VOLTAGE STABILITY CONTROL FOR MICRO GRID WITH ARTIFICIAL INTELLIGENCE TECHNIQUE

LIANG CAI HONG

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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LIANG CAI HONG

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2019

DECLARATION

I declare that this thesis entitled “VOLTAGE STABILITY CONTROL FOR MICRO GRID WITH ARTIFICIAL INTELLIGENCE TECHNIQUE 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 : Liang Cai Hong

Date : 24/5/2019

APPROVAL

I hereby declare that I have checked this report entitled “VOLTAGE STABILITY CONTROL FOR MICRO GRID WITH ARTIFICIAL INTELLIGENCE TECHNIQUE” 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

During this semester, I successfully complete Final Year Project 2 (FYP 2). In this 14 weeks, I have received generous help, guidance and caring from many wonderful people.

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ABSTRACT

Voltage stability has become an important issue because there are some blackout incidents have been happened that caused by voltage instability. The main problem of voltage instability is the failure working of reactive power demand as the load demand increases. In this project, the main objective is to investigate the voltage stability control in a power system. A designed micro grid system is modelled without controller to analyze the voltage stability. To maintain the voltage stability of system, Artificial Intelligence (AI) technique as a proposed method is developed with Fuzzy Logic (FL) technique. As a comparison, a micro grid system with Proportional Integral (PI) controller is modelled and compared the analysis results with Fuzzy Logic Controller (FLC). As result obtained, the voltage stability in a power system is investigated with artificial intelligence technique. According the results obtained, a PI controller is performed a better result in high load power while a fuzzy logic controller has a better performance in low load power. Thus, both controller can be used to control the voltage stability of the micro grid system.

ABSTRAK

Kestabilan voltan telah menjadi isu penting kerana terdapat beberapa insiden pemadaman telah berlaku yang disebabkan oleh ketidakstabilan voltan. Masalah utama ketidakstabilan voltan adalah kegagalan kerja permintaan kuasa reaktif apabila permintaan beban meningkat. Dalam projek ini, objektif utama adalah untuk mengkaji kawalan kestabilan voltan dalam sistem kuasa. Sistem grid mikro yang dirancang dimodelkan tanpa pengawal untuk menganalisis kestabilan voltan. Untuk mengekalkan kestabilan voltan sistem, teknik Kecerdasan Buatan (AI) sebagai kaedah yang dicadangkan dibangunkan dengan teknik Fuzzy Logic (FL). Sebagai perbandingan, sistem grid mikro dengan pengawal Integral Proportional (PI) dimodelkan dan membandingkan hasil analisis dengan Pengawal Logik Fuzzy (FLC). Hasilnya, kestabilan voltan dalam sistem kuasa disiasat dengan teknik kecerdasan buatan. Menurut hasil yang diperoleh, pengawal PI dilakukan dengan hasil yang lebih baik dalam daya beban tinggi manakala pengawal logika fuzzy mempunyai prestasi yang lebih baik dalam daya beban rendah. Oleh itu, kedua-dua pengawal boleh digunakan untuk mengawal kestabilan voltan sistem grid mikro.

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LIST OF SYMBOLS AND ABBREVIATIONS

FLC	Fuzzy Logic Controller
PV	Photovoltaic
AI	Artificial Intelligence
PI	Proportional Integral
FL	Fuzzy Logic
ANN	Artificial Neural Network
NL	Negative Large
NS	Negative Small
ZE	Zero
PS	Positive Small
PL	Positive Large

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Chapter 1 defines the research background, motivation, problem statement, objective and scope of the project. The research background of voltage stability in a power system, a microgrid and the method used in this project are described. The motivation, problem statement, objective and scope of the project are clearly explained.

1.2 Research Background

Recently, power system networks that especially the sections of transmission have been conducted under extremely stressful conditions. There are some factors that are affecting the voltage stability of a power system. The factors are unbalancing reactive power, load variation, changing the speed of prime mover, heavy loads and long transmission lines, large different changes in power angle and power transfer, and failure gain in synchronism and short circuit. Under these factors, a power system can display a new type of unstable behavior characterized by slow (or sudden) voltage drops, sometimes escalating into a collapse. Due to history of voltage stability, The problem of voltage stability is first distinguished by Soviet Union scholar Malkovich in the 1940s [1]. Several voltage instability incidents have taken place worldwide. As a consequence, voltage stability has become an important concern in the planning and operation of the power system.

To determine the maximum load power in power system and analyze the voltage stability, P-V curve as shown in Figure 1.1 [2] is popularly used as a tool. After the load power overshoot the limitation power, P-V curve can analyze the load power that a bus may withstand before the breakdown of voltage. The bus voltage begins to fall down until it reaches the critical point or a voltage collapse point (knee of the PV curve) when the load power over a bus's power limit.

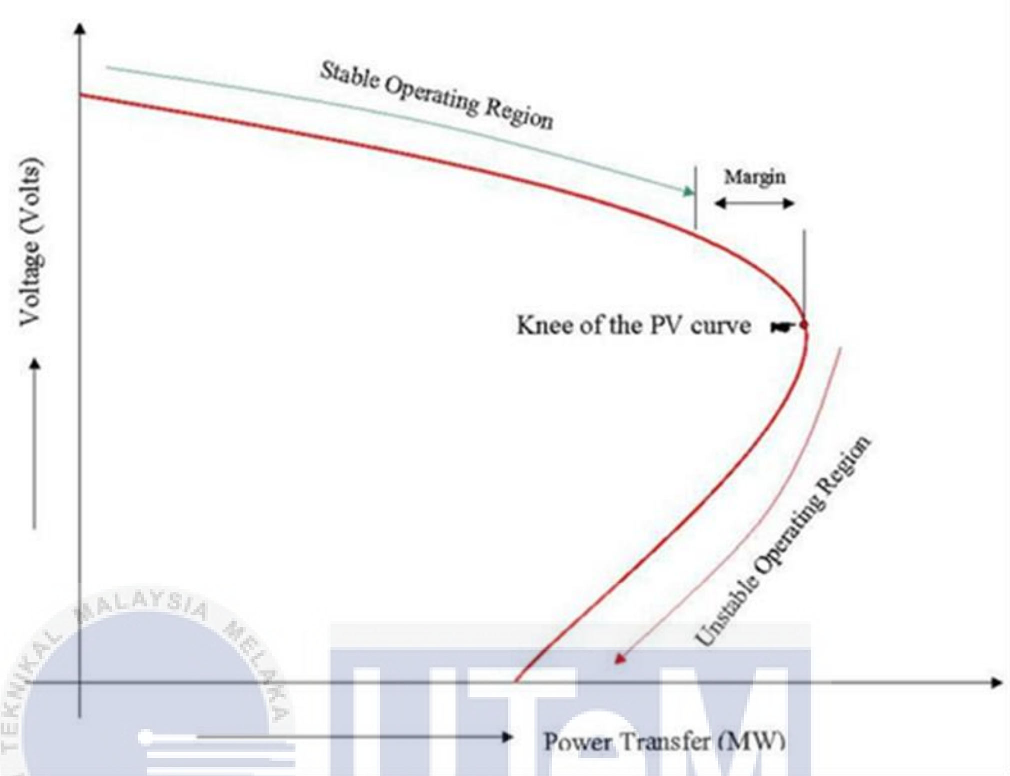

Figure 1-1: P-V curve.

A micro grid is a combination of domestic distributed loads and low voltage energy sources, including micro turbines, wind turbines, photovoltaics (PV) and storage devices [3]. Micro grids comprise various types of power generation resources, storage systems, and effective programs that optimize the use of renewable energy and ease energy management, response of demand and reduction of load. Due to the rapid growth of renewable energy, micro grids also use solar photovoltaic (PV) or wind farm as energy resources. There are many reasons for the importance of micro grid used. They are improving efficiency of the larger power grid, good for the environment with renewable resources, secure from attacks in cyber and physical. It shows that a micro grid play a main role in power system.

In this paper, the main focus is to investigate the voltage stability control in a power system. It also needs to study on voltage stability in a micro grid. To improve the problem of voltage stability in a micro grid, the method that artificial intelligence technique is used.

1.3 Motivation

This section will focus on two main aspects that are voltage stability in a micro grid and artificial intelligence technique. During a small disturbance, increase in load demand, or change in system condition occurs in power system, the voltage of the system will drop and uncontrollable because of the network failure to meet the growing demand of reactive power. This phenomena will lead to voltage instability which make the system collapse. For an example, one of the problems that occurred in Malaysia is the major blackout event on 13 January 2005, which make the local councils to trim some loads for the balancing of the generations and distribution demands [4]. It is very important to maintain voltage in steady state value and make sure that the stable condition in power system.

