ENHANCED DEMAND SIDE MANAGEMENT METHOD IN OPTIMIZING UTILIZATION OF AVAILABLE POWER SUPPLY

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A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Science (Computer Science)

Faculty of Computing
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APRIL 2014

This thesis is dedicated to my family for their endless support and encouragement.

ACKNOWLEDGEMENT

All praise to Allah for everything I have. I would like to thank the following persons who accompanied me during the time I was working for this thesis.

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I would like to express my sincere appreciation to my thesis supervisor **Assoc. Prof. Dr. Kamalrulnizam Abu Bakar** for encouragement, guidance, critics, and advice till the end of glorious successful work.

My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues, En. Herman, Edi Saputra, Oon Erixno, Yoanda Alim Syahbana, Farah Ramadhani and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

I am grateful to all my family members, especially my mother “Hj. Yulmiar” and my sister “Yessy Yusnita” for their prayers and moral support.

ABSTRACT

Optimization of available power supply has become one of solutions to maintain continuity of electric power supply. In order to apply the solution, two essential issues to be considered are peak load and unused power. Peak load is condition when power usage exceeds peak load boundary. This condition causes power generator to operate at its limit and distress the power system. Unused power is excess of power from power generation that cannot be stored. Thus, it decreases efficiency of the power system. Demand Side Management (DSM) is a group of techniques in load management that focuses to tackle the issues. Direct Load Control (DLC) is one of the techniques in DSM method that handles peak load. This technique switches off some feeders in near real-time based on priority. In addition, this technique also applies scheduling mechanism to handle power payback phenomenon inherented in peak load. However, DLC technique does not consider unused power issue. Thus, this study combines DLC technique with proposed Dynamic Power Allocation (DPA) technique to consider the unused power issue. Combination of these two techniques is proposed as enhancement of DSM method to optimize utilization of available power supply. Simulation of power usage has been designed and experiment has been conducted. Two experiments were conducted: experiment that applies DLC technique only and experiment that applies combination of DLC and DPA techniques. To evaluate the performance of enhanced DSM method, load factor parameter is used. Load factor represents average power usage divided by maximum power usage at certain time period. Evaluation result shows that DLC technique only achieves 0.85 in terms of load factor. Moreover, load factor from enhanced DSM method is increased to 0.92. From the results, it can be concluded that the enhanced DSM method has achieved better optimization in utilizing the available power supply.

ABSTRAK

Pengoptimuman bekalan kuasa yang ada telah menjadi salah satu penyelesaian untuk menjaga kesinambungan bekalan kuasa elektrik. Untuk melaksanakan penyelesaian, dua isu yang penting untuk dipertimbangkan ialah kuasa yang tidak digunakan dan beban puncak. Beban puncak ialah keadaan apabila penggunaan kuasa melebihi batas beban puncak. Keadaan ini menyebabkan penjana elektrik beroperasi pada hadnya dan membahayakan sistem kuasa. Kuasa yang tidak digunakan ialah lebihan kuasa daripada penjana elektrik yang tidak boleh disimpan. Oleh itu, ia mengurangkan kecekapan sistem kuasa. Pengurusan pada sisi permintaan (DSM) ialah kumpulan teknik dalam pengurusan beban yang memberi tumpuan untuk menangani dua isu tersebut. Kawalan beban langsung (DLC) ialah salah satu teknik dalam kaedah DSM yang mengendalikan beban puncak. Teknik ini akan mematikan beberapa saluran penghantar hampir pada masa sebenar berdasarkan keutamaan. Di samping itu, teknik ini juga menjalankan mekanisme penjadualan untuk mengendalikan fenomena pengembalian kuasa yang sedia ada dalam beban puncak. Namun, teknik DLC tidak mempertimbangkan isu kuasa yang tidak digunakan. Maka, kajian ini menggabungkan teknik DLC dengan teknik pengagihan kuasa dinamik (DPA) bagi mempertimbangkan isu kuasa yang tidak digunakan. Gabungan dua teknik ini dicadangkan sebagai peningkatan kaedah DSM untuk mengoptimumkan penggunaan bekalan kuasa yang ada. Simulasi penggunaan kuasa telah dirancang dan eksperimen telah dilakukan. Dua eksperimen telah dilakukan: eksperimen yang menggunakan teknik DLC sahaja dan eksperimen yang menggunakan kombinasi teknik DLC dan DPA. Untuk menilai pencapaian peningkatan kaedah DSM, parameter faktor beban digunakan. Faktor beban merupakan purata penggunaan kuasa dibahagikan dengan penggunaan kuasa maksimum pada tempoh masa tertentu. Hasil penilaian menunjukkan bahawa teknik DLC hanya mencapai 0.85 dari segi faktor beban. Tambahan pula, faktor beban dari peningkatan kaedah DSM meningkat ke 0.92. Berdasarkan keputusan, dapat disimpulkan bahawa peningkatan kaedah DSM telah mencapai pengoptimuman lebih baik dalam menggunakan bekalan kuasa yang ada.

