UNIVERSITI PUTRA MALAYSIA

STANDALONE MICROGRID CONTROL USING MULTI-AGENT SYSTEM

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FK 2015 174

STANDALONE MICROGRID CONTROL USING MULTI-AGENT SYSTEM

By

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Thesis Submitted To the School Of Graduate Studies, Universiti Putra Malaysia, In Fulfilment of the Requirements for the Degree of Master of Science

February 2015

DEDICATION

I would like to dedicate my thesis to my beloved family

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

STANDALONE MICROGRID CONTROL USING MULTI-AGENT SYSTEM

By

POUYA BORAZJANI

February 2015

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A review of power systems shows that distribution systems have been changing due to some issues, such as functions of electrical systems, increases in the number of generating equipment and unpredictable behaviour of the distributed energy resources. According to the aforementioned changes, it appears that the centralized controlling approaches like the traditional SCADA system are no longer the best ways to control the future distribution systems; therefore, the de-centralized controlling system by using microgrids is recommended as a good alternative controlling method to guarantee power network stability.

In the area of microgrid control, different methods have been proposed, but the multi-agent system (MAS) has attracted much attention. The MAS controls the microgrids through a communication path. In general, a microgrid can operate in two different modes: grid connected and island mode. Although extensive research has been carried out on control of the microgrid in the island mode by the MAS, to the knowledge of this researcher, no single study exists that consider the security of communication path, and what would happen if a failure or an error occurred in the communication between the MAS and the microgrid. This work proposed a new structure of the MAS to eliminate the consequences of failure in the communication between the MAS and the microgrid, which is a threat to the stability of the microgrid.

The aim of this thesis is to develop the MAS to control the critical loads in different situations including failure in the communication between the MAS and the

microgrid (emergency condition). Also, to pay more attention to the economic aspects a microgrid is developed by using a battery bank as a storage device.

As a matter of fact, this work redesigns the conventional MAS and challenges it with different scenarios to exhibit its weakness and finally compares it with the proposed MAS.

Both the conventional MAS and the proposed one are designed in the coding command and the microgrid model is developed in Matlab/Simulink environment. The simulation results indicate that the proposed MAS can have a seamless transition from the grid connected mode to the island mode in all situations even in the event of a communication failure between the MAS and the microgrid

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk ijazah Master Sains

KAWALAN MIKROGRID SECARA BEBAS DENGAN MENGGUNAKAN SISTEM MULTI-AGEN

Oleh

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Kajian ini menunjuk bahawa sistem kuasa, sistem pembahagian telah berubah kerana beberapa kes, seperti fungsi sistem elektrik, peningkatan dalam bilangan menjana peralatan dan tingkah laku tidak menentu daripada sumber tenaga diedarkan. Menurut perubahan, ia kelihatan bahawa pendekatan kawalan berpusat seperti sistem SCADA tradisional tidak adalah cara terbaik untuk mengawal sistem pengedaran masa depan, dan juga yang de-berpusat sistem kawalan dengan menggunakan microgrids disyorkan sebagai alternatif yang baik untuk mengawal kaedah jaminan kestabilan rangkaian kuasa.

Dalam bidang kawalan mikrogrid, kaedah yang berbeza telah dicadangkan, tetapi sistem multi-ejen (MAS) telah menarik banyak perhatian. Secara umum, microgrid yang boleh beroperasi dalam dua mod yang berbeza; grid yang berkaitan dan mod pulau. Walaupun penyelidikan yang meluas telah dijalankan ke atas kawalan microgrid dalam mod pulau itu oleh MAS, tiada satu kajian yang wujud mempertimbangkan keselamatan jalan komunikasi, dan apa yang akan berlaku jika kegagalan atau kesilapan berlaku dalam komunikasi di antara MAS dan microgrid itu. Kerja ini mencadangkan satu struktur baru MAS untuk menghapuskan akibat kegagalan dalam komunikasi di antara MAS dan microgrid, yang merupakan satu ancaman kepada kestabilan microgrid.

Tujuan karya ini adalah untuk membangunkan MAS untuk mengawal beban kritikal dalam situasi yang berbeza termasuk kegagalan dalam komunikasi di antara MAS dan microgrid (keadaan darurat) itu. Juga, untuk membayar perhatian yang lebih kepada aspek mesra alam microgrid yang dibangunkan dengan menggunakan bank bateri sebagai peranti simpanan. Sebagai perkara fakta, kerja ini redesigns MAS konvensional dan cabaran itu dengan senario yang berbeza untuk

mempamerkan kelemahannya dan akhirnya membandingkannya dengan MAS yang dicadangkan.

Kedua-dua MAS konvensional dan MAS yang dicadangkan direka dalam arahan pengekodan dan model microgrid yang dibangunkan dalam persekitaran Matlab/Simulink. Keputusan simulasi menunjukkan MAS yang dicadangkan boleh mempunyai peralihan yang lancar dari grid mod berhubung dengan mod pulau itu dalam semua keadaan walaupun sekiranya berlaku kegagalan komunikasi antara MAS dan microgrid itu.

