ENERGY MANAGEMENT SYSTEM USING DOUBLE LAYER APPROACH FOR RESIDENTIAL MICRO-GRID SYSTEM

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DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

This project proposes a double-layer coordination of energy management system (EMS) in stand-alone mode micro-grid (MG) system that considering demand response (DR) scheme in order to reduce electricity cost at power and demand side. The main advantage of this method is that the coordination between power side and demand side can be ensured. While ensuring that operations at power side is economically controlled, the satisfaction of load demands can also be achieved. In this work, two strategies has been implemented, load shifting process based on pricing strategy as well as micro sources scheduling strategy. The performance of proposed approach will be tested based on two different load conditions; fixed and varies load conditions. For first layer EMS, the goal is to reduce the electricity bill through load shifting process. Therefore, each house will experience 5 different selective modes of operation during the load shifting process and then the electricity bill can be determined. Then, the load profile from all 20 houses is used as input to the second layer EMS. In this layer, the aim is to ensure that the MG operates economically while ensuring a continuous electricity supply to demand. Later, the operation and maintenance (O&M) cost of MG will be determined. From first layer strategy, the maximum cost saving of electricity bill is 4.96%. In the second layer EMS, the cost of O&M saving for fixed load condition is 1.92% and for varies load condition is 4.58%. Therefore, the proposed approach has achieved the objective of this research which is reducing the cost of electricity at demand and power side.

ABSTRAK

Kajian ini mencadangkan koordinasi dua lapisan EMS dalam sistem MG berdiri sendiri yang menimbangkan skim tindak balas permintaan (DR) untuk mengurangkan kos elektrik di sisi kuasa dan permintaan. Kelebihan utama kaedah ini adalah koordinasi antara sisi kuasa dan sisi permintaan dapat dipastikan. Semasa memastikan operasi di bahagian kuasa dikendalikan secara ekonomi, kepuasan permintaan beban juga dapat dicapai. Dalam kerja ini, dua strategi telah dilaksanakan iaitu proses peralihan beban berdasarkan strategi harga dan juga strategi penjadualan sumber tenaga mikro. Prestasi pendekatan yang dicadangkan akan diuji berdasarkan dua keadaan beban yang berlainan; keadaan beban tetap dan berbeza-beza. Untuk EMS lapisan pertama, matlamatnya adalah untuk mengurangkan bil elektrik melalui proses peralihan beban. Oleh itu, setiap rumah akan mengalami 5 mod operasi terpilih yang berlainan semasa proses peralihan beban dan bil elektrik boleh ditentukan. Kemudian, profil beban daripada semua 20 buah rumah digunakan sebagai input kepada lapisan kedua EMS. Dalam lapisan ini, matlamatnya adalah untuk memastikan MG beroperasi secara ekonomi semasa memastikan bekalan elektrik berterusan. Kemudian, kos operasi dan penyelenggaraan (O & M) MG akan ditentukan. Dari strategi lapisan pertama, kos maksimum penjimatan bil elektrik ialah 4.96%. Dalam lapisan kedua EMS, kos penjimatan O & M untuk keadaan beban tetap ialah 1.92% dan untuk keadaan beban yang berlainan adalah 4.58%. Oleh itu, pendekatan yang dicadangkan telah mencapai matlamat penyelidikan ini iaitu dapat mengurangkan kos elektrik pada permintaan dan kuasa.

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LIST OF ABBREVIATIONS

MG - Micro-grid
PCC - Point of common coupling
EMS - Energy management system
DR - Demand response
RES - Renewable energy sources
ESS - Energy storage system
DG - Distributed generation
SMA - Simple moving average
CMA - Central moving average
GA - Genetic Algorithm
CCHP - Combined cooling, heating and power system
WT - Wind turbine
FC - Fuel-cell
MT - Micro-turbine
DE - Diesel engine
TOU - Time-of-use
PEV - Plug-in electric vehicle
DSM - Demand side management

LIST OF SYMBOLS

$P_{L,n}(t)$	-	Daily total household power consumption
$P_{avg,n}(t)$	-	Average load power
$Price_{peak}$	-	Electricity price during peak hour
$\sum P_{trans\text{-}tot,n}(t)$	-	Total transferable load power
ΔP	-	Operational power variation margin
$P_{L1,n}$	-	Modified load profile
P_{PV}	-	Output power of solar PV
P_{WT}	-	Output power of wind turbine
P_{BATT}	-	Output power of battery
P_{MT}	-	Output power of micro turbine