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LIST OF ABBREVIATIONS

AC	-	Air Conditioning
CB	-	Circuit Breaker
CPP	-	Critical Peak Pricing
DG	-	Distributed Generation
DLC	-	Direct Load Control
DPA	-	Dynamic Power Allocation
DR	-	Demand Response
DSM	-	Demand Side Management
GUI	-	Graphical User Interface
HVAC	-	Heating, Ventilation and Air Conditioning
LC	-	Load Control
LM	-	Load Management
RTP	-	Real Time Pricing
SSM	-	Supply Side Management
TOU	-	Time of Use

LIST OF SYMBOLS

P_{cs}	-	Power Capacity of System
P_{peak}	-	Peak Power
P_{th}	-	Power Threshold
P_u	-	Power Usage
P_{pal}	-	Power Allocation
T_{pu}	-	Total Power Usage
U_p	-	Unused Power

CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, electric power has become essential necessity for people to do the activities. Electric power simplifies human activities so that people may accomplish the activities quickly such as writing the article, printing the document, or washing the clothes. Moreover, electric power also supports people to improve quality of life. For example, the use of some appliances may provide entertainment such as television and video games and improve productivity such as computer, tablet and smartphone.

Electric power is produced through long and complex process by electric power company. The process involves three main components i.e. power generation, power transmission, and power distribution. Power generation converts energy sources into electric power. The electric power from power generation is transmitted as high voltage through overhead line transmission. The electric power is received in substations that have some feeders. These feeders distribute the electric power to customers e.g. residential, commercial and industrial.

1.2 Motivations

In order to maintain availability of electric power, electric power company has to manage the availability of energy sources that can be categorized as non-renewable energy and renewable energy sources. However, there are several challenges that must be faced by electric power company. Non-renewable energy sources have limited availability and the price tends to increase. On the other hand, renewable energy sources depend on weather, climate, and topography. Availability of electric power is also related with rapid growth of population and advancement in technology. These aspects triggered escalation of power demand. Unfortunately, the escalation of power demand cannot be followed by provision of power supply. Hence, continuity supply of electric power may be disrupted.

One of efforts from electric power company to resolve this problem is to develop new power generation by exploiting non-renewable or renewable energy sources. However, this approach also comes into some problems such as limitation of source, high operational cost, and long development time (Kulkarni and Katti, 2013; Babu and Kumar, 2013). As an alternative, optimizing utilization of available power supply becomes a preferable solution (Jabbar *et al*., 2010; Ravibabu *et al*., 2009).

1.3 Problem Statement

In optimizing utilization of available power supply, two issues that always become a focus are peak load and unused power issue. Peak load can be defined as condition where almost all of electric power is used by customer. In other words, peak load is power usage that exceeds peak load boundary. During the peak load, power generator units generate electric power that is on the verge of its capacity limit. Hence, the electrical power system becomes stressed and the reliability of the whole system is damaged (Teive and Vilvert, 2002). Furthermore, this condition may cause instability and entire black out of the electrical power system (Guo *et al*.,

2010). In the long term, this condition may decrease power generation efficiency (Bakker *et al*., 2010).

Meanwhile, unused power is remaining electric power from power generation that cannot be stored in large scale. The unused power will be wasted if it is not allocated (Duy Long *et al*., 2007). In the long term, it influences electricity production cost. Ultimately, this condition also affects efficiency of electrical power system.

In order to maintain continuity and stability of electric power, the peak load should be handled and unused power should be minimized. Load Management (LM) is one of popular methods that try to handle the issues (Bellarmine, 2000). In general, there are two categories of method in LM i.e. Supply Side Management (SSM) and Demand Side Management (DSM) method. The development of new power generation is one of SSM method. Due to limitations, constraints, and challenges that previously explained, this method is difficult to be implemented. Therefore, DSM method becomes alternative to handle both of the issues.

