# VOLTAGE VARIATION SOURCE IDENTIFICATION SYSTEM


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**VOLTAGE VARIATION SOURCE IDENTIFICATION SYSTEM**

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**DECLARATION**

I declare that this thesis entitled "VOLTAGE VARIATION SOURCE IDENTIFICATION SYSTEM" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ----------------------------------------

Name : ----------------------------------------

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## APPROVAL

I hereby declare that I have checked this report entitled "voltage variation source identification system" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ..........................................................

Supervisor Name : ..........................................................

Date : ..........................................................

**DEDICATIONS**

To my beloved mother and father

## ACKNOWLEDGEMENTS

Alhamdulillah. I am greatly indebted to Allah on His mercy and blessing for making this research successful

Secondly, I wish to express my sincere appreciation to my supervisor, PM. Ir. Dr. Abdul Rahim Abdullah for his encouragement, guidance and valuable advices, without his continued support and interest, this thesis would not have been the same as presented here. Besides that, I would like to express my thankfulness to the technical staff of the Research Laboratory of Advance Digital Signal Processing (ADSP) for their assistance and opinion while performing the work of the research.

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# ABSTRACT

In this report, the power quality (PQ) disturbance which is the voltage variations consist of voltage swell, sag and interruption are model and analyse. Different types of voltage variations PQ disturbances models are developed and created by using MATLAB/Simulink. The Simulink model are display in terms of time-frequency representation (TFR). The Simulink models include shutting down enormous capacities from system to resemble voltage swell, large loads energizing and three-phase fault to simulate voltage sag as well as implementing permanent three-phase fault to simulate voltage interruption. The signals generated are analysed by using linear time-frequency distribution (TFD). The signal parameters such as root mean square voltage (Vrms), total harmonic distortion (THD) and power value are estimated from the TFR to identify the characteristics of the voltage variation. The results of analysis on the PQ disturbance waveforms generated are identical to the actual real-time PQ signals and the models can be modified to any desired situation respectively. The PQ waveforms obtained are suitable to be further analysed.

# *ABSTRAK*

Dalam laporan ini, gangguan kualiti kuasa (PQ) yang merupakan variasi voltan yang terdiri daripada pembengkokan voltan, kekacauan dan gangguan adalah model dan analisis. Jenis-jenis variasi voltan yang berbeza PQ gangguan model dibangunkan dan dibuat dengan menggunakan MATLAB / Simulink. Model Simulink dipaparkan dari segi perwakilan frekuensi masa (TFR). Model Simulink termasuk menutup kapasiti besar dari sistem untuk menyerupai pembengkakan voltan, beban besar yang bertenaga dan kesalahan tiga fasa untuk mensimulasikan bebola voltan serta melaksanakan kesalahan tiga fasa tetap untuk mensimulasikan gangguan voltan. Isyarat yang dihasilkan dianalisis dengan menggunakan pengedaran frekuensi masa linear (TFD). Parameter isyarat seperti voltan kuasa min (Vrms), jumlah penyelewengan harmonik total (THD) dan nilai kuasa dianggarkan dari TFR untuk mengenal pasti ciri-ciri variasi voltan. Hasil analisa pada bentuk gelombang gangguan PQ yang dihasilkan adalah sama dengan isyarat PQ masa nyata sebenar dan model-model boleh diubah suai ke mana-mana keadaan yang dikehendaki masing-masing. Borang gelombang PQ yang diperoleh adalah sesuai untuk dianalisis selanjutnya.

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| PQ | - | Power Quality |
| TFR | - | Time-Frequency Representation |
| TFD | - | Time-Frequency Distribution |
| THD | - | Total Harmonic Distortion |
| RMS | - | Root-Mean-Square |
| ADSP | - | Advance Digital Signal Processing |
| AC | - | Alternative Current |
| IEEE | - | Institute of Electrical and Electronics Engineers |
| IEC | - | International Electrotechnical Commission |
| FFT | - | Fast Fourier Transform |
| GUI | - | Graphical User Interface |
| STFT | - | Short-Time Fourier Transform |
| SLG | - | Single Line-to-Ground |

# LIST OF APPENDICES

## CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Power quality (PQ) of the power system has become a major concern for consumers at all levels of use, as the impacts and losses caused by the quality of power cannot be ignored. The term power quality is the blend of voltage and current quality, yet the union point is presently centered around the nature of the supply voltage, since just the power framework itself can control the nature of the voltage. [1][2]. Various types of faults, improved nonlinear loads and power system operations often create disturbances in the power quality. Any voltage, current or frequency deviation that results in equipment failure or failure is a problem with power quality. [3][4][5]. Poor power quality can cause issues, for example, decrease the lifetime of the heap, insecurities and interferences underway and also deadly expenses because of downtime of the hardware as shown by IEEE Std. 1159-2009 [6][7]. It is imperative that unsettling influences inside the power framework are disposed of or decreased. So as to play out the power quality flag investigation technique, it is important to get an unmistakable perspective of the essential attributes of intensity quality and the parameters of every occasion. [8][9].

This report inspects voltage variety, which incorporates voltage droop, swelling and intrusion in the substance of intensity quality aggravations and outlines their parameters. Voltage hang can be created by short circuits in the transmission arrange, the beginning of extensive engine bundles or the exchanging activity with short supply disengagement.

Similarly, voltage swell can be caused by system failure, by exchanging a state on a large condenser bank or by switching off a large load on a power system. Voltage interruption is usually caused by permanent power failure [8][9][10][11][12].

Waveform perturbations of power quality can be artificially generated using software - based simulation models. Various types of simulation software can be used to model voltage variation events. The most widely used are ATP/EMTP, MATLAB/Simulink and PSCAD/EMTDC. In [13][14][15]16], the authors used PSCAD / EMTDC software to replicate the actual variation signals. However, the transfer of data to MATLAB software is necessary for further analysis. MATLAB / Simulink is one of the simulation devices for real time systems design and interpretation [17][18]. The Simulink tool stash can be utilized to show the power quality aggravations in real appropriation framework in adequate way [19]. This report presents re-enactment models in MATLAB/Simulink used to produce different sorts of voltage variety.

Numbers of techniques were discussed by research workers for analyzing power quality problems [20][21][22]. The spectrogram strategy is utilized in this answer to break down the aggravations by speaking to the procured flags as time recurrence portrayal (TFR). The parameters got from the model Simulink, for example, control, root-mean-square voltage (Vrms) and aggregate symphonious mutilation (THD), are then evaluated from the TFR and after that arranged.

## 1.2 Motivation

In this part stated why this research has been done. This research more refers to the voltage variation that's include voltage sags, voltage swells and interruption. Each type of voltage variation has their own characteristic and the cause for all of each type were different and the effect of the three variation also different that can be monitoring by signal processing techniques. The attraction to the voltage variation is that it's could determine the waveform that produce from voltage to analyses whether there is distortion or not in the waveform that can be display using the spectrogram.

This research has been done because the machine in the industry always breakdown without knowing the causes of the breakdown. The characteristics of the voltage variations can be used to identify the causes of the breakdown. That's why the analyzation of the signal has been done to reduce the breakdown of the machine and to find the causes of the breakdown using the voltage sags, voltage swells and interruption signal characteristics.

## 1.3 Problem Statement

There were many issues within the industry nowadays, the issue that have been produced will affect everything about the industry and will not be satisfied the consumer. One of the issues that always been disputed are the machine always breakdown without knowing the source of the breakdown and it is too hard to determine which one of the machines were breakdown. If the machine of the industry is breakdown it will affect everything such as slow down the work, the quality of the product will be worse and many others more.



A monitoring system is required to display the voltage variation of the machine in industry. It is important to monitoring the voltage variation of the machine of in industry which why if the breakdown occur it just only can be found by monitoring the machine in industry and can be classify without hesitation which machine were breakdown because the result that have been produced from monitoring the machine were accurate.

The signal processing method is required in analyzing the variation signals. The function to analyzing the signal so that it can be determined the source of the breakdown of the machine and the causes of the breakdown can be repair or can be prevent earlier before it happens.

## 1.4 Objective

The objectives of this research are:

- To analyze voltage variation signal using digital signal processing technique
- To classify voltage variation signals
- To evaluate the performance of the classification system

## 1.5 Scope

The scope for this research is the identification of voltage variation signal between:

- Voltage sags
- Voltage swells
- Interruption



The experimental for this research are by using the MATLAB/Simulink for the modelling then classify the signal using digital signal processing technique.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Introduction

This chapter will discuss about the voltage variation in the topic of power quality. Voltage variation is one of the power quality phenomena. There are 3 type of voltage variation according to power quality phenomena that is voltage sags, voltage swells and interruption. This chapter will explain briefly about the phenomena of each type.

### 2.2 Power Quality

The nature of power or just the nature of intensity incorporates voltage, recurrence and waveform. Great power quality can be characterized as a steady supply voltage inside the recommended AC extend. Recurrence near the evaluated esteem and smooth waveform of the voltage bend (like a sine wave). As a rule, it is helpful to consider control quality as the similarity between what results from an electrical outlet and the heap associated with it. The term is utilized to portray power that drives an electric charge and the correct working of the heap. An electrical gadget (or load) may glitch, bomb rashly or not work at all without the right power. There are various ways that power can be of low quality and a lot more reasons for such low quality. The power business includes power age (AC control), power transmission and at last power circulation to a power meter toward the end client 's premises. The power at that point travels through the wiring arrangement of the end client until the point when it achieves the heap. The framework's intricacy in moving power from the purpose of creation to the point of utilization, joined with varieties in climate, age, request and different variables, offers numerous chances to bargain the nature of the supply.

Despite the fact that control quality is a helpful term for many, the term really depicts the nature of the voltage instead of the power or electric flow. Power is basically the vitality stream and the current requested by a heap can't be controlled.

### 2.2.1 Definition of Power Quality

The electrical gear's capacity to utilize the vitality provided. There are various issues with power quality, including electrical music, poor power factor, voltage insecurity and a lop-sidedness in the productivity of electrical frameworks. This has various results, including expanded vitality utilization and costs, expanded upkeep expenses and shakiness and disappointment of hardware.

### 2.2.2 Power Quality Standards (IEEE)

Table 2.1: IEEE Standards of Voltage Variations

| Categories | Typical Duration | Typical Voltage Magnitude |
|---|---|---|
| Variations | | |
| 1.1 Instantaneous | | |
| 1.1.1 Sag | 0.5-30 cycles | 0.1-0.9 pu |
| 1.1.2 Swell | 0.5-30 cycles | 1.1-1.8 pu |
| 1.2 Momentary | | |
| 1.2.1 Interruption | 0.5 cycles-3 s | <0.1 pu |
| 1.2.2 Sag | 30 cycles-3 s | 0.1-0.9 pu |
| 1.2.3 Swell | 30 cycles-3 s | 1.1-1.4 pu |
| 1.3 Temporary | | |
| 1.3.1 Interruption | >3 s-1 min | <0.1 pu |
| 1.3.2 Sag | >3 s-1 min | 0.1-0.9 pu |
| 1.3.3 Swell | >3s-1 min | 1.1-1.2 pu |

### 2.3 Power Quality Phenomena

#### 2.3.1 Voltage Variation

The empowerment of substantial burdens requiring high beginning flows or irregular free associations in power wiring quite often cause voltage varieties. The deformity can cause impermanent voltage builds (swells), voltage plunges (droops) or a total loss of voltage (interferences) contingent upon the area of the imperfection and the framework conditions. The state of the blame can be close or remote from the focal point. In either case, the effect of the present blame condition on the voltage is a brief length variety. Changes in current qualities that fall into classes of span and greatness are likewise incorporated into transient variations.

##### 2.3.1.1 Voltage Sag

The voltage list is a momentary decline in the voltage of the Root-Mean-Square (RMS) between 10 percent and 90 percent, typically somewhere in the range of 0.5 and 10 cycles [23]. The terminology used to describe the voltage sag's magnitude is often confusing. A " 20 percent sag " may refer to a sag resulting in 0.8 pu or 0.2 pu voltage. When describing rms variations, the preferred terminology is retained voltage or the remaining voltage. Voltage sags are caused by short circuit miscues [8]. Voltage lists are generally identified with framework disappointments, yet can likewise be caused by substantial burdens or vast motors. Exchanging occasions on huge motors, jolt stroke and transmission disappointments can likewise prompt this issue. These occasions can prompt the shutdown of intensity plants and lead to misfortunes in influence plants [24][25]. Voltage drops can likewise be caused by vast changes in load or by the beginning of substantial motors. An acceptance engine can draw its full load current six to multiple times amid start-up.

This high current causes a voltage drop through the framework's impedance. On the off chance that the present extent with respect to the accessible framework blame current is substantial, the subsequent voltage outline might be noteworthy.

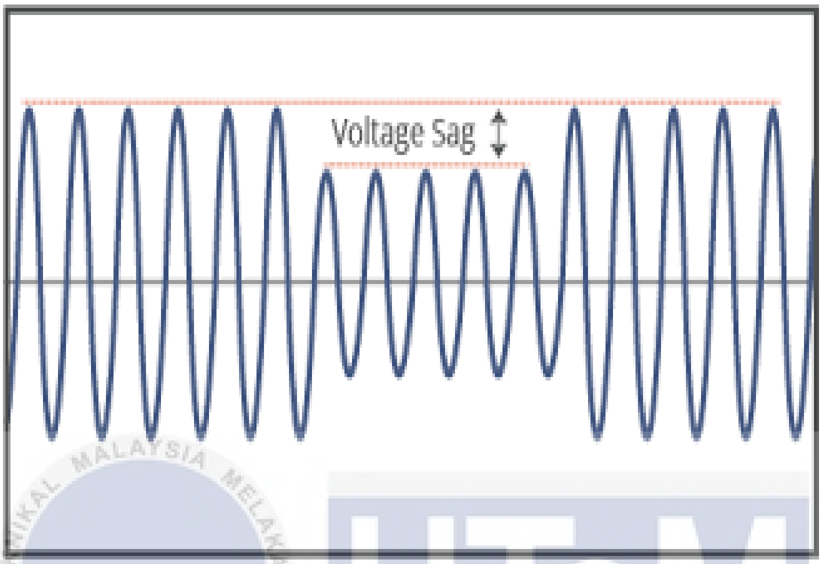


Figure 2-1: Voltage Sag

The term sag has for some time been utilized in the power quality network to depict a decrease in momentary voltage. The thought is clearly obtained straightforwardly from the word droop's exacting definition. Although not formally defined in the authoritative dictionary, the term used in the power quality community. Utilities, manufacturers and end - users have increasingly been accepted and used. In this phenomenon the IEC definition is dip. The two terms are viewed as exchangeable with list being favoured in the power quality network in North America.

### 2.3.1.3 Voltage Swells

The voltage swell is an increase in the RMS voltage from 1.1 per unit to 1.8 per unit, maintaining a period of 0.5 to 1 minute [23]. Typical magnitudes range from 1.1 pu to 1.2 pu. The magnitude of the swell is also described by the remaining voltage and therefore always exceeds 1.0 pu. The voltage swells also relate to the short circuit failures of the power system. Voltage swelling can be created by overloading and so on [18]. Swells are typically connected with framework disappointment conditions, similarly as with lists, however they are significantly less normal than voltage disappointments. A SLG disappointment on the framework can cause a swell, prompting a brief increment in voltage in the unfailing stages.

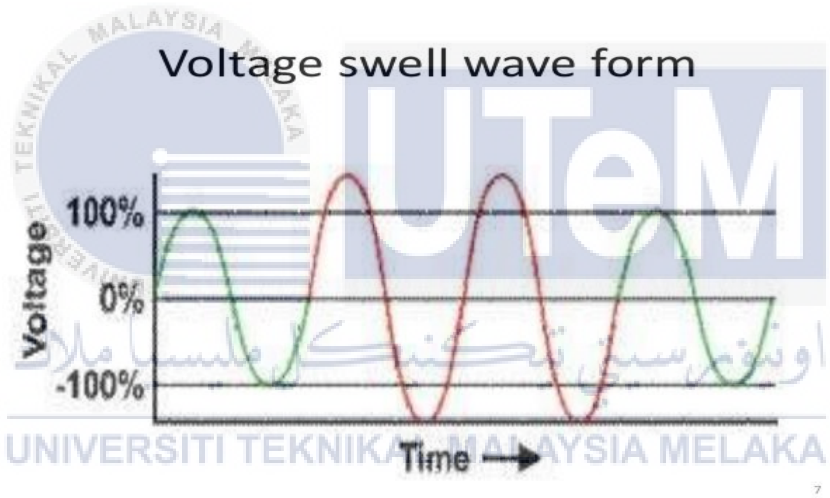


Figure 2-2: Voltage Swell

Swells have their greatness (rms esteem) and their term. The seriousness of a voltage swell amid an imperfection condition relies upon the area of the deformity, impedance of the framework and establishing. On an ungrounded framework, the line-to-ground voltages on the unfaulted stages will be 1.73 pu amid a line-to-ground blame condition. In the region of the substation on a proficiently grounded framework, there will be no voltage increment in the unfailing stages in light of the fact that the substation transformer is normally delta-wye associated and gives a low impedance zero-arrangement way for the blame current. Some of the time, the term impermanent overvoltage is utilized as an equivalent word for the term swell. The formal meaning of swell is a fleeting increment in power-recurrence voltage from the mains, outside typical resilience's, with a length of in excess of one cycle and not exactly a couple of moments. This definition isn't favoured by the power quality network.

#### 2.3.1.4 Interruption

Voltage interruption of a total supply voltage loss not exceeding 1 minute for a short time. Interruptions are due to transient mistakes [23][24]. Interruption might be caused by power framework disappointments, hardware disappointments and glitches in charge. The interferences are estimated by their length on the grounds that the voltage level is in every case under 10% of the ostensible voltage. The voltage extent is around 0 when a break happens. The causes might be a broken circuit or a breaker hole which makes the power framework lose significantly. Power system failures and failures of equipment are the consequences of interruptions [26]. The term of an interruption because of an imperfection in the utility framework is dictated by the defensive gadgets of the utility and the explicit occasion that causes the deformity. The length of an interference because of glitches of the gear or free associations can be uneven.

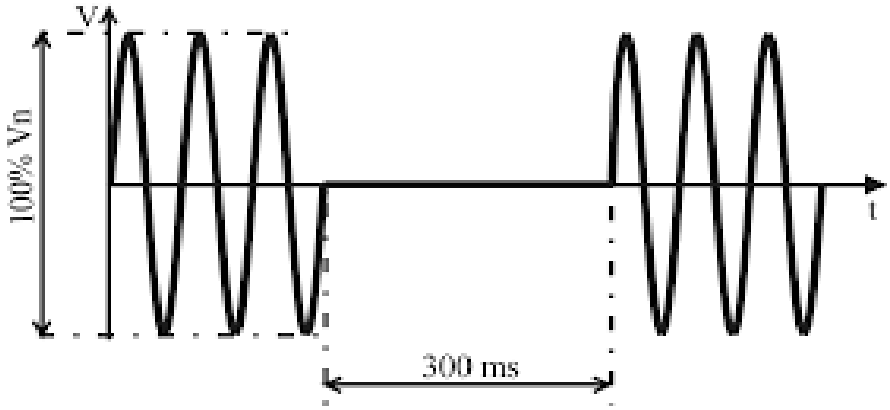


Figure 2-3: Voltage Interruption

A few interferences can be gone before by a voltage chart when these intrusions are caused by a source framework disappointment. The voltage switch happens between the time the deformity starts and the defensive gadget works. The heaps encounter a voltage droop on the fizzled feeder, pursued instantly by an intrusion. The span of the intrusion relies upon the defensive gadget's reclosing ability. Instant reclosure usually limits the interruption due to a non-permanent error to less than 30 cycles. Delayed protection device reclosure may cause a momentary or temporary interruption.