To implement the artificial intelligence technique in a micro grid is another aspect that focused on this section. Due to new era technology, the Fourth Industrial Revolution (IR 4.0) is a transformation in economies, jobs and also society. Under IR 4.0, artificial intelligence (AI) as one of physical and digital technologies is perfectly met the challenges to make digital companies that can communicate, analyze, and use data to drive smart physical action. With the smart technology, AI technique is used to improve the problem of voltage stability in micro grid.

1.4 Problem Statement

The major issue and equipment loading without modifying the capacity of transmission line is to preserve the voltage stability in power system. The voltage will become unstable when the load demand increases and the capacity of transmission insufficiency. This situation will lead to failure meet the reactive power demand. Due to the limitation of reactive power / voltage control of the generator, the system will lead to voltage instability. As the voltage instability, the power system's inability in keeping with the demand of reactive power. Furthermore, the instable voltage will also occur in a micro grid system and it makes the most disruption in power system. Hence, this paper will propose an artificial intelligence technique as a method to improve the voltage stability.

1.5 Objective

The main objective of this project is to investigate the voltage stability control in a power system.

The following objectives of this project are:

i. To develop reactive power control using artificial intelligence (AI) technique.

ii. To verify the impact of voltage stability control for micro grid network.

1.6 Scope

This project is focusing on power system voltage stability analysis. To analyze the results of the project, a designed system is modelled and tested as a micro grid system. In this system, it will be developed using DC voltage as energy sources. A Fuzzy Logic technique will also be used to improve the voltage stability control of micro grid system. The simulation results will be obtained by using MATLAB Simulink.

1.7 Project Outline

The main focus of this project is to investigate the voltage stability control in a power system. This report is divided into five chapters. The chapters are:

Chapter 1: Introduction about the voltage stability control for micro grid with artificial intelligence technique. Explanation about the motivation, problem statement, objective, scope and project outline.

Chapter 2: Literature Review about the voltage stability, micro grid and Fuzzy Logic (FL).

Chapter 3: Methodology discusses about the flowchart of the project, the model micro grid without controller, micro grid with Proportional Integral (PI) controller and micro grid with Fuzzy Logic Controller (FLC).

Chapter 4: Results and discussion which are the results of the test system and the performance of the voltage in the system.

Chapter 5: Conclusion about the summaries of results and the recommendation of future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Investigation will be discussed on voltage stability, micro grid and artificial intelligence technique. Section 2.2 describes a concept of voltage stability. Section 2.2.1 describes the different method on voltage stability. Section 2.3 discusses the concept of micro grid. Micro grid structure is presented in section 2.3.1 and the impact of micro grid on voltage stability is discussed in section 2.3.2. Artificial intelligence (AI) technique is discussed in section 2.4. Fuzzy Logic (FL) is presented in section 2.4.1. Finally, a comparison on other controller is presented in 2.4.2.

2.2 Concept of Voltage Stability

Voltage stability is described as a power system's capability to conserve the voltages in stable condition at all buses after having a disturbance from a balanced point. An overview on voltage stability is presently one of the most important research fields in power systems. In some literature papers, numerous problems of voltage stability have been investigated from many multiple perspectives. According to [5], the problems of voltage instability that caused voltage fall down have been reported in many countries , such as Canada, France, Japan, USA, and otherwise. In paper [6]–[8], the main factor that make voltage collapse is increase in load demands which will lead to failure of the reactive power demand. As it impacts the performance and capacity by the delivery of real power to end users, the role of reactive power will not be overstated. It can lead to a voltage collapse phenomenon that has caused several blackout incidents worldwide [9], [10] since the problems of reactive power are rejected.

Voltage stability has divided to some categories as shown in Figure 2.1. Voltage stability is divided to small-disturbance voltage stability and large-disturbance voltage stability. Small disturbance voltage stability is defined as the ability of the system that voltage stability can be preserved after have a small disturbance or load system increases. The load will be affected when the effect of given time. Large disturbance voltage stability states that the voltage stability for all buses system can be preserved after system faces large disturbance, i.e. the failure of system, fault, and the cutting machine. It is determined by the interaction between the system and the characteristic load and between continuous and discontinuous control and protection.

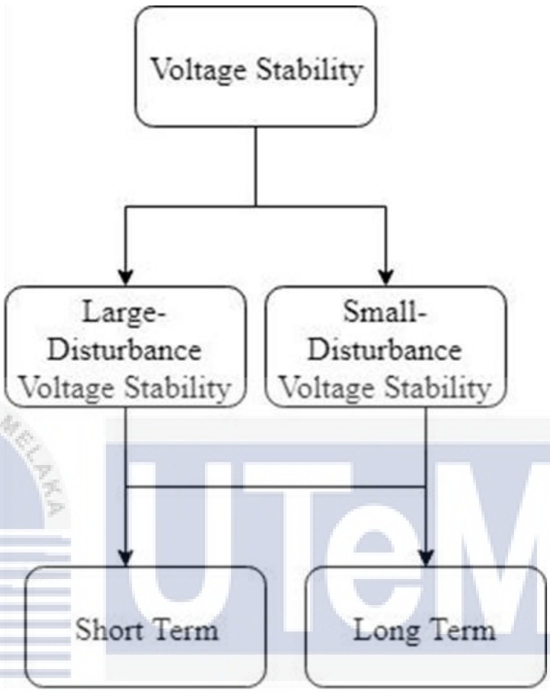

Figure 2-1: Categories of voltage stability

2.2.1 Different Method on Voltage Stability

In paper [11], a problem of voltage instability in power system is well described. The paper analyse the voltage instability of power system using real power-voltage (PV) modal analysis, voltage stability margin (VSM), reactive power-voltage (QV), load real power (P) margin, and reactive power (Q) margin. The result is reliable with the method.

Many methods are discussed as many journal papers. One of journal paper [12] stated that the analysis of the short-term voltage stability method using the stability limit in the P-V plane. The authors advance an analysis method using the stability boundary and transient P-V curves. The result show that the induction motor's acceleration or declaration status by comparing the load's operating point to the limit line. It is also a useful method in determine the short-term voltage stability.

To improve the voltage stability, previous studies in [13] was discussed the method is using Artificial Neural Network (ANN). In this paper, several types of line voltage stability indices (LVSI) are differentiated to determine the weakest line of power system. IEEE 9-bus and IEEE 14-Bus system are used to analyse the results. By implement of feed forward back propagation neural network (FFBPNN) which is type of artificial neural network (ANN), the results were analyse. It can concluded that ANN is sufficient and suitable method to prevent the voltage instability.

2.3 Concept of Micro Grid

In recent years, voltage stability in the context of micro grids has caught the eye of researchers because renewable energy sources have penetrated the world's power networks [14].

A large-scale power system usually contains of generating, transmitting and distributing systems in which the power plants are somehow far from the power system. As both in terms of operation and in order to secure the power systems, even though this is not always the case in all systems, the operators tend to bring the units of power generation nearer to the distribution systems. There are some cases that called micro grid power systems.

Many descriptions for micro grid have been created. One of the definition in [15], micro grids are electrical distribution networks of low voltage, heterogeneously composed of distributed generation, storage, load and organized autonomously from the bigger early grid.

However, there are three modes of a micro grid that are island mode, grid connected mode and transition to grid connected mode [16].

Many approaches to analyzing the voltage stability of the micro grid were presented in the literature. In [5], PV and QV curves have been used. The voltage stability in low voltage micro grids also described in [8] but it is in aspects of active and reactive power. The frequency and voltage control method for islanded micro grid based on multienergy storages also discussed in [17].

Most of the previous studies have been carried out either on IEEE test systems or on some real systems with changes and assumptions tailored to the study objectives. The study is carried out on a real micro grid system.

2.3.1 Micro Grid Structure

A micro grid is defined as a system consisting of generating sources, focusing on the use of renewable energy, the equipment of storage and the connected loads to meet the energy demand. The general structure of a micro grid as shown in Figure 2.2 [18] includes by energy storage system, different generation systems and units of power management which for examples are pure converter, regulator, grid-tied inverter and converter.

