# MODELLING DC MOTOR VARIABLES (VOLTAGE, TORQUE, EFFICIENCY) TO COMPARE BETWEEN NELDER-MEAD METHOD AND POWELL'S METHOD OF OPTIMIZATION

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**A report submitted in partial fulfillment**
**of the requirements for the degree in**
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"I declare that this report entitle "Modeling DC 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

The project was undertaken to find the optimum efficiency for the Compound Excited DC motor. Compound Excited DC motor is used as a model for this project because the type of motor is widely used in industries. In addition, another factor the project prompted to use the Compound Excited DC motors because is efficiency. However, we are as consumers will not know the range of independent variables for suitable used to obtain the optimum efficiency for Compound Excited DC motors. Because of that, this project will be tried to find the suitable range of the torque and input voltage to generate a maximum efficiency of the Compound Excited DC Motor. To obtain optimum efficiency for DC motor, the project will use two methods of Numerical Optimization such as Nelder-Mead method and Powell's method. Finally, both of these methods will be compared in the efficiency and accuracy. As conclusion for this research, the range of voltage and torque for minimum efficiency compounded excited DC motor will be obtained. For the Nelder Mead Method, the range is 171.88V and 0.45Nm will be generating minimum efficiency 0.0156 equal to 64.1% for compounded excited DC motor. However for Powell's method is more better because the minimum efficiency obtained is 0.01379766 equal to 72.5% by using range 154.915V and 0.41Nm

# ABSTRAK

Projek ini dilaksanakan adalah untuk mencari kecekapan yang optimum untuk motor arus terus. Motor arus terus digunakan sebagai model untuk projek ini kerana ia merupakan sejenis motor yang banyak digunakan di industri. Selain itu juga faktor lain yang mendorong projek untuk menggunakan motor arus terus adalah kerana kecekapan motor tersebut. Walaubagaimanapun, kita sebagai pengguna tidak akan dapat mengetahui julat pemboleh ubah yang sesuai untuk digunakan bagi mendapatkan kecekapan yang baik untuk motor arus terus. Disebabkan itu, projek ini ini akan cuba mencari julat yang sesuai untuk daya kilas, $\tau$ dan arus voltan, $V_{in}$ sebagai pemboleh ubah bebas.untuk mendapatkan kecekapan yang optimum untuk motor arus terus. Projek ini akan menggunakan dua kaedah "Numerical Optimization" iaitu Nelder Mead method dan kaedah Powell's .Dimana, kedua-dua kaedah ini akan dibandingkan dalam usaha untuk mendapatkan anggaran kecekapan yang lebih baik dan tepat. Kesimpulannya, kajian ini adalah bertujuan untuk mendapatkan julat yang sesuai bagi menjana kecekapan motor yang maksimum. Bagi kaedah "Nelder Mead Method" julat yang diperolehi ialah 171.88V dan 0.45Nm dan mendapati kecekapan minimum sebanyak 0.0156 bersamaan kecekapan maksimum sebanyak 64.1% untuk compounded excited DC motor. Walaubagaimanapun, kaedah powell's adalah lebih baik kerana ia jumlah kecekapan minimum diperolehi adalah 0.013797676 bersamaan 72.5% kecekapan maksimum.

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# CHAPTER 1

# 1 INTRODUCTION

## 1.1 Project overview

For this research, the compound excited DC motor (Appendix A1) have been used. The rated value for this compound excited DC motor is 220V, 1.1kW, 0.24A and 60Hz. The compound excited DC motor is the best connection. It is because, the connection of the armature and field winding in a shunt and a series combination to give it characteristic of both a shunt and a series DC motor [1]. This motor is used when both a high starting torque and good speed regulation is needed. Other than that, the connection type also will be effect to the efficiency of motor.

The efficiency will give the impression of how efficiently a motor in converting electrical energy into mechanical energy. In general, the output power of a motor is less than the input power due to the loss inherent in the motor. Part of the power will be lost through the loss of eddy current, hysteresis, the armature reaction, winding resistance and mechanical losses due to friction and air resistance [2]. However, this losses factor will not affect to the objectives of the research, this term for engineering field research. The focus

of this research is to find the highest efficiency of a compound DC motor using numerical optimization methodology.

Optimization has a necessary part of design activity in all disciplines. Especially in engineering field, the optimization can give an initial overview of a product or system to produce economic output quality. Other than that, it can facilitate us to improve our system or product with a synergistic thrust through inexpensive computational resource [3]. Even without significant products, ideas optimization provides the ability to define and explore problems while focusing on solutions to some measure of usefulness. Generally, the optimization use for reflect the best results for a product or system.

Optimization is frequently to associate its design, to be a product or system. In mathematics, computational science, or management science, mathematical optimization (alternatively, optimization or mathematical programming) refers to the selection of a best element from some set of available alternatives [4]. Actually, Optimization is deal to finding the maxima and minima of a function that depends on one or more variables. These can be substituted back into the function to compute its optimal values [5]. The methods of finding a local minimum for several independent variables have been devised by Nelder Mead Method and Powell's Method [6].

