Faculty of Electrical Engineering

MODELLING OF PROPORTIONAL INTEGRAL VOLTAGE CONTROLLER FOR DISTRIBUTED GENERATION DURING ISLANDING OPERATION

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DECLARATION

I declare that this thesis entitled "Modelling Of Proportional Integral Voltage Controller For Distributed Generation During Islanding Operation" 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 : Nurul Syuhada binti Mohd Shari

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature : .....

Supervisor Name : Dr Mohd Hendra bin Hairi

Date : .....

DEDICATION

To my beloved mother and father,

my lovely sisters

and

for you who know how to love yourself

ABSTRACT

A microgrid is defined as a part of an electric power distribution network that is formed by the interconnection of energy source and energy storage. Microgrid operates as a single controllable system that provides power to its local area that can be a residential, commercial or industrial. Main function of microgrid is to ensure the stable operation during normal, fault and variety of network disturbance. It can be disconnected from the rest of the power system either non-intentional or intentional. This leads to concerns over the efficiency, safety and stability of the voltage, frequency and power at microgrid. The operation and control of a microgrid is challenging especially in an off-grid scenario where microgrid is isolated from main utility grid. This situation is known as islanded mode of the operation. When an islanding occurs, the voltage and frequency are out of safety limit as the islanded area cannot be controlled by the grid. This thesis is focused on designing voltage control schemes in low voltage networks by using PSCAD software. The voltage control model then was developed by implementing the droop characteristics with Proportional Integral (PI) controller to control voltage. This thesis also focused on evaluating and analyzing the performance of voltage control schemes of the Distribution Generation (DG) when subjected to islanding and network disturbances. The results show that voltage control scheme can regulate and recover the voltage to its nominal limit during islanding events; normal, fault and network disturbance.

PEMODELAN KAMIRAN BERKADAR KAWALAN VOLTAN UNTUK GENERASI PEMBAHAGIAN SEMASA OPERASI PULAU

ABSTRAK

Grid mikro ditakrifkan sebagai sebahagian daripada rangkaian pengedaran kuasa elektrik yang terbentuk oleh gabungan antara sumber tenaga dan penyimpanan tenaga. Grid mikro beroperasi sebagai sistem terkawal tunggal yang menyediakan kuasa kepada kawasan setempat seperti kediaman rumah, komersial atau perindustrian. Fungsi utama grid mikro adalah untuk memastikan operasi yang stabil semasa normal, kerosakan dan pelbagai gangguan rangkaian. Ia boleh diputuskan dari seluruh sistem kuasa sama ada secara tidak sengaja atau disengajakan. Ini menimbullkan kepada kebimbangan terhadap kecekapan, keselamatan dan kestabilan voltan, frekuensi dan kuasa di grid mikro. Operasi dan kawalan grid mikro sangat mencabar terutamanya dalam senario luar grid di mana grid mikro terisolasi dari grid utiliti utama. Keadaan ini dikenali sebagai mod operasi pulau. Apabila pulau berlaku, voltan dan frekuensi berada di luar batas keselamatan kerana kawasan pulau tidak boleh dikawal oleh grid. Tesis ini memfokuskan pada reka bentuk skim kawalan voltan dalam rangkaian voltan rendah dengan menggunakan perisian PSCAD. Model kawalan voltan kemudiannya dikembangkan dengan melaksanakan ciri-ciri lelai dengan pengawal kamiran berkadar (PI) untuk mengawal voltan. Tesis ini juga memberi tumpuan untuk menilai dan menganalisis prestasi skim kawalan voltan Generasi Pembahagian (DG) apabila tertakluk kepada gangguan pulau dan gangguan rangkaian. Hasil tesis ini menjelaskan bahawa skema kawalan voltan dapat mengatur dan memulihkan voltan ke had nominalnya semasa kejadian di pulau; normal, gangguan dan gangguan rangkaian.

