"I hereby declare that I have read through this report entitle "Modeling Variables By Using Blocking Of Response Surface Methodology (RSM)" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automtion)".

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MODELING VARIABLES BY USING BLOCKING OF RESPONSE SURFACE METHODOLOGY (RSM)

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This report is submitted in Partial Fulfilment of Requirements for the Degree of Bachelor in Electrical Engineering (Control, Instrumentation & Automation)

Faculty of Electrical Engineering

UNIVERSITY TEKNIKAL MALAYSIA MELAKA

JUNE 2012

"I hereby declare that is report entitle "Modeling Variables by Using Blocking of Response Surface Methodology (RSM)" is the result of my own work except as cited in the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

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To my beloved mother and father
Nik Azanis Binti Nik Yusof and Nik Mahadi Bin Nik Mahmood
In appreciation of supported and understanding.

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ABSTRACT

This research is about the study of behaviour of total harmonic distortion (THD) as a dependent variable in leakage current (LC) which is depend on three independent variables which are water flow rate (f), water conductivity (δ), and voltage applied (V) to the specimen insulator. The purpose is to acquire the minimum THD of LC using blocking model in Response Surface Methodology (RSM). The independent variables are varied such as V at 3 kV and 4 kV, f at 3 ml/s and 6 ml/s and lastly δ at 300 Ω/m and 400 Ω/m. After all the data have been collected, they will be analyzed by using blocking model of RSM in Design Expert in order to obtain the minimum THD. After the analysis have been done, the minimum THD can be predicted from 37.97 until 43.30 inside the 95% of confidence interval where all the independent variables are minimum. Also, it is showed that the THD is reduced with the used of increasing conductivity and flow rate but decreasing of voltage

ABSTRAK

Penyelidikan ini adalah mengenai kajian terhadap tingkah laku jumlah gangguan harmonik (THD) di dalam kebocoran arus elektrik (LC) yang mana bergantung kepada tiga pembolehubah yang saling tidak bergantungan iaitu kadar pengaliran air (*f*), kekonduksian air (δ) dan juga voltan (V) yang dibekalkan terhadap specimen penebat. Ini bertujuan untuk mendapatkan THD yang minimum di dalam LC dengan menggunakan model penyekatan di dalam metodologi tindak balas permukaan (RSM). Pemboleh ubah yang saling tidak bergantungan ini berubah iaitu V pada 3 kV dan 4 kV, *f* pada 3 ml/s dan 6 ml/s, dan yang akhir sekali iaitu δ pada 300 Ω/m dan 400 Ω/m. Setelah kesemua data telah dikumpulkan, analisis akan dilakukan dengan menggunakan model penyekatan di dalam metodologi tindak balas permukaan dengan menggunakan perisian Design Expert bagi mendapatkan nilai THD yang minimum. Setelah analisis dijalankan, didapati bahawa nilai THD minimum berada di antara 37.97 sehingga 43.30% di dalam 95% lingkungan kepastian (CI) sekiranya semua pembolehubah yang tidak bersandaran adalah minimum. Analisis juga menunjukkan bahawa THD boleh dikurangkan dengan adanya kenaikan nilai *f* dan δ tetapi berkurang sekiranya ada kenaikan di dalam V.

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CHAPTER 1

1 INTRODUCTION

High voltage (HV) insulators are used in transmission and distribution lines to separate electrical conductors from towers. Polymeric composite type insulators are widely used in electrical supply and distribution lines in numerous countries in the world. This type of insulators have many advantages compared to the conventional porcelain and glass type. The advantages cover weight reduction, higher mechanical resistance, higher electrical resistance in rainfall and dirt conditions, lower costs of transport and installation on electrical supply lines [1]. The prices of the composite insulators are competitive compare with conventional glass or porcelain ones [2].

