AVERAGE DYNAMICAL FREQUENCY BEHAVIOUR FOR ISLANDED MICRO-GRID SYSTEM WITH MULTIPLE GENERATORS

ADLIA BINTI MARODZUAN

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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ADLIA BINTI MARODZUAN

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DECLARATION

I declare that this thesis entitled "AVERAGE DYNAMICAL FREQUENCY BEHAVIOUR FOR ISLANDED MICRO-GRID SYSTEM WITH MULTIPLE GENERATORS 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	:	Adlia binti Marodzuan
Date	:	19 June 2019

APPROVAL

I hereby declare that I have checked this report entitled "AVERAGE DYNAMICAL FREQUENCY BEHAVIOUR FOR ISLANDED MICRO-GRID SYSTEM WITH MULTIPLE GENERATORS" 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

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In the name of Allah, the most Gracious and the most Merciful

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ABSTRACT

A microgrid is a part of a power system which can operates in grid connected and islanding mode with multiple generators connected to the microgrid. When the microgrid operates in island mode, the load is dominantly supplied by the local sources. The crucial situation is supply and demand need to be balance while the generators in the same system is actually not in coherent. If there are any imbalance in the network, the system can lead to significant frequency deviations. This is why this project need to be done to study the behavior effect of the frequency. In order to analyses the network, lots of mathematical equations has been derived to model the physical network. The objective of this paper is to investigate how to model on islanding of microgrid system with multiple generators and to identify an approach in finding the average dynamical frequency, also to analyze the frequency behaviour with variation of load demand. The literature review, reviews other people papers on the understanding of microgrid and distributed generation which related to the power system study involved the large electrical power system network with multiple generator. The two generator model involving tie-line bias control is simulated in linear time invariant through state space equation using Simulink. All the parameters are set and substitute in the state space equation. The simulation results show the frequency behavior of the generator in the system when there is load change occur to the system. The frequency of the generator that is near to the load change will drop more compare to the other generator and with the presence of automatic generation control, the frequency will return back to its nominal value. The average dynamical frequency is find using similarity method and compared with the conventional method.

ABSTRAK

Mikrogrid adalah sebahagian daripada sistem kuasa yang boleh beroperasi dalam mod bersambung dan mod “islanded” dengan beberapa penjana yang disambungkan ke mikrogrid. Apabila mikrogrid beroperasi di mod “islanded”, bebannya dibekalkan oleh sumber-sumber tempatan. Keadaan yang kritikal adalah bekalan dan permintaan perlu seimbang manakala penjana dalam sistem yang sama sebenarnya tidak sepadan. Sekiranya terdapat ketidakseimbangan dalam rangkaian, sistem ini boleh menyebabkan penyimpangan kekerapan yang ketara terhadap frekuensi. Inilah sebabnya mengapa projek ini perlu dilakukan untuk mengkaji kesan kelakuan frekuensi. Untuk menganalisis rangkaian, persamaan-persamaan matematik telah diperoleh untuk model rangkaian fizikal. Objektif projek ini adalah untuk menyiasat bagaimana untuk membuat model di mikrogrid dengan pelbagai generator dan untuk mengenalpasti pendekatan dalam mencari frekuensi dinamik purata, juga untuk menganalisis kelakuan frekuensi dengan variasi permintaan beban. Semakan kesusasteraan, mengkaji kertas orang lain mengenai pemahaman tentang mikrogrid dan generasi yang diedarkan yang berkaitan dengan kajian sistem kuasa melibatkan rangkaian sistem kuasa elektrik yang besar dengan pelbagai generator. Model dua penjana yang melibatkan kawalan bias talian tali disimulasikan dalam invarian linier melalui persamaan ruang menggunakan Simulink. Semua parameter ditetapkan dan menggantikan persamaan ruang. Hasil simulasi menunjukkan kelakuan frekuensi penjana dalam sistem apabila terdapat perubahan beban berlaku pada sistem. Kekerapan penjana yang mendekati perubahan beban akan menurun berbanding dengan penjana yang lain dan dengan kehadiran kawalan generasi automatik, frekuensi akan kembali kepada nilai nominalnya. Frekuensi dinamik purata telah dicari menggunakan kaedah persamaan dan dibandingkan dengan kaedah konvensional.