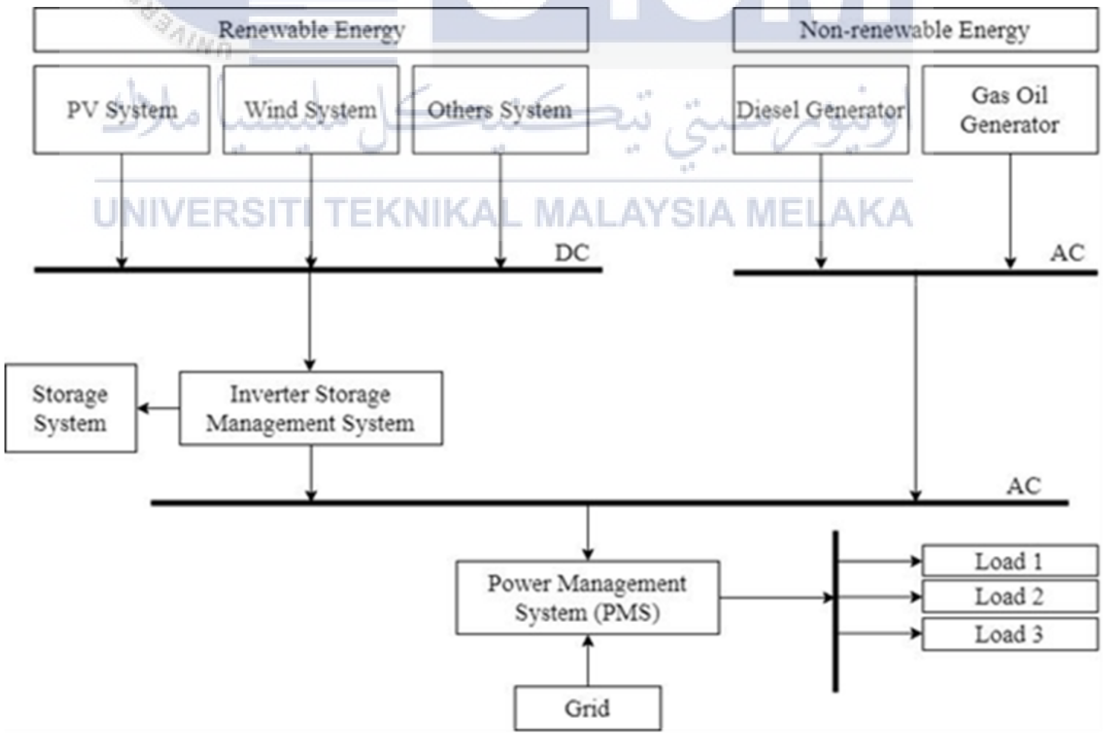

Figure 2-2: General structure of a micro grid

2.3.2 Impact of Micro Grid on Voltage Stability

According to [19], the effects of a micro grid on the voltage stability of power system is proposed. A micro grid is allowed into the IEEE 14 bus system and the impacts of voltage stability is presented. A fault is also added into the system and carried the results. The power system's dynamic reaction time with micro grid is quicker than the basic state system. In a shorter time than the basic system, this system also has a steady state. The voltage of the micro grid power system has better values than the basic state after the steady state has been achieved. The positive impacts have also seen that the changes of reactive power when the power system is with micro grid.

2.4 Artificial Intelligence Technique

Artificial intelligence (AI) is a term which in its broadest sense indicates a machine or artifact 's ability to conduct the identical type of functions that define human thinking. According to [20], AI is the computer science part of the design of smart computer systems, i.e. Systems that display the personality in action of humanity which are language, knowledge, ability to learn, logic, problem solving, etc.

Artificial intelligence (AI) techniques found in the power system are fuzzy logic (FL), expert systems (ESs), artificial neural networks (ANNs or NNWs) and more techniques. The uses of AI techniques are in control, design, estimation, simulation, fault diagnostics, and fault-tolerant control in micro gird and renewable energy system. As paper , some example of application that using artificial intelligence (AI) techniques in smart grid and renewable energy systems are discussed.

2.4.1 Fuzzy Logic

Fuzzy Logic (FL) is one of artificial intelligence (AI) techniques to solve the problems with more accurate results. The Fuzzy Logic (FL) is a principle-based control system where a guideline is a control decision mechanism for correcting the impact of some factors that cause of the power system.[21] Although they are mostly easier to understand and apply, one of major strengths over other AI techniques is the capacity of fuzzy systems to handle such information. Fuzzy systems handle applications with incomplete or imprecise data including approximation of function, categorization

/ clustering, estimation and control. Through some searching, there are two types of Mamdani and Takagi-Sugeno fuzzy controller. The difference between this two types of fuzzy controller is that either linear or constant value is Takagi-Sugeno's output membership function (MF). However, the most used techniques is Mamdani Fuzzy Controller. Two main features of fuzzy systems that give better efficiency for some applications :

i. Fuzzy systems are suitable for uncertain or approximate reasoning, in particular for a system with a difficult to derive mathematical model.

ii. FL permits decision making under imperfect or unclear information with approximately values.

2.4.2 Comparison on Other Controller

Through the searching, some similar method is used which relate to my project. A research journal article with title "Controller Design and Stability Analysis of Grid Connected DC Microgrid" represent a project which discussed about the design of two controllers (PI and Fuzzy Logic PI) to achieve the voltage stability of DC micro grid.[22] In this paper, PI controller and Fuzzy Logic PI (FL-PI) controller are used for the control of DC voltage. As a comparison result, it has seen that the FL-PI controller has a good performance parameters and more stable although both controllers are fast and effectively.

Another research journal paper is [23]. In simulating an automatic voltage regulator in transient stability power system analysis, a controller based on Fuzzy Logic (FL) is developed. As a comparison, the system performance with fuzzy logic is compared to the system with power system stabilizer and without power system stabilizer. As a result, implementation of fuzzy logic shows improved performance in oscillating damping, maintaining terminal voltage and controlling power after disturbance of the system.

2.5 Summary

Based on the previous paper, it shows that many authors have done different methods to improve the problems of voltage stability and the results also successfully achieved. The methods also have done on the problems of micro grid and the results also have been successful. As one of methods in previous paper, Fuzzy Logic (FL) is used to improve the stability of voltage and it also get the ideal result. Thus, this project also investigates the voltage stability control by using fuzzy logic technique for a micro grid system.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter proposes the methodology on how the objectives of this project will be achieved. The modelling of the system used will be explained in this chapter. It will be also discussed the method for the improvement of the system.

3.2 Research Flowchart

The management of this project is shown as a flowchart in Figure 3.1. Before starting the project, the literature review and recommended micro grid system to use have been studied. The first step of the start of this project is designing a micro grid system. The model of micro grid system is designed by MATLAB Simulink for the testing. Three micro grid systems that without controller, with PI controller and with Fuzzy Logic Controller (FLC) are designed and compared the results. The data are collected through some studies on the resources such as journal, conferences, and books. In this project, it major to research on the voltage stability in a power system.

A K-chart project is shown in Figure 3.2 to clearly illustrate the instruction of this project. There are three categories divided in the power stability. They are rotor angle stability, frequency stability, and voltage stability. In this project, voltage stability is the main direction to investigate.