However, when insulators are exposed to the difficult environments such as coastal and industrial for a long period they may get polluted with salt deposits or other industrial dusts. Under high humidity and light rainy conditions the layers become comparatively wet and conductive causing flow of leakage current (LC) along the surface of the insulator. The development of LC leads to the flash over event which short circuits the line and towers [3]. Thus in High Voltage (HV) insulation test, LC measurement can provide information about the surface condition of insulators. Numerous studies have been conducted which carried out with pollution and contamination flashover, and the results have shown that LC is a good way to determine insulator surface condition [4]. The sample of insulator's leakage current (LC) waveform and the Total Harmonic Distortion (THD) correspond well with degree of ageing. The distortion of the LC occurs when there are some values of harmonics that should not be there. The THD can be explained by using formula of Fourier Series and Parseval Theorem [2],[3],[A2],[A3],[A4],[A5].

In this case, the type of insulator that will be analyzed in this area was the type of PP10 insulator which made from polymer. Certain test and analysis will be caried out for minimizing the THD of LC in HV insulator which depend on three parameters such as water flow rate, water conductivity and lastly voltage supplied to the sample. In this research, Blocking model of Response Surface Design will be used.[7],[8]

1.1 Problem statement

In this research, it is found that breakdown analysis is not enough to determine either the insulator is best or not. This is because the leakage current of the insulator need to be considered. Therefore, THD of leakage current produced which depend on three kind of independent variable such as the water conductivity, water flow rate, and then the voltage supplied to the testing insulator will be analyzed. The insulator will be better if the minimum value of THD is obtained.

1.2 Objective

The objectives of the research are:

a) To modeling the behavior of THD of leakage current which is depend on three variables which are water flow rate, water conductivity and voltage applied to the specimen insulator using Design Expert 7.
b) To determine the minimum THD produced in order to determine the quality of the insulator.
c) To analyze the data obtained by using the blocking model of RSM.

1.3 Scope

This project can only be done inside the High Voltage Laboratory of UTeM where we will observe and analyze the behavior of THD of voltage which depend on three independent variable such as the water flow rate, water conductivity and voltage supplied to the tested insulator. The testing sample was the fragment of high voltage insulator which made from the polymer which called as type PP10 insulator.

CHAPTER 2

2 LITERATURE REVIEW

2.1 LC Measurement

There are sixteen sample of PP10 insulator will be tested by using LC measurement. The LC measurement will be carried out by contaminating and wetting the sample through the flowing solution of distilled water (H_2O) and Ammonium Chloride (NH_4Cl) with certain conductivity and flow rate on the surface of the sample. Meanwhile, the high voltage will be applied at the two end point of the insulator to produce the LC. NH_4Cl is used to manipulate the conductivity of water while the water flow rate is controlled by using infusion pump. Also, the voltage is controlled by using voltage transformer. Two water conductivity levels, two levels of water flow rate and two stages of test voltages will be applied in order to find their relationship towards the response of THD produced in LC. In this experiment, there are two levels of the water conductivities which are 300Ω/m and 400Ω/m, two levels of water flow rate which are 3ml/s and 6ml/s, and the two levels of applied voltage at 3kV till to 4kV. Note that the water conductivity (δ), water flow rate (*f*) and voltage applied (V) are independant to each other while THD is depend to these 3 parameters. Therefore, the independant variables will be δ, *f* and V and the dependant variable will be THD.

2.2 Modeling Response Surface Using 2^k Factorial

2.2.1 2^k Factorial Design

There are three independant variables. Then the table will have 2^3design as shown below:

Table 2.1: Table of 2^3 Factorial Design

Treatment Designing	THD
V low, δ low, *f* low	THD_1
V low, δ low, *f* high	THD_2
V low, δ high, *f* low	THD_3
V low, δ high, *f* high	THD_4
V high, δ low, *f* low	THD_5
V high, δ low, *f* high	THD_6
V high, δ high, *f* low	THD_7
V high, δ high, *f* high	THD_8