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LIST OF ABBREVIATIONS

CHP	-	Combination of Heat and Power
DE	-	Distributed Energy
DER	-	Distributed Energy Resources
DG	-	Distribution Generation
ESD	-	Energy Storage Device
MMO	-	Multi Master Operation
MPPT	-	Maximum Power Point Tracking
PCC	-	Point of Common Coupling
PI	-	Proportional Integral
PID	-	Proportion, Integral and Differential
PLL	-	Phase Locked Loop
PR	-	Proportional Resonant
PV	-	Photovoltaic
PVT	-	Process, Voltage, and Temperature
PWM	-	Pulse Width Modulated
VFI	-	Voltage Frequency Island
SMO	-	Single Master Operation
VSC	-	Voltage Source Converter
VSI	-	Voltage Source Inverter

LIST OF PUBLICATIONS

Journal:

1. Nurul Syuhada Binti Mohd Shari, Mohd Hendra bin Hairi, and Muhammad Nizam bin Kamarudin, 2020. Voltage Control of Distribution Power Generation for Intentional Islanding. *Journal of Critical Review, Vol 7, Issue 12*, pp. 3889-3896.

Conference:

1. Shari, N. S., Hairi, M. H., and Kamarudin, M. N., 2016. PV Generation and Its Impact on Low Voltage Network. *2016 IEEE International Conference on Power and Energy (PECon)*, pp. 348-343.

CHAPTER 1

INTRODUCTION

1.1 Research background

As electricity has become one of the important things to live with, microgrid systems have become an important role in power system as a microgrid system can generate power from a conventional source and renewable source. Microgrid system is small scale power that formed by the interconnection of a low voltage network or medium voltage network of Distributed Generation (DG), and with the energy storage such as a battery (Ghanizadeh and Ebadian, 2016). DG associated with renewable energy such photovoltaic (PV), wind, hydro and waves, has created some challenges to researcher because of fossil fuels that have been used for numerous decade till these days. The examples of fossil fuels is coal, natural gas and oil, and another challenges is the increasing request for electrical power usage of these type of fuels had makes their supplier limited entire the world.

One of the advantages of distributed generation are DG can improve the power quality, voltage profile and voltage stability of the power system. Low point of pollution and good overall efficiencies like combination of heat and power (CHP) and micro-turbines are another advantage of DG, while photovoltaic and wind turbines contribute to the reduction of green house gases in DG (Chauhan, 2013). However as renewable energy sources are influenced by unpredictable behaviour and discontinuous generation of renewable energy sources, microgrid requires control system in order to improve the stability of the power system.

In a distribution system if utility network is disconnected for any reason, the DG still supplies the required power to local loads. This phenomenon is called “Islanding Phenomena”. When an islanding occurs, the voltages and frequencies in the islanded area cannot be controlled by the grid system (Rafi, H. Fida Hasan , l. Jahangir, 2015). Islanding can be seen below in Figure 1.1.

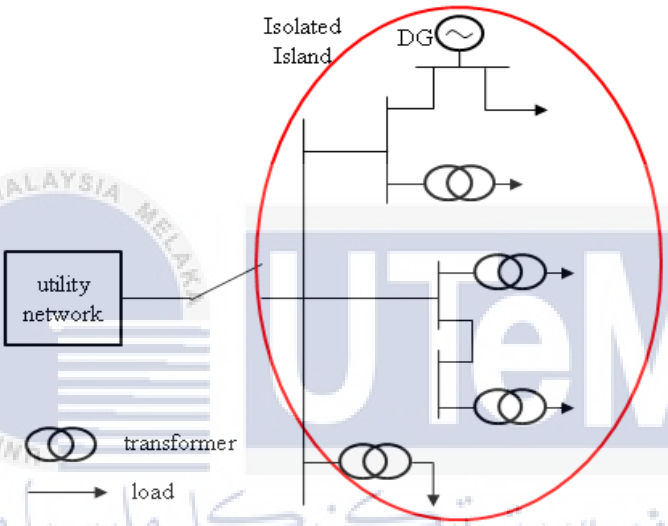

Figure1.1: The study system illustrated in single line diagram

Islanding can be classified into two types of group that is unintentional islanding and intentional islanding (Álvarez, 2011) :

- Unintentional islanding is an unwanted islanding due to the fault happen in a power system. It occurs when a certain part or component of the distribution system turn into electrically isolated from the entire power system and is still being supplied by the DG.
- Intentional Islanding is a desirable or wanted islanding mode of operation of a microgrid system from the existing power system.