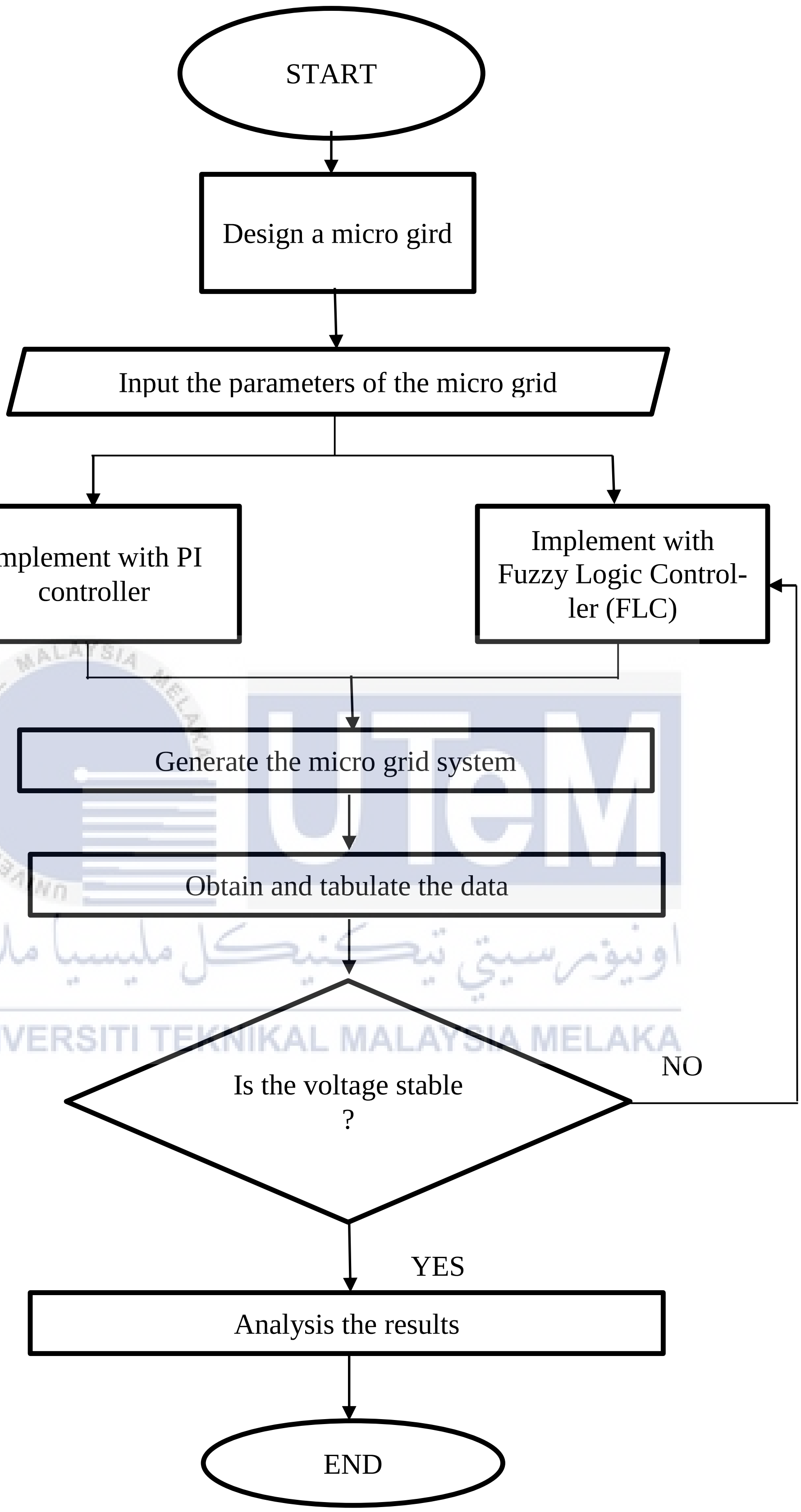

Figure 3-1: Flowchart of project

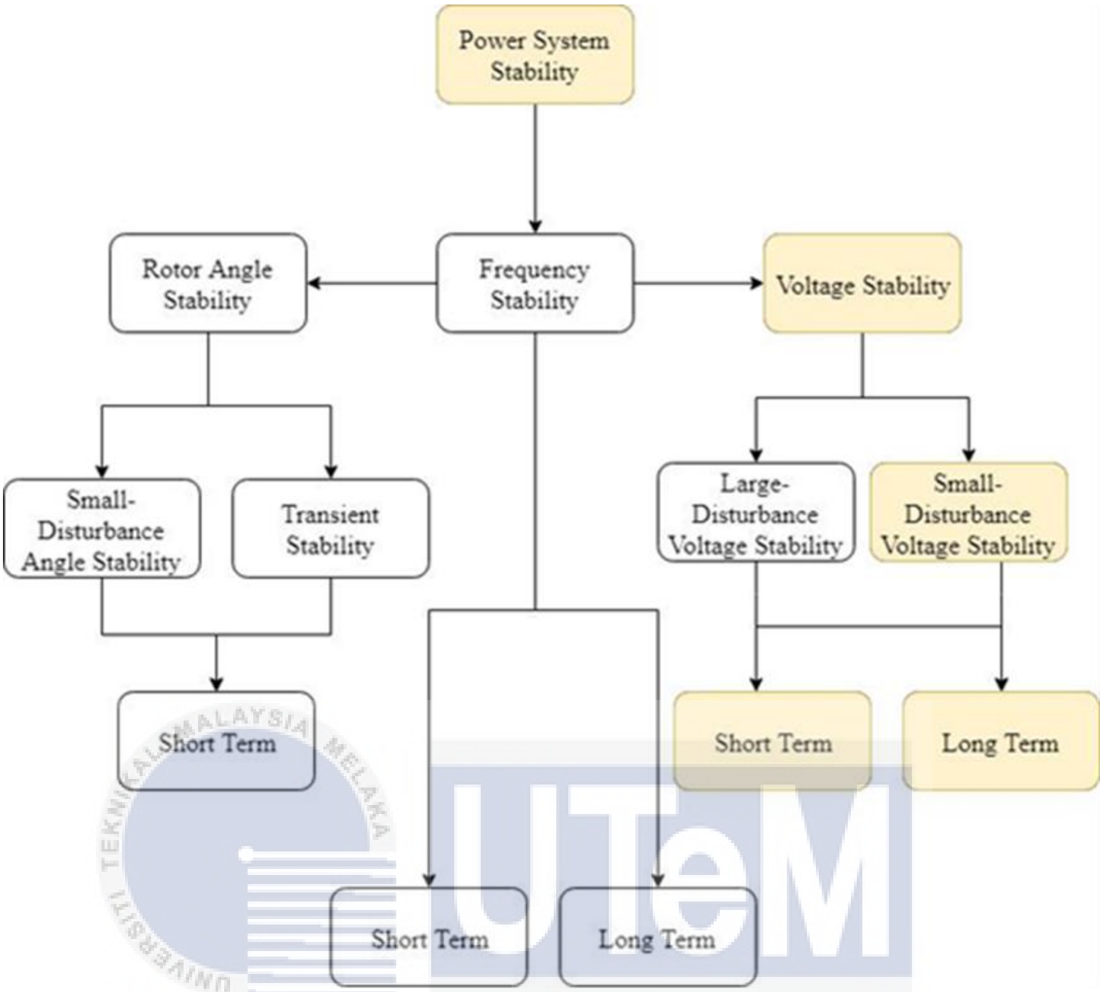

Figure 3-2: The K-chart of the project

3.3 A Designed Micro Grid System Without Controller

In Figure 3.3, it shows the designed micro grid system without controller by MATLAB Simulink. This micro grid is designed with a DC voltage, a universal bridge which use for IGBT / diodes, current measurements, a three-phase series RLC branch, a three-phase V-I measurement, voltage measurements, displays, scopes and a three-phase parallel RLC load. The parameters are set with the value :

i. 650V of amplitude is set in a DC voltage source.

ii. IGBT/ diode is set in universal bridge.

iii. Resistance, R is set with 10 ohms, Inductance, L with 1e-3 H and Capacitance, C is set with 1 F in RLC branch.

iv. In RLC Load , 60 Hz frequency is set. Active power of load are set with difference values.

After set the parameters of micro grid system, simulation is run for 0.05 seconds. Result is recorded and tabulated.

