A COST BENEFIT ANALYSIS OF ELECTRICAL ENERGY STORAGE SYSTEM FOR COMMERCIAL BUILDINGS IN MALAYSIA: A CASE STUDY

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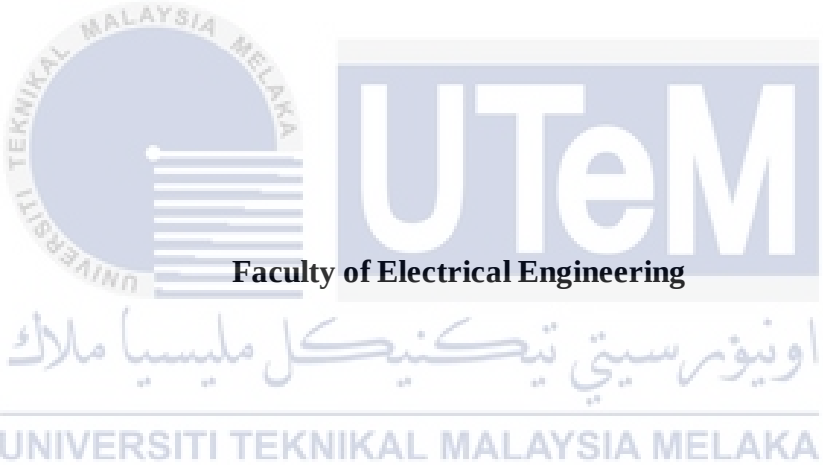

Faculty of Electrical Engineering

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DECLARATION

I declare that this thesis entitled "A COST BENEFIT ANALYSIS OF ELECTRICAL ENERGY STORAGE SYSTEM FOR COMMERCIAL BUILDINGS IN MALAYSIA: A CASE STUDY" 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.

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APPROVAL

I hereby declare that I have checked this report entitled "A COST BENEFIT ANALYSIS OF ELECTRICAL ENERGY STORAGE SYSTEM FOR COMMERCIAL BUILDINGS IN MALAYSIA: A CASE STUDY" 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 : DR JUNAINAH BINTI SARDI

Date : 5/7/2021

DEDICATION

To my beloved parents, family, friends and supervisor that helped me to complete this report.

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In the name of Allah, The Most Merciful and The Most Gracious. All the thanks and glory to Allah for allowing me to complete this final year project with ease on the journey. I am able to complete my project successfully with His love and blessing and to accomplish everything in my entire life, not just with this project. Each large or small project is successful thanks to the efforts of many wonderful people who have often provided helpful advice or offered support. Special gratitude and thanks to Puan Aziah binti Yahaya, my mother and all the members of my family. Your prayer for me, which has supported me so far and continues to support me until the completion of the project of this final year. To finish my final year thesis, this project requires me to learn so much understanding, experience, courage and support.

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ABSTRACT

Intensive research has been made due to the rapid draining of the conventional energy sources. Due to high energy demand, new technology is being studied which can be more efficient and eco-friendly system. One of the technologies that are being studied is renewable energy sector which is power system using solar photovoltaic (PV). The penetration rate of solar PV system depends on sunlight and weather condition. With the increase of the penetration rate, it helps to reduces the greenhouse gases and also expand the reliability of the infrastructure. Solar PV technology can help in reducing the maximum demand (MD). However, there are some factors such as the environmental elements such as weather condition, irradiation and the temperature affecting the solar PV output power. It is expected that battery energy storage system combined with the solar PV system in commercial building and industries used as solution for peak shaving and shifting. The purpose of this project is to analyse the cost and benefit of installing electrical energy storage system into a commercial building in Malaysia. As known, electrical energy storage can reduce the cost of electricity by applying the optimum sizing of energy storage in commercial building. In this project, the optimal size of energy storage is determined. Firstly, dispatch strategy for energy storage is modelled using an analytical method. Secondly, the efficiency of the dispatch strategy in terms of its ability in reducing peak demand and reverse power flow is evaluated. Lastly, the optimal size of energy storage is identified using genetic algorithm (GA). With the help of the methods developed, energy storage designs can be optimized according to practical applications for any solar PV application with the necessary changes. Finally, the results show that the proposed optimization strategy will reduce electricity bills and assess the optimal size of solar PV energy storage.

