, or torque. As a result, the motor rotates in the direction of the resultant torque.

The stator is made up of several thin laminations of aluminum or cast iron. They are punched and clamped together to form a hollow cylinder (stator core) with slots. Coils of insulated wires are inserted into these slots. Each grouping of coils, together with the core it surrounds, forms an electromagnet (a pair of poles) on the application of AC supply. The number of poles of an AC induction motor depends on the internal connection of the stator windings. The stator windings are connected directly to the power source.

The rotor is made up of several thin steel laminations with evenly spaced bars, which are made up of aluminum or copper, along the periphery. In the most popular type of rotor (squirrel cage rotor), these bars are connected at ends mechanically and electrically by the use of rings. Almost 90% of induction motors have squirrel cage rotors. This is because the squirrel cage rotor has a simple and rugged construction. The rotor consists of a cylindrical laminated core with axially placed parallel slots for carrying the conductors. Each slot carries a copper, aluminum, or alloy bar.[10]

### **2.3 Voltage and Speed (Angular velocity)**

Speed of a motor is proportional to the voltage. When the supply specified voltage to a motor, it rotates the output shaft at some speed. This rotational speed or angular velocity  $\omega$ , is

typically measured in radians/second {rad/s}, revolutions/second {rps}, or revolutions/minute {rpm}.

$$\omega = 2\pi f \quad (2.0)$$

The relationship between voltage and angular velocity can influence the efficiency the induction motor [16][17].

## 2.4 Efficiency

The efficiency is ratio between  $P_{out}$  and  $P_{in}$ . Efficiency is a picture of how efficiently a motor in converting electrical energy into mechanical energy.

The formula of efficiency is;

$$\text{Efficiency, } \eta = \frac{P_{out}}{P_{in}} \quad (2.1)$$

where,

$$P_{out} = \frac{2\pi \cdot \omega \cdot \tau_{out}}{60}$$

$$P_{in} = V_L \cdot I_L$$

$\eta$  : Efficiency

$P_{out}$  : Output power (W)

$P_{in}$  : Input power (W)

$\tau_{out}$  : Output torque (Nm)

$\omega$  : Motor speed (rpm)

$V_L$  : Input voltage (V)

$I_L$  : Output current (A)

In this research, the efficiency will be optimized by using Nelder-Mead Method and Powell's Method. And get the minimum efficiency.

$$\text{Min efficiency} = \frac{1}{\eta} = \frac{P_{in}}{P_{out}} \quad (2.2)$$

## 2.5 Optimization

Optimization is in essence, a search for the best objective when operating within a set of constraints [9]. Optimization deal with finding the maxima and minima of a function that depends on one or more variables. The goal is to determine the values of the variables that yield maxima or minima for the function. These can then be substituted back into the function to compute its optimal values [7]. There are three major aspects of optimization which are identified as theory, algorithms and application [15]

## 2.6 Nelder-Mead method

The method is a pattern search that compares function values at the three vertices of a triangle. The worst vertex, where function is largest, is rejected and replaced with a new vertex. A new triangle is formed and the search is continued. The process generates a sequence of triangles (which might have different shapes), for which the function values at the vertices get smaller and smaller. The size of the triangles is reduced and the coordinates of the minimum point are found [8].

## 2.7 Powell's method

Let  $X_0$  be an initial guess at the location of the minimum of the function. Assume that the partial derivatives of the function are not available. An intuitively appealing approach to

approximating a minimum of the function is to generate the next approximation  $X_1$  by proceeding successively to a minimum of function along each of the  $N$  standard base vectors. The process generates the sequence of points and the coordinates of the minimum point are found [8].

## CHAPTER 3

### 3 METHODOLOGY

#### 3.1 Introduction

This chapter discuss on the method that will be used to achieve the objective of projects. Methodology is a part that will explain about the projectpath from the beginning until it is completed. Every selection and action that has been done while implementing the project must be explain in stages. The process involved through this project will be discussed in this chapter.

#### 3.2 Methodology Project

There are several phases or method to be used to achieve the objectives of the propose project. The first method is a literature review of the project. It is important to gain more information of the idea of this project. The related to the project is found from journals,

articles, books and internet. The second method is based on logical decision of Nelder-Mead method algorithm and Powell method algorithm.