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CHAPTER 1

INTRODUCTION

1.1 Project Background and Motivation

Microgrid is a part of a power system which used an electricity sources consist dispatchable generation and non-dispatchable renewable energy that are capable of operating in either parallel or independent towards the main power grid (macro grid). The microgrid can operate in both grids connected and islanded mode. When the microgrid is operates in island mode, the load is dominantly supplied by the local sources. The crucial situation in this case is supply and demand need to be balance. If there are any imbalance in the network, the system can lead to significant frequency deviations. Many researches which related to the power system study with variety of motivation has been done and most of the research work involved the large electrical power system network with multiple generator. In order to analyses the network, lot of mathematical equations has been derived to model the physical network. These mathematical models are crucial to implement and make the researcher think about the way to simplify by removing the unwanted parameter and put some assumption and approximation. According to page 511 of [2], generators that belong in the same area are said to be coherent and one equivalent generator can represents the group of coherent generators. One of the steps in controlling the microgrid in islanded mode are having coherent generators because it is easier to simplify and to analyze. However, in reliability of the data analysis, the machine that swings together in the same station is actually not coherent because, each of the generators is connected in different distance of transmission line. Therefore, this project considered the transmission line model and also the different parameters for each generator. Hence, an average dynamical behavior of system frequency is determined.

1.2 Problem Statement

When the islanded microgrid system with multiple generators are not coherent, the transmission line in the microgrid system and the parameters of the generator need to be considered. Also, during islanded mode, the microgrid is very sensitive to the disturbance or varying of loads. Load disturbance will affect the system frequency which correspond to the change of generator's dynamical behaviour and may causing to the stability problem.

1.3 Objective

1. To develop linear model for islanded micro-grid system consist of multiple generators
2. To analyze the effect of each generator in terms of frequency dynamical behavior
3. To anzlyze the average dynamical frequency behavior under sudden variation of load demand
4. To identify an approach in finding average dynamical frequency of the microgrid system

1.4 Scope

The scope of the project is to model multiple generators for islanded microgrid system in order to study and analyze the average frequency behavior. Also, the microgrid system is described through state-space linear time invariant. Simulation program that can be used for this project is SIMULINK.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains on the theories related to the microgrid power system. The understanding on the theories and operation of microgrid power system, is important before the simulation starts. This chapter includes the operation and theories of islanded microgrid, distributed generation, and islanded microgrid system with multiples generators.

2.2 Islanded Microgrid

According to the operating characteristics of Microgrid, the islanded Microgrid stability mainly depends on the structure of Microgrid, the capacity of stored-energy DGs, and the control strategy of DGs [1]. Figure 2.1 shows an example of islanded microgrid network.

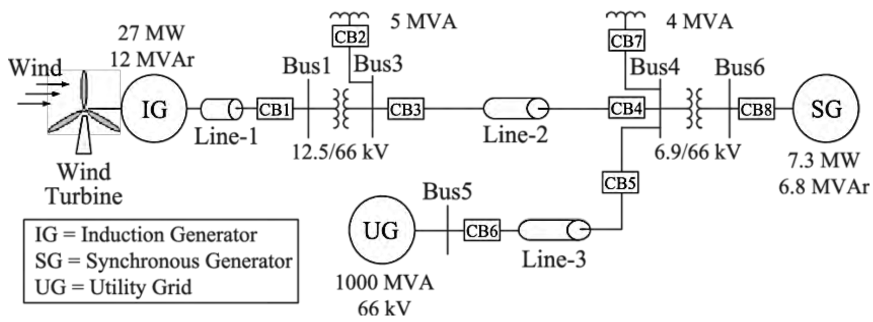

Figure 2.1: Example of islanded microgrid

In order for the consumers to be able to utilize their electrical appliance and electronics in daily life, the consumers loads are connected to the power sources through the main grid. When there are utility disturbance or fault occur in the grid system, the main grid will breakdown and it will affect all the consumers if there are no backup energy[2][3]. With microgrid system, when the main grid is disconnected due to disturbance occur, the microgrid can operate independently and able to supply power to the consumer. This will lead to the islanding mode of the microgrid. A microgrid operation can be operated in both grids connected and islanded modes of operation [4][5]. Microgrid operated in islanded mode is very sensitive to power imbalance between supply and demand and can cause frequency deviation. If the demand is more than the supply and the microgrid network operating in severe condition even after the secondary control, the separation of less important load need to be performed [6][7].