ACKNOWLEDGEMENTS

First and foremost I take this opportunity to express my sincere gratitude to Dr. Noor Izzri Abdul Wahab, my supervisor for his guidance, support, motivation, enthusiasm, and immense knowledge. I also wish to thank my committee members, Assoc. Prof. Dr. Hashim Hizam, and Dr. Azura Che Soh for their encouragement, and effective comments.

Last but not least, I would like to to thank my family especially my mother and sister without their continuous support I never would have been able to achieve my goals.

APPROVAL

I certify that a Thesis Examination Committee has met on 17 February 2015 to conduct the final examination of Pouya Borazjani on his thesis entitled "Standalone Microgrid Control Using Multi-Agent Systems" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

AC	Alternating Current
BAG	Bus Agent
Batt	Battery
CB	Circuit Breaker
DC	Direct Current
DER	Distributed Energy Resources
DESS	Distributed Energy Storage System
DG	Distributed Generation
DMS	Distribution Management System
DNO	Distribution Network Operator
ESR	Equivalent Series Resistance
ESS	Energy Storage System
FAG	Facilitator Agent
LC	Load Controller
Li-ion	Lithium Ion
M	Modulation index
MAS	Multi-agent System
MGCC	Microgrid Central Controller
MO	Market Operator
MS	Micro Source
MSC	Micro Source Controller
Ni-Cd	Nickel–Cadmium
Ni-Cd	Nickel–Cadmium
Ni-MH	Nickel Metal Hydride
p.u	Per unit
PCM	Power Control Mode
PLL	Phase Locking Loop
PMS	Power Management System
SCADA	System Control and Data Acquisition
SVC	Static Var Compensator
SVR	Step Voltage Regulator
VCM	Voltage Control Mode
VSI	Voltage Source Inverter

CHAPTER 1

INTRODUCTION

In traditional power systems, constructed and employed throughout the past few decades, the consuming power is generated by centralized power plants and is then transferred to consumers through transmission lines. However, these traditional power grid systems are rapidly aging and it appears that they will not be capable of meeting the requirements of consumers in the near future.

Today, concerns over global warming have influenced changes in the patterns of electricity generation and consumption. In fact, many micro sources such as photovoltaic, micro turbine, fuel cells, etc. which are referred to as distributed generators (DGs) have been connecting to the network at the distribution level and have been combining with energy storage systems (ESSs) to form the distribution of energy resources (DERs). Augmentation of DERs into the distribution systems disturbs the radial nature of power flow through the distribution feeders. In other words, with the insertion of the DERs into the conventional existing power systems which are operating at their stability point, controlling the electrical network has become more complicated. As a result, the power systems have to be more intelligent to increase the reliability of employing the DERs. Using the smart grids is a good solution to provide the distribution systems with intelligence. An electrical power grid which is equipped with new advanced information techniques, computer_technologies and communication systems; could be a good representation of the smart grid [2]. In fact, the smart grid uses sensors, communication devices and controllers to control the power systems. A typical smart grid is shown in Fig.1.1 [3].

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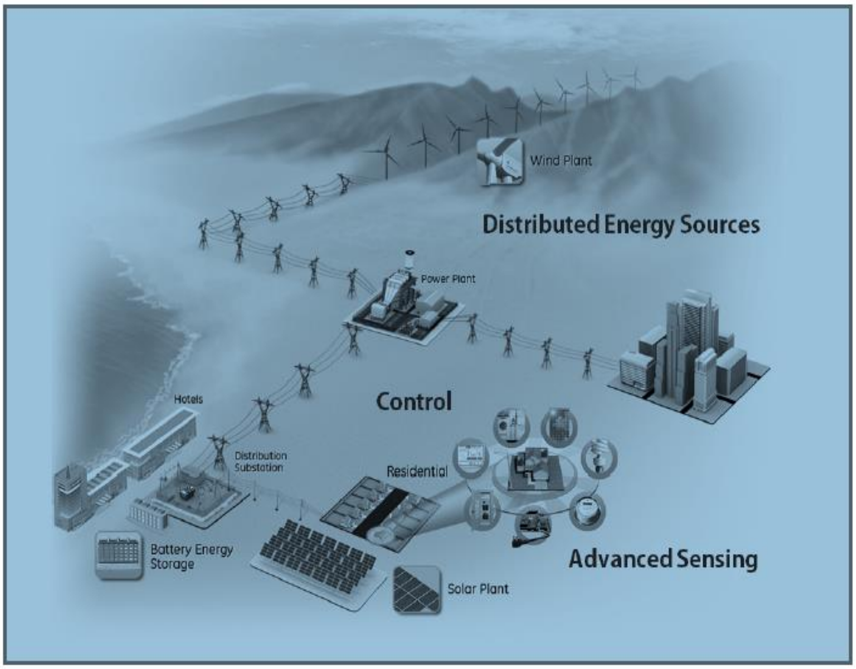

Figure 1.1. A typical smart grid application [3]

In order to decrease the complexity of the smart grid, engineers divide it into small subsystems, which are called microgrids.