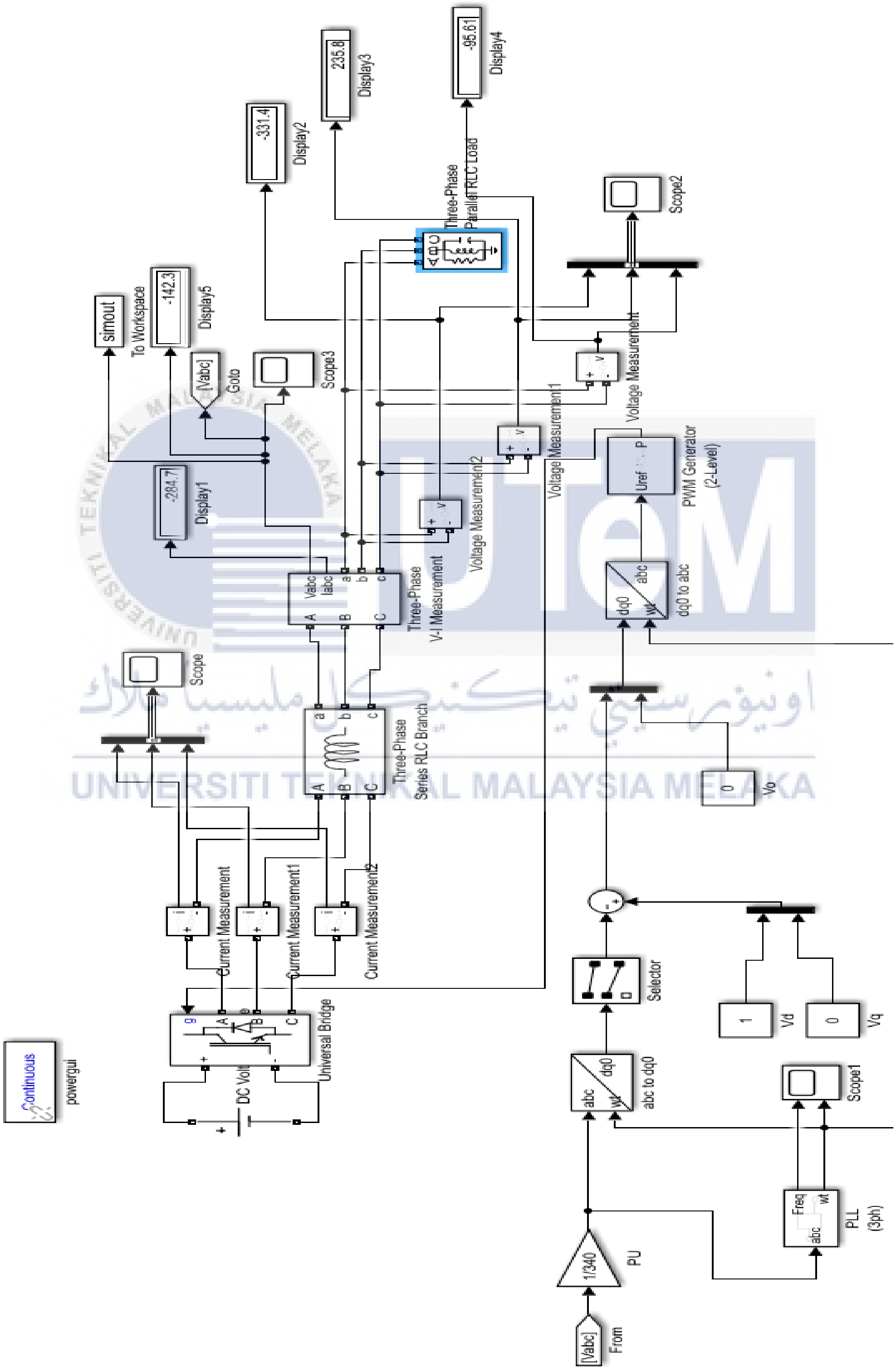

Figure 3-3 : Micro grid system without controller

3.4 Micor Grid System With Proportional Integral (PI) Controller

A micro grid system with proportional integral (PI) controller is designed as Figure 3.4. The closed-loop PI controller is constructed with the previous micro grid system that does not have controller. It runs the simulation for 0.05 s and records and evaluates the result.

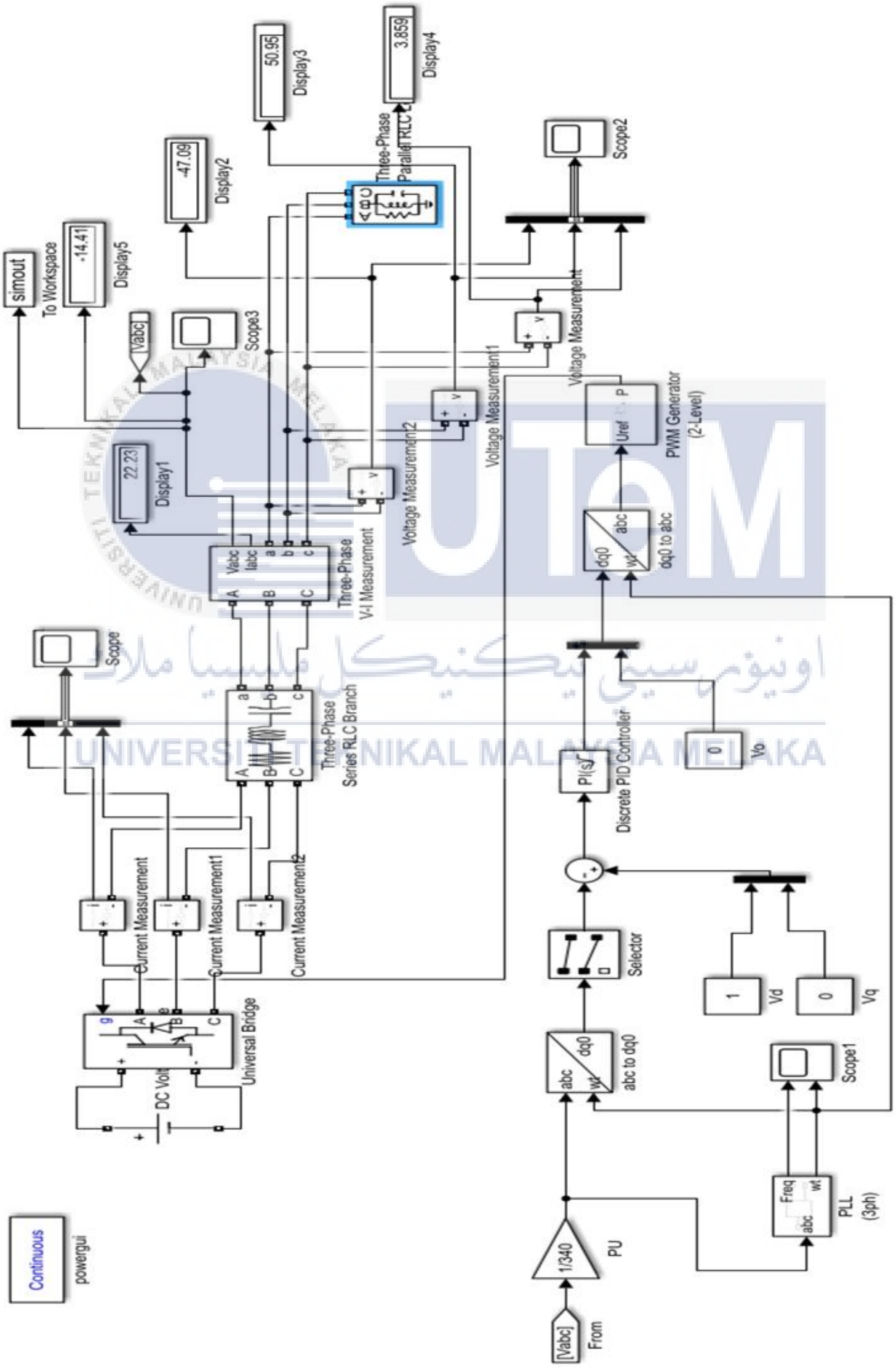

Figure 3-4 : Micro grid system with PI controller

3.5 Micro Grid System With Fuzzy Logic Controller (FLC)

A micro grid system with Fuzzy Logic Controller (FLC) is modelled as Figure 3.5. As shown in Figure 3.6, Fuzzy command is executed in the MATLAB command window to launch Fuzzy Logic Designer.