2.3 Distributed Generation

Distributed energy resources are demand and supply side resources that is distributed throughout the electric distribution system to meet the energy needs by the customers [8]. There are two types in distributed generation units which are dispatchable and non-dispatchable sources. A dispatchable DG source can quickly response to the system and has a capacity to meet the real and reactive power commands. In the grid-connected mode, the dispatchable DG units are expected to supply pre-specified power, similar to a conventional utility system [9]. In the autonomous mode of operation. The Non-dispatchable DG on the other hand unable to response quickly because the source is depending to the power that is provided by the main source from the main grid [10]. Therefore, when the microgrid is disconnected from the main grid, only dispatchable sources can quickly response and backup the rest connected system so that the local loads can have continuously supply.

2.4 Islanded microgrid with multiple generators

An islanded microgrid may consists of multiple numbers of local distributed generators [11]. A formation of the microgrid with multiples generators is far more economical than a single generator that serve a single load [12][13]. If there are two distributed generators connected in the islanded microgrid, the generators are commanded to each other to supply power to the demand when the power from main grid is disconnected. Both of the generators will generate active and reactive powers based on the demand from the local loads of the system [14]. The generators on the system might not be stable and can cause the frequency of in each of them to deviate.

2.5 Micro-grid network Frequency Response

During islanding condition, the frequency in the network can deviate below the nominal system frequency [15]. This is due to the large load variation in the system. The load can suddenly change and the system may become unstable. When the load demand is higher than the supply, the frequency will drop. On the other hand, When the supply is more than the load demand, the frequency will increase. When the frequency critically drops because of generator outage, this will lead to microgrid breakdown [22]. The location of the load variation also will affect the frequency response in each generator. If the variation of load increase near the first generator, the frequency at the first generator will oscillate more than the other generator. The frequency stability of an islanded microgrid and its sensitivity is different for the certain changes in system configuration [23][24].

2.6 State Space

The state space of a dynamical system is consist of the set of all possible states that describe the behavior of that system. Each coordinate is a state variable, and the values of all the state variables completely describes the state of the system[25]. In other words, each point in the state space is corresponds to a different state of the system The state of a dynamic system is in refer to a minimum set of variables that is known as state variables which are fully describe the system and its response to any given set of inputs[26]. A standard form for the state equations is used throughout system dynamics. For standard form, a mathematical description for the system is expressed as a set of n coupled first-order ordinary differential equations which are known as the state equations. This is where the time derivative of each state variable is expressed in terms of the state variables x1(t),...,xn(t) and the system inputs u1(t),...,u r(t).According to [26], each of the functions fi (x,u,t), (i =1,...,n) may be a general nonlinear, time varying function of the state variables, the system inputs, and time. Hence, the general case the form of the n state equations for linear system is written as:

$$\dot{x}_n = fn\ (x,u,t) \tag{2-1}$$

2.7 Two Area with Tie-Line Connection

The load variation on a power system causes changes in frequency from their nominal values resulting in loss of generation due to tripping of lines and even blackouts [15][16]. The reactive power is less sensitive to the changes in frequency and is mainly dependent on the changes in voltage magnitude. While, changes in real power mainly affect the system frequency [15][17]. Interconnection of electrical power systems has been the main trend in modern power grid construction [18][19]. Distributed power systems can assist each other in case of emergencies due to their varied load demand [20][21].

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter contains method of modelling an islanded microgrid system with multiple generators. The work was divided into two phases. In the first phase, the microgrid network was modelled with involve only one generator without automatic generation control (AGC). In the second phase, multiple generator, tie-line and automatic generation control (AGC) was considered. Both of modelling phases was using the state space averaging technique. At the end of the process, average dynamical behavior of the frequency was determined using decomposition and similarity transformation approach.

