SMALL SIGNAL DYNAMIC STUDY OF A MICROGRID

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In the name of Allah the Most Gracious the Most Merciful

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ABSTRAK

Sistem grid mikro merupakan bidang kajian berpotensi yang akan menentukan perkembangan sistem pengagihan elektrik pada masa akan datang atas kemampuan sistem ini meningkatkan reliabiliti dan mengekalkan kestabilan keseluruhan jaringan pengagihan. Tujuan projek ini adalah untuk mengkaji sifat dinamik sistem grid mikro apabila berlaku perubahan pada sistem jaringan elektrik disebabkan aktiviti dan gangguan kecil yang berlaku semasa beroperasi dengan grid, pulau dan dalam proses pemulauan. Aktiviti-aktiviti jaringan dibincangkan dan dibentangkan secara khusus di dalam laporan ini yang melibatkan lima (5) kajian kes iaitu senario asas, kajian permulaan motor, kajian belantik beban, kajian belantik generator dan kajian semasa proses pemulauan. Parameter elektrik melibatkan frequensi, voltan, kuasa sebenar (real power), kuasa reaktif (reactive power) adalah dikaji dengan menggunakan perisian SKM Powertools for Windows v6.5 untuk pemodelan dan simulasi sistem grid mikro Hasil kajian ini adalah penting untuk menyumbang kepada perkembangan strategi sistem kontrol yang terbaik untuk *mirosources/generators* yang akan memastikan had kestabilan yang mencukupi semasa dikendalian dalam pelbagai keadaan termasuk keadaan dinamik. Pada masa akan datang, diharapkan kajian ini boleh ditambahbaik dengan melibatkan *microsources* yang lain seperti fotovoltaik, turbin mikro, dan sistem simpanan tenaga dalam mod operasi yang berlainan serta mengeksplorasi dan menambahbaik tindak balas sistem kontrol yang melibatkan punca kuasa daripada *inverter*. Kajian akan datang juga perlu melibatkan kesan gangguan yang besar seperti lintar pintas tiga fasa dan dapat memastikan sifat dinamik pada pepasangan yang sedia adalah seiring dengan kajian yang dibuat.

ABSTRACT

The microgrid system has been identified as a potential field of research that determines the future electrical distribution network due to its capability of increasing the system reliability and maintaining the stability at the distribution network. This purpose of this project is to investigate the microgrid dynamics behavior when subject to small change in the network state due to disturbances during grid-connected and the transition from grid-connected to islanding process. The network activities which discussed and presented in this report based on five (5) case studies, namely base case scenario, motor starting study, load trip study, generator trip study and islanding process. Electrical parameters include frequency, voltage, active power, reactive power are observed by simulating the microgrid system modeling using the SKM Powertools for Windows v6.5 software. The result of the study will contribute in the development of the best control strategies for the mirosources/generators that provide adequate stability margins during the various operating conditions and system dynamics. In future, further study should be carry out to include other microsources such as photovoltaic, microturbine, energy storage with different modes of microgrid operations and to explore and improve the control system response that is related to inverter-controlled sources. The future study should also include the impact of large signal disturbances due to fault and should be able to validate the dynamics behavior on existing installation.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
DER	-	Distributed Energy Resources
DFIG	-	Doubly-fed Induction Generator
DG	-	Diesel Generator
FC	-	Fuel Cell
Hz	-	Hert
MT	-	Microturbine
MV/LV	-	Medium Voltage/Low Voltage
P	-	Real Power
PCC	-	Point of Common Coupling
PV	-	Photovoltaic
Q	-	Reactive Power
SC	-	Short Circuit Current
SD	-	Static Switch
VSI	-	Voltage Source Inverter
WTIG	-	Wind Turbine Induction Generator

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Microgrid is a distributed generation system integrating the small capacity synchronous machine with the emerging generation technology, comprises of microsources such as photovoltaic system, microturbine, wind power and fuel cell. These microsources are the distributed energy resources, connected to low voltage electrical distribution system with power electronics interface and storage devices [1][2][3]. It may be operated in grid-connected or island mode with or without the synchronous machine running in parallel at the distribution network [4][5]. Since 2000s, there are increasing numbers of researches and testbeds being developed in some countries like Japan, United States, Europe and Canada. These testing facilities and the pilot projects are able to demonstrate the feasibility of microgrid operation in various modes that enable the researchers to investigate the best control techniques of the microgrid system and understand the system behavior [1]. In Malaysia, the distributed generation installation was introduced in 1990s with the synchronous machine being connected to the distribution system. The integration of the microsources to the system such as photovoltaic is still under small scale study.

Small signal dynamic analysis refers to the study of dynamic behaviours in a microgrid system when subject to small disturbances in the distribution system. In reality, the undesirable dynamic responses of the microgrid system is a not an issue to the stability of the transmission system when it is grid-connected as they are designed to satisfy their predetermined local load with insignificant generation capacity with reference to the bulk power system. However the network activities in the microgrid system whether it operates in the grid-connected mode or in island operation can create problems to maintain dynamic stability of the microgrid system.