ABSTRAK

Pengaliran sumber tenaga konvensional yang cepat dan permintaan tenaga yang terus meningkat hari ini menyebabkan penyelidikan intensif untuk loji kuasa baru, lebih cekap, dan hijau dengan teknologi canggih. Pada masa kini, teknologi tenaga baru dan bahan bakar bersih sedang dikejar dan diterokai secara intensif berkat peningkatan keprihatinan alam sekitar di seluruh dunia. Peningkatan kadar penembusan sistem penjanaan fotovoltaik solar (FS) dalam grid utiliti mengurangkan gas rumah hijau, meningkatkan kebebasan tenaga, dan meningkatkan kebolehpercayaan infrastruktur. Sistem FS suria juga dapat menawarkan penyelesaian alternatif untuk pengurangan permintaan maksimum (PM) kerana berpotensi memberikan tenaga pada waktu puncak. Malangnya, faktor persekitaran, seperti penyinaran dan perubahan dalam suhu, mempengaruhi kuasa output FS. Penggunaan bateri dalam kombinasi dengan sistem FS di bangunan komersial dan industri tenaga diharapkan dapat menjadi solusi penyimpanan tenaga yang digunakan secara meluas untuk memenuhi pencukuran puncak dan pergeseran puncak. Tujuan projek ini adalah untuk menganalisis kos dan faedah memasang sistem penyimpanan tenaga elektrik ke bangunan komersial di Malaysia. Seperti diketahui, penyimpanan tenaga elektrik dapat meminimumkan kos elektrik dengan menerapkan ukuran penyimpanan tenaga yang optimum di bangunan komersial. Dalam projek ini, akan ada kaedah untuk mencari simpanan tenaga ukuran. Pertama, strategi penghantaran model untuk penyimpanan tenaga menggunakan kaedah analisis. Kedua, menilai strategi penghantaran. Terakhir, pendekatan pengoptimuman yang merupakan algoritma genetik (AG) untuk mencari ukuran simpanan tenaga yang optimum. Penyimpanan tenaga ukuran akan digunakan kaedah pengoptimuman. Dengan bantuan kaedah yang dikembangkan, reka bentuk penyimpanan tenaga dapat dioptimumkan untuk mana-mana aplikasi solar FS dengan perubahan yang diperlukan mengikut aplikasi praktikal. Akhirnya, hasil menunjukkan bahawa pendekatan pengoptimuman yang dicadangkan dapat meminimumkan bil elektrik dan ukuran simpanan tenaga optimum untuk solar FS.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL AND ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
FKE	-	Faculty of Electrical Engineering
ESS	-	Energy Storage System
BESS	-	Battery Energy Storage System
RE	-	Renewable Energy
PV	-	Photovoltaic
SME	-	Superconductor Magnetic Energy
EMEER	-	Efficient Management of Electrical Energy Regulation
SEDA	-	Sustainable Energy Development Authority
PHES	-	Pumped Hydro Energy Storage
TOU	-	Time of Use
FiT	-	Fit in Tariff
TNB	-	Tenaga Nasional Berhad
NREL	-	National Renewable Energy Laboratory
PHES	-	Pumped Hydro Energy Storage
CAES	-	Compressed Air Energy Storage
NiCd	-	Nickel-Cadmium
Li-ion	-	Lithium Ion
NaS	-	Sodium sulphur
EV	-	Electric Vehicle
SOC	-	State of Charge
DOD	-	Depth of Discharge
SPBP	-	Simple Payback Period

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Fossil fuel energy sources contribute almost 80% of the energy supply in world wide. Many countries are using fossil fuel as sources to generate their economies. This has contributed to the increasing of the carbon dioxide gases in Earth and cause global warming. This has led to intensive research for new energy sources that can reduces the problems.

Nowadays, renewable energy sources are being researched in order to solve the problems. The renewable energy such as solar PV and wind turbine system can help in reducing the greenhouse gas emissions [1]. For solar PV system, it is often studied and commonly is used with the energy storage system such as battery energy storage system (BESS) [1]. Energy storage technology has becoming a reliable system to be used in buildings and industries. In order to implement the technology to the commercial buildings, it is important to research about the potential and profitability in investment of the system. With energy storage system, it should help in reducing the cost of electricity for the consumer monthly as the ES function is to reduce load demand, which reducing the price of the electricity bills.

Residential, commercial and industrial buildings all has different pricing and electricity tariff. For dynamic pricing, smart meters which is one of the examples of smart-grid technology can be used. Example of the dynamic pricing is the time of use (TOU) pricing. The charges are fixed in certain period and usually offer a few price levels for example off peak, mid peak and on peak. It is depending on what type of the consumers' buildings category. Consumer can reduce the higher TOU rates with the ES system. The ES system usually store energy during off peak demand period where the price is lower than the on peak demand rates. The TOU charges is increased with the maximum demand charge. Maximum demand charge is the calculated for commercial and industrial buildings per kW usage [2].

Solar PV system has been applied in Malaysia for the past recent years. However, the implementation is still in early stages due to the high investment cost of the solar panel and also due to the lack of knowledge and researched about the system. This project is to evaluate a cost and benefit analysis about the solar PV system with electrical energy storage system for commercial buildings in Malaysia

1.2 Motivation

Energy generation today depending a lot in electrical energy. This is because in reducing the fossil fuel energy generation, electrical energy is used. Today, there are a lot of electrical energy storage implemented worldwide. The operation cost and the system efficiency are determined by the system performance.