3.2 Flowchart

Below in Figure 3.1 shows the flowchart of overall project

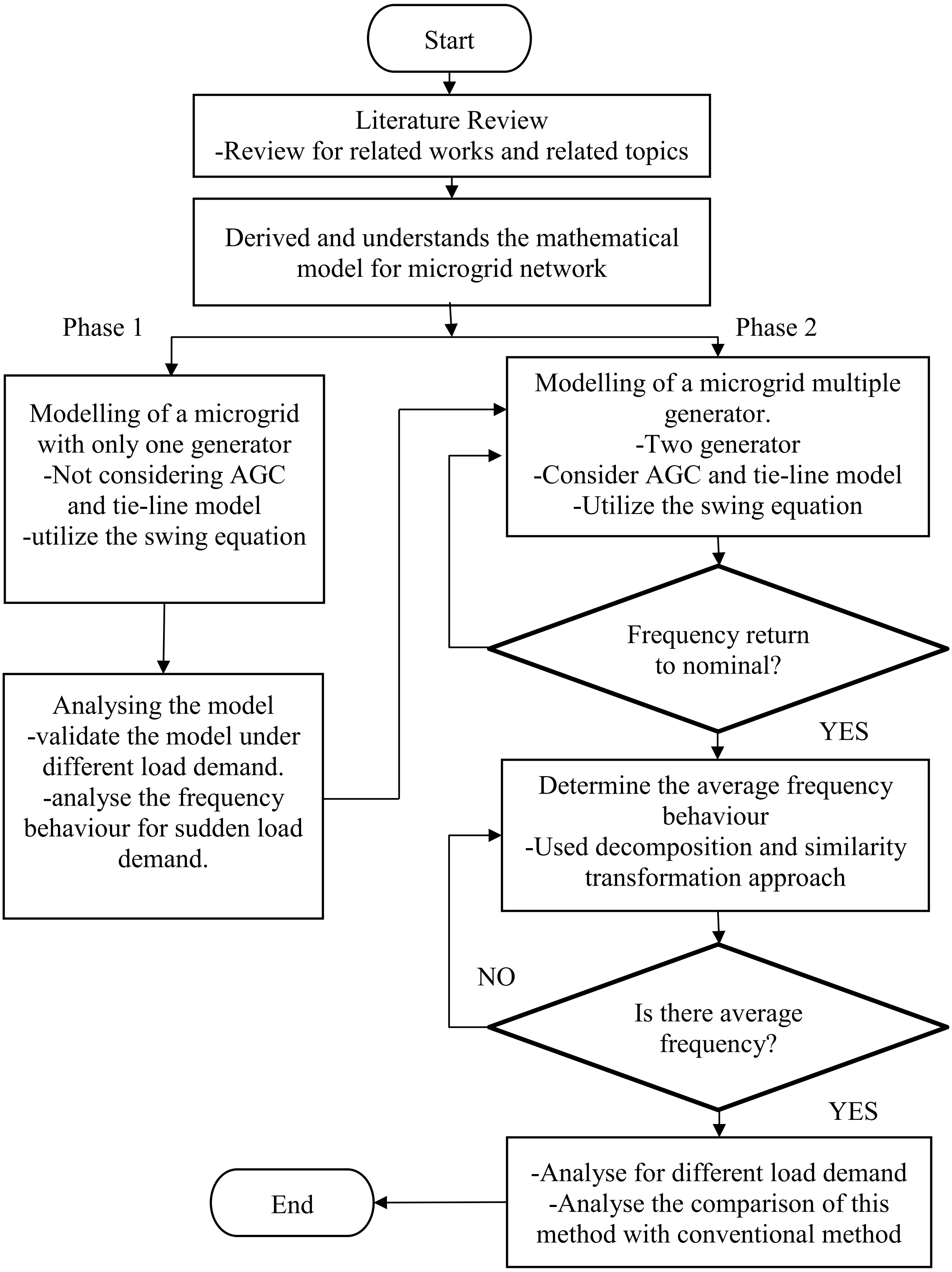

Figure 3.1: Flowchart of overall process

3.3 Mathematical Modelling

3.3.1 Generator Model

Swing equation is used in this model in order to describe the behavior of generator.

