CONTROLLING VARIABLES DATA BY USING THE FIRST-ORDER MODEL OF RESPONSE SURFACE METHODOLOGY

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Bachelor of Electrical Engineering

June 2012

"I hereby declare that I have read through this report entitle "Controlling Variables Data by Using The First-Order model of Response Surface Methodology" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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June, 2012

I declare that this report entitle "Controlling Variables Data by Using the First-Order model of Response Surface Methodology" 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 : .....

Student's Name : Ahmad Afiq Hassan

Date : 27/6/12

To my beloved father,

Hassan b Abd Jalil,

My lovely mother,

Wan Lijah Bt Wan Long,

Brothers and Sister,

Friends,

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ABSTRACT

Polymers insulators that used in outdoor electric power transmission are exposed to outdoor environmental contaminations include rain, humidity, pressure, and light that will cause the degradation of the insulator surface caused by leakage current that flow on the surface of insulator for a long period with large magnitude. The analysis is focused on the harmonics that occur from the waveforms because the changing of the variables. The signal of Total Harmonic Distortion as dependent variable can be analyzed and minimized by using the first-order model of Response Surface Methodology by controlling three variables which are flow rate, conductivity and voltage supply. The collected data will be computed in Design Expert software. Statistical techniques together with good engineering knowledge usually lead to sound conclusion. Linear model for the THD response was successfully developed and the model was validating by generated sixteen samples that were examined. By applying this methodology, the minimum value of THD was obtained by controlling these three independent variables.

The minimum values of each factor are 3ml/s for flow rate of water, 300Ω/m for conductivity of water and 3kv for voltage supply. The analysis shows that the best value of THD for the first-order model response is 37.8637. Data that have been collected was been analyzed by using the first-order model of Response Surface Methodology. Finally, this result from the analysis of THD can be used to improve the outdoor insulation for future installation.

ABSTRAK

Polimer penebat yang digunakan dalam penghantaran kuasa elektrik luar yang terdedah kepada pencemaran luar alam sekitar seperti hujan, kelembapan, tekanan, dan cahaya akan menyebabkan degradasi pada permukaan penebat yang disebabkan oleh kebocoran arus yang mengalir di atas permukaan penebat untuk tempoh yang lama dengan magnitud yang besar. Analisis adalah lebih tertumpu kepada harmonik yang berlaku dari bentuk gelombang kerana perubahan pembolehubah. Isyarat Penyelewengan Jumlah Harmonik sebagai pembolehubah bersandar boleh dianalisis dan diminimumkan dengan menggunakan model pertama dalam Response Surface Methodology dengan mengawal tiga pembolehubah iaitu kadar aliran air, kekonduksian air dan bekalan voltan. Data yang dikumpul akan dianalisis dalam perisian Design Expert. Teknik statistik bersama-sama dengan pengetahuan kejuruteraan yang baik biasanya membawa kepada bunyi kesimpulan. Model linear untuk tindak balas THD telah berjaya dikeluarkan dan model telah mengesahkan oleh janaan 16 sampel yang di analisis. Dengan menggunakan kaedah ini, nilai minimum THD telah diperolehi dengan mengawal ketiga-tiga pembolehubah bebas.

Nilai minimum setiap masing-masing ialah faktor 3ml/s bagi kadar aliran air, 300Ω/m untuk kekonduksian air dan 3kv untuk bekalan voltan. Analisis menunjukkan bahawa nilai terbaik THD untuk sambutan model tertib pertama adalah 37,8637. Data yang telah dikumpul telah dianalisis dengan menggunakan model pertama dalam Response Surface Methodology. Akhirnya, keputusan ini THD boleh dimulakan dan dilaksanakan untuk kebaikan bahan penebat.

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THD	-	Total Harmonic Distortion
ATH	-	Alumina Trihydrate
RSM	-	Response Surface Methodology
f	-	Flow rate of water
δ	-	Conductivity of water
v	-	Voltage supply

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CHAPTER 1

INTRODUCTION

1.1 Background

Since long time ago the world used glass and porcelain insulators in the name ceramic insulators. These insulators are used in high voltage transmission lines since last quarter of 18th century. These insulators are the only type of insulator that has been used before the introduction of newer insulators. The terms of newer insulators refer to insulators that made up from organic polymer materials and these types of insulators have been commercially about 30 years ago and nowadays as know as polymer insulators [1].

Today, polymeric insulation materials have to suffer some degradation mechanisms throughout their service life. There are many factors that cause aging and degradation process on insulator such as humidity, pollution, high temperature, high pressure, rain, etc. One of the main reasons that cause failure in high voltage systems is surface tracking on the insulator. Surface tracking will produce leakage current. If the leakage current with large magnitude flow on the insulator surface for a long time, it can cause degradation of the insulator surface. The magnitudes of harmonic content of leakage current were analyzed. By using Total Harmonic Distortion, the harmonic content of the leakage current will be quantified [2], [3].