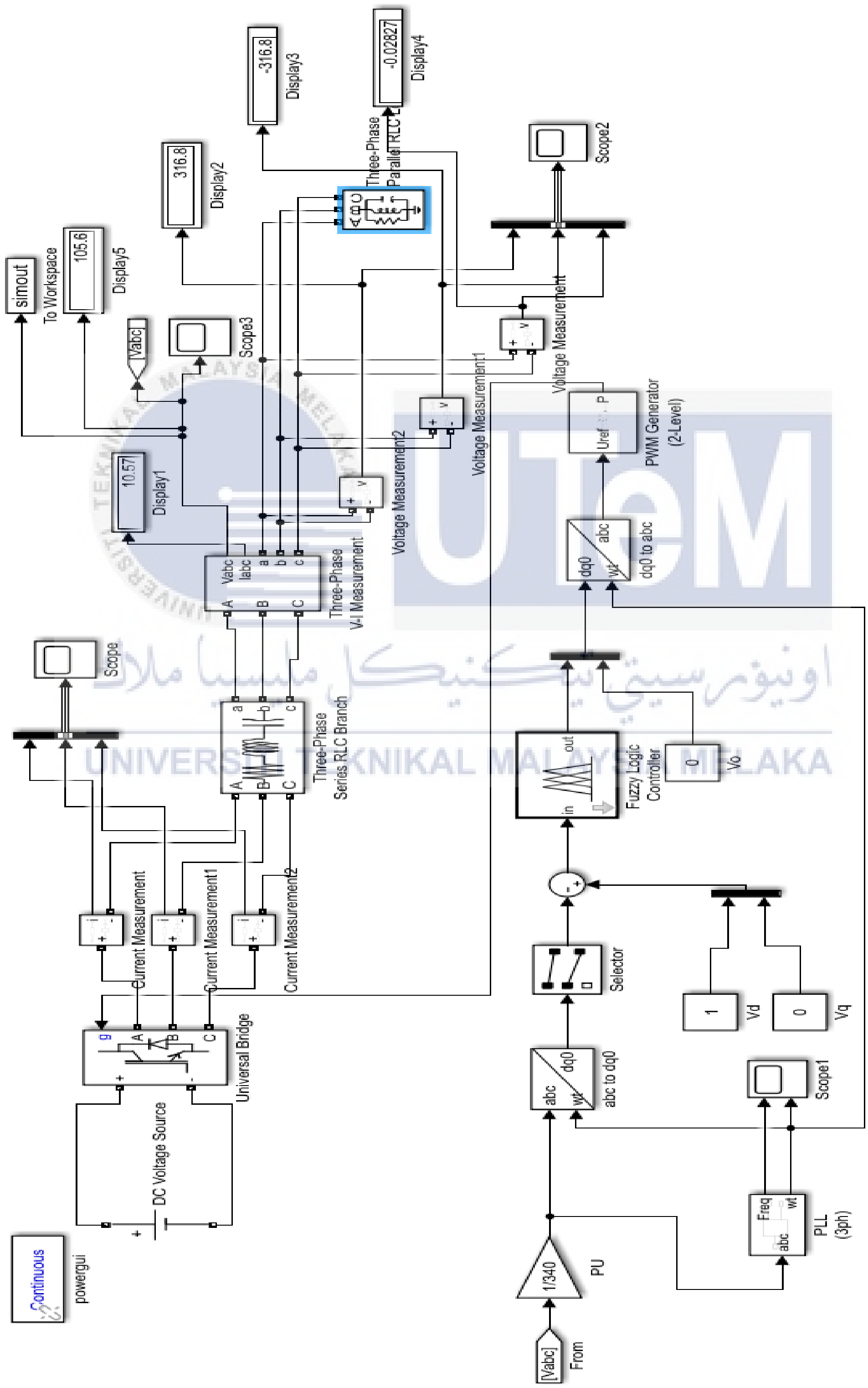

Figure 3-5 : Micro Grid System With Fuzzy Logic Controller

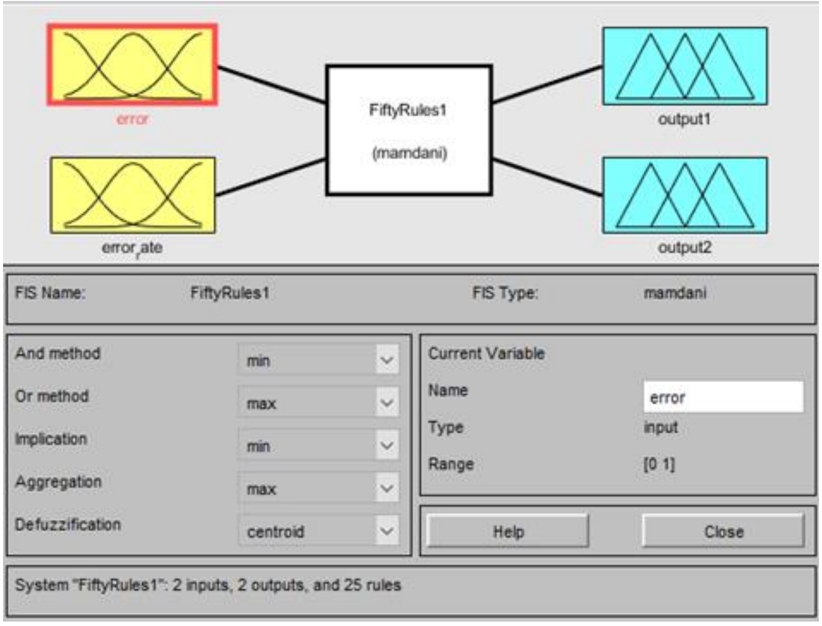

Figure 3-6: Fuzzy Logic Designer

It is inserted to two inputs and two outputs for the design. The inputs name are changed to "error" and "error rate" while the outputs remain the same.Each input and output has 5 x 5 membership features (triangular membership feature).The membership function for input and output have set negative large (NL), negative small (NS), zero (ZE), positive small (PS), and positive large (PL) as shown in Figure 3.7. Input 1 is set error variables [0 1], input 2 is set error rate variables [-0.5 1] in Figure 3.8, output 1 is set variables [0 1] in Figure 3.9 and output 2 is set variables [0 1] in Figure 3.10.

Figure 3-7: Membership function of error variable

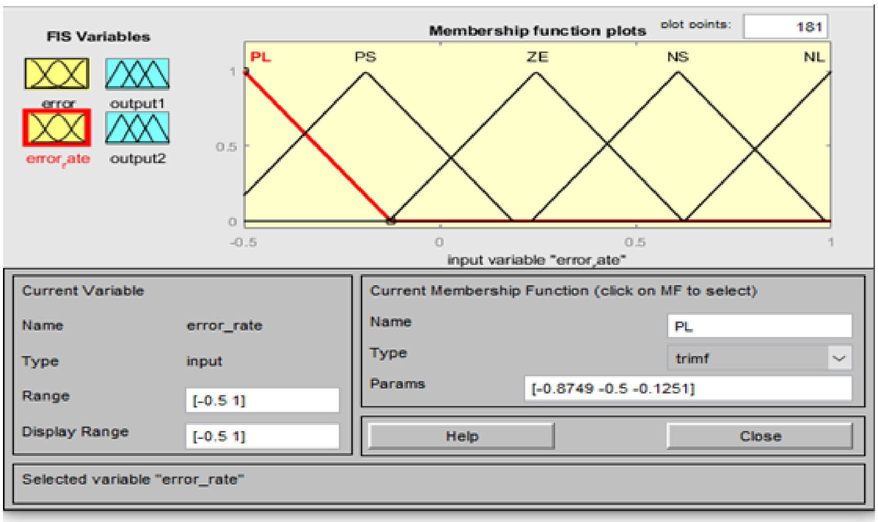

Figure 3-8: Membership function of error rate variable

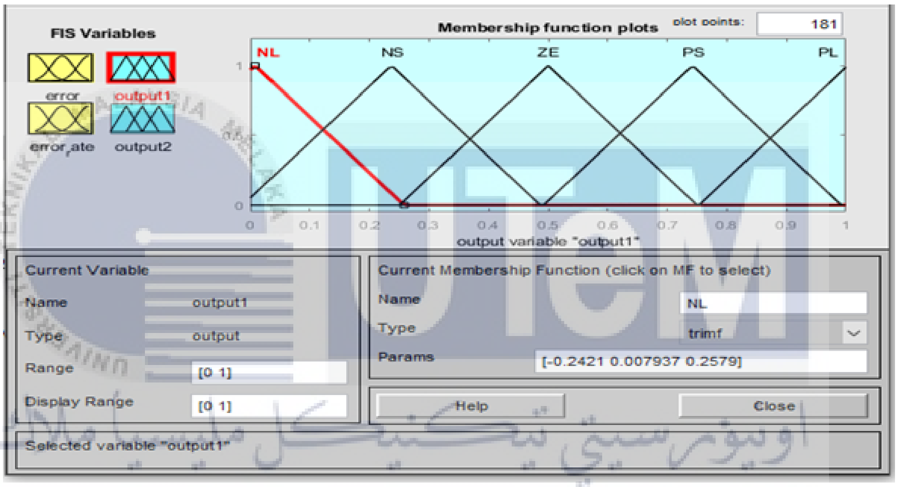

Figure 3-9: Membership function of output 1 variable

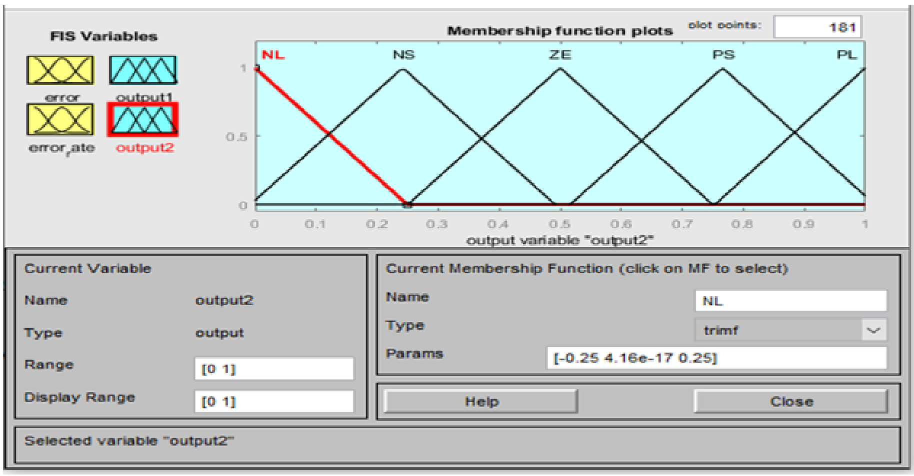

Figure 3-10: Membership function of output 2 variable

The rules are designed to described the relationships between two input variables (error and error rate) and two output variables as shown in Table 3. 1 with the fuzzy rules ‘IF_AND_THEN’. For an example, a fuzzy rule reads as follows : Rule 1 : If error is NL and error rate is PL, then output 1 is ZE and output 2 is ZE. The rules have been named “FiftyRules1” and saved in file and export to workspace with a given name of “FiftyRules1”. Before running the simulation, the name of FLC is changed to the file name and saved. For running 0.05s simulation, the results are recorded and analyzed.