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CHAPTER 1

INTRODUCTION

1.1 Research Background

With the growth of global population, energy demands continue to rise as energy is essential to life and all living creatures to continue their routine life. Same goes to electrical energy, in which this type of energy is required to develop economic growth the whole world. Previously, generation of electricity utilized fossil fuels to extract the energy through the combustion process. As the energy demand increases, high power generation produced led to the depletion of fossil fuels and also contribute to the emission of greenhouse gasses such as carbon dioxide, methane, nitrous oxide, and etc. [1], [2]. It has been concerned worldwide that the released gasses led to climate change and environmental pollutions. Therefore, renewable energy sources (RES) such as solar, wind, hydro and biomass are utilized or integrated to the main grid to generate electricity and act as alternative resources to mitigate the emission of greenhouse gasses as well as using clean energy [3]. The integration of this RES into grid system introduced a micro-grid concept.

Micro-grid (MG) requires several number of distributed generation resources, loads and energy storages to enable power exchange process with the grid through a single coupling point, called the point of common coupling (PCC) [4]–[7]. Figure 1.1 shows the component in MG system which consists of various RES, energy storage system and loads. The idea of bringing electricity generation closer to the loads, is to enhance the reliability, efficiency and quality of power support development of MG [8]. MG can operate in 2 different modes which are the grid-connected mode and the stand-alone (autonomous) mode, as in Figure 1.2 and 1.3 respectively [4]–[7].

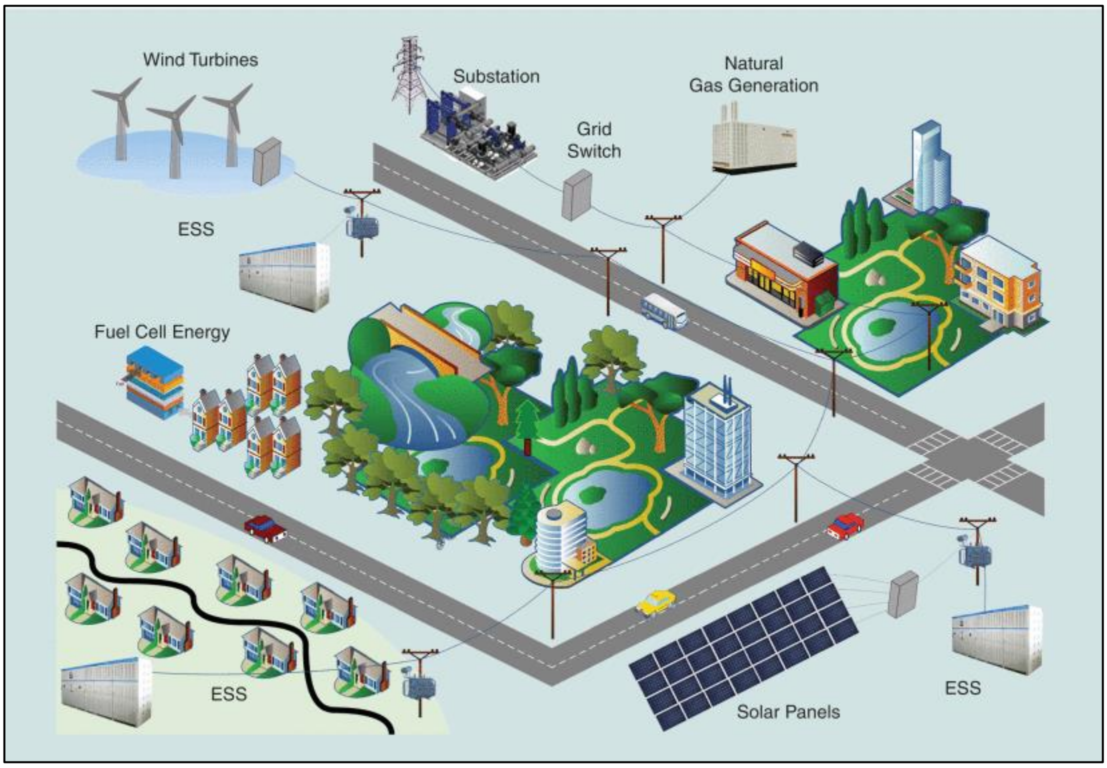

Figure 1.1 The Component of Micro Grid System [9]