## 2.4 Summary

Table 2.2: Summary of Literature Review

| No. | Title | Objective | Methods | Limitation |
|---|---|---|---|---|
| 1 | A Comparative Modelling and Analysis of Voltage Variation by Using Spectrogram | To analyze the power quality disturbances created by mathematical model and Simulink model were close to the actual situation or not | Spectrogram | Their reliance on the parameters utilized and the working of squares in MATLAB Simulink to replicate the needed yield of the power quality circumstance |
| 2 | Power Quality Signals Classification System using Time-frequency Distribution | To identify and classify the signals for diagnosis purposes | Spectrogram | The framework is fit for estimating all standard electrical cable estimations, for example, voltage and flow in RMS esteem, recurrence, genuine power, responsive power, evident power and power factor which are additionally plotted in diagram. |
| 3 | Power Quality Signals Detection and Classification Using Linear Time Frequency Distribution | To ensure signal quality, reduces diagnostic time and rectifies failures. | Spectrogram Gabor Transform | Focuses on time frequency analysis techniques to analyse power quality problems |

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter will discuss about the procedure for this research. The section 3.2 will discuss about the power quality signal analysis that will analyses the signal have been produced. Section 3.3 will discuss about power quality signal modelling using MATLAB/Simulink for the analyzation of the signal. Section 3.4 will discuss about the fast fourier transform (FFT) that is analyzing using the spectrum. Section 3.5 discussing about the time-frequency distribution (TFD) on which techniques were used to analyses the signal. Section 3.6 will explain about the signal parameters that will be used for the analyzation of the signal. Section 3.7 and 3.8 will discuss about the signal characteristics and signal classifications. Section 3.9 will discuss about the system development. For the last part that is section 3.10, it's will show the flowchart of the project as the summary of the methodology



## 3.2 Power Quality Signal Analysis

The signal that have been produced will be analyses from stage to stage by following the flowchart in the Figure 3-1. By following the step from the flowchart, the signal that have been produced will be analyses accurately and the signal will classify at the end of the flowchart.

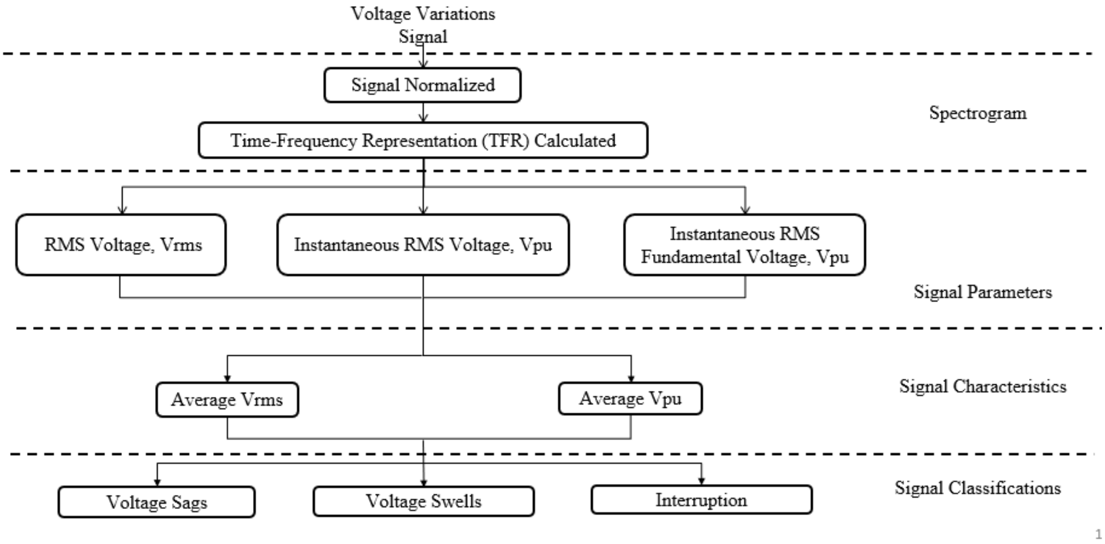


Figure 3-1: Flowchart of The Signal Analysis

## 3.3 Power Quality Signal Modelling

The model for each type has been modelling by using the MATLAB/Simulink. The model of each type has been modelling by following the characteristics of each type. Figure 3-2, Figure 3-3 and Figure 3-4 shows that the modelling of the voltage sags, voltage swells and interruption model to be used to analyses the signal that have been produced.



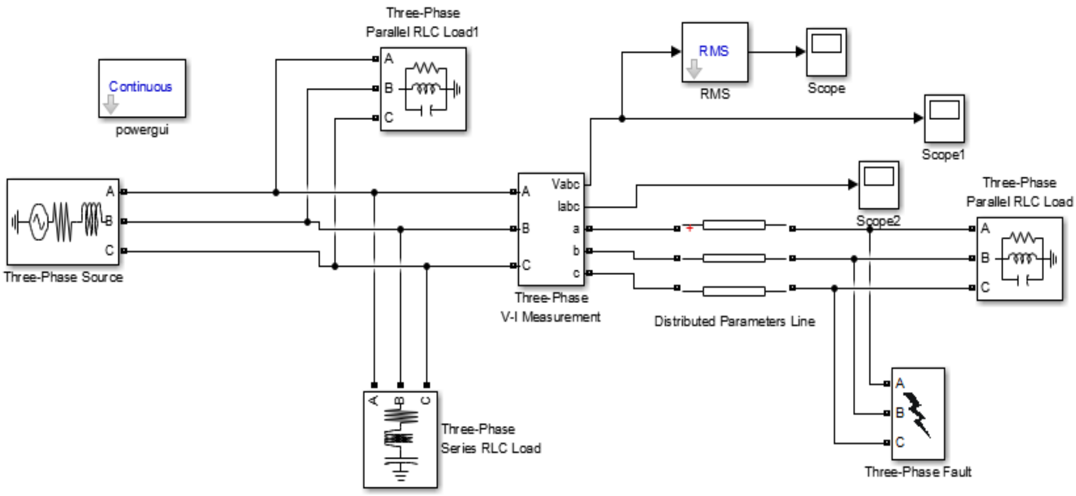


Figure 3-2: Voltage Sag Model

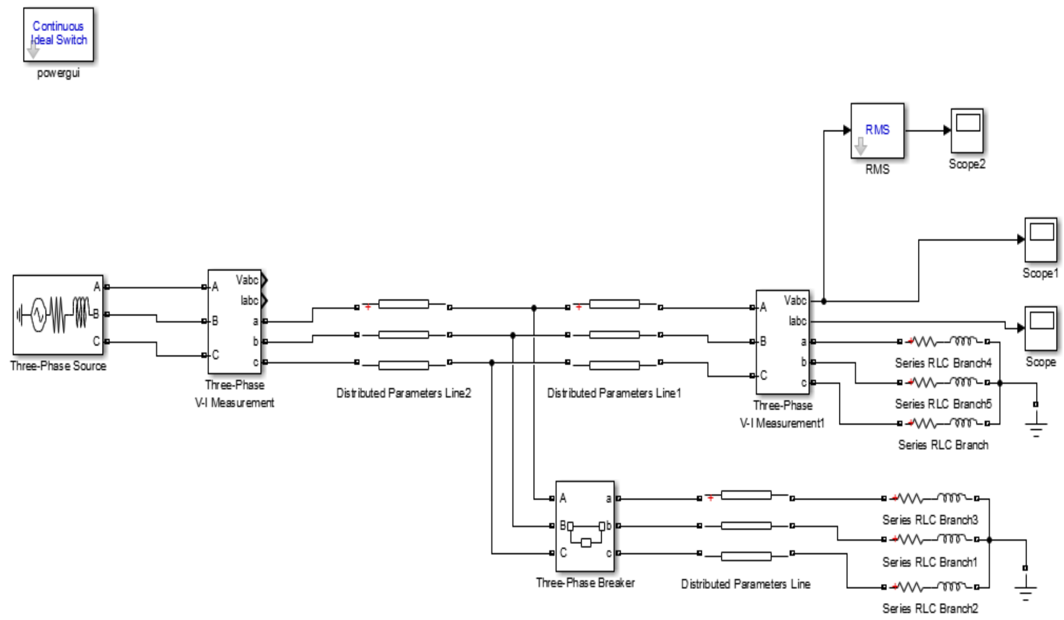


Figure 3-3: Voltage Swell Model



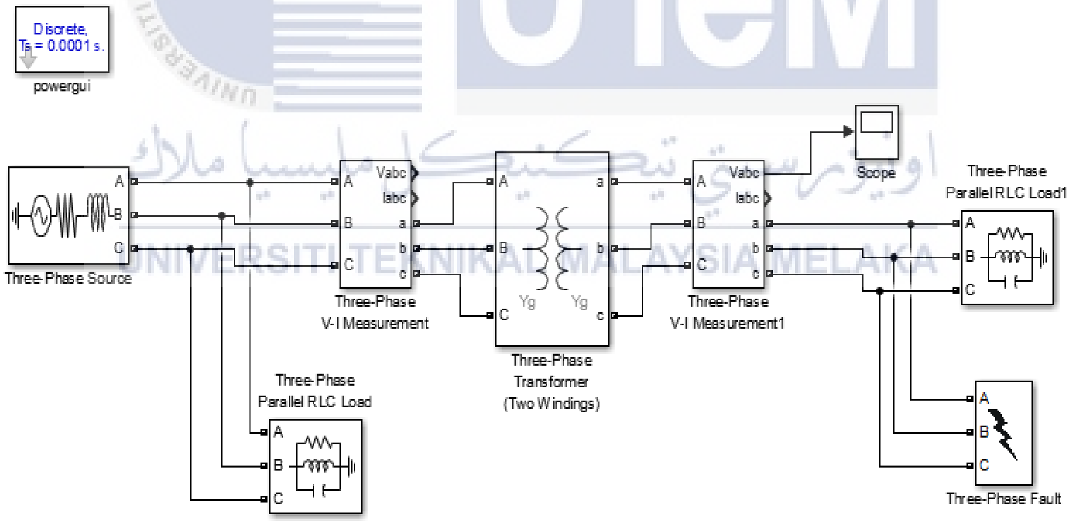


Figure 3-4: Voltage Interruption Model

### 3.4 Fourier Transform

Fourier transform is one of the techniques have been implemented to analyses the signal before using the time-frequency distribution (TFD) and develop the system. The Fourier transformation is a mathematical formula that relates a time or space sampled signal to the same frequency sampled signal. The Fourier transform can reveal important features of a signal in the processing of signals, namely its frequency components.

The equation for Fourier transform expressed by

$$x(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}\, dt \qquad (3\text{-}1)$$

### 3.5 Time-Frequency Distribution

#### 3.5.1 Spectrogram

The spectrogram includes a trade-off between time goals and recurrence goals. The time has come recurrence conveyances (TFD) that depicts the flag in time and recurrence portrayals [22]. It registers and shows square extent of STFT [10]. The condition can be expressed as:



$$S_v(t, f) = |\int_{-\infty}^{\infty} v(t)w(\tau - t)e^{-j2\pi f}\, dt| \qquad (3\text{-}2)$$

where *v(t)* is the input signal, *w(t)* is the observation window.

## 3.6 Signal Parameters

### 3.6.1 RMS Voltage

The estimation of RMS voltage will be determined to recognize the flag from the supply voltage. The RMS voltage, Vrms can be gotten from TFR and the condition can be expressed as:

$$V_{rms}(t) = \sqrt{\int_0^{f_{max}} P_x(t,f)\,df} \tag{3-3}$$

where $P_x(t, f)$ is the TFD, $f_{max}$ is the maximum interest frequency.

### 3.6.2 Instantaneous RMS Voltage

The instantaneous RMS Voltage is:

$$V_{rms}(t) = \sqrt{\int_0^{f_{max}} P_x(t,f)\,df} \tag{3-4}$$

where $P_x(t, f)$ is the time-frequency distribution and $f_{max}$ is the maximum frequency of interest.

### 3.6.3 Instantaneous RMS Fundamental Voltage

Instantaneous RMS fundamental voltage is defined as the RMS voltage at power system frequency. It can be calculated as:

$$V_{Irms}(t) = \sqrt{2\int_{f_{lo}}^{f_{hi}} P_x(t,f)\,df} \tag{3-5}$$

$$f_{hi} = f_1 + \frac{\Delta f}{2}, \quad f_{lo} = f_1 - \frac{\Delta f}{2} \tag{3-6}$$

Where $f_1$ is the fundamental frequency that corresponds to the power system frequency and $\Delta f$ is the bandwidth.

### 3.7 Signal Characteristics

Signal characteristics will be determined from the signal parameters that have been calculated from the equation. The value that have been calculated will be analyses by finding the average value of the Vrms and the value of the Vpu to classify the signal that have been produced.

### 3.8 Signal Classifications

The signal can be classified into each type by following the conditions of each type. The signal that have been calculated and analyses can be classified into three group that is voltage sags, voltage swells and interruption.



### 3.9 System Development

#### 3.9.1 Software Development

The software that have been used is MATLAB/Simulink and Visual Basic. The modelling from the MATLAB/Simulink will be analyses by using the system from the visual basic by using the Graphical User Interface (GUI) that will analyses the system in the software development. The Graphical User Interface (GUI) will be displayed on the screen of the computer.

## 3.10 Summary

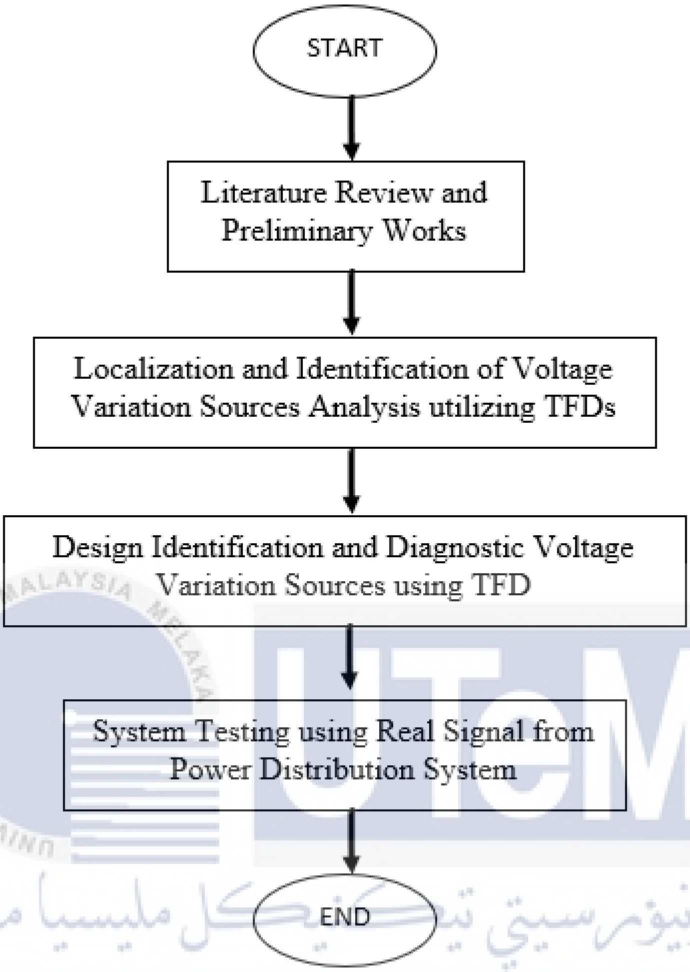




Figure 3-5: Project Flowchart

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Introduction

The chapter will discuss about the preliminary results that have been obtained, the result that have been obtained were refer on the classification of the voltage sags, voltage swells and interruption. It also shows the different between voltage sags, voltage swells and interruption.

## 4.2 Power Quality Signal Analysis, Detection and Classification System

The result that were obtained separate into 3 parts. The different of the result can be seen when the signal of the voltage sags, voltage swells and interruption were compared to the normal voltage 50 Hz sine waveform.



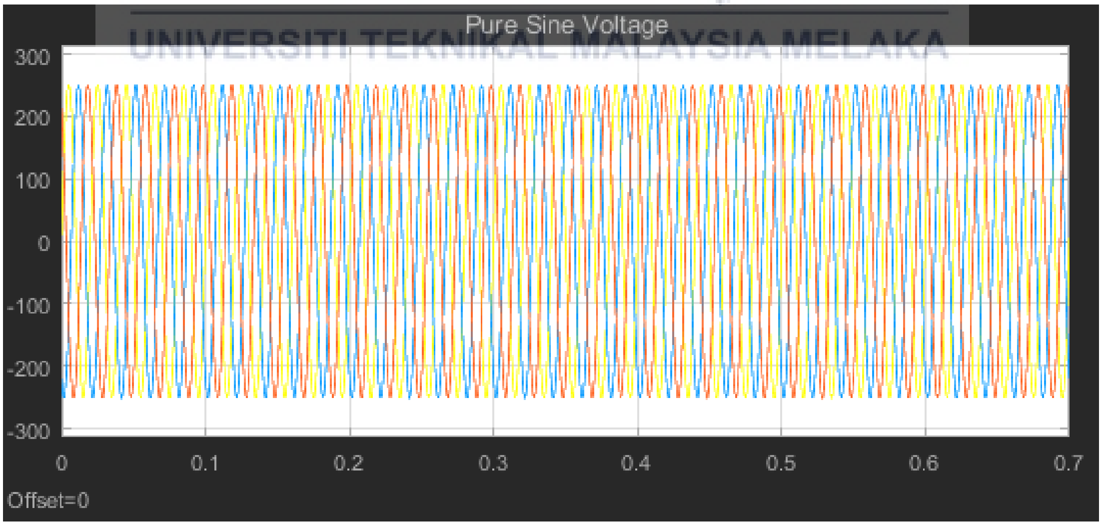


Figure 4-1: 3-Phase Normal Voltage Sine Waveform

Figure 4-1 shows that the waveform of the normal voltage sine waveform. There were no distortion or disturbances in the signal. The signal was fully stable when there is no disturbances or distortion.

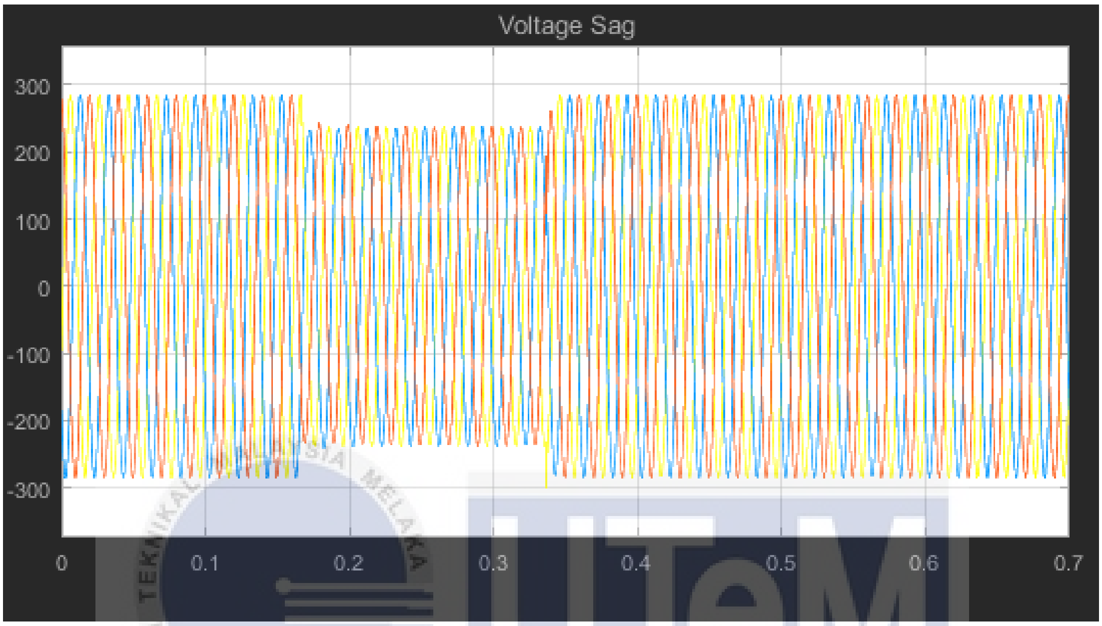


Figure 4-2: 3-Phase Voltage Sags Waveforms

Figure 4-2 shows that the waveform of the voltage sags. The signal was drop within a duration that causes of the large load that have been connected within the circuit breaker until it back to its steady state. Voltage sags will suddenly drop when the disturbances occur as has been shows in the figure above.

