COMMUNITY ENERGY STORAGE DISPATCH STRATEGY FOR MAXIMIZING THE TECHNO-ECONOMIC BENEFITS

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DECLARATION

I declare that this thesis entitled "COMMUNITY ENERGY STORAGE DISPATCH STRATEGY FOR MAXIMIZING THE TECHNO-ECONOMIC BENEFITS" 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 : ....

Date : ....

APPROVAL

I hereby declare that I have checked this report entitled "Community Energy Storage Dispatch Strategy For Maximizing The Techno-Economic Benefits" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Energy storage is a type of support devices at the power system. Energy storage consists of many applications that depends on the location it is implemented. One of the applications of energy storage is Community Energy Storage (CES) that is installed at the distribution system purposely to boost feeder level benefits. The implementation of CES is crucial to prevent technical problems that usually occurred at the distribution system with renewable energy generation such as reverse power flow, uneven voltage profile, fluctuation of frequency and power losses. Besides, the alternative for economic problems faced by the customers which is high electricity prices during peak demand can also be recognized. These problems can be solved if the CES is properly managed in terms location and power capacity deployment. The main purpose of this report is to develop an optimal dispatch strategy of CES in terms of techno-economic benefits by using optimal power flow (OPF) method. The OPF method is solved in MATLAB by using Genetic Algorithm (GA) Tool. The techno-economic benefits are determined by the cost of electricity and the technical performance of the distribution system such as voltage distribution and peak demand. The OPF analysis is computed by using forward-backward sweep method. The developed dispatch strategy of CES in tested on the 15-bus radial distribution system since the test system located in residential area. Numerical results obtained show that the developed dispatch strategy of CES may reduce the electricity cost and peak demand while improves the voltage profile of the system.

ABSTRAK

Penyimpan tenaga adalah sejenis alat pembantu dalam sistem kuasa. Penyimpan tenaga mempunyai banyak aplikasi bergantung kepada lokasi penyimpan tenaga tersebut digunakan. Salah satu daripada aplikasi penyimpan tenaga telah digunakan adalah penyimpan tenaga komuniti yang digunakan di sistem pengagihan untuk kawasan perumahanyang bertujuan untuk menggalakkan kebaikan pada aras penerima. Penggunaan penyimpan tenaga komuniti sangat penting bagi menyelesaikan masalah-masalah teknikal yang dihadapi pada sistem pengagihan seperti pengaliran kuasa terbalik, ketidakseragaman voltan, gangguan frekuensi dan kehilangan kuasa. Selain itu, aternatif kepada masalah ekonomi yang dihadapi oleh pelanggan iaitu kos bil elektrik yang tinggi yang tinggi ketika permintaan kemuncak juga dapat dikenalpasti. Masalah-masalah ini boleh diatasi jika penyimpan kuasa diuruskan dengan baik dari segi penempatan lokasi dan kapasiti kuasa . Tujuan utama laporan ini adalah untuk memaksimumkan kebaikan tekno-ekonomi menggunakan kaedah pengaliran kuasa optimum (OPF). Kaedah OPF berkenaan diselesaikan dalam MATLAB menggunakan alat Algoritma Genetik (GA). Kebaikan tekno-ekonomi dapat ditentukan dengan mengetahui harga bil elektrik dan keberkesanan aliran kuasa dalam sistem pengagihan seperti taburan nilai voltage dan permintaan kemuncak.. OPF ditentukan dengan cara pengiraan sapuan ke hadapan dan ke belakang. Strategi yang diusahakan telah diuji ke atas sistem pengagihan radial dengan 15-bas berikutan sistem yang diuji terletak di Kawasan perumahan. Hasil berangka yang diperolehi menunjukkan strategi yang diusahakan menggunakan CES dapat mengurangkan kos bil elektrik dan permintaan pada waktu puncak, sekaligus memperbaiki profil voltan pada sistem pengagihan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