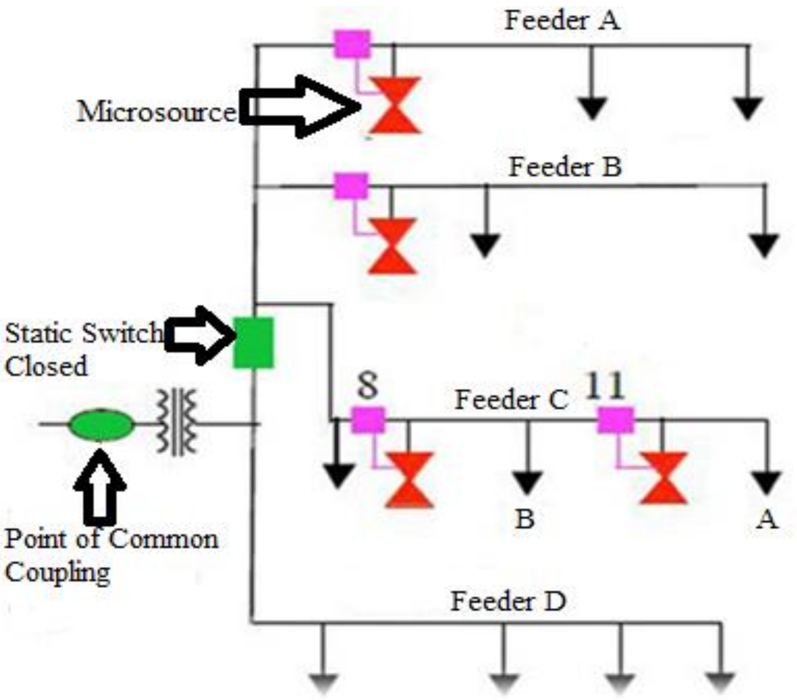

Figure 1.2 Grid Connected Mode [10]

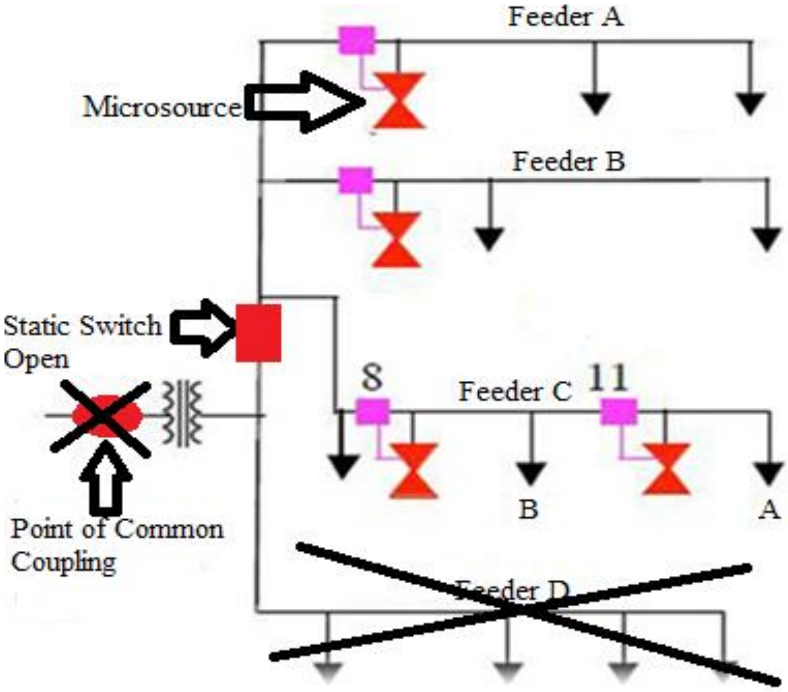

Figure 1.3 Stand-Alone Mode [10]

In grid connected mode as depicted in Figure 1.2, when the static switch is closed, all feeders will be electrically supplied by the utility grid [10]. In this mode, MG will regulate the power balance between supply and demand (through a buying or selling process with the main grid) to achieve the maximum operating benefits [11]. When fault occurs in the power system, MG will be automatically isolated from the main grid and works as stand-alone system. In stand-alone mode as depicted in Figure 1.3, the static switch is opened, and MG will be isolated from main grid. As consequences, will be disconnected from the main grid, whereby the remains feeders are now supported by the micro-source system [10].