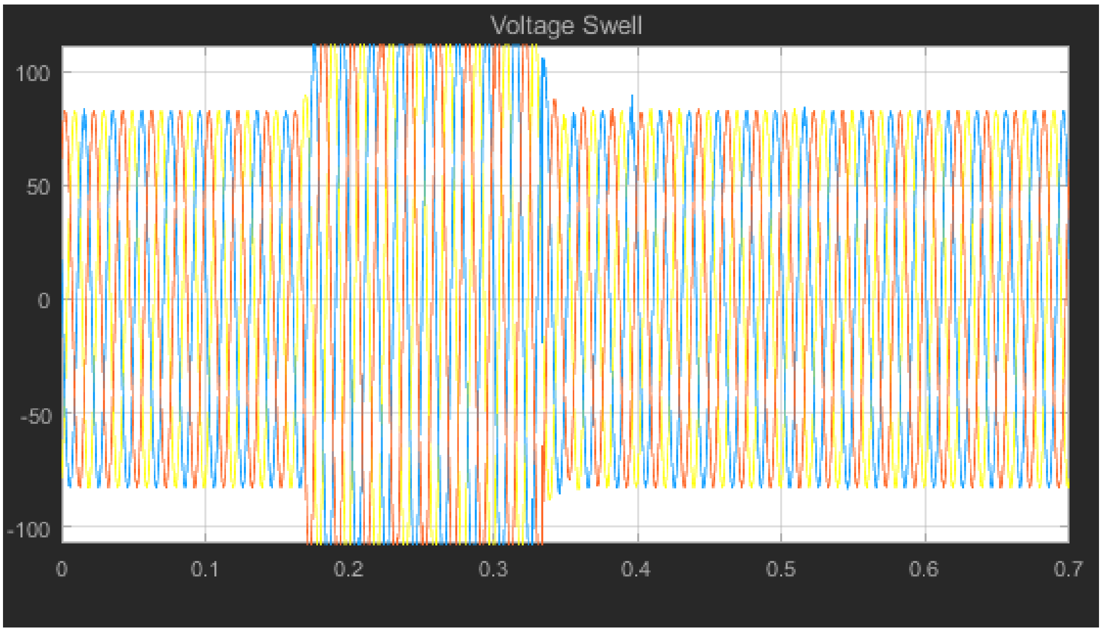


Figure 4-3: 3-Phase Voltage Swell Waveforms

Figure 4-3 shows that the waveform of the voltage swells. The signal was rises within a duration that causes from the unbalanced load fault or the load that have been removed. Voltage swells will rise suddenly when the disturbances occur.

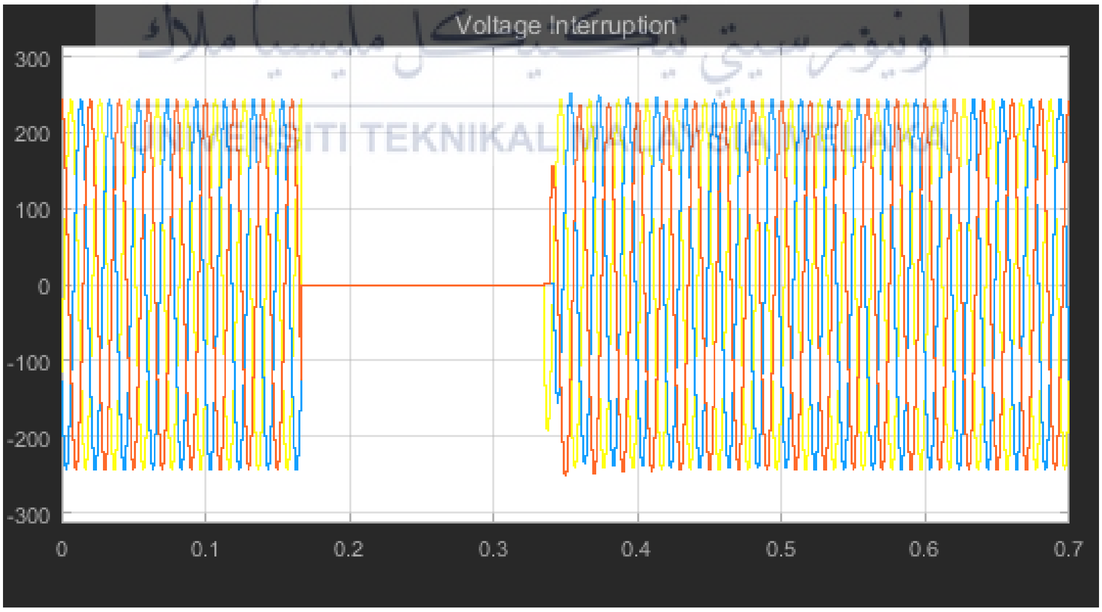


Figure 4-4: 3-Phase Voltage Interruption Waveforms

Figure 4-4 shows that the waveform of the interruption. The magnitude of the signal was approximately close to 0 within a duration when the interruption occurs. The voltage interruption is created due to permanent fault.

## 4.3 Voltage Signal

### 4.3.1 Voltage Sag

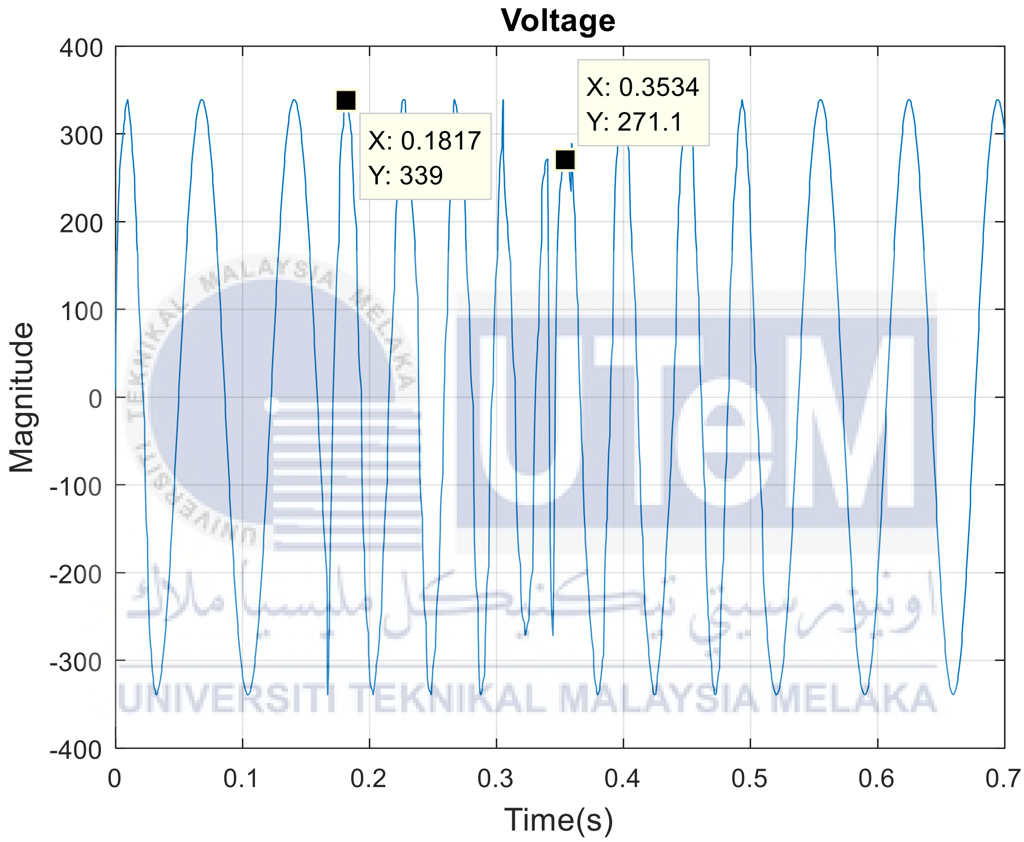


Figure 4-5: Phase 1 of Voltage Signal for Sag

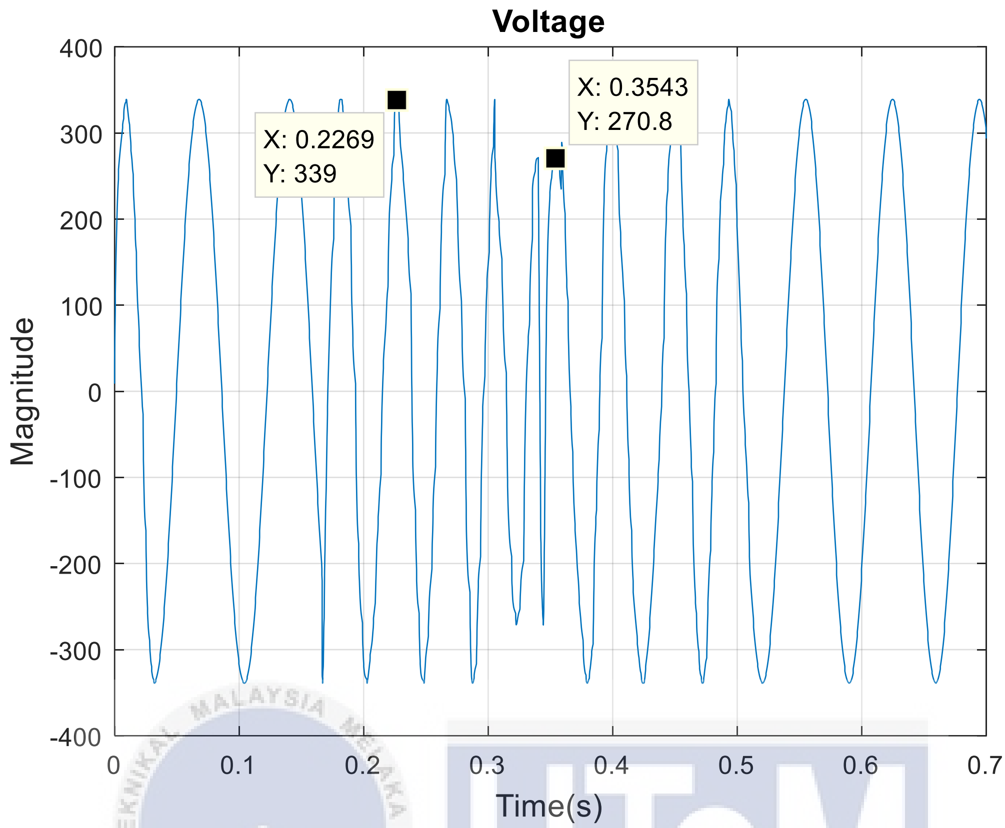


Figure 4-6: Phase 2 of Voltage Signal for Sag

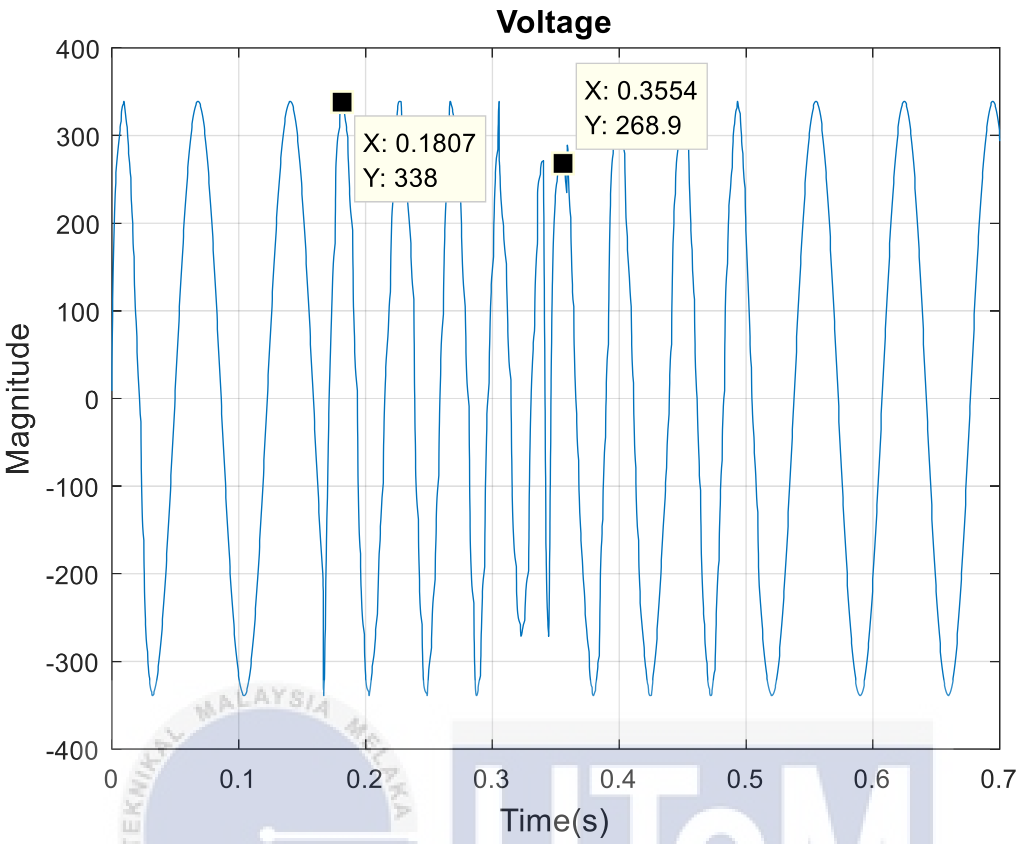


Figure 4-7: Phase 3 of Voltage Signal for Sag

Table 4.1: Average of Voltage Signal for Sag

| | Voltage | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Durations (s) | 0.09 | 0.09 | 0.09 |
| Without Disturbances (V) | 339 | 339 | 338 |
| With Disturbances (V) | 271.1 | 270.8 | 268.9 |
| Average Without Disturbances (V) | 338.67 | | |
| Average With Disturbances (V) | 270.27 | | |

### 4.3.2 Voltage Swell

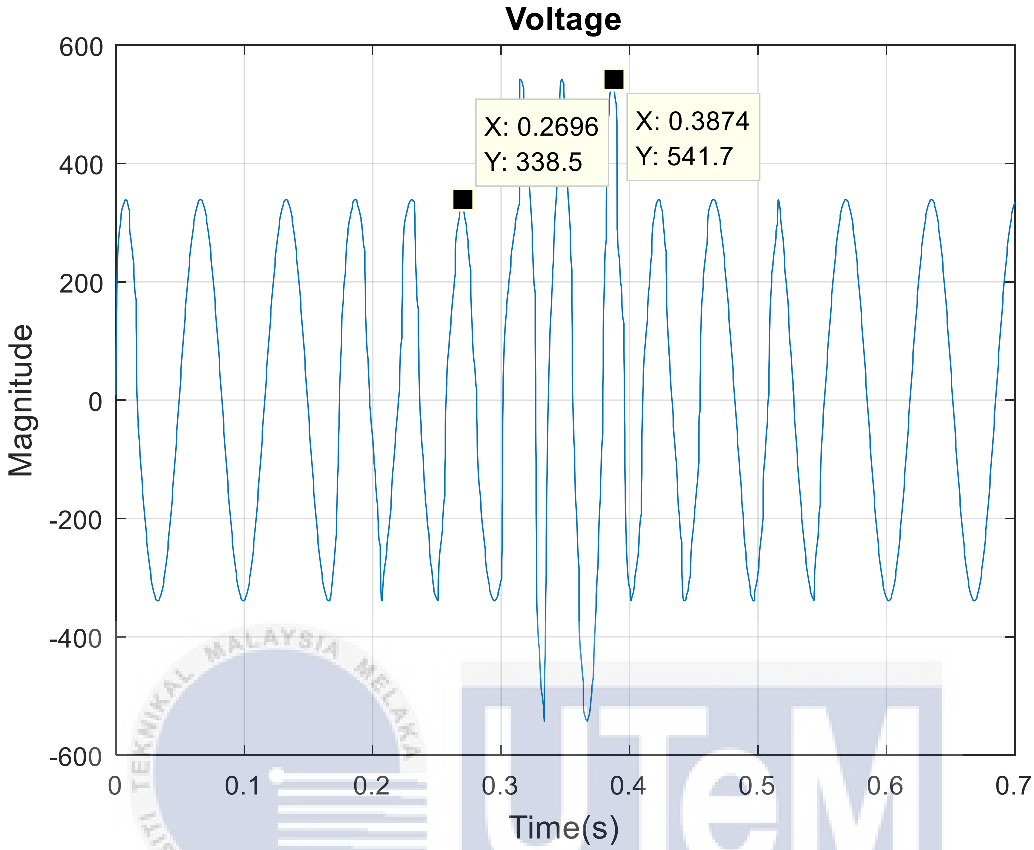


Figure 4-8: Phase 1 of Voltage Signal for Swell

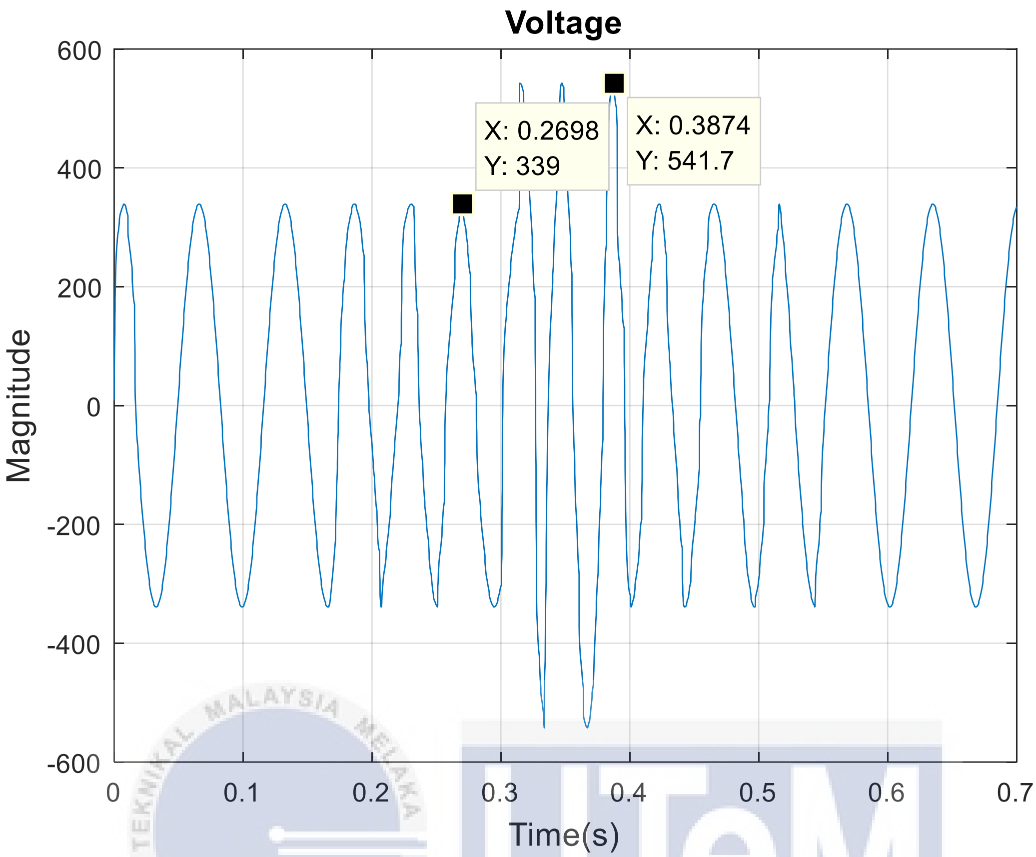


Figure 4-9: Phase 2 of Voltage Signal for Swell

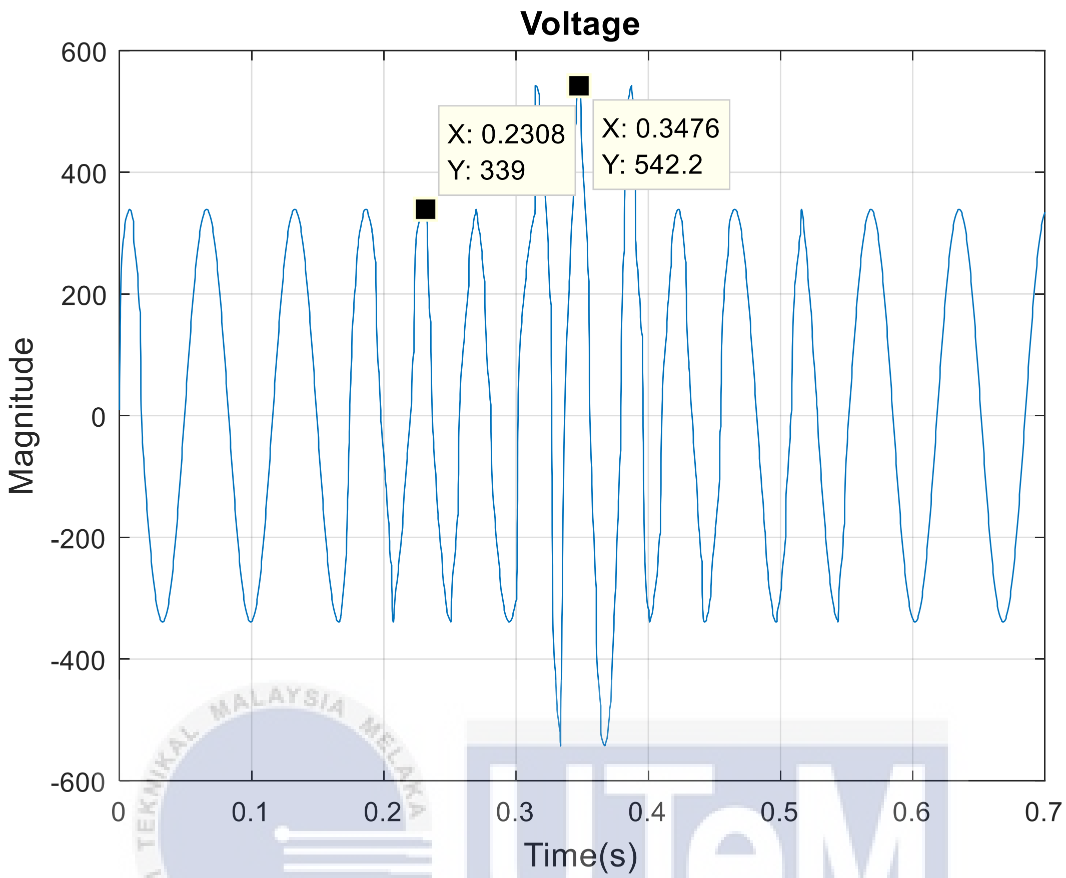


Figure 4-10: Phase 3 of Voltage Signal for Swell

Table 4.2: Average of Voltage Signal for Swell

| Voltage | | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.1 | 0.1 | 0.1 |
| Without Disturbances (V) | 338.5 | 339 | 339 |
| With Disturbances (V) | 541.7 | 541.7 | 542.2 |
| Average Without Disturbances (V) | 338.83 | | |
| Average With Disturbances (V) | 541.87 | | |