DSM method is described as planning and implementation of activities to influence customer in order to reach best adaptation between power supply and customer power usage (Duy Long *et al*., 2007). There are three popular methods of DSM i.e. Demand Response (DR), Distributed Generation (DG), and Load Control (LC) method. DR method is a program to control customer power usage by providing incentive and regulating different energy price between peak time and non-peak time. However, this technique cannot immediately handle the peak load since it depends on customer willingness and awareness toward the program.

Distributed Generation (DG) method is small scale power generation that located close to load. This method is usually managed by customer as an alternative electric power source other than electric power from electric power company. The customers can use this electric power when electric power company cannot fulfill

customer power demand. Therefore, total power demand to the electric power company will be reduced. However, this method requires additional investment cost at the customer side.

Meanwhile, LC method is a method to handle peak load issue by switching off some loads or shifting the loads from peak time to non-peak time. Direct Load Control (DLC) technique is one of the techniques in LC method. This technique handles peak load by switching off some loads (Ravibabu *et al*., 2009). This technique is one of the best approaches to handle peak load issue (Duy Long *et al*., 2007; Kun-Yuan and Yann-Chang, 2004). This technique also has quick response in reducing peak load.

Many researches have been conducted using DLC technique. Some of the researches develop load priority mechanism. In this mechanism, customer defines priority to the loads that will be switched off. When the peak load is occurred, DLC that uses load priority switches off the lowest priority load. Ravibabu *et al*. (2009) has implemented this technique for domestic loads. A Fuzzy logic controller is developed to switch off the loads when peak load is occurred. A multi-scale mechanism optimization technique has been implemented using load priority by Duy Long *et al*. (2007). Furthermore, Teive and Vilvert (2000) also develop a controller that will work to switch off the corresponding load based on priority list when peak load is occurred.

Kun-Yuan and Yann-Chang (2004) use Fuzzy dynamic programming to satisfy customer' requirements and determine optimal pre-scheduling of the DLC. Chi-Min *et al*. (2007) also develop the g-DLC controller in order to arrange the DLC schedule of all air conditioning units. Moreover, Tsair-Fwu *et al*. (2008) implements DLC schedule using relaxed dynamic programming for large air conditioner loads. This research also proposes schedule on DLC to avoid power payback phenomenon. However, according to Duy Long *et al*. (2007), DLC technique has limitation. When peak load has been successfully handled, there is possibility of unused power to occur in the system.

Based on the previous background, enhancement of existing DLC performance is essential to maintain the reliability and continuity power to customer. At the same time, DLC is also important to minimize unused power in order to optimize utilization of available power supply. The technique also should be applied in near real-time to avoid further issue in the system such as power generator damage, system blackout, and the unused power to become wasted. Therefore, this research proposes enhanced DSM method in order to enhance the existing DLC technique.

Figure 1.1 summarizes this entire research background that lead to problem of the research.