Based on the research executed in [3], the presence of MG helps to mitigate the greenhouse gases emission issues, improve voltage profile by supplying reactive power, integration of heat load for cogeneration, demand response (DR) and ancillary services. In addition, the event of line losses and outages in distribution and transmission system can be reduced [3]. Another reason that MG is preferred as distributed power system is that this system employs information and communication technologies (ICT) to be integrated with RES. MG not only allow customers to access the real time information and control but also capable to restore the system in a short time against physical or cyber-attack [12]. Yet, there are some constraints that need to be faced during having this MG system such as this system requires high investment cost of RES, optimal usage of energy sources, control issues and inadequacy of system protection, and regulatory standards and customer privacy. The utilization of RES in electricity generation kept increasing as well as the integration of controllable loads with MG, therefore a proper energy management system (EMS) is required [3].

Sturdy MG system requires reliable EMS to stipulate active and reactive power references and to ensure that controllable units in MG can comply each other in order to obtain a stable and economic operation. Most research studies stated that the aim of EMS is to ensure the capital and operation costs such as fuel costs, maintenance operation cost and also the cost of electricity purchased from the main grid is being minimized [11]. Besides minimizing the total operating cost, the EMS also has the capability to perform real time energy forecasting for renewable resources, energy storage elements and controllable loads [12]. Therefore, it is very crucial to consider an EMS in MG so that both supply and demand sides can be managed to be more economical, sustainable and reliable [3]. Hence, there is a need to explore on the optimization operation strategy potential of MG model based on the demands response as this strategy is projected may offer more environmental friendly and cheaper electricity price [13].

1.2 Problem Background

In some remote areas, residential consumers are highly depending on electricity from RES to fulfil their load demands. Typically, RES can provide limited power capacity and they are intermittence [14]. During peak hour, RES needs to supply higher power and this leads to highest generation costs. For certain types of RES, it takes longer time to provide useful energy due to its limitation. This results in insufficient electricity supply and disturbance at the distribution sides. Nowadays, consumers are well aware regarding the penetration of RES in MG system. They are very concern regarding the reliability of continuous electricity supply and also low electricity bill [15]. In MG system, in particular during islanded mode (stand-alone MG mode), the power balance is very difficult to achieve without a proper EMS in the

MG system. Hence, study on the smart EMS in residential MG system is very necessary to be executed.

1.3 Research Objective

The main goal of this research is to investigate how electricity price could be minimized when customers' DR is considered in the MG system. To achieve this goal, some objectives are set as the following:

(a) To propose a double-layer coordination of EMS in stand-alone mode MG system by considering demand response scheme.

(b) To assess the performance of the proposed approach in terms of electricity cost of RES and residential customer sides.

1.4 Scope of Research

In this research, EMS in stand-alone MG system is studied and a double-layer coordinated control EMS approach is applied while considering demand response scheme. The proposed EMS emphasizing on 20 houses in residential area and aimed to minimize the electricity cost both at power and demand side. Solar and wind are selected as RES in the MG system and this system will be supported by micro-turbine and battery as energy storage. In this research, residential loads are classified into two groups; important loads and transferable loads. The impact of fixed and variable load conditions towards proposed EMS will be analysed in this research.

1.5 Research Contribution

The main contribution of this research is the implementation of a double-layer coordinated control EMS approach in the stand-alone MG system. Using this approach, the generation cost can be minimized while enhancing the system reliability and stability by considering customer's demand response scheme. Through this approach, energy consumption during peak hour can be clipped and transferred to the valley curve side. This then enables lower generation costs at the RES side and in the end will lowering the electricity bill at the customers' side a well. The diversity of generation costs also can be demonstrated for the proposed MG system through the fixed and variable loads test.

1.6 Report Outline

This report contains five chapters and further details on this work are presented in those chapters. Literature reviews related to this research work are discussed in Chapter 2. The research framework and proposed method are explained in detail in Chapter 3. In following chapter, results based on proposed method is represented and being discussed in Chapter 4. Lastly, the conclusion and recommendation based on this research is concluded in Chapter 5.

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