### 4.3.3 Voltage Interruption

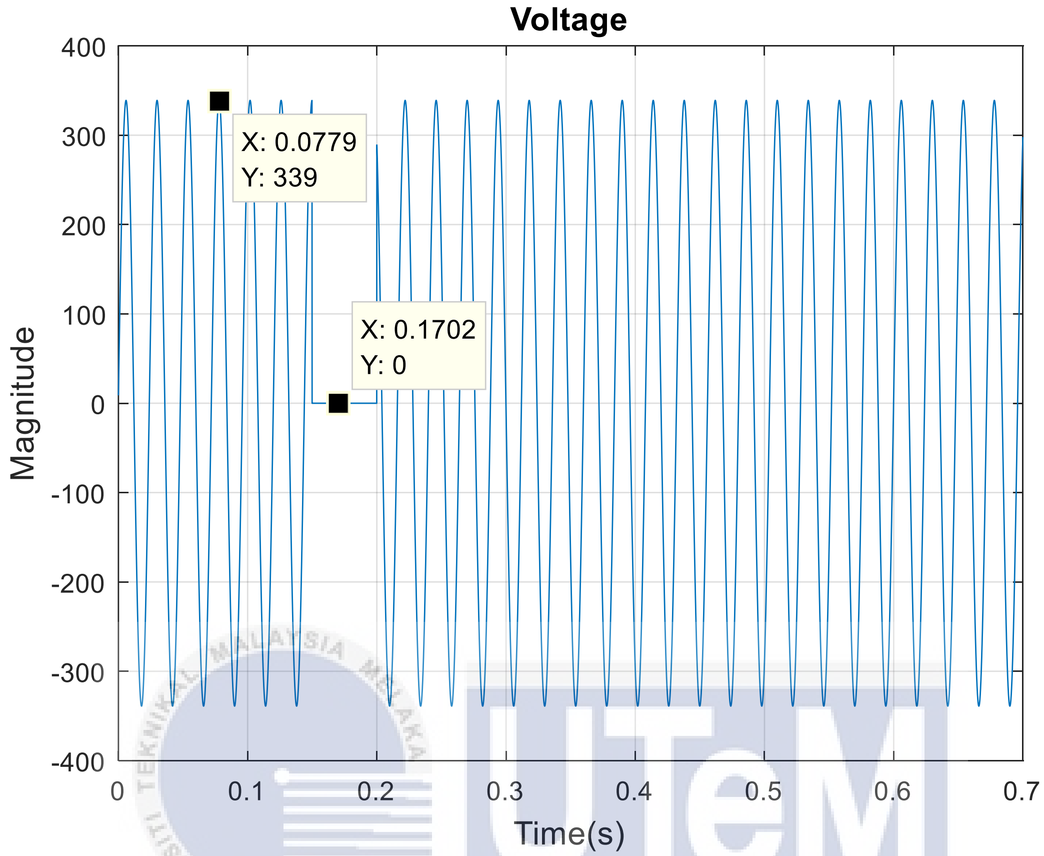


Figure 4-11: Phase 1 of Voltage Signal for Interruption

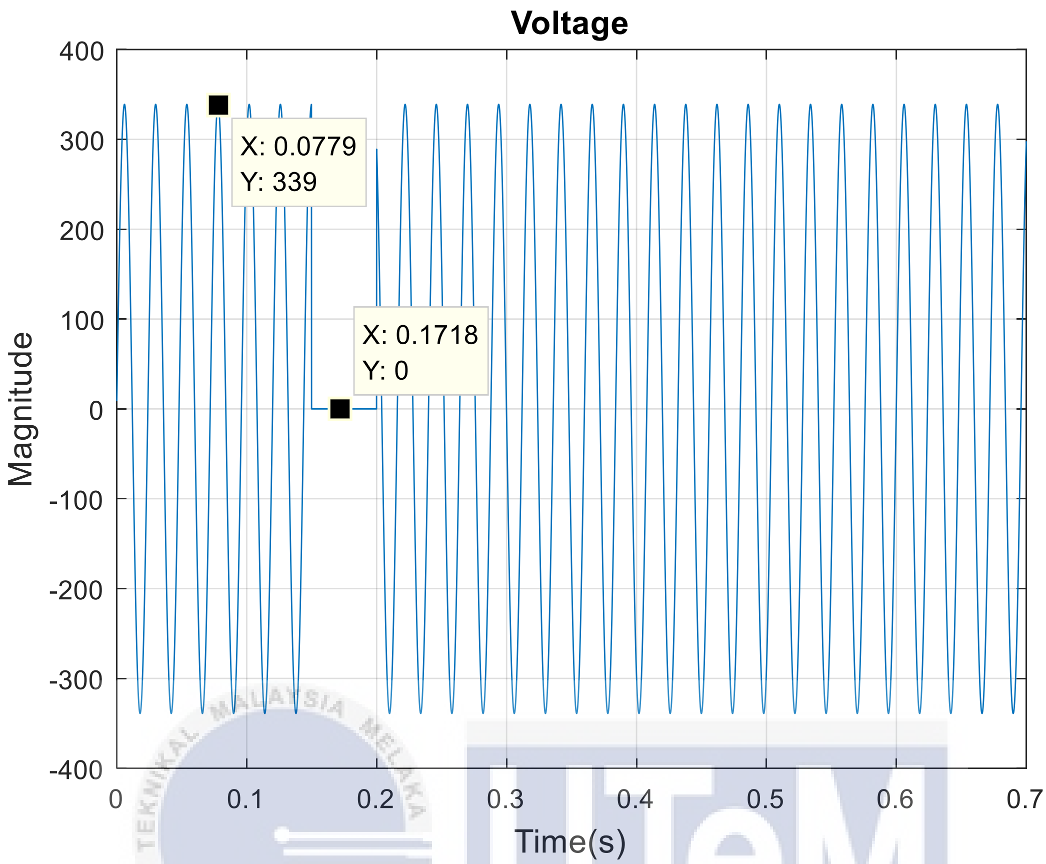


Figure 4-12: Phase 2 of Voltage Signal for Interruption

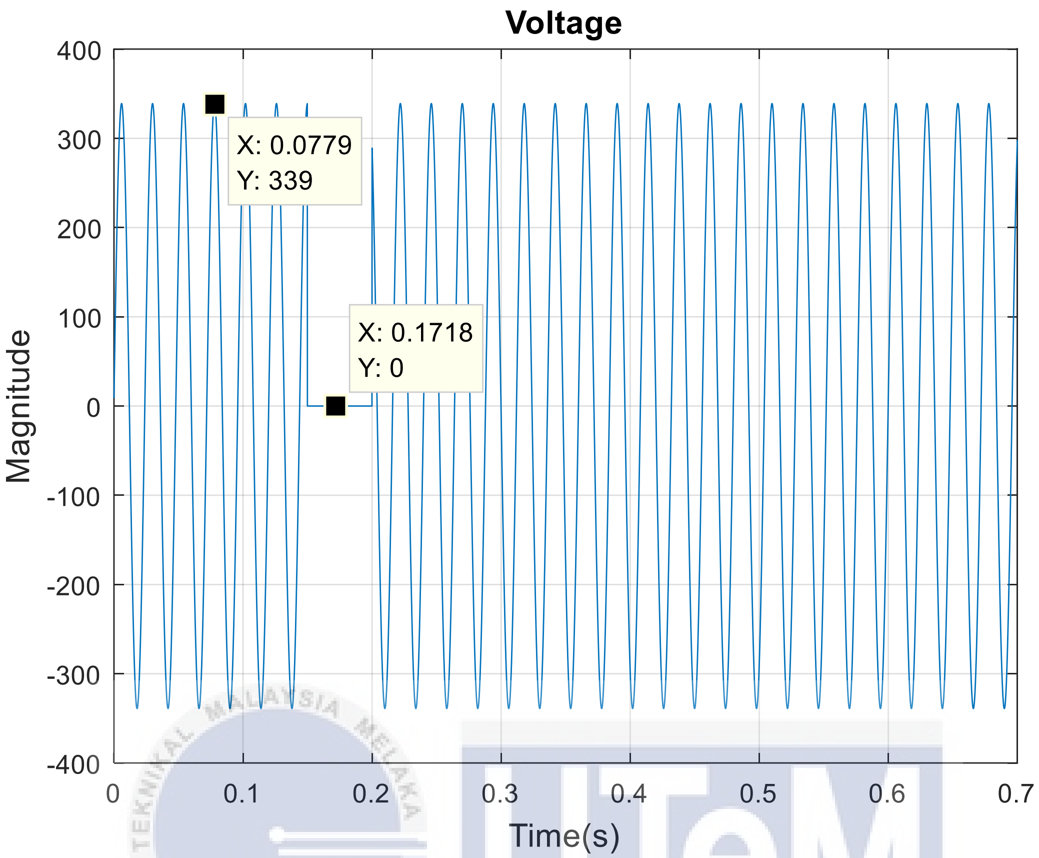


Figure 4-13: Phase 3 of Voltage Signal for Interruption

Table 4.3: Average of Voltage Signal for Interruption

| | Voltage | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.065 | 0.065 | 0.065 |
| Without Disturbances (V) | 339 | 339 | 339 |
| With Disturbances (V) | 0 | 0 | 0 |
| Average Without Disturbances (V) | 339 | | |
| Average With Disturbances (V) | 0 | | |

Table 4.4: Summary of Voltage Signal for Sag, Swell and Interruption

| Voltage | | | |
|---|---|---|---|
| | Sag | Swell | Interruption |
| Duration (s) | 0.09 | 0.1 | 0.065 |
| Average Without Disturbances (V) | 338.67 | 338.83 | 339 |
| Average With Disturbances (V) | 270.27 | 541.87 | 0 |

Table 4.4 shows that the value of voltage without disturbances and with disturbances which have been summarized for each phase in each condition. The value of voltage for each condition were different and there were increasing and decreasing in the table. For sag condition, the voltage value drop from 338.67 V to 270.27 V within the duration of 0.09 s. Therefore, it has been proof that the value of voltage will drop within the disturbances in sag condition. The voltage value in swell drop from 338.83 V to 541.87 V within the duration of 0.1 s. By following swell rules, the value should be drop during the disturbances and rise up to the normal condition when the disturbances ended. Interruption shows that the value of voltage drops from 339 V to 0 V when disturbances occurred about 0.065 s because there was no power supply when the disturbances occurred. This shows that the three condition of voltage variation valid by following the characteristics of each conditions.

## 4.4 Voltage Time-Frequency Representation (TFR)

### 4.4.1 Voltage Sag

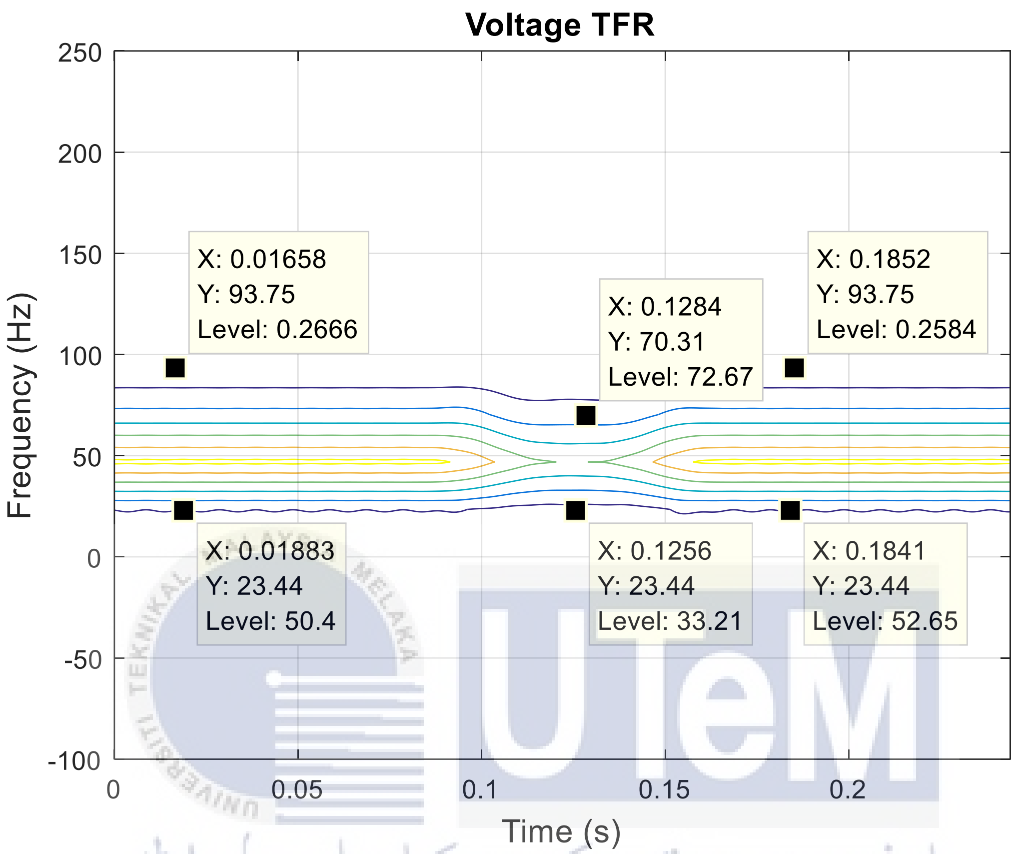


Figure 4-14: Phase 1 of Voltage TFR for Sag

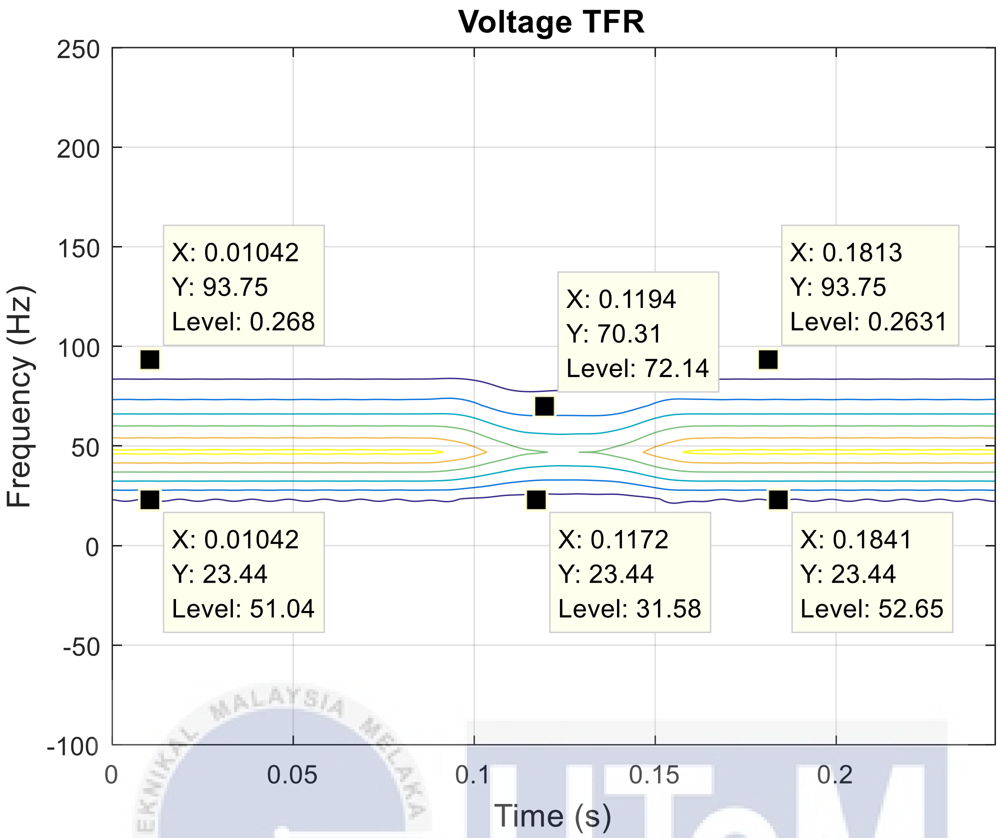


Figure 4-15: Phase 2 of Voltage TFR for Sag

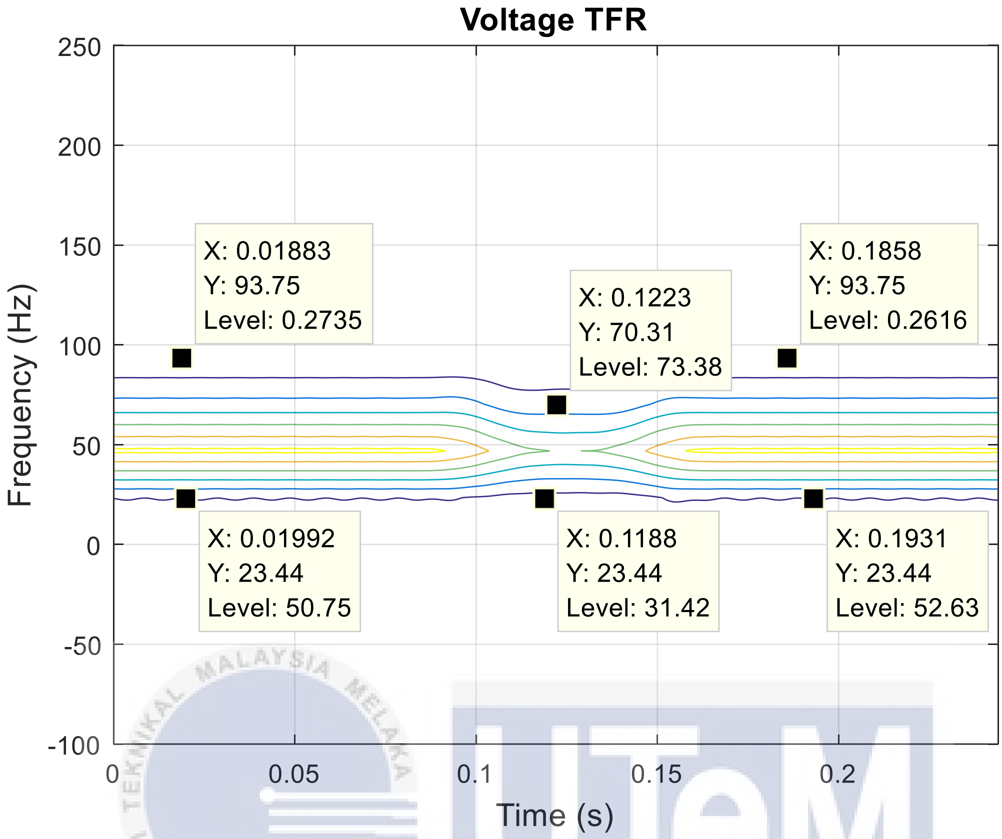


Figure 4-16: Phase 3 of Voltage TFR for Sag

Table 4.5: Average of Voltage TFR for Sag

| Voltage TFR | | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.05 | 0.05 | 0.05 |
| Frequency (Hz) | 50 | 50 | 50 |
| Average Frequency (Hz) | 50 | | |