The concept of integrating the inverter-controlled microsources with power electronics interfacing to the existing electrical distribution system has become an important research area on its own which would give a new challenge to the control system designer. In the presence of only microsources in a system, the converter control system must be able to provide the response during dynamics conditions and to supply real and reactive power requirements which previously obtained from the directly connected rotating masses. The adaptation of energy storage must also be understood and exploited which enhances the overall performance of microgrid systems by stabilizing the microsources output despite fluctuation, providing outage ride through capability due to momentary power disturbances and seamlessly operates as an uninterruptible power supply unit. Another new technology introduced in the microgrid system is the utilization of various power and switching functions such as power switching, protective relaying, metering, and communications at the utility interface into a single system with a digital signal processor (DSP) which are traditionally provided by relays, hardware, and other components [1]. The microgrid system is capable to increase the system reliability and stability at the distribution network as the system is no longer solely depends on the centralized utility electrical supply. The generation system at the distribution network may reduce power losses at the transmission line and enhance the voltage profile at the load level. Other benefit of the integration of the microsources into the microgrid system is to motivate the utilization of renewable energy resources which would give the important contribution towards the reduction of green house gases [6]. Further research and development of the microgrid has to be expedited as the concept is identified to be a potential field of research that determines the future trend of electrical distribution network.

1.2 PROBLEM STATEMENT

The microgrid is expected to provide most efficient control to power system security, quality, reliability and availability while matching the needs for environment sustainability and cost-effectiveness. The integration of microsources in the network has introduced new distribution system architecture with the power electronics interfacing. Lack of understanding on the source of dynamics in the electrical network and the cause of the system responses behavior may not be able to optimize the capability of the system. This may lead to power system instability when it is subject to system disturbances due to various network activities.

1.3 OBJECTIVES

The objectives of the study are stipulated as follows:

1. To learn and understand the microgrid concept and system architecture
2. To identify the types of the network activities that cause small signal dynamics to the microgrid system
3. To study and analyze the performance and responses of the microgrid system components based on case study simulation results by using SKM Powertools for Windows v6.5.
4. To determine the factors that influence the behavior of the system dynamics.

1.4 SCOPE OF STUDY

The area of interest for this project is to examine the microgrid power system stability when subject to small signal dynamics analysis during grid-connected and the transition from grid-connected to islanding process. The dynamics behavior during islanding operation will not be discussed in this report. This involves the system analysis of the small change in the network state due to disturbances resulted from network activities such as load changes, motor starting, generators tripping and utility tripping that lead to islanding of the system. Electrical parameters include frequency, voltage, active power, reactive power are observed.

The scenarios are developed to identify the network system behaviors and responses to various conditions. The project focus on simulation of a microgrid network model consists of a diesel engine generator as a synchronous machine, one induction machine, one type of microsources - a wind turbine doubly-fed induction generator (DFIG) and three numbers of pump motors and a capacitor bank. The wind turbine DFIG represents the behavior of other microsources such as microturbine and photovoltaic. The following case studies had been simulated to observe the dynamic behaviors:

1. Base Case Study: Initial condition of microgrid operation, followed by a steady-state operation without dynamics event.
2. Motor Starting Study: System behavior during big motor start event, and comparison between big and small motor starting condition.
3. Load Tripping Study: Dynamics behaviors during bus load increase and also motor tripping event.
4. Generators / Microsources Tripping Study: Tripping events of individual wind turbine DFIG, induction generator wind turbine and diesel engine generator.
5. Utility tripping: System responses due to utility tripping that causes microgrid to operate under island operation mode during real and reactive power flowing into the microgrid from utility, and flowing out to utility.

1.5 SIGNIFICANCE OF THE STUDY

The significance of the study is to contribute to the development of the best control strategies for the mirosources/generators that provide adequate stability margins during the various operating conditions or when subject to the small signal disturbances. The results would assist in designing necessary operational strategies to fulfill various types of microsources/generators controller, for example governor and excitation systems of synchronous generator and voltage-source inverter controller of electronically interfaced generator or microsources. The design will be used for parameters optimization to take advantage of the microsources controllers' fast responses in controlling real/reactive power, voltage and frequency, while maintaining stability during dynamics condition [7].

As the integration of renewable energy resources to the distribution system has become more important, the study would be crucial for better understanding of the design procedures and the dynamics interaction of the energy resources to the distribution system. The study may provide some basis of the feasibility study inputs, by giving examples of case study simulations, guide for selection of microgrid architecture and identify components with the appropriate specifications. This understanding will lead to better design of the system for future implementation.

1.6 REPORT OUTLINE

This report consists of five chapters; introduction, literature review, methodology, results and discussion, and conclusion and future work.

Chapter 1 discusses some introduction on the project selected which includes the background, problem statement, objectives, scope of the study, and the significance of the study to be carried out.

Chapter 2 will elaborate on the literature review related to microsources, microgrid architecture, control strategies and the small signal dynamic analysis. In this chapter, the theoretical aspects of the components or systems are highlighted based on the previous research and work done by others. The differences between the microgrid and the conventional system are presented to give some comparison of the two systems. Chapter 3 will present the methodology adopted by identifying the procedures to perform the small signal dynamic simulation study of a microgrid system by using SKM Powertools for Windows. Microgrid System Design, selection of microgrid model and related mathematical modeling equation, scenario development, simulation and result analysis and tools and equipment required are detailed out in this chapter.

Chapter 4 focuses on the discussion of the simulation results of the study. The results presented based on the scenarios developed to represent the dynamics behavior of the microgrid.

Conclusion and future work is elaborated in Chapter 5 which concluded the findings of simulation results and the potential of the research area which should be explored further in future.

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