The purpose for this research is to obtain the minimum $(\frac{1}{\eta})$ of DC motor with use torque, $\tau$ and voltage, $V$ as independent variables by using two methods of optimization process. So by this way, we can determine the range of the torque and voltage that suitable to achieve an optimum efficiency. Indirectly, it can reduce the cost in terms of electricity usage. Actually the usages of electric motor in the world already convert about 70% of the word energy. Any improvement can give impact in efforts of conserving and reducing the operating cost.

## 1.2 Problem Statement

At most on DC motor, the power between input and output is not exacly similar. That is reason, why this reseach propose is to optimize effeciency of DC motor parameters especially to get a proper output power, $P_{out}$ and input power, $P_{in}$. To optimize the number of system manually, should be taking a long time and many steps to follow. So, to apply the numerical optimization process, a system can be optimized more easily and accurately.

## 1.3 Objectives

1) To obtain the maximum efficiency of Compound Excited DC motor.
2) To compare the two methodology are used.

## 1.4 Project Scopes.

For this project, we will use a compound DC motor with the rate values of the motor are 220V, 1.1kW, 60nM and 0.24A. The brand of compound excited DC motor is De Lorenzo motor. We will use the Machine Electrical Lab 1 (Universiti Teknikal Malaysia Melaka, UteM) to do the experiment. In the experiment, we will collect the data computed by MATLAB and Microsoft Excell. The result will be use in MATLAB simulation to get the minimum surface for torque, $\tau$ and input voltage, $V_{in}$.

# CHAPTER 2

# 2 LITERATURE REVIEW

## 2.1 Introduction

In this chapter, the variety of sources such as journals, article reviews and other research material used to get an idea of the scenes of the project, the concept and related information with it. In addition, this chapter also shows the other projects that have been done by the previous person which is correlated with this research. It is very important to enhance the understanding of this project as well as making this project functioning.

## 2.2 Literature survey

Based on the previous research, optimization has become a necessary part of design activity to developed some product or system. Tajjudin. M, Ishak.N, Ismail.H, Rahiman M.H.F and Adnan.R applied the optimization process to optimize the PID controller using nelder mead method. In this research, they want to improve the performance of electro-hydraulic position control. The first step that has be they do is to do experiments for

finding the appropriate number of variables to make the system more stable. After researchers get the sample data, they will be computing the data with using the Nelder-Mead methodology based on the programing language in MATLAB tool [7]. Besides that, this method also has been used by Chen W.C and Tzou.Y.Y in term to optimize the efficiency of controller DC motor but what the difference is this paper utilizes the current-control scheme to improve the current response and remove the current spike at the beginning and ending each commutation cycle.

For this research, the propose is to obtain the sample data based on the experiment for compound excited DC motor. After the sample data is obtained, this project will use Nelder-Mead method and Powell's method algorithm to compute the data.

### 2.2.1 DC Motor

There are three types of connections used for DC electric motors: series, shunt and compound. This connection type is to configure how the field and the motor armature windings are connected together. This type of connection is important because it determines the characteristics of a suitable motor for the rateable load [9]. Based on the three types of direct current motor connections, connections compound the best connection. It is because, the connection of the armature and field winding in a shunt and a series combination to give it characteristic of both a shunt and a series DC motor [4]. This motor is used when both a high starting torque and good speed regulation is needed [1].

As we know the efficiency is the ratio between output power and input power $\eta = \frac{P_{out}}{P_{in}}$. Parameters that will be affecting to the power output and power input are torque, current, voltage and angular velocity. Because of that, this research proposed to use the efficiency as independent variables. Other than that, this research will be set the value torque and voltage as independent variables [2]. The equation state below will show that, how the torque and voltage parameter will be effect the efficiency.

As we know that the efficiency can be calculated by;

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{2.1}$$

Where the output power can be calculated by;

$$Pout = \frac{2\pi \times \omega_m \times \tau}{60}(W) \tag{2.2}$$

And the input power can be calculated by

$$P_{in} = V \times I_{in} \tag{2.3}$$

Where,

$\omega_m$: $angular\ velocity(rpm)$

$\tau = torque$

$V = inputvoltage\ for\ DC\ motor$

$I_{in} = amature\ current\ of\ DC\ motor\ \times shunt\ excitation\ current\ of\ the\ DC\ motor.$

So, based on the equation (1.1) and (1.2) when the values of torque, $\tau$ and voltage, $V$ are varied, it will be affect to the output power $P_{out}$ and input power $P_{in}$. From this way, we can control the power output $P_{out}$ to approach the DC motor input power $P_{in}$. When the output power, $P_{out}$ become more closely with input power, $P_{in}$, the efficiency will be become a better

However, in this optimization method, we need to find the minimum efficiency, so that

$$Min\ \frac{1}{\eta} = \frac{P_{in}}{P_{out}} = \frac{V \times I \times 60}{2\pi \times \omega \times \tau} \tag{2.4}$$

### 2.2.2 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 point, is rejected and replaced with a new vertex. A new triangle is generates and the search is continued. The process will be 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 lastly the coordinates of the minimum point are can be found [6].