### 4.4.2 Voltage Swell

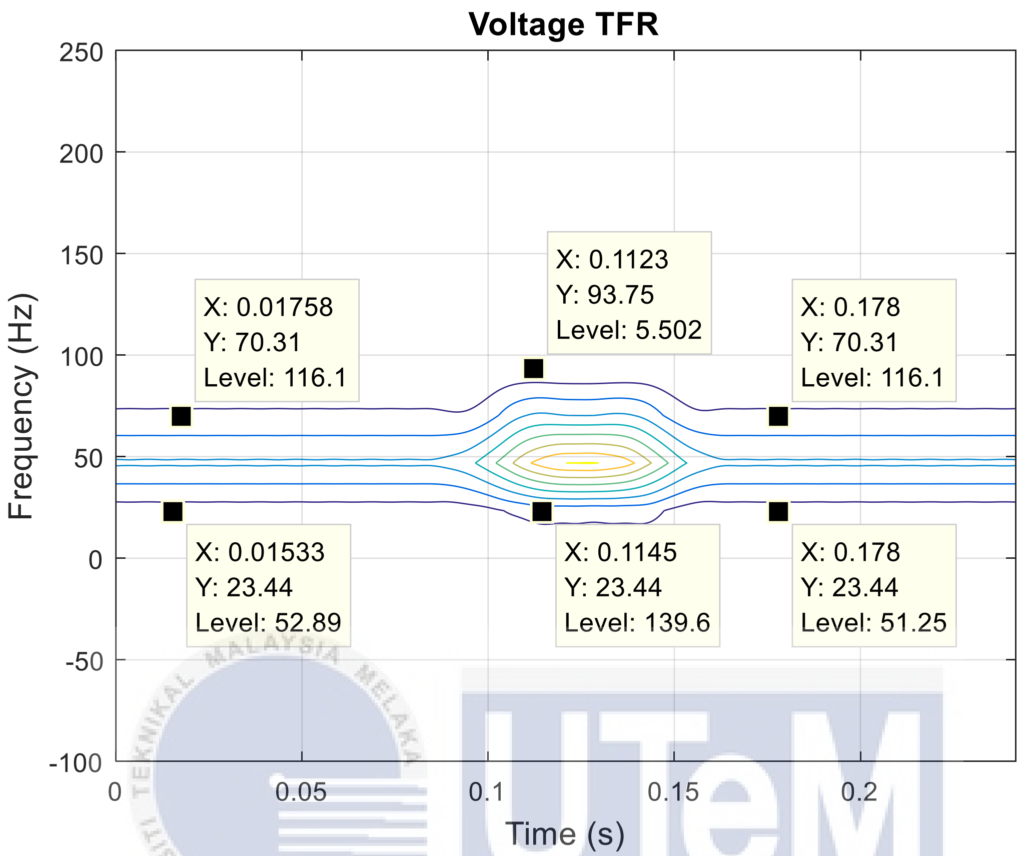


Figure 4-17: Phase 1 of Voltage TFR for Swell

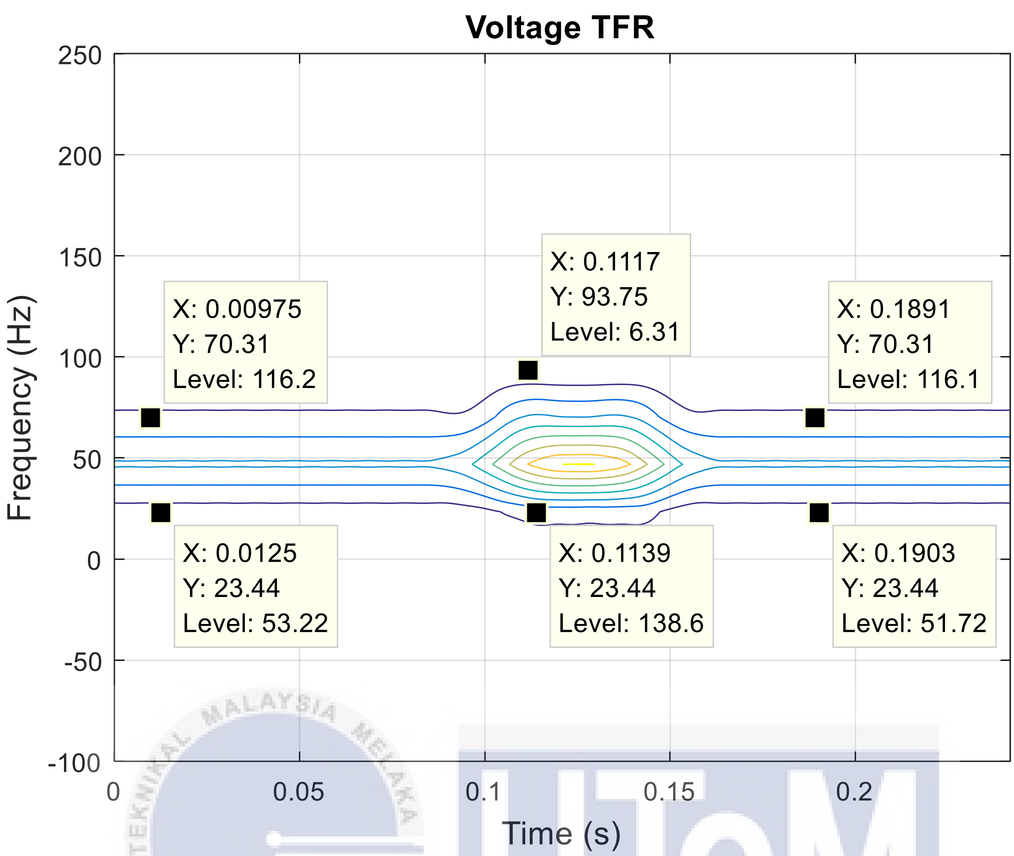


Figure 4-18: Phase 2 of Voltage TFR for Swell

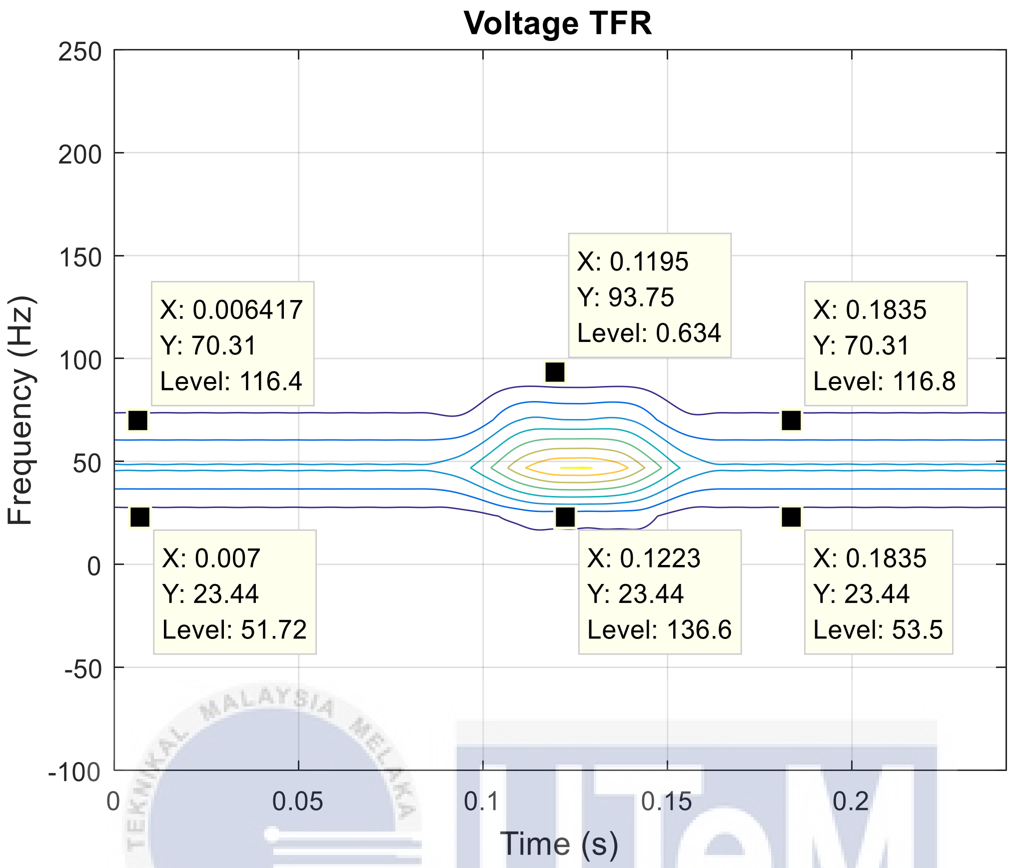


Figure 4-19: Phase 3 of Voltage TFR for Swell

Table 4.6: Average of Voltage TFR for Swell

| Voltage TFR | | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.05 | 0.05 | 0.05 |
| Frequency (Hz) | 50 | 50 | 50 |
| Average Frequency (Hz) | 50 | | |

### 4.4.3 Voltage Interruption

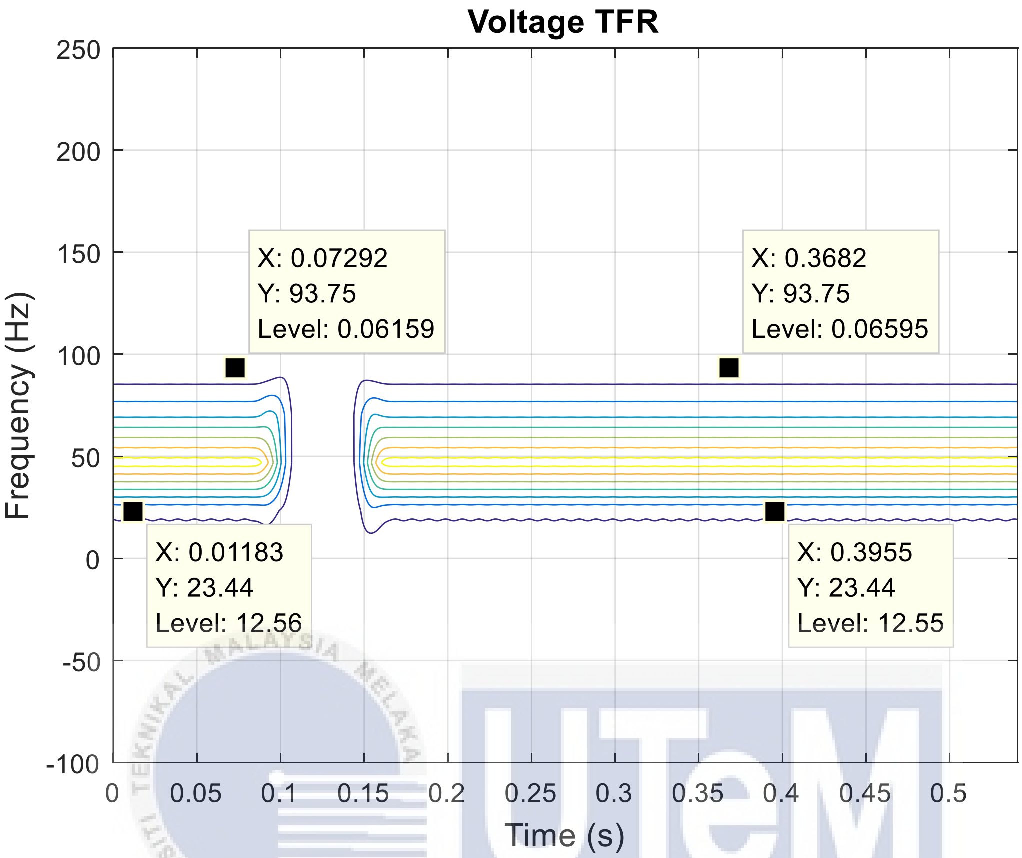


Figure 4-20: Phase 1 of Voltage TFR for Interruption

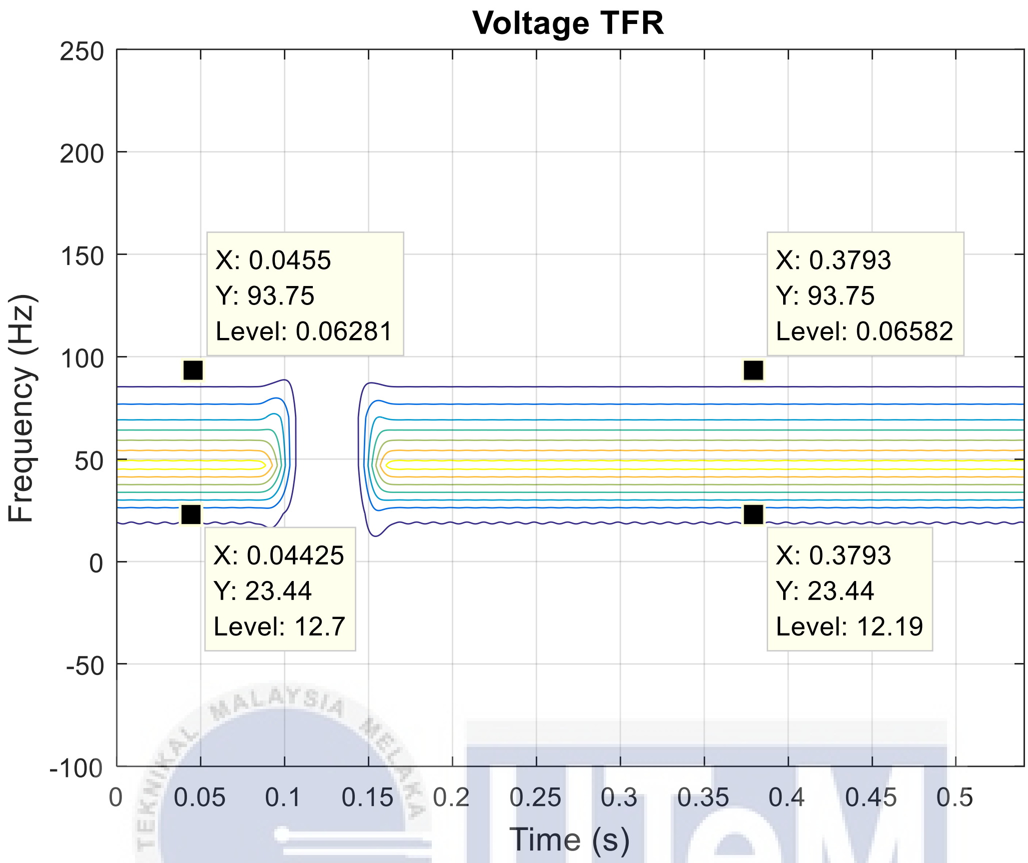


Figure 4-21: Phase 2 of Voltage TFR for Interruption

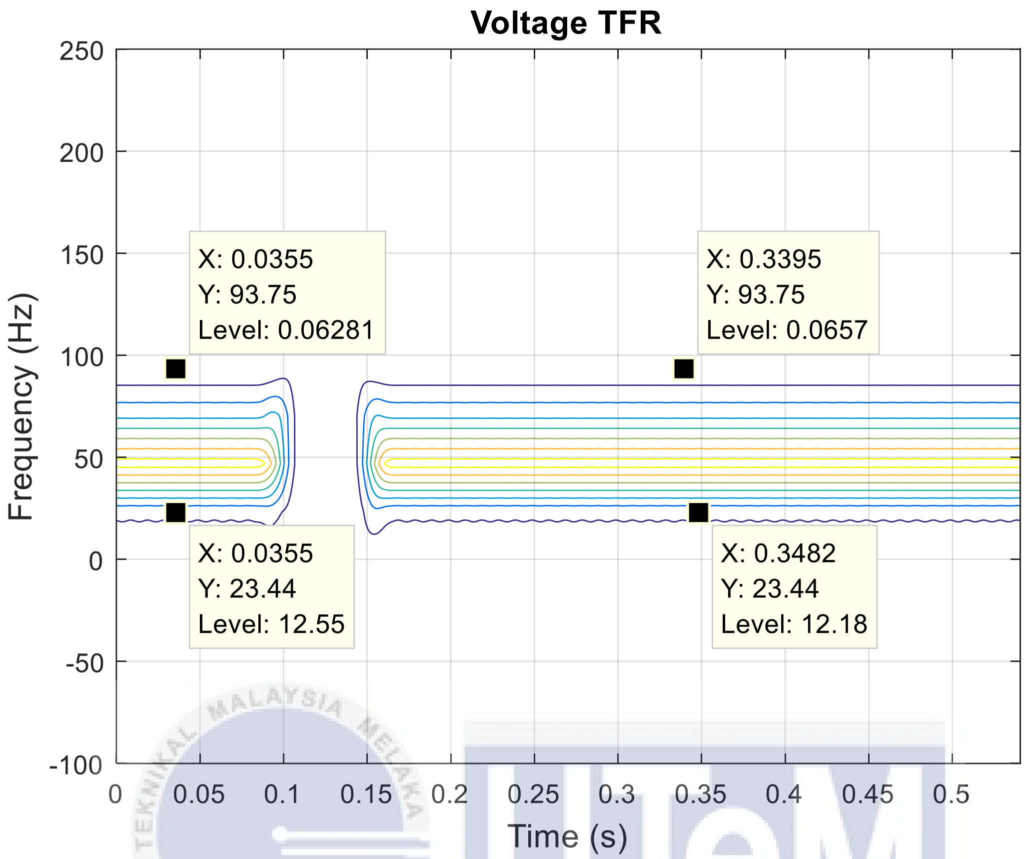


Figure 4-22: Phase 3 of Voltage TFR for Interruption



Table 4.7: Average of Voltage TFR for Interruption

| Voltage TFR | | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.05 | 0.05 | 0.05 |
| Frequency (Hz) | 50 | 50 | 50 |
| Average Frequency (Hz) | 50 | | |

Table 4.8: Summary of Voltage TFR for Sag, Swell and Interruption

| Voltage TFR | | | |
|---|---|---|---|
| Frequency | Sag | Swell | Interruption |
| Duration (s) | 0.05 | 0.05 | 0.05 |
| Average Frequency (Hz) | 50 | 50 | 50 |

Table 4.8 shows that the average value of frequency and duration which have been summarized for each type of phase in each condition. The frequency value of sag condition shows that the value of frequency was 50 Hz. Figure 4-14, Figure 4-15 and Figure 4-16 shows the decreasing number of windows within the duration of 0.05s. It proofs that when sag happen, the value of frequency will drop from its normal condition for a duration. The frequency value of swell was 50 Hz. The number of windows in swell condition increase that have been shows in the Figure 4-17, Figure 4-18 and Figure 4-19 within the duration of 0.05 s. It follows the rule of swell that there will be a rising for a duration. For interruption condition, the frequency value was 50 Hz. When interruption happen, it will lose its power supply during a duration and that's why number of windows also been cut-off during the duration of 0.05 s that have been shows in Table 4.8. This shows that the three condition of voltage variation valid by following the characteristics of each conditions.