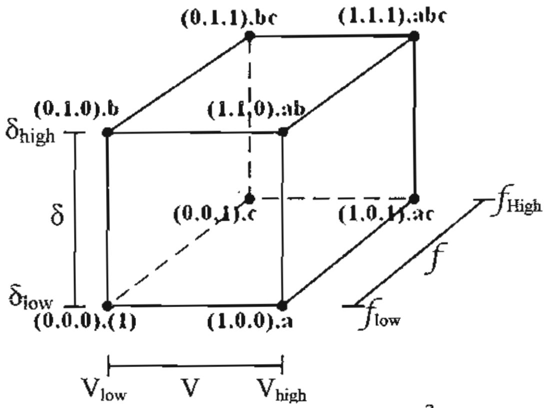

Figure 2.1: Geometric View of 2^3 Factorial Design

2.3 Analysis of Variance (ANOVA)

Table 2.3: Table of ANOVA

Source of Variation	Sum of Squares, SS	Degrees of Freedom, df	Mean Square, SS/df	F_o
V	SS_V	1	$MS_V = SS_V$	MS_V/MS_{Error}
δ	SS_δ	1	$MS_\delta = SS_\delta$	MS_δ/MS_{Error}
f	SS_f	1	$MS_f = SS_f$	MS_f/MS_{Error}
Vδ	$SS_{V\delta}$	1	$MS_{V\delta} = SS_{V\delta}$	$MS_{V\delta}/MS_{Error}$
δf	$SS_{\delta f}$	1	$MS_{\delta f} = SS_{\delta f}$	MS_{BC}/MS_{Error}
Vf	SS_{Vf}	1	$MS_{Vf} = SS_{Vf}$	MS_{Vf}/MS_{Error}
$V\delta f$	$SS_{V\delta f}$	1	$MS_{V\delta f} = SS_{V\delta f}$	$MS_{V\delta f}/MS_{Error}$
Error	SS_{Error}	$2^3(n-1)$	$MS_{Error} = \frac{SS_{Error}}{8(n-1)}$	-
Total	SS_{Total}	2^3n-1	$MS_{Total} = \frac{SS_{Total}}{8n-1}$	-

Where:

n = number of repeatition

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

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

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

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

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

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

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

$$SS_{Model} = SS_V + SS_\delta + SS_f + SS_{V\delta} + SS_{\delta f} + SS_{Vf} + SS_{V\delta f}$$

$$SS_{Total} = \sum_{j=1}^{8}\sum_{k=1}^{n} T_{jk}{}^2 - \frac{[(1)+a+b+c+ab+bc+ac+abc]^2}{8n}$$

$$SS_{Error} = SS_{Total} - SS_{Model}$$

The further information about the *contrast* can be refered to Appendix 1

$$R^2 = \frac{SS_{Model}}{SS_{Total}} = 1 - \frac{SS_{Error}}{SS_{Total}} \tag{2.1}$$

The quality of the data can be measured by the value of R^2 which lies between interval of 0 and 1. When R^2 is closer to the 1, the estimation of regression equation will be more better.

2.4 The Regression Model & Response Surface

Coded Variables Equation:

$$x_1 = \frac{V - V_{low}}{V_{high} - V_{low}}$$

$$x_2 = \frac{\delta - \delta_{low}}{\delta_{high} - \delta_{low}}$$

$$x_3 = \frac{f - f_{low}}{f_{high} - f_{low}}$$

By using the Coded Variables equation, the independant variables will be coded as 0 and 1. This is because there are only 2 levels of independant variables were used which is high and low. Therefore, the regression analysis will be simple and more easier.