A microgrid consists of micro sources (MSs) and loads; it works as a single controllable power system, which can cooperate with its upstream grid [4]. Also, energy storage systems, such as batteries and flywheels, could play a prominent role in the microgrids to compensate for the weaknesses of renewable energy sources or employed as a power generation unit [5-9].

Generally, a microgrid has two operational strategies; the grid connected mode and the island mode [10-12]. In the grid connected mode, the frequency and the voltage amplitudes are determined by the main grid, and DERs supply the total or a part of the microgrid loads [13]. In this operational strategy, the main objective of the microgrid is to improve the energy management of the system and some loads are supplied by the upstream grid. However, in the island mode, the internal MSs must be controlled in order to insert the desired voltage and frequency into the load buses [1, 14].

With the advancement of technology and the emergence of intelligent techniques, the microgrid has been transformed into an intelligent autonomous subsystem[15]. It is called autonomous because it can control itself with its internal power sources in the island mode [11].

In the area of controlling microgrids, the multi-agent system (MAS) has attracted much attention [16] as it is identified as a system, which breaks down complex problems handled by a single entity - a centralized system - into more and smaller problems controlled by several entities - distributed systems [17]. In other words, MAS is a computerized system that consists of intelligent agents which interact with the environment.

So far, there is no specific definition of an intelligent agent although there are some common specifications between intelligent agents that have been employed to control the systems; such as independent direct interposition of humans, bringing about a fast reaction to the environment changes, and the ability to cooperate with the other agents [18].

1.1 Problem Statement

Due to the major changes in structures and functions of the power systems, it seems that the centralized approaches are not appropriate to control the distribution system [19]. Due to increase in the number of generation units connected to the power systems and their unpredictable characteristics, the amount of data collected for the centralized controlling systems has been growing significantly [20, 21]. In fact, a large amount of data should be gathered, treated at the same time and provided quickly for further processes. Thus, the centralized approaches are not fast enough, as they are neither feasible nor economical and may be unable to work correctly. In order to reduce the complexity of the network, de-centralized approaches and using the microgrids are suggested [16, 22-24].

In the case of the decentralized controlling systems, the multi-agent system (MAS), based on an intelligent controlling and communication system is recommended. As a matter of fact, the MAS acts in the cyberspace environment and will be connected to the microgrid by a communication path such as the Internet and fibre optics [3, 22, 25].In the area of cyberspace, interruption, error and disconnection are common and happen because of many reasons such as disconnection in optical fibre, hackers' attacks, etc..

.

Control of microgrids using the MAS in the island mode has been reported in [1, 16, 26-29], but failure in communication between the MAS and the microgrids always threatens the health of the system [3]. In other words, this work claims that common conventional MAS cannot control the microgrids in the presence of any disturbance in the communication between the conventional MAS and the microgrids and proposes a solution to prevent the drawbacks of failure in this intercommunication. This work also, investigates the role of battery bank in microgrid.

1.2 Objectives of the Study

The main aim of this work is to design, develop, and simulate the MAS and a microgrid. The proposed MAS must have the ability of dynamically controlling the microgrid in emergency situation. In order to achieve this aim, three objectives are considered and listed below:

i. To develop a microgrid based on previous studies with the existence of a storage device.
ii. To propose a new MAS structure to control the microgrid operation.
iii. To validate the proposed MAS and compare its performance with the conventional MAS.

1.3 Scope of the Study

Generally, there are two types of MAS control structures; hierarchical and single layer. This work concentrates on controlling microgrids using the single layer structure in the island mode. External fault is the cause of islanding. It should be mentioned that different types of fault and their respective effects are not addressed in this research and a three phase fault is considered as the cause of islanding.

In order to compensate for the inability of the single layer structure in emergency conditions, this work transforms the single layer into double layer MAS controlling structure.

1.4 Contribution of the Study

This study contributes a new design structure to improve the performance of the MAS in different conditions. It is hoped that this work will provide an insight into the implementation of the MAS in the practical environment by decreasing the probability of failure in controlling microgrids. Furthermore, this work implements the concept of DERs by adding a storage device to a distributed generator (DG) in a microgrid; in other words, this work has developed a microgrid with a battery bank. Also, it has redesigned the conventional MAS to compare and exhibit the excellence of the proposed MAS.

1.5 Organization of the Thesis

The rest of the thesis is organized as follows: Chapter 2 is the literature review which summarizes the basic knowledge and related works on the control of microgrids. Chapter 3 presents the methodology and discusses the controlling algorithm used in this work, while Chapter 4 provides the results and discussion of different scenarios and case studies to make a comparison between the conventional and the proposed MAS. Finally, Chapter 5 presents the conclusion of the study as well as recommendations for future related researches.

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LIST OF PUBLICATIONS

Borazjani, P., Wahab, N. I. A., Hizam, H. B., & Soh, A. B. C. (2014, May). A review on microgrid control techniques. In *Innovative Smart Grid Technologies-Asia (ISGT Asia), 2014 IEEE* (pp. 749-753). IEEE.