## 4.5 Voltage RMS

### 4.5.1 Voltage Sag

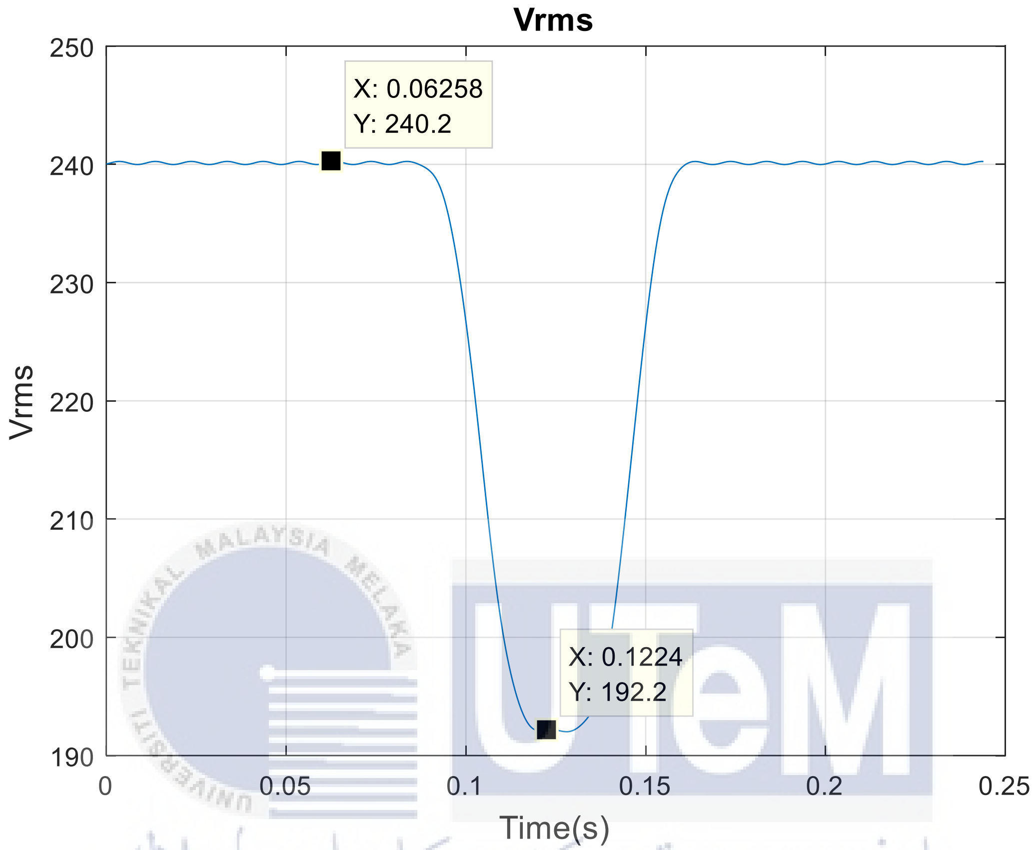


Figure 4-23: Phase 1 of Vrms for Sag

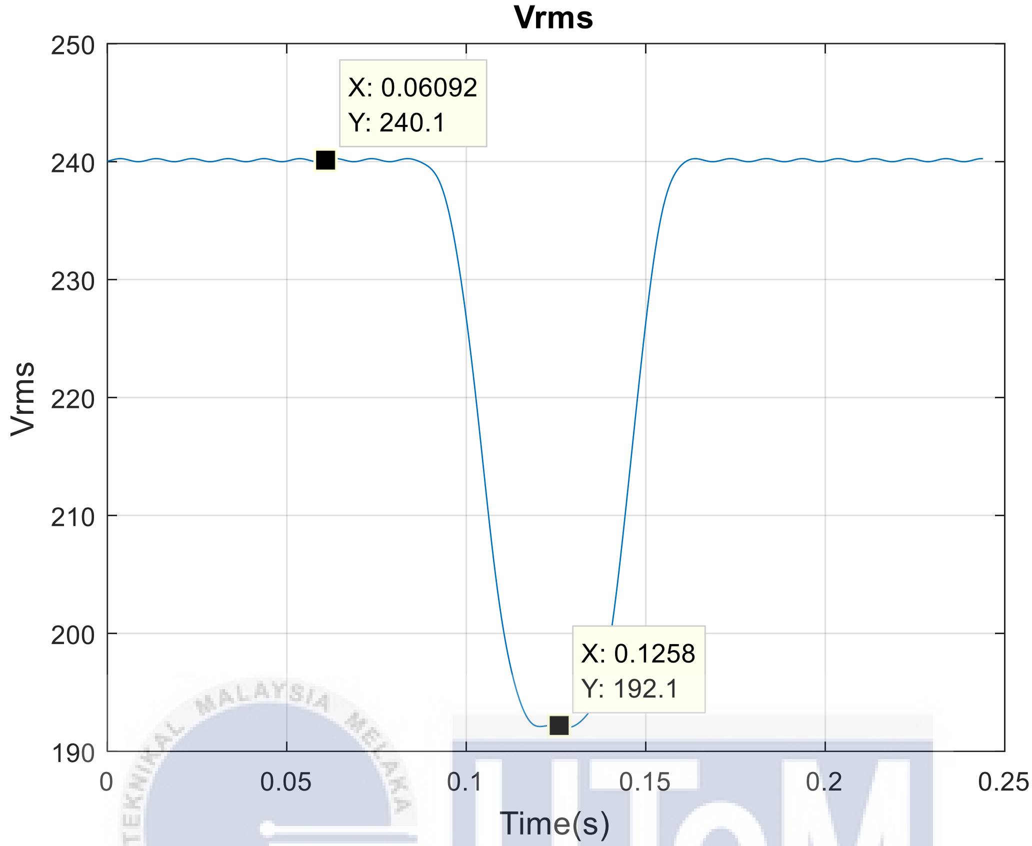


Figure 4-24: Phase 2 of Vrms for Sag

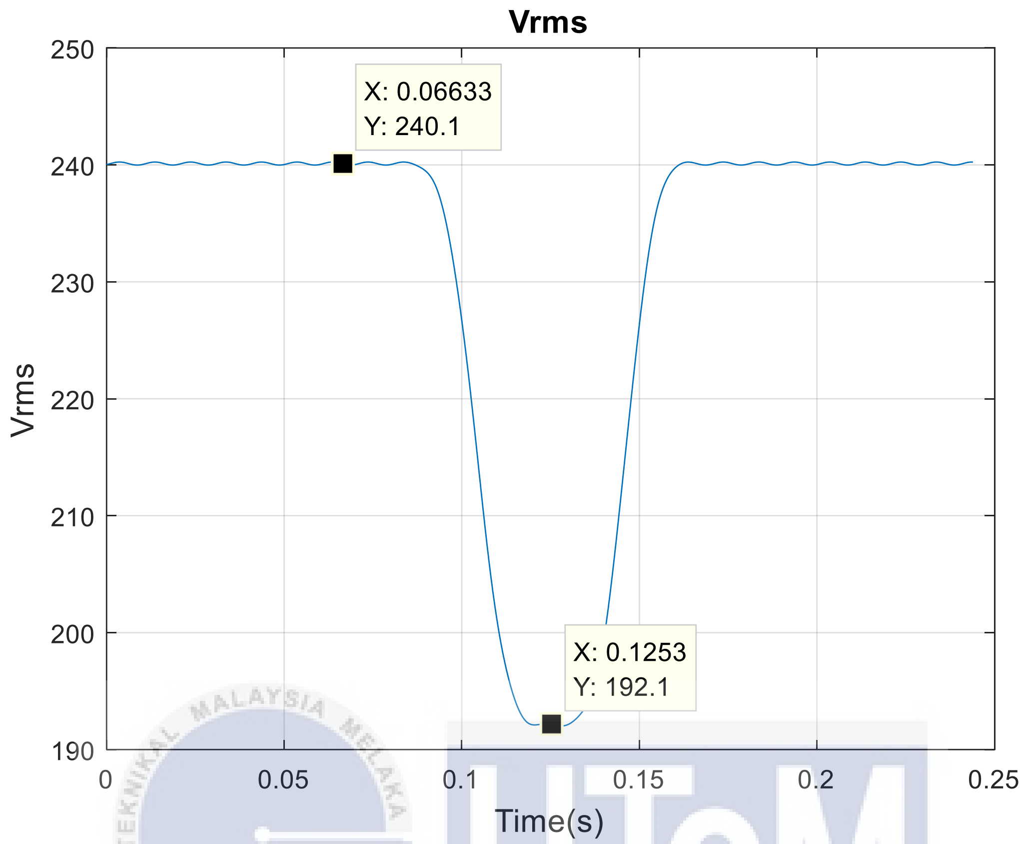


Figure 4-25: Phase 3 of Vrms for Sag

Table 4.9: Average of Vrms for Sag

| | Vrms | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.07 | 0.07 | 0.07 |
| Without Disturbances (V) | 240.2 | 240.1 | 240.1 |
| With Disturbances (V) | 192.2 | 192.1 | 192.1 |
| Average Without Disturbances (V) | 240.13 | | |
| Average With Disturbances (V) | 192.13 | | |

### 4.5.2 Voltage Swell

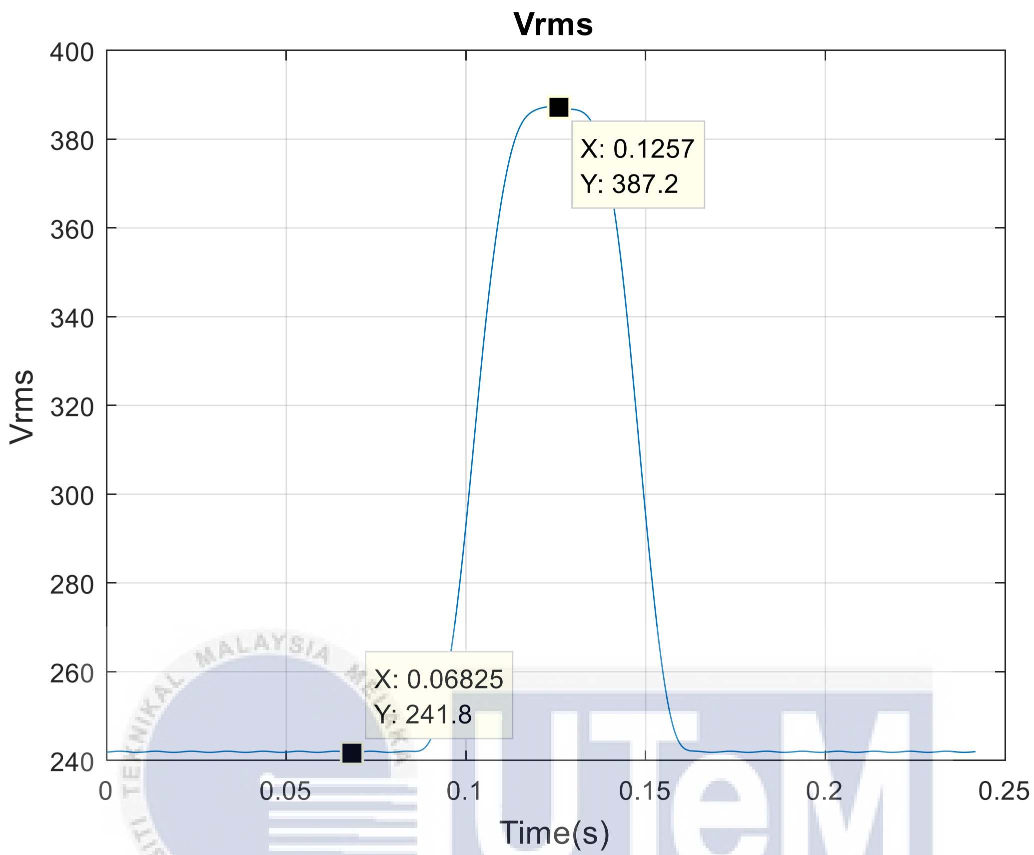


Figure 4-26: Phase 1 of Vrms for Swell

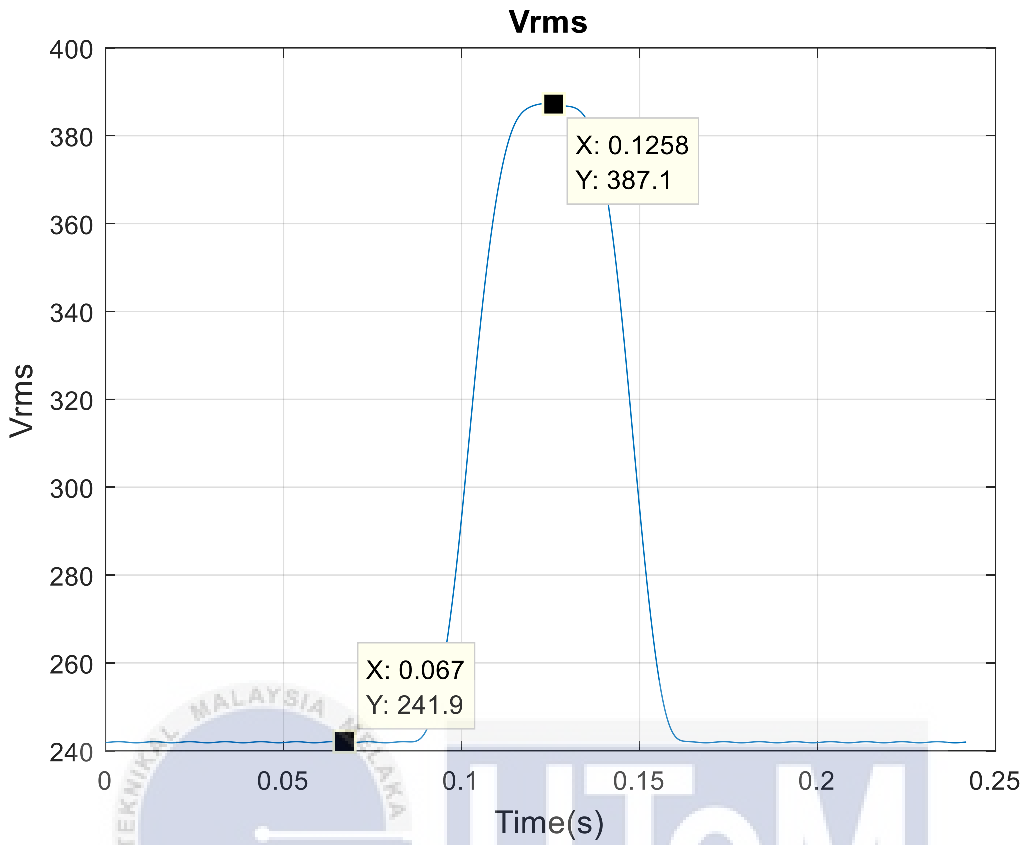


Figure 4-27: Phase 2 of Vrms for Swell

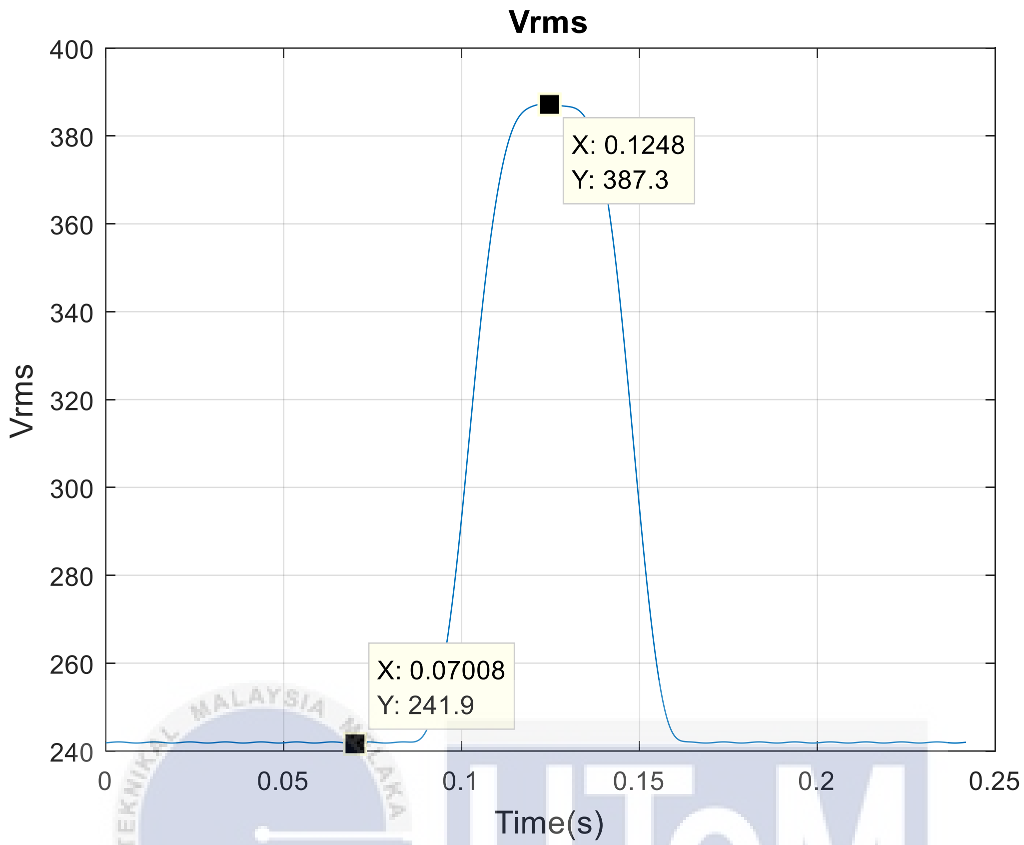


Figure 4-28: Phase 3 of Vrms for Swell

Table 4.10: Average of Vrms for Swell

| | Vrms | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.07 | 0.07 | 0.07 |
| Without Disturbances (V) | 241.8 | 241.9 | 241.9 |
| With Disturbances (V) | 387.2 | 387.1 | 387.3 |
| Average Without Disturbances (V) | 241.87 | | |
| Average With Disturbances (V) | 387.2 | | |