Table 3-1: Rule table of Mamdani FLC

ERROR RATE \ **ERROR**	**NL**	**NS**	**ZE**	**PS**	**PL**
PL	ZE	PS	PL	PL	PL
PS	NS	ZE	PS	PL	PL
ZE	NL	NS	ZE	PS	PL
NS	NL	NL	NS	ZE	PS
NL	NL	NL	NL	NS	ZE

3.6 Summary

In this chapter, the method and solution is obtained and discussed. A designed micro grid system is tested and run the simulation without any controller by MATLAB Simulink. For a comparison, a micro grid system with PI controller is also tested and analyzed the results. To achieve the objective, artificial intelligence techniques that are fuzzy logic controller (FLC) have been implemented in the micro grid system and run the simulation to analyze the results.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Overview

In this chapter, the early results will be discussed and analyze the reading of a micro grid system. The performance of micro grid is carried out without controller, with PI controller and with Fuzzy Logic Controller (FLC). As the main objective discussed, the voltage stability control in a power system is investigating.

4.2 Results and Analysis

A micro grid system is modelled with three cases and the results are carried out by using MATLAB Simulink. These three cases as shown in Table 4.1 are developed to test and observe the effect of voltage stability in a power system. All the models have a constant reactive power that are Q = 100 Var while changing the active power. All the models are run simulation for 0.05 seconds.

Table 4-1: The type of cases in micro grid system

Cases of system	Specification
Case 1	Without any controller
Case 2	With Proportional Integral (PI) Controller
Case 3	With Fuzzy Logic Controller (FLC)

4.2.1 Result in Case 1

In Case 1, a micro grid system is modelled without any controller. Table 4.2 has been shown the voltages of micro grid that without controller for different value of active power. From 0 kW to 900 kW, it shows that the active power increases, the voltage decreases. With the voltage drop, the system will become unstable. When reach the point for 1000 kW, the voltage starts to increase. According to the table, two graphs of voltage against active power are separately plotted as shown in Figure 4.1.

Table 4-2: The voltage of micro grid without controller for different active power

Without Controller	
Active Power, P (kW)	**Voltage (V)**
0	-
100	-7.468
200	-48.5
300	-81.15
400	-107.3
500	-128.2
600	-144.5
700	-156.4
800	-164.1
900	-167.5
1000	-167.4
1100	-164.3
1200	-158.5
1300	-150.3
1400	-140.2
1500	-128.3
1600	-115.1
1700	-100.6
1800	-85.27
1900	-69.21
2000	-52.8
2100	-36.62
2200	-20.46
2300	-4.635
2400	10.71
2500	25.37
2600	39.34
2700	52.61
2800	65
2900	76.52
3000	87.08

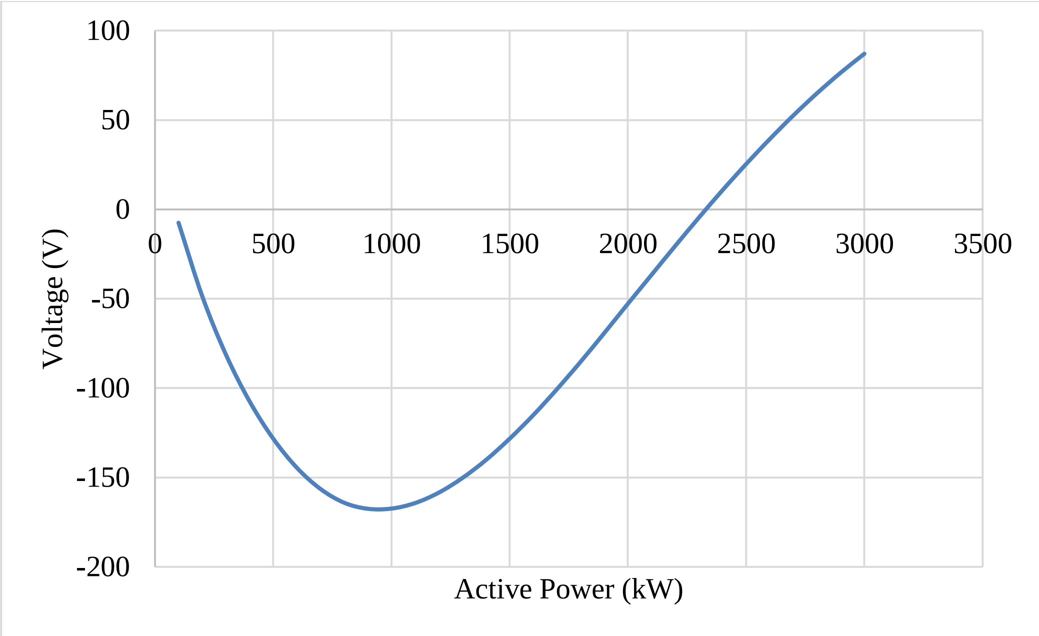

Figure 4-1: The graph of V against P

4.2.2 Result in Cases 2

In Case 2, a micro grid system is modelled with PI controller. The data voltage of micro grid with PI controller for difference active power has been tabulated in Table 4.3. It can be seen that the voltage increases when the active power increases. However, the voltage starts to drop from 1900 kW. From the Figure 4.2, the graph shows that the data of the system with PI controller.

Table 4-3: The voltage of micro grid with PI controller for different active power

	With PI Controller	
	Active Power, P (kW)	**Voltage (V)**
LOW LOAD	0	-
	100	-212.1
	200	-138.9
	300	-103.3
	400	-82.26
	500	-68.35
	600	-58.47
	700	-51.08
	800	-45.36
	900	-40.79
	1000	-37.06

	1100	-33.94
	1200	-31.32
	1300	-29.07
	1400	-27.12
	1500	-25.42
	1600	-23.92
	1700	-22.58
	1800	-21.39
HIGH LOAD	1900	12.64
	2000	11.86
	2100	11.28
	2200	10.75
	2300	10.31
	2400	9.904
	2500	9.487
	2600	9.186
	2700	8.845
	2800	8.569
	2900	8.292
	3000	8.015

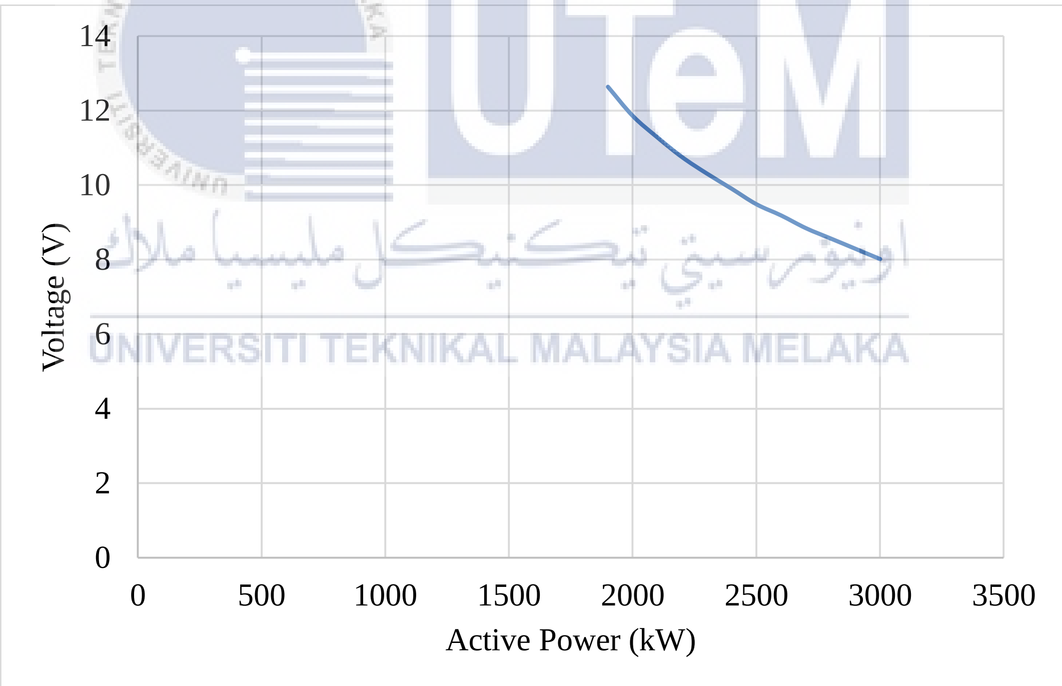

Figure 4-2: The graph of V against P

4.2.3 Result in Case 3

To obtain the objective, the fuzzy logic controller is used and modelled with the designed micro grid system. The result is shown in Table 4.4 and also analyze in Figure 4.3. The simulation is started from the 100 kW active power. The higher the active power, the lower the voltage with FLC. The voltage is dropped until the voltage collapse point and the graph shows that the system is in stable region.

