ENERGY MANAGEMENT SYSTEMS OF GRID-CONNECTED PHOTOVOLTAIC GENERATION WITH ENERGY STORAGE SYSTEM USING PARTICLE SWARM OPTIMIZATION

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DEDICATION

This project report is intended as a gift to my parents, Shamsuddin bin Majid, Hasnah binti Abas, and my family who have encouraged and inspired me on my journey to further my studies. I would not have been able to complete this work without their support, encouragement, and motivation.

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ABSTRACT

Nowadays, Renewable Energy System (RES) like Photovoltaic (PV) widely used to increase energy generation. Solar PV installation as a Distributed Generation (DG) on the utility scale is commercially feasible, particularly for residential applications. This energy available abundantly and considered clean energy that harnessed and transformed the radiant light energy generated by the sun into electric current. However, the best use of solar energy has been prevented by nature or weather mismatches between the maximum of solar PV generation and usual residential load. In residential, the PV output is not fully utilized when the load is at the minimum (off-peak load). The wastage of power occurs due to PV excess generation during off peak load and causes an increase in the cost of electricity consumption. To optimize load demands and power flow in the connected grid, RES need to be scheduled. The Battery Energy Storage System (BESS) stores the excess power generated in peak hours and returns it to the system when there is not enough PV. While the energy management system (EMS) is required in operating renewable energy sources connected to a grid to ensure the renewable energy power is fully utilized. Therefore, this project to design the EMS strategy for the network that cooperating PV and BESS. This focused on PV modelling for improved EMS and the designation of storage devices. Optimize the PV size as well to reduce power consumption from the main grid. In this project, MATLAB Software was used to implement the Particle Swarm Optimization (PSO) technique. BESS capacity and PV size are acquired in accordance with the energy dispatch stored in the BESS. This strategy can reduce grid power generation by implementing EMS in the operation of existing residential PV with BESS.

ABSTRAK

Pada masa kini, Sistem Tenaga Diperbaharui (RES) seperti Photovoltaic (PV) banyak digunakan untuk meningkatkan penjanaan tenaga. Pemasangan PV solar sebagai Penjanaan Penghantaran (DG) pada skala utiliti dapat dilaksanakan secara komersial, terutama untuk aplikasi kediaman. Tenaga ini banyak terdapat dan dianggap sebagai tenaga bersih yang boleh memanfaatkan dan mengubah tenaga cahaya terpancar yang dihasilkan oleh matahari menjadi arus elektrik. Walau bagaimanapun, penggunaan tenaga suria yang terbaik telah dicegah oleh ketidaksesuaian alam atau cuaca antara. maksimum penjanaan PV solar dan beban kediaman biasa. Di kediaman, pengeluaran PV tidak digunakan sepenuhnya ketika beban berada pada tahap minimum (beban di luar puncak). Pembaziran kuasa berlaku kerana lebihan penjanaan PV berlaku semasa beban luar puncak dan menyebabkan kenaikan kos penggunaan elektrik. Untuk mengoptimumkan keperluan beban dan aliran daya di grid yang disambungkan, RES perlu dijadualkan. Sistem Penyimpanan Tenaga Bateri (BESS) menyimpan lebihan kuasa yang dihasilkan pada waktu puncak dan mengembalikannya ke sistem apabila tidak ada PV yang mencukupi. Sementara sistem pengurusan tenaga (EMS) diperlukan dalam mengoperasikan sumber tenaga boleh diperbaharui yang disambungkan ke grid untuk memastikan tenaga tenaga yang boleh diperbaharui digunakan sepenuhnya. Oleh itu, projek ini untuk merancang strategi EMS untuk rangkaian yang bekerjasama PV dan BESS. Ini tertumpu pada pemodelan PV untuk EMS yang lebih baik dan penentuan peranti penyimpanan. Optimumkan juga ukuran PV untuk mengurangkan penggunaan kuasa dari grid utama. Dalam projek ini, MATLAB Software digunakan untuk menerapkan teknik Particle Swarm Optimization (PSO). Kapasiti BESS dan ukuran PV diperoleh sesuai dengan penghantaran tenaga yang disimpan di BESS. Strategi ini dapat mengurangkan penjanaan kuasa grid dengan menerapkan EMS dalam operasi PV kediaman yang ada dengan BESS.