CES	-	Community Energy Storage
GA	-	Genetic Algorithm
RE	-	Renewables Energy
NRE	-	Non-renewables Energy
PV	-	Photovoltaic
IFOM	-	In Front of Meter
TES	-	Thermal Energy Storage
BTM	-	Building Thermal Mass
PCM	-	Phase Change Material
PCC	-	Point of Common Coupling
OPF	-	Optimal Power Flow
TNB	-	Tenaga Nasional Berhad
MATLAB	-	Matrix Laboratory
ESS	-	Energy Storage System
BES	-	Battery Energy Storage
MCB	-	Miniature Circuit Breaker
PU	-	Per Unit
Eprice	-	Electricity Prices
P_{CES}	-	Power of Community Energy Storage
P_d	-	Power Demand
t	-	Time / Hour
F	-	Objective Function
O&M	-	Operational and Maintenance
C_{batt}	-	Capacity of Battery
x	-	Level of Peak Shaving
L	-	Load
LF	-	Load Factor
$P(t)$	-	Active Power for Every Hour
$Q(t)$	-	Reactive Power for Every Hour

$P_{bus}(i)$	-	Active Power at each 15-bus Data
$Q_{bus}(i)$	-	Reactive Power at each 15-bus Data
E_{load}	-	Energy at load
E_{PV}	-	Energy generated from PV
i	-	Number of bus
PV_p	-	PV data gain from Solar Energy
P_L	-	Active Power of Load Demand
Q_L	-	Reactive Power of Load Demand
P_G	-	Active Power generated
Q_G	-	Reactive Power generated
Y	-	Line Admittance
∂	-	Phase angle of voltage
θ	-	Phase angle of line admittance
P_{PVR}	-	PV generation profile

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

In recent decades, energy storage (ES) has been widely used in the endeavor for better flow and technical performance of the power distribution system. ES is initially a battery that is used for large scale application especially in the distribution system because its implementation can overcome many problems occurred at the distribution side of the system. The fundamental of ES is to store and accumulated the energy until it reaches certain capacity to be used later. This fundamental is developed because the energy that have been generated cannot be created or destroyed, but it can be transfer from one object to another object through conversion [1].

Based on these concepts, the implementation of ES is applied practicably into the distribution systems. However, to make sure the usage of ES is worth the investments towards it, proper strategies of energy management are crucial to ensure maximum benefits can be obtained by strategic ES deployment. This is because even the ES deployed at the right place, the benefits of ES in terms of technical performance of distribution system and economic profits will not fully utilized.

There are many types of ES according to its deployment. For example, home ES system is the implementation of ES for the single home usage where the capacity of storage is 3.8kWh which is a small value [2]. The substation ES that implemented at the substation for receiving energy from grid and assisting in distribution network would be with capacity of more than 1 MWh. The usage of the energy storage is based on the where it has been deployed. The capacity of energy storage is higher when the location is at the higher energy transfer region. The newest technology provide from the application of ES is Community Energy Storage (CES) that applied at distribution system near residential area.

1.2 Problem Statement

The generation of power have been massively evolved by the development of renewable energy (RE) generation to supply energy in distribution system network. This development occurred as the community have the awareness about the harm cause by non-renewable energy (NRE) generation that will be used up before long. The NRE generation also lead to the environment effect such as air pollution and global warming that resulted from the burning of coal at coal energy power plant. Besides, there are about 175 countries that already sign the global agreement for reducing the emission of carbon [3]. Thus, the generation of RE such as solar, wind and biomass are utilized to reduce the unfriendly NRE generation.

Most RE used recently is Photovoltaic (PV) system that implemented on the rooftop of the residential estate. There are many houses that were provided with PV system that used to generate electricity through solar energy. These PV systems are very useful to help generating the energy so that the customers can use the energy generated themselves and minimize the energy from the supplier. However, the increasing usage of PV systems in a community will cause another problem to be occurred. The increasing numbers of small-scale PV installation cause many impacts towards power distribution system such as voltage fluctuation and maximum voltage limitation. In this case, the high amount of energy generated from the PV system especially during peak solar energy generation at noon is not utilized because the residential dwellers are mostly not around at home cause energy generated by the PV system accumulated.

If the limit of the reversed power flow has reached the limits, the power will be discarded [4]. When this problem occurred, it shows the power generated from the PV system is not efficiently managed. The power generated discarded is futile because the customers still needs to buy energy from the power utility without using the power that generated itself. The purpose of implementation of PV system to reduce the power usage from the grid is not successfully achieved. Thus, by utilizing Community Energy Storage (CES), the reverse power flow phenomenon can be avoided and will reducing the electricity cost for the customers.