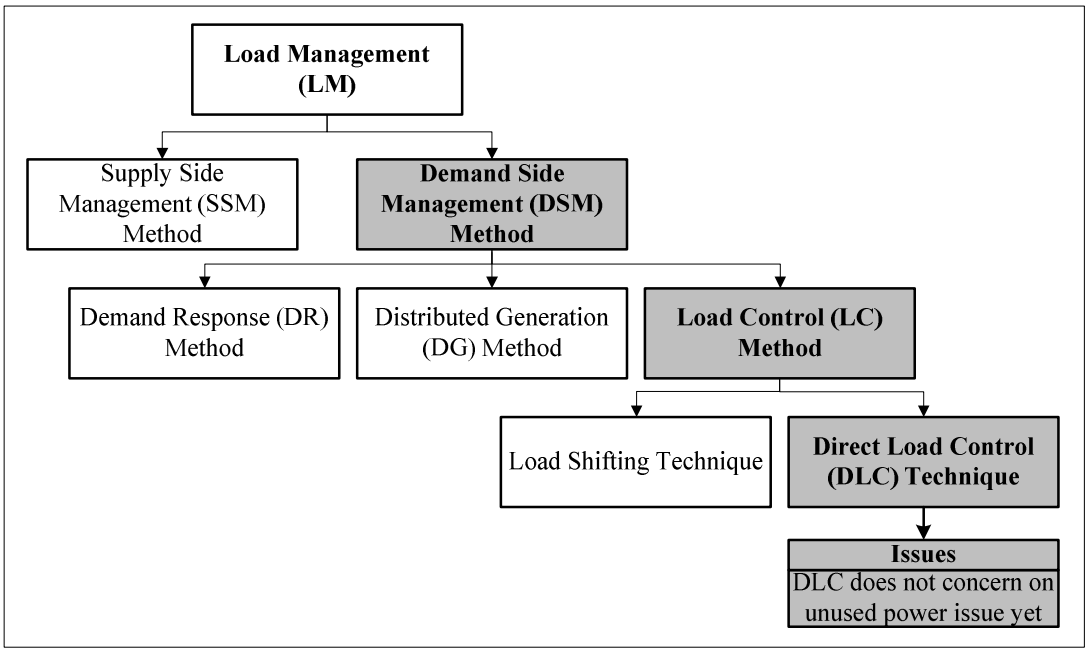

Figure 1.1 Research background

1.4 Research Question

Development and implementation of enhanced DSM method have some research questions that have to be addressed. The questions are:

i. How to develop a technique that can handle peak load in near real-time controlling and monitoring?

ii. How to develop a method that can handle peak load and minimize unused power in order to optimize utilization of available power supply?

iii. How to evaluate the performance of the proposed method?

1.5 Research Purpose

The purpose of this research is to develop enhanced DSM method that improves the existing Direct Load Control (DLC) technique. The improvement is aimed to make the existing DLC technique not only can handle peak load but also can minimize unused power

1.6 Objective

This research is aimed to reach the following objectives:

i. To develop Direct Load Control (DLC) technique that handles peak load occurrence precisely in near real-time controlling and monitoring.

ii. To develop enhanced DSM method that combines DLC and Dynamic Power Allocation (DPA) technique to enhances performance of the DLC technique in optimizing utilization of available power supply.

iii. To evaluate performance of enhanced DSM method using load factor.

1.7 Research Scope

The main focus and general assumptions of this research are as follows:

i. Daily load profile data in Ampere (A) unit is used as input data for simulation.

ii. The designed system that is used to simulate the proposed method consists of one power generator, three substations and twelve feeders.

iii. In this research, DLC technique is used to switch off feeders and not used to switch off loads.

iv. In this research, each of feeders have device that can measure power usage data and send the data using network communication system.

v. The proposed method is assumed to be implemented on industrial complex that has limited electric power. The complex consists of residential area, commercial area (office and shop), and industry area. It is also assumed that the complex has its own power generation, transmission, and distribution system.

1.8 Research Contribution

The main contributions of the research are summarized as follows:

i. The Direct Load Control (DLC) technique can handle peak load occurrence precisely in near real-time controlling and monitoring.

ii. The enhanced DSM method will enhance the performance of Direct Load Control (DLC) technique in optimizing utilization of available power supply. This method can handle peak load and minimizing unused power so that it can enhance the efficiency of electrical power system.

1.9 Organization of Thesis

This thesis is organized into six chapters as shown in Figure 1.2. Chapter I provides essential introduction to the research. Chapter II discusses basic information and review of related literature that leads to problem formulation in this thesis. Chapter III details the research methodology. Chapter IV elaborates development of enhanced DSM method. Chapter V describes experiment and evaluation. Chapter VI summarizes the entire of research.

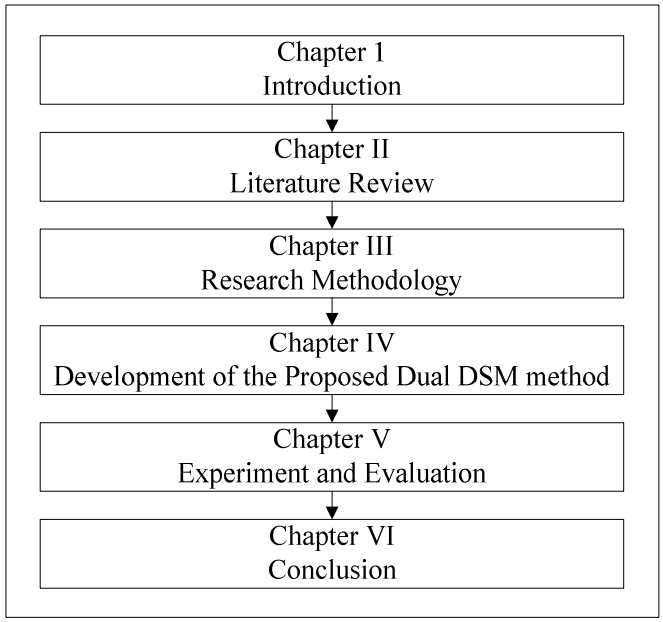

Figure 1.2 Organization of thesis

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