#### 2.2.2.1 Initial Triangle BGW

Assume the function $f(x, y)$ is to be minimized. We need to start with a three vertices of a triangle: $V_k = (x_{k,} y_k)$ where the range of $= 1, 2, 3$ . The function $f(x, y)$ is then evaluated at each of the tree points: $\eta_k = f(x_{k,} y_k)$ for $k = 1, 2, 3$. After that the function will be reordered, so that $z_1 \leq z_2 \leq \cdots \leq z_n$. We assume the function as

$$B = (x_1, y_1), \qquad G = (x_2, y_2) \qquad W = (x_3, y_3) \tag{2.5}$$

Where;

B= the best vertex G=the good vertex( next to best) W=worst vertex.

#### 2.2.2.2 Midpoint of the good side

To find the midpoint of the line segment from $B\ to\ G$, we are used by found the averaging the coordinates:

$$M = \frac{B + G}{2} = (\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2})$$

(2.6)

#### 2.2.2.3 Reflection Using the point R

When we move along the side of the triangle from $W\ to\ B$, the function will be decreases and also happen when we move along the side from $W\ to\ G$. The test point $R$ will be obtained by "reflecting" the triangle. To determined R, we need to find the midpoint $M$ of the side$BG$. After that, we need to drag the line segment from $W\ to\ M$ and it's called as length, $d$. These last segments drag a distance, $d$ through $M$ to locate the point $R$ (Appendix A 2). The vector formula for R is

$$R = M + (M - W) = (2M - W)$$

(2.7)

#### 2.2.2.4 Expansion using the point $E$.

Sign of, we have moved in the correct direction is the value at $R$ is smaller than the function value at $W$. After that, the line segment trough $M$ and $R$ will be extend to the point $E$. This point will be generate a new triangle, $BGE$. The point $E$ will be found with moving an additional distance, $d$ along the line joining $M$ and $R$ (Appendix A 3). If the function value at $E$ is less than the function value at $R$, we need to obtain the better vertex than $R$. The point $R$ can be calculated by:

$$E = R + (R - M) = 2R - M$$

(2.8)

#### 2.2.2.5 Contraction using the point C

Another point must be tested when the function value of $R$ and $W$ are the same. Let two midpoints $C_1$ and $C_2$ of the line segment $WM$ and $MR$, respectively (Appendix A 4). The smaller function is called $C$, and the new triangle will be produced.

#### 2.2.2.6 Shrink toward B

If the function value at $C$ is bigger than the value at $W$, the points $G$ and $W$ must be shrunk toward B(appendix A 5). The point $G$ will be replace by $M$, and $W$ is replaced by $S$, which is the midpoint of the line segment joining $B$ with $W$.

#### 2.2.2.7 Logical Decision for Each Step

If is needed a computationally efficient algorithm should perform function evaluations. In each step, a new vertex is found, which is the new point will be replaces$W$. As soon as it is found, further investigation is not needed, and the iteration step is completed

### 2.2.3 Powell's Method

Let X0 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 X1 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 [6].

### 2.2.4 MATLAB

MATLAB is used to compute the data after the sample data is obtained. MATLAB is actually a standard tool for fundamental courses in mathematics, engineering and science. In industry, it is a famous tool selected for the research, development and analysis. MATLAB function is to translate the algorithms into code functioning, the fraction of the time required in other languages such as C Optimization Toolbox provides widely used algorithms for standard optimization. These algorithms will be solving constrained and unconstrained continuous and discrete problems [3]. The toolbox includes functions for linear programming, quadratic programming, binary integer programming, nonlinear optimization, nonlinear least squares, systems of nonlinear equations, and multi-objective optimization. MATLAB also can use find optimal solutions, perform trade off analyses, balance multiple design alternatives, and incorporate optimization methods into algorithms and models.

# CHAPTER 3

# 3 METHODOLOGY

## 3.1 Introduction

The overview of methodology and approach projects is discribed in this chapter. The planning and steps have been proposed and the information gathered to produce the necessary steps then to achieve the project objectives.

## 3.2 Reseach Activities Overview

This research is conducted to identify the maximum efficiency of a direct current motor in the electrical machines Lab 1 (Universiti Teknikal Malaysia Melaka, UTeM). As we know, the efficiency of the motor has been influenced by life expectancy, how the motor is used at certains time. Furthermore, the parameters used in this motor should be appropriately. Because of that, the purpose of this study is to obtain maximum efficiency of a direct current motor by determining the suitable values of a torque and current based on its ability. After receiving the data from experiment in the laboratory, the analysis will

be done to get the efficiency of the compound DC motor. The reseach procedure of the proposed is depicted in Figure 3.1.