Table 4-4: The voltage of micro grid with FLC for different active power

	With Fuzzy Logic Controller (FLC)	
	Active Power, P (kW)	**Voltage (V)**
LOW LOAD	0	-
	100	105.6
	200	66.11
	300	45.68
	400	35.84
	500	29.83
	600	25.58
	700	22.25
	800	19.63
	900	17.54
	1000	15.84
	1100	14.48
	1200	13.32
	1300	12.33
	1400	11.48
	1500	10.73
	1600	10.08
	1700	9.494
	1800	8.977
HIGH LOAD	1900	8.519
	2000	8.104
	2100	7.726
	2200	7.379
	2300	7.06
	2400	6.768
	2500	6.5
	2600	6.251
	2700	6.022
	2800	5.808
	2900	5.607
	3000	5.422

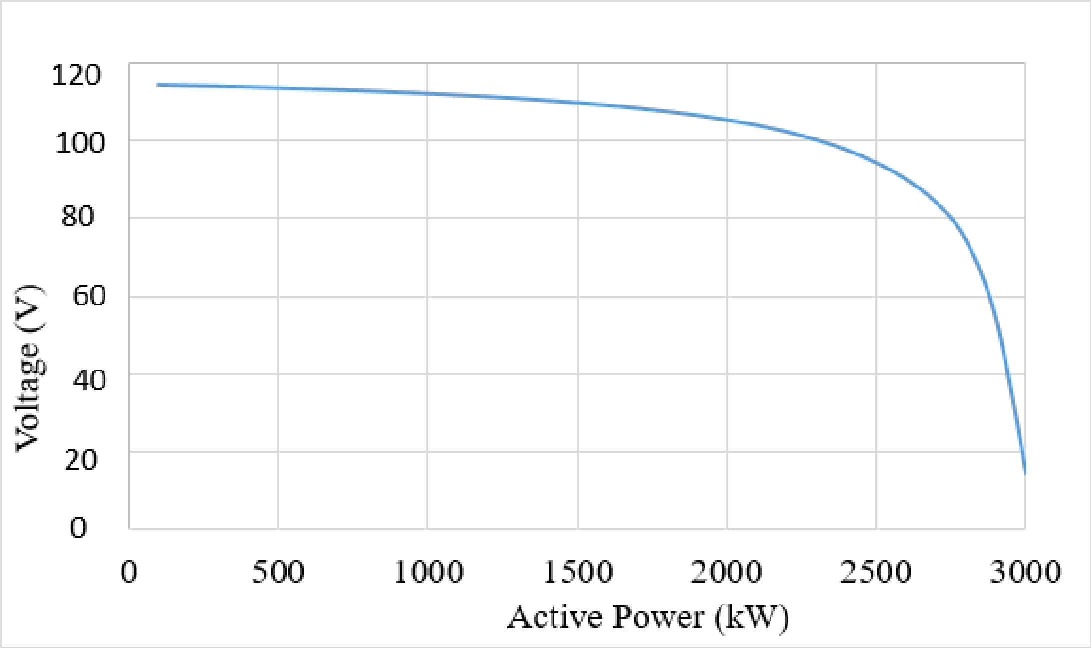

Figure 4-3: The graph of V against P

4.2.4 Comparison Among Three Cases

As a comparison, the graphs of voltages for active power among three cases are combined in Figure 4.4. Table 4.5 shows the voltages in three cases with difference active power. Due to the graph obtained, it occurred an oscillation in voltage case 2 and show that the system still in unstable condition. For case 3, the graph is in fluency condition.

Table 4-5: The voltage among three cases

Active Power, P (kW)	Voltage case 1, Vc1(V)	Voltage case 2, Vc2 (V)	Voltage case 3, Vc3 (V)
0	-	-	-
100	-7.468	-212.1	105.6
200	-48.5	-138.9	66.11
300	-81.15	-103.3	45.68
400	-107.3	-82.26	35.84
500	-128.2	-68.35	29.83
600	-144.5	-58.47	25.58
700	-156.4	-51.08	22.25
800	-164.1	-45.36	19.63
900	-167.5	-40.79	17.54
1000	-167.4	-37.06	15.84
1100	-164.3	-33.94	14.48

1200	-158.5	-31.32	13.32
1300	-150.3	-29.07	12.33
1400	-140.2	-27.12	11.48
1500	-128.3	-25.42	10.73
1600	-115.1	-23.92	10.08
1700	-100.6	-22.58	9.494
1800	-85.27	-21.39	8.977
1900	-69.21	12.64	8.519
2000	-52.8	11.86	8.104
2100	-36.62	11.28	7.726
2200	-20.46	10.75	7.379
2300	-4.635	10.31	7.06
2400	10.71	9.904	6.768
2500	25.37	9.487	6.5
2600	39.34	9.186	6.251
2700	52.61	8.845	6.022
2800	65	8.569	5.808
2900	76.52	8.292	5.607
3000	87.08	8.015	5.422

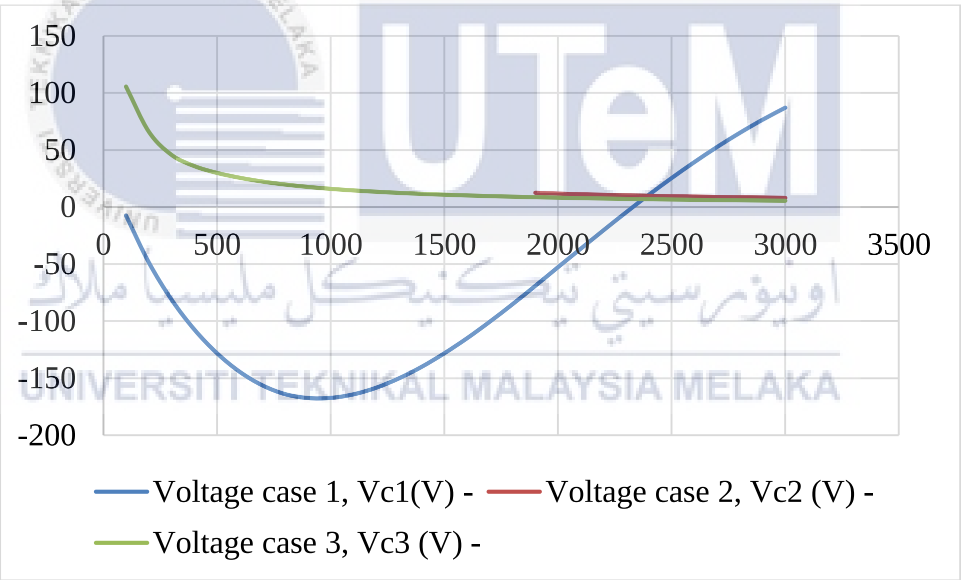

Figure 4-4: The graph for comparison of voltage among three cases

4.3 Summary

After obtaining the results as shown in this chapter, the voltage will decreases when the active power increases. Thus, to control the voltage stability limit, the system is controlled by PI controller and fuzzy logic controller (FLC). As the results obtained, both controller has a good performance in the voltage stability control.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this project, the main objective which is to investigate the voltage stability control in a power system is achieved without any proposed method. As the system is tested, the result without controller shows that the graph of voltage decreases from 0 kW until 900kW and slightly increases from the point of 1000 kW. The system without controller shows that it is still unstable to control the voltage and does not have the best PV curve as well because it goes down and goes up the graph very fast. With PI controller, the voltage is gradually increases but it has a significant change from 1900 kW and it starts to drop. The system with PI controller shows that it is in stable condition with higher load power from 1900 kW until 3000 kW and has a good performance as compare to the system without controller. To obtain the objective, a fuzzy logic technique is used. The result shows that the significant changes with fuzzy logic controller as compare to other cases. The graph with fuzzy logic controller is gradually decreases and it is able to stabilize. The graph is very fluency and shows the voltage is controlled to reach the voltage collapse limit. Among two controllers used, PI controller has a better performance in high load power and a small voltage stability margin while a fuzzy logic controller shows a better function in low load power and has a larger voltage stability margin. Thus, both controller is suitable used to control the voltage stability.

5.2 Future Recommendations

As a recommendation, the designed micro grid system is not very perfect and stable. It can be added renewable energy like solar photovoltaic (PV), wind turbine and others to improve the stability of the system. Although a fuzzy logic technique is simple and easier to understand, but as a better and clear performance, artificial neural network (ANN) is a better method to get the more accuracy result.

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APPENDICES

APPENDIX A GANTT CHART OF PROJECT

		WEEK													
No	**Activities**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Investigation of voltage stability control for a micro grid and artificial intelligence technique														
2	Design a micro grid without any controller, with PI controller and with Fuzzy Logic Controller (FLC)														
3	Run the simulation of the system														
4	Analyze the data collected from the system														
5	Compare the results														
6	Report completion and preparation for presentation														