The Main Effect Model:

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{\epsilon} \tag{2.2}$$

Where:

$$\boldsymbol{y} = \begin{bmatrix} \mathrm{THD}_1 \\ \mathrm{THD}_2 \\ \mathrm{THD}_3 \\ \mathrm{THD}_4 \\ \mathrm{THD}_5 \\ \mathrm{THD}_6 \\ \mathrm{THD}_7 \\ \mathrm{THD}_8 \end{bmatrix}$$

$$\boldsymbol{X} = \begin{bmatrix} 1 & x_{i1} & x_{i2} & x_{i3} & {x_{i1}}^2 & {x_{i2}}^2 & {x_{i3}}^2 & x_{i1}x_{i2} & x_{i1}x_{i3} & x_{i2}x_{i3} \\ & & & & & \vdots & & & & \\ 1 & x_{81} & x_{82} & x_{83} & {x_{81}}^2 & {x_{82}}^2 & {x_{83}}^2 & x_{81}x_{82} & x_{81}x_{83} & x_{82}x_{83} \end{bmatrix}$$

$$\boldsymbol{\beta} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_{11} \\ \beta_{22} \\ \beta_{33} \\ \beta_{12} \\ \beta_{13} \\ \beta_{23} \end{bmatrix}$$

The Fitted Regression Model:

$$\widehat{\boldsymbol{y}} = \boldsymbol{X}\widehat{\boldsymbol{\beta}} \tag{2.3}$$

Where:

$$\widehat{\boldsymbol{\beta}} = (\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{X}'\boldsymbol{y} = \begin{bmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \hat{\beta}_2 \\ \hat{\beta}_3 \\ \hat{\beta}_{11} \\ \hat{\beta}_{22} \\ \hat{\beta}_{33} \\ \hat{\beta}_{12} \\ \hat{\beta}_{13} \\ \hat{\beta}_{23} \end{bmatrix}$$

2.5 Blocking In Response Surface Design

In response surface design, blocking is used to eliminate the nuisance variable. A response surface design can be blocked orthogonally if it is divided into blocks as long as the blocks didn't affect the parameter estimates of the RSM. For a second order design, if there are n_b observation in b_{th} block, the 2 condition term must be followed as below [7],[8]:

1. Each block must be a first order orthogonal design which:

$$\sum_{u=1}^{n_b} x_{iu}x_{ju} = 0 \quad (2.4)$$

$i \neq j = 0, 1, \ldots, k$ for all b

Where x_{iu} and x_{ju} are the level of i_{th} and j_{th} level variables in u_{th} runs of the experiment with $x_{0u} = 1$ for all u.

2. The ratio of sum of squares of each variables contributed in each block must be equal to ratio of the total observation that occur in the block which is :

$$\frac{\sum_{u=1}^{n_b} x_{iu}^2}{\sum_{u=1}^{N} x_{ju}^2} = \frac{n_b}{N} \quad (2.5)$$

$i = 1, 2, \ldots., k$ for all b

N =Number of runs in designs

In general, the central composite design can always be constructed to block orthogonally in two blocks with the first block consist of n_F factorial points plus n_{CF} center points and the second block consisting of $n_A = 2k$ axial points plus n_{CA} center points. The first condition for orthogonal blocking will always hold regardless of the value used for α in the design. For the second condition to hold [7],[8],

$$\frac{\sum_{u=1}^{n_2} x_{iu}^2}{\sum_{u=1}^{n_1} x_{iu}^2} = \frac{n_A + n_{CA}}{n_F + n_{CF}} = \frac{2\alpha^2}{n_F} \quad (2.6)$$

and

$$\alpha = \sqrt{\frac{n_F(n_A + n_{CA})}{2(n_F + n_{CF})}} \quad (2.7)$$

If the design also required spherical or rotatable, then:

$$\alpha = (n_F)^{\frac{1}{4}}$$

and

$$(n_F)^{\frac{1}{2}} = \alpha^2 = \frac{n_F(n_A + n_{CA})}{2(n_F + n_{CF})}$$

There are another two important points that need to be considered which is about the analysis of variance during blocking. First is about the use of center points to calculate an estimate pure error. Only center point that is run in the same block can be replicates so the pure error can be calculated between each block. If the variability across the blocks is consistence, then these pure error estimates can be put together. The second point is about the block effect. If the design block is orthogonally in m blocks, the sum of squares for blocks is [7],[8]:

$$SS_{Blocks} = \sum_{b=1}^{m} \frac{{B_b}^2}{n_b} - \frac{G^2}{N} \qquad (2.10)$$

B = Sum of n_b observations in the b_{th} block

G = Sum of all N observations in all m blocks.