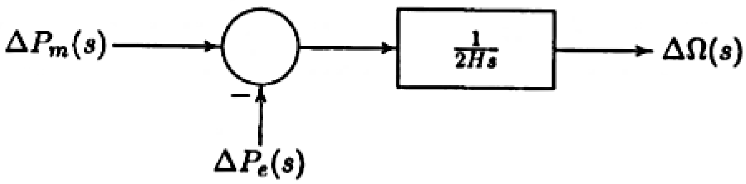

Figure 3.2: Generator Model

Where,

$\Delta\Omega(s) = \Delta\omega$, ΔP_m is mechanical power deviation, ΔP_e is electrical power deviation and $\Delta\omega$ is rotation speed deviation. By applying the swing equation of synchronous generation:

$$\frac{2H}{\omega_S}\frac{d^2\Delta\delta}{dt^2} = \Delta Pm - \Delta Pe \tag{3-1}$$

In terms of small deviation in speed:

$$\frac{d\Delta\frac{\omega}{\omega_s}}{dt} = \frac{1}{2H}[\Delta Pm - \Delta Pe] \tag{3-2}$$

With the speed expressed in per unit and without explicit per unit notation:

$$\frac{d\Delta\omega}{dt} = \frac{1}{2H}[\Delta Pm - \Delta Pe] \tag{3-3}$$

The real power transferred over the tie-line is described by

$$P_{12} = \frac{|E_1||E_2|}{X_{12}} \sin\delta_{12} \tag{3-4}$$

Where $X_{12} = X_1 + X_{tie} + X_2$ and $\delta_{12} = \delta_1 - \delta_2$. Linearizing this equation by assuming the small deviation in the tie line power flow ΔP_{12} from the nominal value,

$$\Delta P_{12} = \frac{dP_{12}}{d\delta_{12}}|_{\delta 12}\ \delta_{12} = P_s \Delta\delta_{12} \quad (3\text{-}5)$$

Ps = P1 is the slope of the power angle at the initial operating angle δ_{12°

As shown in Figure 3.3

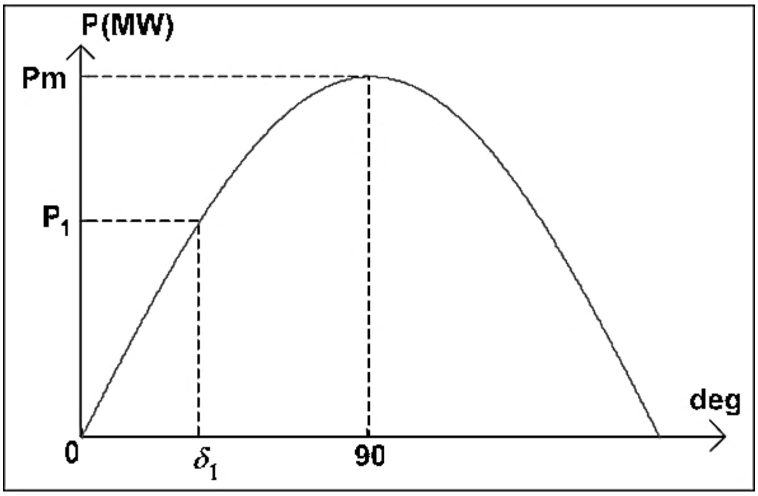

Figure 3.3: Power angle curve

The tie line power deviation:

$$\Delta P_{12} = P_s(\Delta\delta_1 - \Delta\delta_2) \quad (3\text{-}6)$$

The Eq.(3-6) and Eq.(3-3) is combine and become complete equation for rotating generator as follows

Generator 1:

$$\frac{d\Delta}{dt}\omega_1 = \frac{1}{2H_1}(\Delta P_{m1} - P_s(\Delta\delta_1 - \Delta\delta_2) - D_1\Delta\omega_1 - \Delta P_{L1}) \quad (3\text{-}7)$$

$$\frac{d\Delta}{dt}\omega_1 = \frac{1}{2H_1}(\Delta P_{m1} - P_s\Delta\delta_1 - P_s\Delta\delta_2 - D_1\Delta\omega_1 - \Delta P_{L1}) \quad (3\text{-}8)$$

Where,

$$D_1\Delta\omega_1 - \Delta P_{L1} = \Delta P_e \quad (3\text{-}9)$$

Therefore,

$$\frac{d\Delta}{dt}\omega_1 = \frac{\Delta P_{m1}}{2H_1} - \frac{P_s\Delta\delta_1}{2H_1} - \frac{P_s\Delta\delta_2}{2H_1} - \frac{D_1\Delta\omega_1}{2H_1} - \frac{\Delta P_{L1}}{2H_1} \quad (3\text{-}10)$$