### 4.5.3 Voltage Interruption

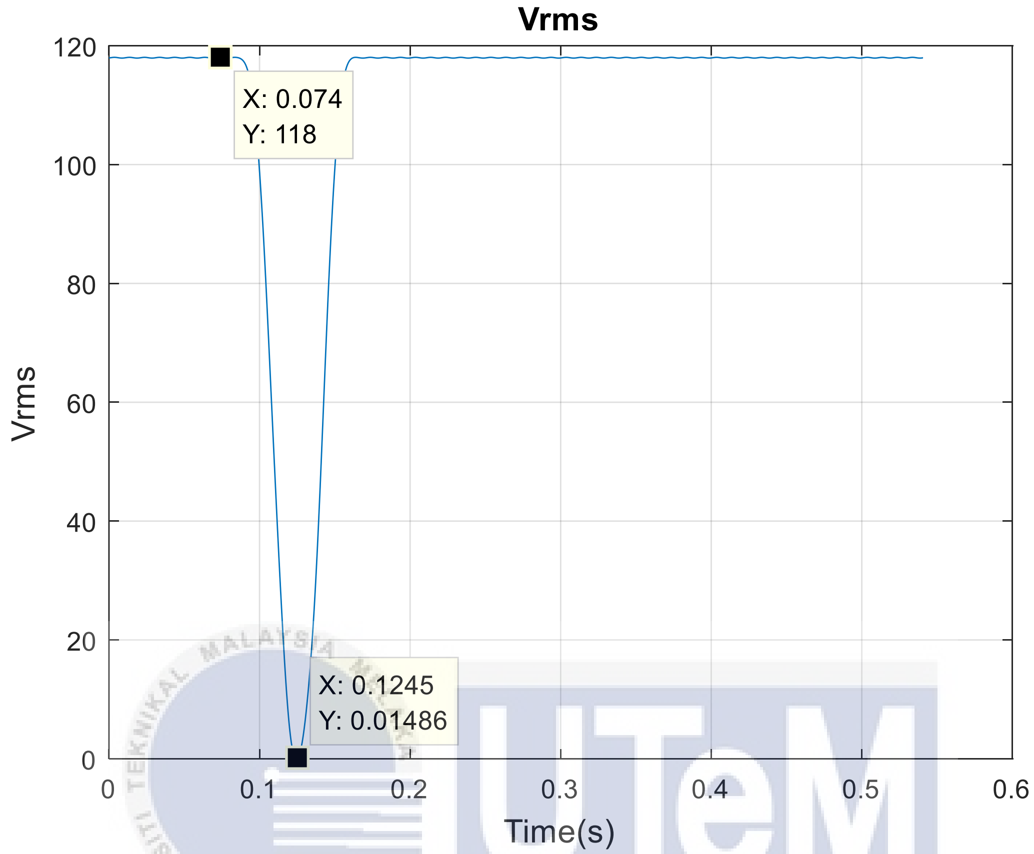


Figure 4-29: Phase 1 of Vrms for Interruption

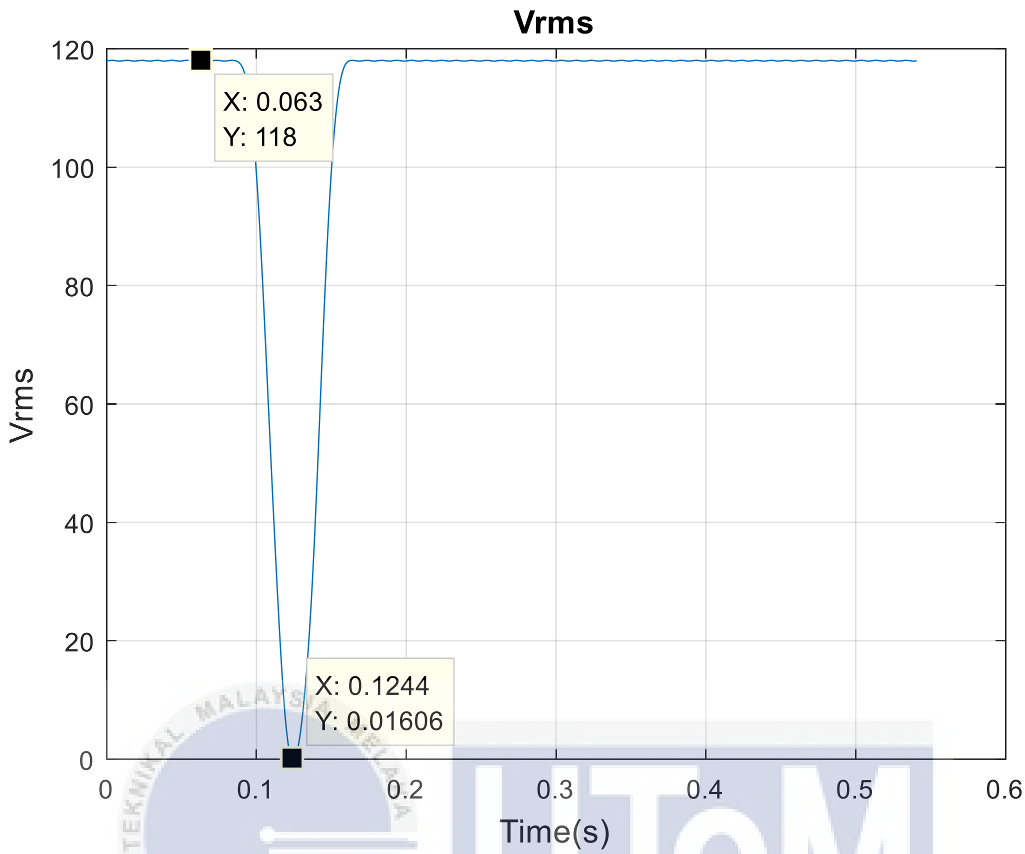


Figure 4-30: Phase 2 of Vrms for Interruption

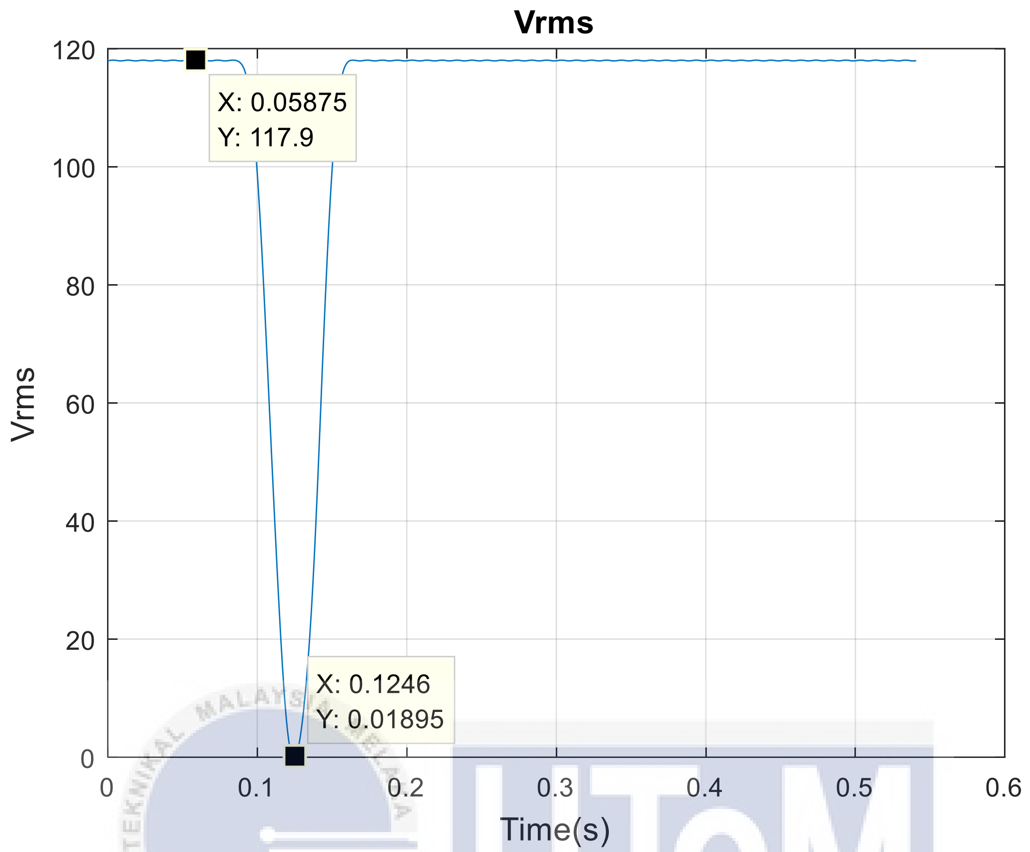


Figure 4-31: Phase 3 of Vrms for Interruption

Table 4.11: Average of Vrms for Interruption

| | Vrms | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.05 | 0.05 | 0.05 |
| Without Disturbances (V) | 118 | 118 | 117.9 |
| With Disturbances (V) | 0.01486 | 0.01606 | 0.01895 |
| Average Without Disturbances (V) | 117.97 | | |
| Average With Disturbances (V) | 0.017 | | |

Table 4.12: Summary of Vrms for Sag, Swell and Interruption

| Vrms | | | |
|---|---|---|---|
| | Sag | Swell | Interruption |
| Duration (s) | 0.07 | 0.07 | 0.05 |
| Average Without Disturbances (V) | 240.13 | 241.87 | 117.97 |
| Average With Disturbances (V) | 192.13 | 387.2 | 0.017 |

Table 4.12 shows that the average value of voltage root-mean-square (Vrms) without disturbances and with disturbances which have been summarized for each type of phase in each condition. The value of Vrms for sag decreasing from 240.13 V to 192.13 V within the duration of 0.07 s. The value decreasing within the duration of the disturbances and back to normal condition when the disturbances ended. The increasing value of Vrms for swell was 241.87 V to 387.2 V within the duration of 0.07 s. Swell shows that the value should be increase within the duration of the disturbances. When disturbances in interruption occurred, the Vrms value in interruption drop to 0 V from 117.97 V within the duration of 0.05 s. The value drop to 0 because when interruption occurred, the were no power supply during the duration of the disturbances until the disturbances ended. This shows that the three condition of voltage variation valid by following the characteristics of each conditions.

## 4.6 Instantaneous RMS Voltage (pu)

### 4.6.1 Voltage Sag

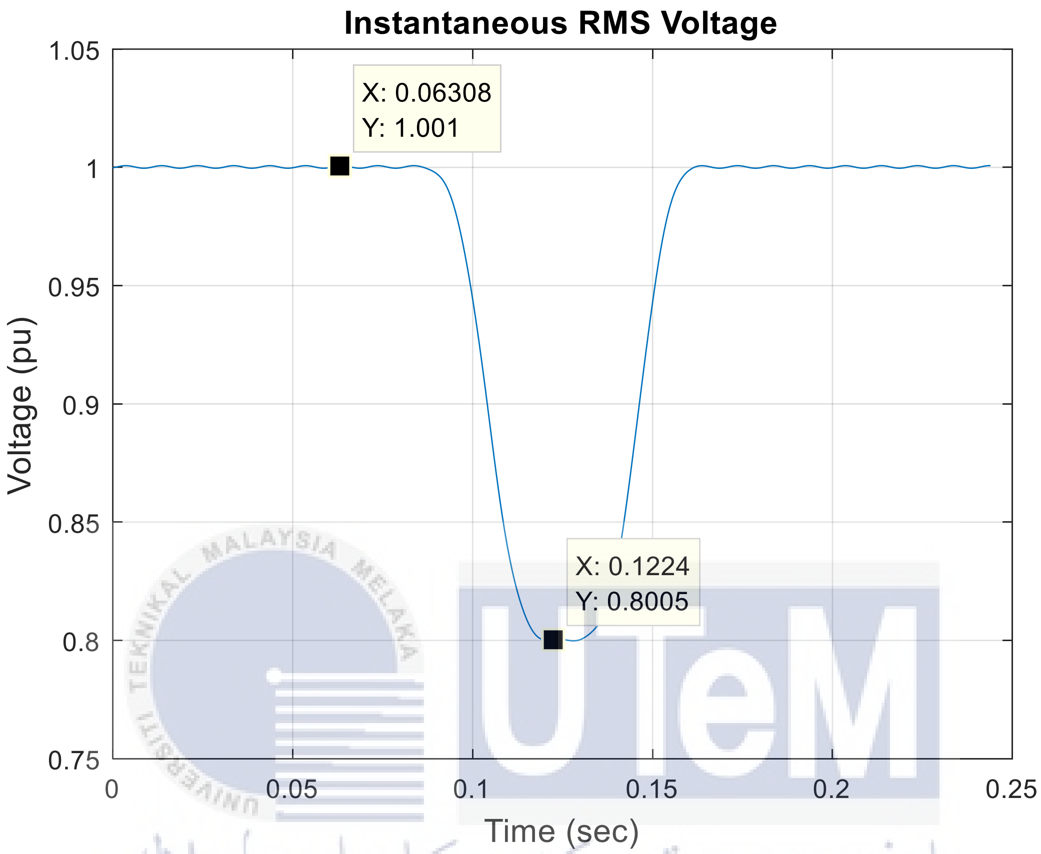


Figure 4-32: Phase 1 of Instantaneous RMS Voltage for Sag

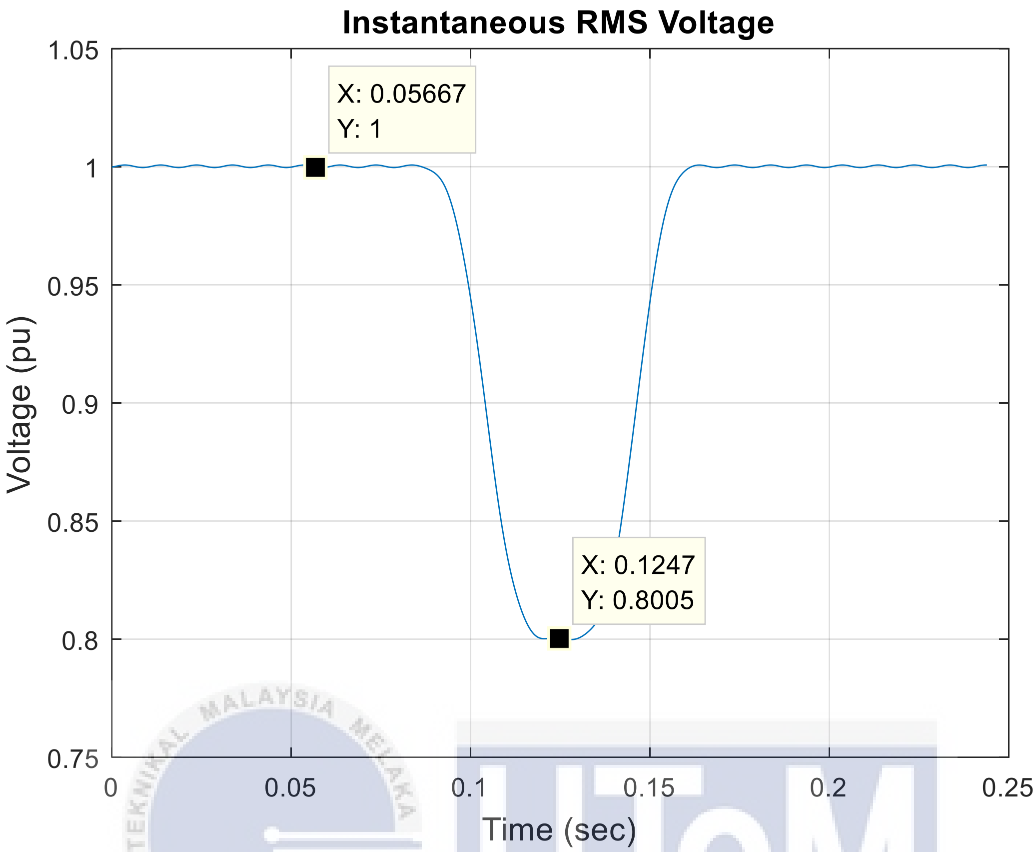


Figure 4-33: Phase 2 of Instantaneous RMS Voltage for Sag

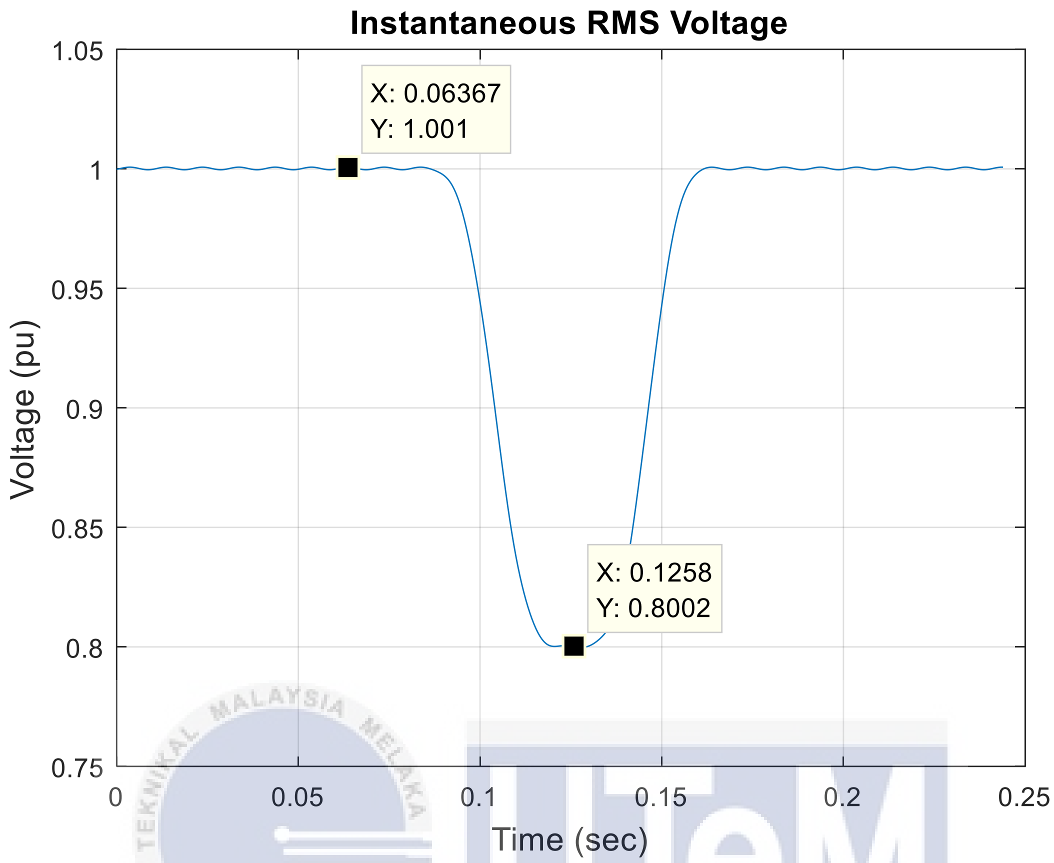


Figure 4-34: Phase 3 of Instantaneous RMS Voltage for Sag

Table 4.13: Average of Instantaneous RMS Voltage for Sag

| | Instantaneous RMS Voltage (pu) | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.07 | 0.07 | 0.07 |
| Without Disturbances (pu) | 1 | 1 | 1 |
| With Disturbances (pu) | 0.8 | 0.8 | 0.8 |
| Average Without Disturbances (pu) | 1 | | |
| Average With Disturbances (pu) | 0.8 | | |