2.6 THD as The Independent Variable

The sample of insulator's leakage current (LC) waveform and the Total Harmonic Distortion (THD) correspond well with degree of ageing. The distortion of the LC occurs when there are some values of harmonics that should not be there. In order to obtain the smoother LC, we need to minimize the THD by controlling 3 independent variables. For further information about the THD, please refer to Appendix 2 until Appendix 5.

CHAPTER 3

3 METHODOLOGY

The methodology of the project is simplified in the flow chart below:

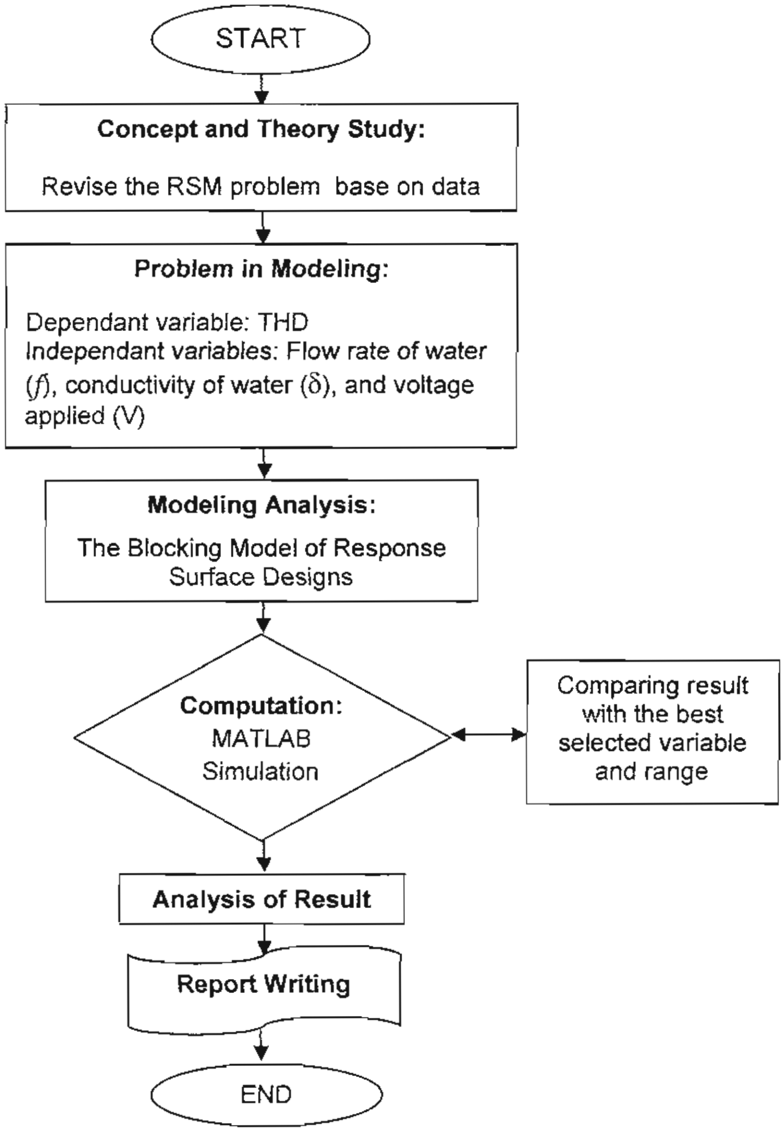

Figure 3.1: Methodology Flow Chart