Islanding has harmful outcome on utility power system, for examples, harmful to the utility power network staff who still not notice that the DG is still supplying the load demand, enormous destruction to the DG itself after the reconnected or synchronization to grid system after islanding event happen, and effect on the power quality since voltage, V and frequency, f, of power system cannot be controlled after the event of islanding.

To stabilize the occurrence of islanding phenomena, many control schemes have been proposed for example the author Vidyasagar (2016) studied about the stability and power quality of the microgrid by implementing the droop characteristics with PI controller to control frequency and voltage. Author Alobeidli et al (2015) has designed the control of instantaneous power in voltage sourced converters operating under unbalanced load. The control is based on an adaptive transformation that instantaneously adjusts itself to the dynamic voltage conditions. However the study of voltage control during islanding was very limited.

1.2 Problem statement

A microgrid can be described as a component of an electric power distribution network that formed by the interconnection of energy source and energy storage. Microgrid operates as a single controllable system that provides power to its local area that can be a residential, commercial or industrial. Main function of microgrid is to ensure the secured operation throughout variety of network disturbance and faults.

However, microgrid can be disconnected or cutoff from the remained of the utility power system either non-intentional or intentional. This leads to anxiety over the efficiency, stability and safety of the voltage, frequency and power at microgrid system. The operation and control of a microgrid is challenging particularly in an off grid event when microgrid system is cutoff or isolated from primary utility power grid. This situation is recognized as island mode of the operation.

When an islanding occurs, the voltage and frequency are out of safety limit as the islanded area cannot be controlled by the grid. According to IEEE 929 1988 standard, demand the disconnection or cutoff of DG once the event of island take place (IEEE STANDARDS, 1987). In IEEE 1574.1 2003 standard islanding is required to be detected and disconnected from the distribution generation at most within 2 seconds. In IEEE 1574.1 2005 the non-intentional islanding which can occur due to any type of faults may cause control problem, protection and stabilization of operational issues (IEEE STANDARDS, 2005). The controller of microgrid can be designed to maintain continuously supplying power, the controller must acquire different control depending on the state of the grid connection.

1.3 Research objective

Due to the instability of the voltage during islanding in the microgrid the objective of the study are:

- To design and develop voltage control scheme during islanding mode in low voltage network using PSCAD software.
- To evaluate and analyse the performance of voltage control scheme of the DG when subjected to islanding and network disturbances. i.e. unbalanced load and fault.

1.4 Scope of work

This study will focus on the development of the voltage control scheme in terms of the voltage stability of the network system. The network used in this study is three phase photovoltaic (PV) generation connected to low voltage (LV), 240V via a 1MVA transformer. To analyse the impact of development voltage control on the system voltage and power quality of the network system during the islanding mode, proportional and integral (PI) controller have been used in this study. The PI controller is determined by using a symmetrical optimum (SO) method. Voltage and frequency are most important parameters during microgrid operation. However, the frequency of the islanding system is assumed stable as in islanding power system the frequency deviation is too small due to the load connected to the DG are light load. The simulations were carried out by using PSCAD software under three main cases which is without the application of voltage control, with the application of voltage control and during faults conditions.

1.5 Contribution

The following are the major contributions resulting from this research:

- Low voltage microgrid system has been developed in PSCAD programming in order to measure and monitor the utility and microgrid parameters.
- Voltage controller system has been developed in islanding condition in order to supply the load demands.
- PI controller system has been developed in islanding condition in order to supply the load demands.

1.6 Thesis outline

This thesis is organized in five chapters. The background of the research, problem statements and objectives of this research as well as project scopes and contribution have been describes in this chapter, Chapter 1.

Chapter 2 will discuss the literature review of microgrid system, especially during islanding mode of operation. The control system with considering the relevant standard will also covered in this chapter.

Chapter 3 presents the methodology of this study based on the microgrid. In this chapter, the important theories and concept as well as equation related to this study will be addresses.

In chapter 4, the simulation and results of test network will be discussed. It shows how each case is carrying out to achieve the objectives. There are three main group of cases which is case studies of the network model without the application of voltage control, case studies of