The type of insulator that will be using is made of from composition of sea shell ($CaCO_3$), glass and polymer or as known as Artificial Wollastonite ($CaSiO_3$). This type of insulator containing Alumina Trihydrate (ATH) that will improve dielectric strength and tracking resistance that is good material for the insulator.

The analysis is focused on the harmonics that occur because of the changing of the variables. The signal Total Harmonic Distortion can be analyzed by using the first-order model of Response Surface Methodology.

The purpose of the analysis is to find the minimum Total Harmonic Distortion as a dependent variable by controlling three variables which are voltage supply, flow rate and conductivity as independent variables.

1.2 Problem Statement

Polymer insulation materials have to suffer some degradation mechanisms throughout their service life. The degradation will cause the insulator having aging by different environmental effects include rain, pollution, humidity, etc. By controlling independent variables which are voltage supply, flow rate and conductivity, the insulator can be analyzed to sustain for a long period by determine the minimum Total Harmonic Distortion as a dependent variable of the waveform.

1.3 Objectives of Project

- To find the minimum of Total Harmonic Distortion (THD) by controlling in independent variables.
- Data analyzing by using the first-order model of Response Surface Methodology.
- The minimum of Total Harmonic Distortion result can be applied to produce a good quality of insulator material.

1.4 Scope of Project

The insulator will be tested by controlling the three variables which are voltage supply, flow rate and conductivity. These data experiment will show the distortion waveform which are evaluated into Total Harmonic Distortion. By using the first-order of Response Surface Methodology, the minimum Total Harmonic Distortion can be obtaining.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is covering about the variables parameters, the first-order model of Response Surface Method processed by Design Expert.

2.2 The Variables Parameters

There are three main factors that accelerate the degradation process on the insulator. By assuming the pressure, humidity and temperature as constant (room condition), the three independent variables that need to be control are flow rate, voltage supplied and conductivity. Total Harmonic Distortion will become the dependent variable for this analysis that came from the data of the experiment.

There are the ranges of independent variables that need to be controlled on the insulator to get the minimum Total Harmonic Distortion.

2.3 Response Surface Method and Designs

Response Surface Methodology is a collection of mathematical and statistical techniques useful for the modeling and analysis of problems in which a response of interest is

influenced by several variables. The method of Least Square is used to estimate the parameters in the approximating polynomials.

The response surface analysis is then performed using fitted surface. If the fitted surface is an adequate approximation of the true response function, then analysis of the fitted surface will be approximately equivalent to analysis of the actual system. The model parameters can be estimated most effectively if proper experimental design is used to collect the data [4], [5]. For example, the growth of a vegetable is affected by a certain amount of water x_1 and sunshine x_2. The vegetable can grow under combination of treatment x_1 and x_2. Therefore, water and sunshine can be controlled continuously. When treatments are from a continuous range in values, then the Response Surface Methodology is useful for developing, improving, and optimizing the response variable. In the case, the vegetable growth y is the response variable and it is a function of water and sunshine. It can be expressed as

$$y = f(x_1, x_2) + e \tag{2.1}$$

The variables x_1 and x_2 are independent variables where the response y depends on them. The term y as the dependent variable is a function of x_1, x_2 and e as the experimental error. The error can be understood as any measurement error on the response.

After collected the data of experiment, the Method of Least Square is used to estimate the parameters in the polynomials and this response surface analysis is performed by using the fitted surface.

There are two goals for Response Surface Method which are to find the optimum response and to understand how the response changes in a given direction by adjusting the design variables [6]. This response surface can be visualized graphically. Furthermore, this graph is useful to understand the shape of a response surface, hills, valleys, and ridge lines.

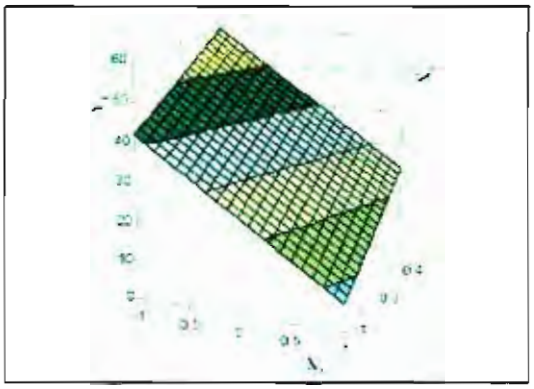

Figure 2.1 Response surface plot

This figure show the function of $f(x_1, x_2)$ be plotted versus the levels of x_1 and x_2. Each value of x_1 and x_2 generates a y-value.

2.4 2^k Factorial Design

For three independent variables, the design will be 2^3. So the total of sample is 8 samples.