### 4.6.2 Voltage Swell

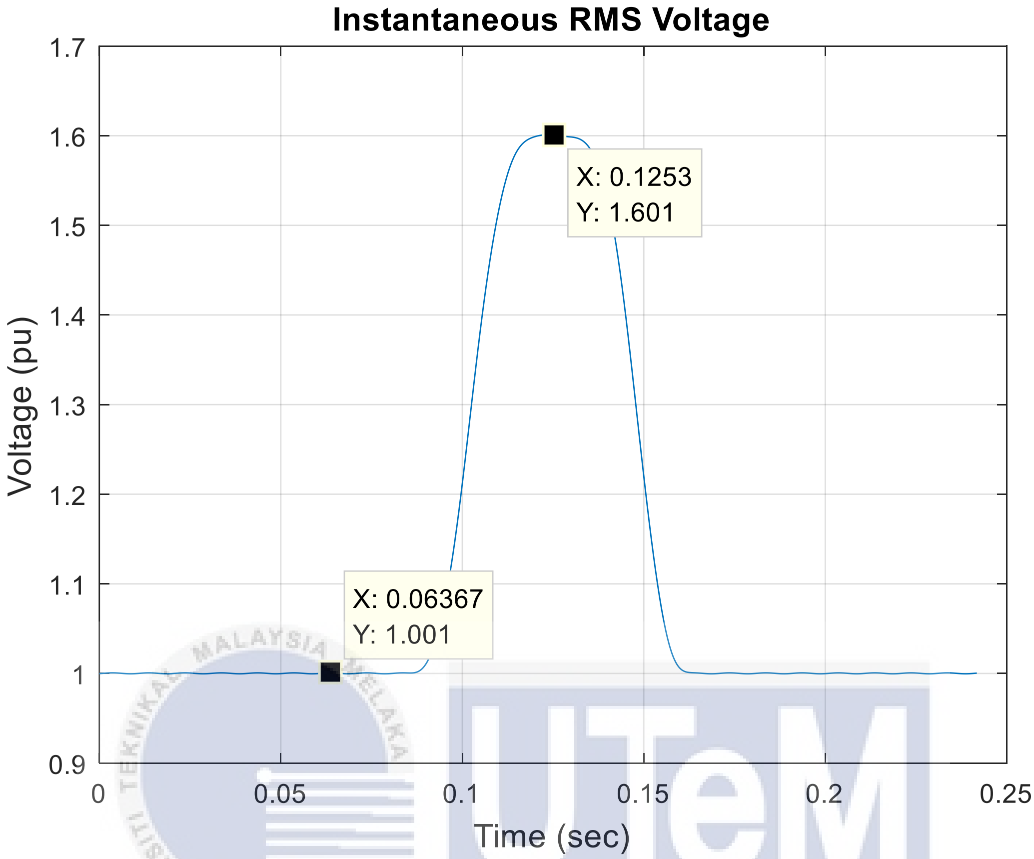


Figure 4-35: Phase 1 of Instantaneous RMS Voltage for Swell

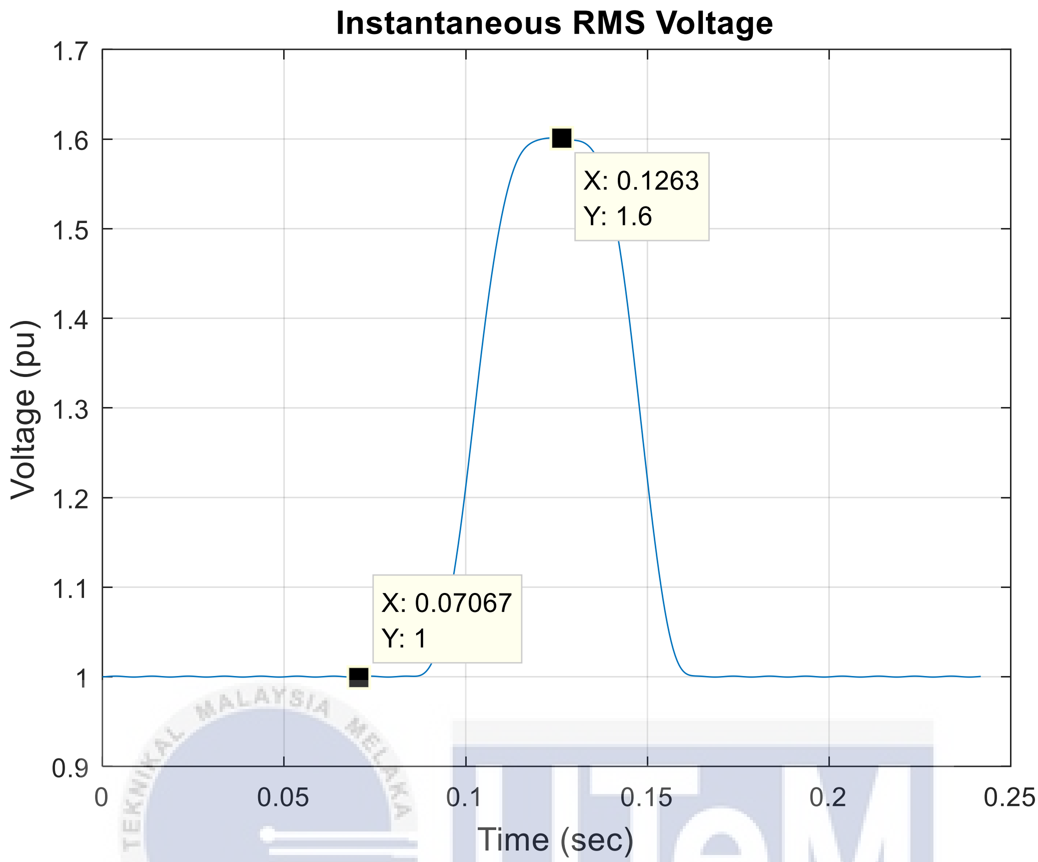


Figure 4-36: Phase 2 of Instantaneous RMS Voltage for Swell

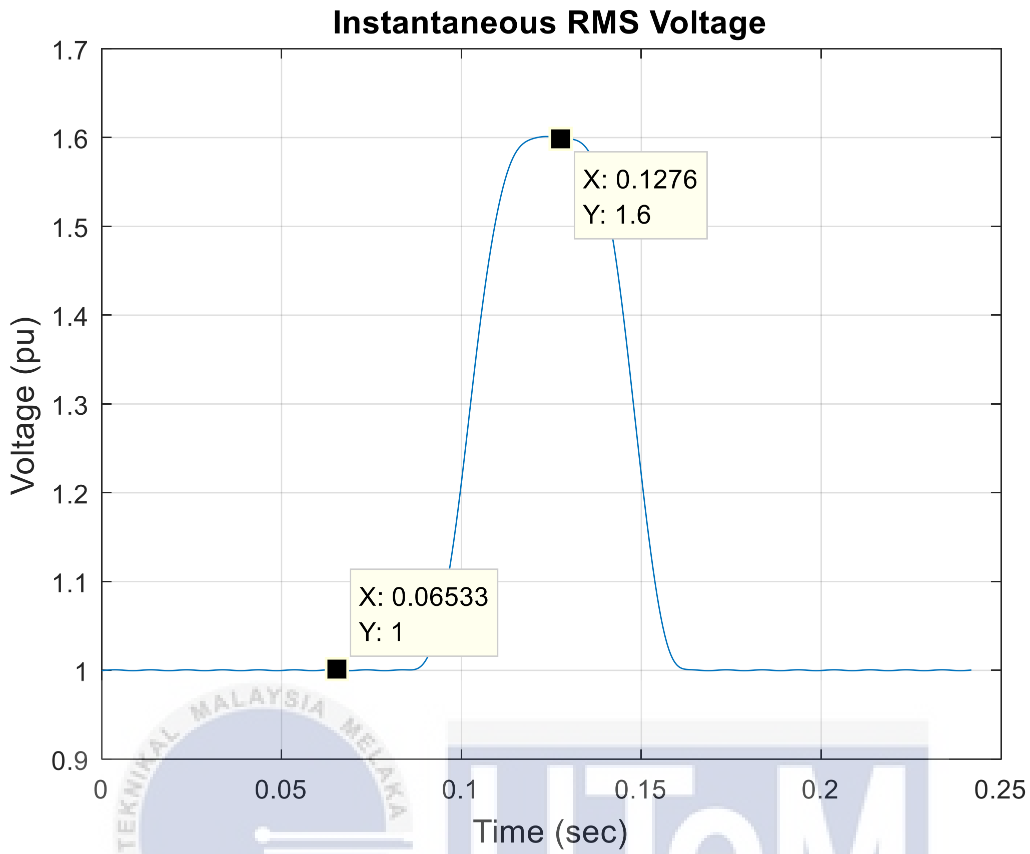


Figure 4-37: Phase 3 of Instantaneous RMS Voltage for Swell

Table 4.14: Average of Instantaneous RMS Voltage for Swell

| Instantaneous RMS Voltage (pu) | | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.07 | 0.07 | 0.07 |
| Without Disturbances (pu) | 1 | 1 | 1 |
| With Disturbances (pu) | 1.6 | 1.6 | 1.6 |
| Average Without Disturbances (pu) | 1 | | |
| Average With Disturbances (pu) | 1.6 | | |

### 4.6.3 Voltage Interruption

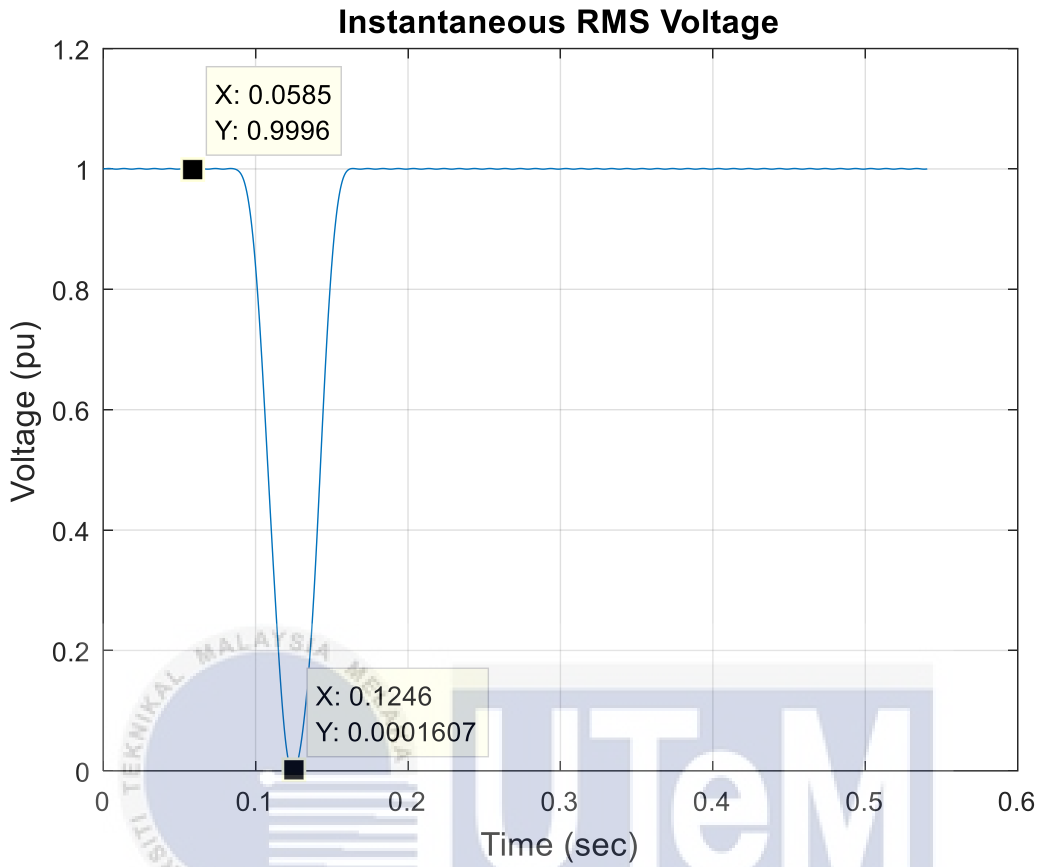


Figure 4-38: Phase 1 of Instantaneous RMS Voltage for Interruption

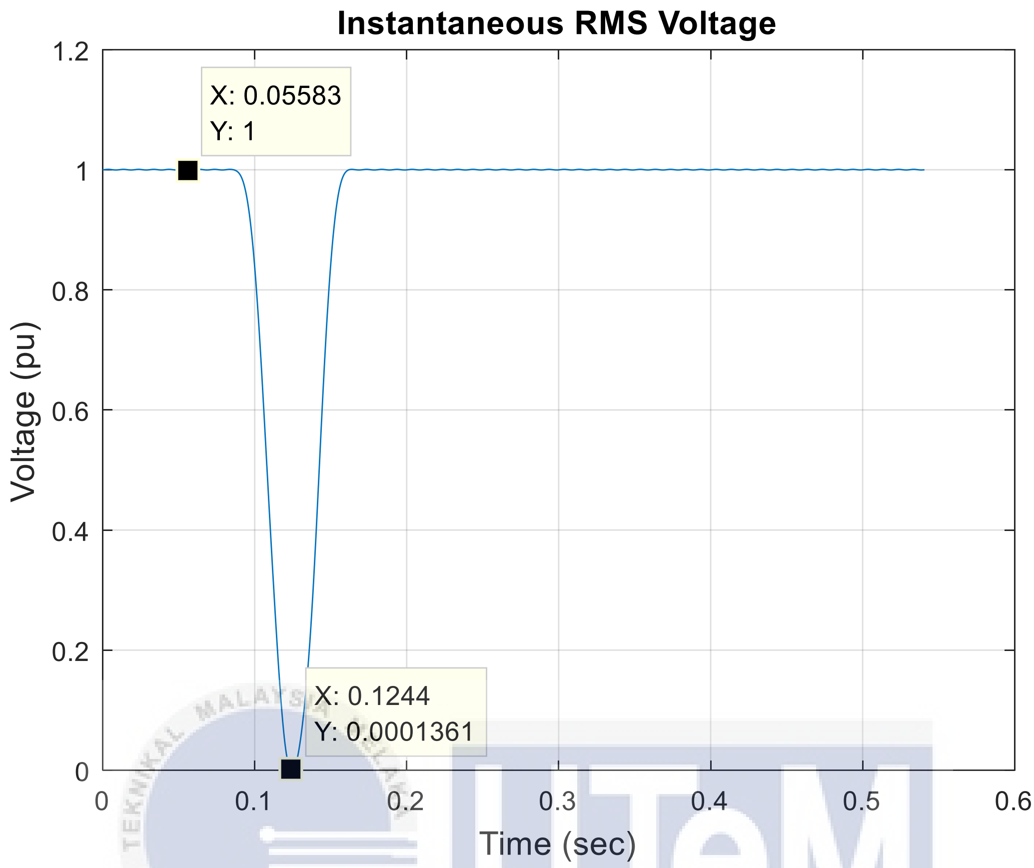


Figure 4-39: Phase 2 of Instantaneous RMS Voltage for Interruption

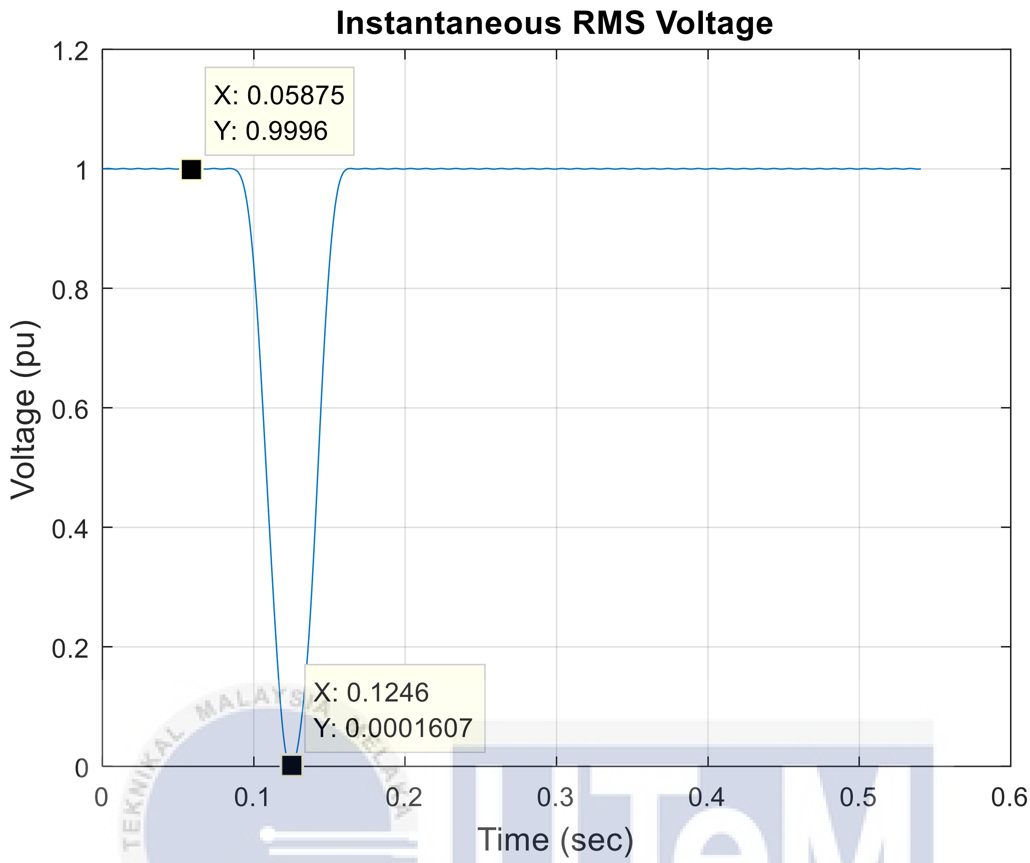


Figure 4-40: Phase 3 of Instantaneous RMS Voltage for Interruption

Table 4.15: Average of Instantaneous RMS Voltage for Interruption

| | Instantaneous RMS Voltage (pu) | | |
|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 3 |
| Duration (s) | 0.05 | 0.05 | 0.05 |
| Without Disturbances (pu) | 1 | 1 | 1 |
| With Disturbances (pu) | 0 | 0 | 0 |
| Average Without Disturbances (pu) | 1 | | |
| Average With Disturbances (pu) | 0 | | |

Table 4.16: Summary of Instantaneous RMS Voltage for Sag, Swell and Interruption

| Instantaneous RMS Voltage (pu) | | | |
|---|---|---|---|
| | Sag | Swell | Interruption |
| Duration (s) | 0.07 | 0.07 | 0.05 |
| Average Without Disturbances (pu) | 1 | 1 | 1 |
| Average With Disturbances (pu) | 0.8 | 1.6 | 0 |

Table 4.16 shows that average value of Instantaneous RMS Voltage in per-unit (pu) without disturbances and with disturbances which have been summarized for each type of phase in each condition. Value of instantaneous RMS voltage drop from 1 pu to 0.8 pu in sag condition within the duration of 0.07 s. The value drops when the disturbances occurred within its duration. The phenomena valid by following the characteristics of sag. For swell, the value of instantaneous RMS voltage increases from 1 pu to 1.6 pu within the duration of 0.07 s. The value increase within the duration of the disturbances and back to its normal condition when the disturbances ended. There was cut-off supply in interruption condition within the duration of the disturbances that make the value drop to 0 pu from 1 pu within the duration of 0.05 s. This shows that the three condition of voltage variation valid by following the characteristics of each conditions.

## 4.7 Summary

In conclusion, after the result have been collected and calculated from the graph, the signal parameters and signal characteristics can be determined. The results that have been collected shows accurately about the three type of voltage variations. The classifications of the signal can be determined within the three type of voltage variations that is sag, swell and interruption. Voltage sag can be evaluated if there were suddenly drop of the voltage within the duration of the disturbances that causes of the large load that have been connected within the circuit breaker. Voltage swell can be determined if there were rising of the voltage within the duration of the disturbances that causes from the unbalanced load fault or the load that have been removed. Lastly, voltage interruption can be valid if the value suddenly drops approximately to 0 within the duration of the disturbances. The voltage interruption is created due to permanent fault. Table 4.17 shows that IEEE standard of voltage variation due to voltage sag, voltage swell and voltage interruption.

Table 4.17: IEEE Standard for Voltage Variation

| Categories | Typical Duration | Typical Voltage Magnitude |
|---|---|---|
| Variations | | |
| 1.1 Instantaneous | | |
| 1.1.1 Sag | 0.5-30 cycles | 0.1-0.9 pu |
| 1.1.2 Swell | 0.5-30 cycles | 1.1-1.8 pu |
| 1.2 Momentary | | |
| 1.2.1 Interruption | 0.5 cycles-3 s | <0.1 pu |
| 1.2.2 Sag | 30 cycles-3 s | 0.1-0.9 pu |
| 1.2.3 Swell | 30 cycles-3 s | 1.1-1.4 pu |
| 1.3 Temporary | | |
| 1.3.1 Interruption | >3 s-1 min | <0.1 pu |
| 1.3.2 Sag | >3 s-1 min | 0.1-0.9 pu |
| 1.3.3 Swell | >3s-1 min | 1.1-1.2 pu |

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

A voltage variation analysis is used to determine the probability of nuisance tripping of sensitive electrical and electronic loads and to evaluate the effectiveness of possible corrective measures. In some cases, a substation or circuit may be prone to generating voltage sags and momentary interruptions. Some commercial and industrial customers may use electrical and electronic equipment or may be operating processes too sensitive to these disturbances.

Signal processing techniques have been presented as a critical piece of intensity of power quality analysis. Exact techniques are expected to identify, characterize and survey diverse related signal in twisted condition. Consequently, an exploration of time-recurrence investigation systems for ongoing force quality signal examination and other application is given. The methods considered is Spectrogram.



In order to achieve the objective, the voltage variations simulation has been performed by using Simulink models with the help of MATLAB software. The simulation results and TFD analysis show that the power quality disturbances created by these methods are almost identical as well as close to the actual situation. The voltage variation signals constructed by Simulink models are flexible to be altered by manipulating the blocks in Simulink according to any situation desired. The signals simulated can be then applied for further analysis.

The problem have been solved when the objective have been achieved. After the data have been collected from the graph that have been produced by Simulink in the MATLAB software, monitoring system can be perform accurately by following the data that have been collected. Monitoring system will be efficient to be use in the industry to prevent the same problem to happen again.

## 5.2 Recommendations

As the recommendation, most equipment manufacturers don’t own a power quality monitor. Those that do have come to recognize the importance of engaging in monitoring when failures of their products occur in the field. Unfortunately, most of the time manufacturers don’t record the right data to get an idea of what disturbances or conditions are occurring that might be causing the product failures. This project can be upgrade by monitored at the right point on their electrical system with the right monitor set up will reveal the power quality data needed to understand the problem. Other than that, upgrading this project by selecting the right monitor, setting it up to capture the right data, connecting it to the Internet to provide remote monitoring to industry Power Quality Monitoring Centre and analyzing the data to determine the location and cause of the power quality disturbances. This research can be wider by adding more type of disturbances that can be produce in power quality such as overvoltage, undervoltage and momentary interruption.

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# APPENDICES

## APPENDIX A GANTT CHART