In these recent years, many types of system storage are studied and focused on factor which is scale back cost ensuring longevity [3]. At this time, initial cost investment is one of the main issues in using electrical energy storage. Another researchers' goal is to ensure that the ES does not give negative impact to the environment. Electrical energy storage systems are classified into a few types, which are the mechanical storage system, electrochemical systems, chemical storage and thermal storage systems [4]. All the type of the systems has same purpose but with different method of operation.

Malaysia has initiated a range of primary RE initiatives. In 1997, Malaysia signed on to the Kyoto Protocol and dedicated itself to reducing greenhouse gas emissions [31]. The fifth power strategy for RE is an alternate generation of energy, apart from four previous sources of fuel, namely oil, gas, coal and hydro were announced in 1999. The Effective Control of Electric Power Regulations (EMEER) 2008 was introduced by Malaysia in 2008 on energy quality (EE). Malaysia dedicated itself to the COP 15 in the next year, where the county committed to a 40% pollution reduction. The most significant influence on the RE market was the implementation of the FiT scheme. This incentive was quota-based and was handled by SEDA [31]. This system encouraged RE developers with a premium tariff rate.

Generally, commercial buildings consumed a lot of electricity to operate its loads and the purpose of the energy storage is to reduce demand profile and cost of electricity bills in commercial building. Therefore, it gives motivation to reduce the peak demand load in the network. With the solar PV system and also with the electrical energy storage system which is battery storage system type, the commercial buildings can be independent which is not 100% depending on the power supplied by the grid system and consequently decrease the electricity bills. In this project, the energy storage using battery for commercial building with solar PV is studied and evaluated for its effectiveness and the optimization of energy storage system.

1.3 Problem statement

Nowadays, the application of the energy storage system is widely used in many types of commercial buildings. For many types of purposes, the consumers install the energy storage system. This system basically a technology related to renewable energy has available in Malaysia for few years ago. But, does the energy storage system succeed in doing its jobs such as to reduce peak demand and cut high electricity cost monthly. Energy Storage (ES) is one of the key solutions in advancing in technologies using renewable energy [1]. ES can also be used to deliver smarter and more dynamic energy services and address peak demand challenges. However, the cost of ESS mainly in battery system is the main obstacle to its implementation [19]. In some research, it shows that the current deployment of ES is still unprofitable because the benefit after installation cannot overcome the cost of its installation [7]. The authors in [7] established an approach to mitigate the aggregated impact to PV and electric vehicles using optimization of sizing and scheduling for ES. The authors also recommended to install ES to transformer at every distribution network system, however it may be excessive in the installation and investment cost and thus will not gain profit from it.

For commercial building that already have RE system installed such as solar Photovoltaic Voltage (PV) system which functioning as device that absorb energy from the sun and transfer into electrical energy that can be used during peak load demand at peak hours. However, the source of solar PV system is unstable and inconsistent due to the weather, it will be needed to have another device to stabilize the energy generated by the solar PV and the suitable device is the battery bank as the

storage element for the system [8]. It will overcome the weaknesses of the solar PV system such as during the night time where there is no energy to be absorbed to the system, the batteries can be used to supply the demanded load system.

Solution of the common issues in using the battery ESS is applying the system optimization for the ESS. It has getting attraction for its benefit for the consumers. From [6], in order to govern the suitable size of ES, a two tiers optimization system is projected. However, in that research, only load shaving and loss reduction were measured. Hence, the cost and benefit analysis for the application of the ESS in commercial buildings is conducted.

1.4 Objectives

The objectives of this project are:

a. To model a dispatch strategy of energy storage in commercial building for reducing the peak demand and reverse power flow.

b. To evaluate the effectiveness of energy storage system for commercial building in reducing operating cost for commercial buildings.

c. To determine the optimal energy storage sizing that needed to be applied for commercial building.

1.5 Project scope

The scope for this project is focused on the analysis of the cost and benefit for the energy storage system for commercial building in Malaysia. This energy storage system will be analyzed and evaluated to find the suitable type of energy storage system for the commercial building. All the benefit and cost are calculated and presented in this report. The optimization of the energy storage is also considered in this research as the optimum size for the ESS and electricity cost for the commercial building is calculated. The commercial building chosen for this research is commercial building in Universiti Teknikal Malaysia Melaka (UTeM) which is the Faculty of Electrical Engineering (FKE) building.

From this research, in order to level the daily load demand profile energy storage system is exhibited to generate its active power by using iterative method. This method will undertake the whole energy charged by energy storage is equivalent to the whole energy discharged by energy storage in a day [8].