Let f = Flow rate of water, δ = Conductivity of water and v = Voltage supply. The table of 2^3 design will be shown as in table below:

Table 2.1: Table of 2^3 Factorial Design

Treatment Designing	**THD_i**
f =low, δ =low, v =low	THD_1
f =low, δ =low, v =high	THD_2
f =low, δ =high, v =low	THD_3
f =low, δ =high, v =high	THD_4
f =high, δ =low, v =low	THD_5
f =high, δ =low, v =high	THD_6
f =high, δ =high, v =low	THD_7
f =high, δ =high, v =high	THD_8

2.5 Analysis of Variance (ANOVA)

An ANOVA is an analysis of the variation that present in an experiment. It is a test of the hypothesis that the variation in an experiment is no greater than due to normal variation of individuals' characteristics and error in their measurement.

The tables of ANOVA below show the data that we get from the equation before and how the data fix in this table.

Table 2.2: Table of ANOVA

Source of Variation	**Sum of Squares, SS**	**Degrees of Freedom, df**	**Mean Square, SS/df**	**F_o**
f	SS_f	1	$\mathrm{MS_f} = SS_f$	$\mathrm{MS_f}/\mathrm{MS_E}$
B	SS_δ	1	$\mathrm{MS}_\delta = SS_\delta$	$\mathrm{MS}_\delta/\mathrm{MS_E}$
v	SS_v	1	$\mathrm{MS_v} = SS_v$	$\mathrm{MS_v}/\mathrm{MS_E}$
Error	$\mathrm{SS_{Error}}$	$2^3(n-1)$	$\mathrm{MS_E} = \frac{\mathrm{SS_{Error}}}{8(n-1)}$	-
Total	$\mathrm{SS_{Total}}$	$2^3(n-1)$	$\frac{\mathrm{SS_{Total}}}{8n-1}$	-

Where;

$$SS_f = \frac{1}{8n}[(a-1)(b+1)(c+1)]^2 \quad (2.2)$$

$$SS_\delta = \frac{1}{8n}[(a+1)(b-1)(c+1)]^2 \quad (2.3)$$

$$SS_v = \frac{1}{8n}[(a+1)(b+1)(c-1)]^2 \quad (2.3)$$

$$SS_{Model} = SS_f + SS_\delta + SS_v \quad (2.4)$$

$$SS_{Total} = \sum_{j=1}^{8} \sum_{k=1}^{n} \left[T_{jk}{}^{2} - \frac{[(1)+a+b+c]^2}{4n} \right] \quad (2.5)$$

$$SS_{Error} = SS_{Total} - SS_{Model} \quad (2.7)$$

$$R^2 = \frac{SS_{Model}}{SS_{Total}} = 1 - \frac{SS_{Error}}{SS_{Total}} \quad (2.8)$$

The error sum of squares SS_{Error} is a measurement of the amount variation explained by the regression, the smaller the SS_{Error}, the better the regression model.

The estimated model fits the data can be measured by the value of R^2. The R^2 lies in the interval [0,1]. When R^2 is closer to the 1, will be better to estimate the regression equation fits in sample data.

2.6 Multiple-Regression Model

Regression model is known as the relationship between a set of independent variables and the response y is determined by a mathematical model [4]. The term multiple-regression refers to independent variables that have more than two. A multiple-regression model with q independent take a form of

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots\ldots\ldots\ldots \beta_q x_{iq} + e_i \quad (2.9)$$

$$= \beta_0 + \sum_{j=1}^{q} \beta_j x_{ij} + e_i$$

$$(i = 1,2, \ldots\ldots, N)$$

$$(j = 1,2, \ldots\ldots, q)$$

where $n > q$. The parameter β_j measured the expected change in response y per unit increase in x_i when the other independent variables are held constant. The i^{th} observation and j^{th} level

of independent variable is donated by x_{ij}. Table 3.1 is shown the data structure for the multiple-regression model:

Table 2.3 Data for Multiple-Regression Model

Y	x_1	x_2	...	x_q
y_1	x_{11}	x_{12}	...	x_{1q}
y_2	x_{21}	x_{22}	...	x_{2q}
.	.	.	...	.
.	.	.	...	.
.	.	.	...	.
y_n	x_{n1}	x_{n2}	...	x_{nq}

These can be write in matrix form as;

$$y = X\beta + e \tag{2.10}$$

Where

$$\mathbf{y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}_{(nX1)} \quad \mathbf{X} = \begin{bmatrix} 1 & x_{11} & x_{12} \cdots & x_{1q} \\ 1 & x_{21} & x_{22} \cdots & x_{2q} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} \cdots & x_{nq} \end{bmatrix}_{(nX\bar{k})} \quad \mathbf{ß} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_q \end{bmatrix}_{(\bar{k}X1)} \quad \mathbf{e} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}_{(nX1)}$$

y is an (n X 1) vector of observations, X is an (n X k) matrix of levels of independent variables, β is a (k X 1) vector of regression coefficients and e is an (n X 1) vector of random error [5].