1.3 Objectives

In this project, there are a few objectives that need to be fulfilled. The objectives are as follows:

i) To identify the benefits and costs of energy storage deployment at residential distribution system.

ii) To develop an optimal dispatch strategy of community energy storage for maximizing the techno-economic benefits.

iii) To evaluate the performance of the dispatched strategy on radial distribution system in terms of electricity cost, load demand and voltage profile.

1.4 Project scope

There are a few scopes that have been decided to accomplish this research. These scopes need to be followed to make sure this research achieved the research objectives. These scopes have been decided based on the researches of information obtained from the literature review.

i) The study is conducted at radial residential distribution network system as this type of network is widely used at the residential state.

ii) The CES is installed in front of meter (IFOM) because it used to serve the local customers.

iii) This research uses Genetic Algorithm in MATLAB software to obtain the optimum timing and value of charge and discharge power of CES for minimizing the electricity cost.

iv) The dispatched strategy to improve the CES is only focus on active power where the power factor is unity.

1.5 Motivation

Based on the problem faced by community, ES is very crucial to be installed within the community especially at the residential area. This is following to the impact cause by high implementation of PV in the distribution network. The uses of ES give great benefits as it can manage the RE generation that is not stable with proper way. The energy storage development tends to focus on large scale region such as substation.

Recent years, the deployment of ES have been spread to the smaller scale of electrical system which is Community Energy Storage (CES) that served customer at the residential region. The motivation of this step has been made due to the enhancement of PV system usage that deployed on every rooftop of each community region that will disturb the flow of energy at the distribution system which is reverse power flow. The reverse power flow phenomenon occurred when the energy generated by PV system on the rooftop of residential area is not used especially during peak hours of solar energy which is during noon. When this problem occurs, the energy will reverse back to the substation from the residential area of distribution system. This will cause the disturbance of energy in the system.

The deployment of energy storage that introduced can gives a lot of benefits to the distribution and can act as ways of solutions for various problems of it is appropriately managed and controlled. Fitting the name Community Energy Storage as in Figure 1.1, it served the community where it connected to the secondary transformer because it only serves some residential area. The placement CES is much more reliable for the residential area distributed system because the scope covered the energy from the substation until the distribution feeder located near residential region. By following this scope, the benefits obtained from this placement is much wider than any other location of ES.

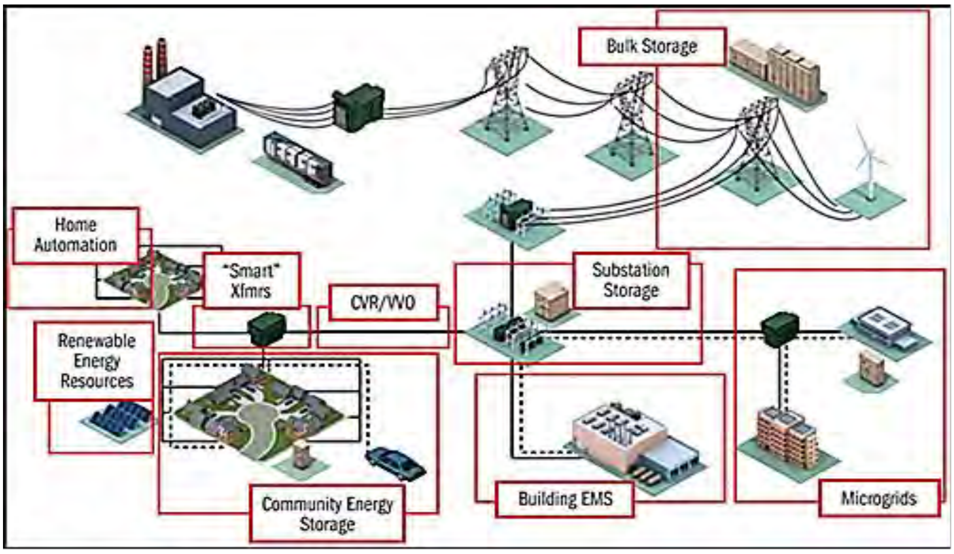

Figure 1.1: Potential location and application of Energy Storage in Power System [5]

CHAPTER 2

LITERATURE REVIEW

2.1 Energy Storage

The Energy Storage is very important to ensure a constant supply of power unlike wind and solar generation which particularly non dispatchable even though it have been advanced to a greater level. The benefits Energy Storage of includes three aspects which are technical, economy and environment. The uses of CES that connected at the utility distribution grid at distribution feeder is giving many benefits to the community.