This study, involves the process of analysing the load data which is the load demand of the building, PV data and electricity price data of a commercial building which is using a grid connected PV system. The irradiance data with one minute interval for one year which is year 2016 have been collected from the weather station installed on the rooftop of FKE, UTeM building. The total monocrystalline solar PV system installed capacity is 23.88 kWp. For this work, the same PV profile is used but with a larger generated capacity. The daily energy generated by the PV system considered in this work is 5754.49kWh. The electricity data analysed in this study is using C1 tariff category under Tenaga Nasional Berhad (TNB) tariff. Load data consumption of the building and the PV data is used to find an optimum size for the battery energy storage is by using that particular data. The finding of the optimum battery capacity means that it minimizes the cost associated with the operation of the PV system. The optimization approach is one of the research methodologies where an algorithm developed in MATLAB simulation software to compute the optimum value of energy storage system and the electricity cost. In this approach, it can analyze the differences of load profile and electricity costs when applying energy storage system and when using conventional system.

1.6 Structure of report

Chapter 1 gives the introduction to this case study project.

Chapter 2 describes the literature review of this project. In this chapter, it discussed about the energy storage system, the way of the system is working and the elements and components of the system. Finally, it discussed about the technical aspect for this case study.

Chapter 3 describes about the methodology of this case study in order to fulfil the objectives of this study. This methodology discussed about the modelling and optimizing the energy storage system which is more focussed on battery energy storage system. This chapter also carried the method to analyse and evaluate the cost and benefit of this system.

Chapter 4 describes the simulation results after implementing the strategy using the MATLAB software. In this chapter, it discussed about the obtained results of the system with and without the battery storage and optimization of energy storage size. It also discussed the evaluated costs and profit from the implemented system.

Chapter 5 gives the conclusion of this case study project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section will explain the details about the Malaysia's electricity tariff, energy storage system, benefit of energy storage system, the application, specification and technologies that involves in the energy storage.

2.2 Electricity tariff

Malaysia's electricity tariff for commercial buildings in January 2014 has increased, from the regular rate of MYR 0.3354/kWh to MYR 0.3853/kWh [2]. The increasing of the charges rate is because of it is one of the steps taken by the country to stabilize the economy sector. Moreover, because of the increasing price of fossil fuel, the electricity charges are also increase. Most of the contribution for the increasing demand of fossil fuels sources are from commercial and industrial sector. New power plant and grid reinforcement that are using fossil fuel to generate electricity is further developed in order to generate energy for maximum demand in the sectors [2]. Tenaga Nasional Berhad (Kuala Lumpur, Malaysia) (TNB) claimed that electricity demand is powered by growth which is expected to rise by 3 percent annually until 2030. However, the net electricity tariff nowadays has been reduced to MYR 0.365/kWh for commercial buildings category.

The commercial building tariff rate in Malaysia is shown in Table 2.1. C1 is the general commercial of medium voltage and C2 is the commercial of the peak/off-peak medium voltage [24]. For Category C1, MD charges are received between 8.00 a.m., according to the electricity tariff rates. and at 10:00 p.m. for net consumption costs separately from a flat rate. Net usage will be paid for Category C2 according to peak and off-peak times [2].

Table 2.1 tariff rate commercial building Malaysia [24]

Tariff	**Unit**	**C1**	**C2**
Peak	RM/kwh	0.0	0.365
Off-peak	RM/kwh	0.0	0.224
Net consumption	RM/kwh	0.365	0.0
Maximum demand (MD)	RM/kwh	30.3	45.1

The calculation for the electricity cost as below:

$$\text{Total cost (RM)} = (\text{Net, kWh} * \text{tariff}) + (\text{MD, kW} * \text{MD tariff}) \qquad (2\text{-}1)$$

Where the Net is the total consumption of the building in kWh and MD is the maximum demand value in the month in kW.

2.3 Energy Storage System

Energy storage is described as the transformation of electrical energy from a power grid into a form in which it can be stored until it is transformed back into electrical energy. Basically, it is a technology which its function is store energy for afterward usage [9]. Energy storage system represent as a tool that can store energy such as batteries and accumulator. Energy storage can improve a likelihood of renewable energy by flattening fluctuation between load and generation. A renewable energy source with high penetration has many benefits from energy storage devices. Most of energy storage system operates by storing or charging the energy during low peak demand periods (off peak period) and excess energy is available as the operation cost for the period is less expensive [22[23]. As in Figure 2.1 obtained from [22], the electrical energy can be stored in another form of energy such as chemical, mechanical, thermal, electrostatic and electromagnetic. The energy storage system can advantageous over the demand response program in allowing the consumers to use electricity as usual while reducing the peak demand charge (peak shaving).