2.2 Types of Energy Storage

The energy storages consist of many types that can be used for different application in the power system. The energy storage option that can be used like batteries, thermal and mechanical type. Each of the type have different ways to be used depend on the application of each types. There are various types of energy storage that have been revealed by many researchers and it already can be used as a safe accommodate component for the power system.

Figure 2.1 below shows the graph of currently most used types of energy storage in practical application. As shown in the figure below, pumped hydro energy storage have the highest rated power compared to other energy storages types and the most commonly used types of energy storage. For thermal storage, the Molten Salt Thermal Storage have the most installation which is 75% installation. For Electrochemical Energy Storage, the lithium ion batteries have the most installation with 59% and for Electrochemical, the most used is flywheel type that consist of 59% installation.

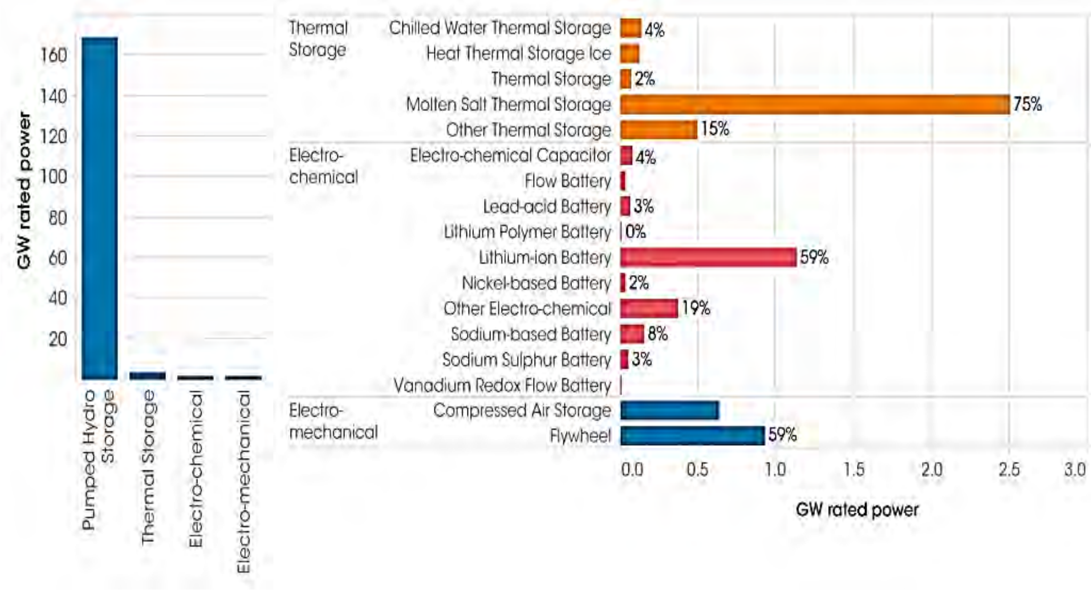

Figure 2.1: The current distribution of ESS by the most commonly used types by mid-2017 and the distribution of installed capacity among thermal, electrochemical and electromechanical systems for energy storage[6]

2.2.1 Battery

There are many types of battery that have been used recently such as lithium-ion, flow, lead acid, sodium, and others designed to meet specific power and duration requirements [7]. However, between these batteries, battery type that have been used the most is Li-ion type. As shown in Table 2.1, the properties of Li-ion type proved it as the preferred types of energy storage. Li-ion batteries presently have become large range and become the spearhead of the battery types which include smaller residential systems and larger systems that can store multiple megawatt hours and can be used to support the electric grid. These systems typically house many batteries together on a rack, combined with monitoring and management units. Lithium ion batteries have received a lot of press for their declining costs, due to the growing popularity of electric vehicles. Separately, flow batteries are electrochemical, energy is provided by two chemicals that are dissolved in liquids and stored in tanks. They are well suited for four or more hours of energy storage.