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LIST OF ABBREVIATIONS

PV	-	Photovoltaic
DG	-	Distributed Generation
RES	-	Renewable Energy System
BESS	-	Battery Energy Storage System
EMS	-	Energy Management System
PSO	-	Particle Swarm Optimization
NEM	-	Net Energy Metering
FiT	-	Fit-in Tarif
SOC	-	State of Charge
GA	-	Genetic Algorithm
FA	-	Firefly Algorithm
HSA	-	Harmony Search Algorithm
HRES	-	Hybrid Renewable Energy System
Ni-Zn	-	Nickel-Zinc
NiCd	-	Nickel-Cadmium
HESS	-	Hybrid Energy Storage System
CSA	-	Cuckoo Search Algorithm
PCC	-	Common Coupler Point

LIST OF SYMBOLS

x	-	Variables
v	-	Speed
x_i	-	Current Position
v_i	-	Current Velocity
j	-	Iteration
i	-	Particle Position
rand()	-	Random Number
C_1, C_2	-	Acceleration Factor
w	-	Inertia Weight Factor
f	-	Function
kWh	-	Kilo Watt Hour
Ah	-	Ampere Hour
V	-	Volt
h	-	Hours
Wp	-	Wattpeak

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

The development of Photovoltaic (PV) based Distributed Generation (DG) has increased continuously as PV system produces clean and quiet electricity from solar cells. The PV system does not emit toxic air, deplete of natural resources, or endanger the health of animals or humans by not using source other than sunlight. However, the inconsistency of nature or weather between the generation of full solar energy and the normal residential load has prevented the optimal use of solar energy [1]. Solar energy is a variable energy source, with energy generation depending on the sun and electricity production does not consistently occurred. In residential area, the use of electricity is higher at night and in the morning, which is the time off peak of the PV power. PV power is generated by sunlight which only occurs during the day, so most residential areas use grid connections as power sources. The national grid infrastructure is a major obstacle in managing the large-scale availability of power from PV distributed to grid connections [2].

The connection of the PV generation system to customers internal system under the implementation of Net Metering, necessitates a review of the existing connection scheme and requirements. There are two types of feeding method for the connection of solar PV generation system, which are Direct Feed and Indirect Feed. Direct Feed system is the connection point at Distribution Licensee's Grid, which is adopted for Feed-in Tarif (FiT) Meanwhile, Indirect Feed method is the connection point at consumer. The study of this project focus on the Indirect Feed System of PV residential generation to reduce their import from the Distribution Licensee. The Indirect Solar PV generation system is installed within its own system. Connection of Indirect Solar PV power generation system should not cause breach of reliability, power quality, and security of the network, as well as the safety of the operator and the public. The PV residential generation for Indirect Feed System overview is given in Figure 1.1.

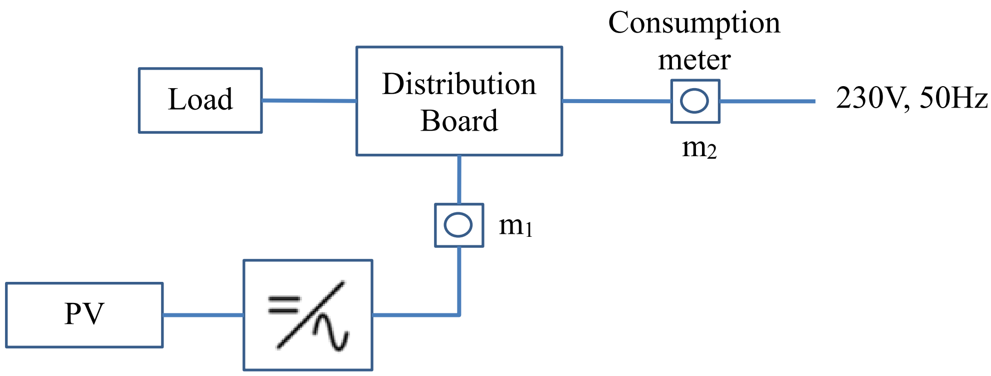

Figure 1.1 Connection of Indirect Feed System

The connection point is located within the consumers' network, independent of the Distribution Licensees' system. This is the approach used in Net Energy Metering (NEM) and Self-Consumption Schemes. Meter, m_1 is used to measure power consumption and export, while meter, m_2 is used to measure power generation. Meter, m_1 must be capable of recording both import and export units for net metering. Meter m_2 is a dedicated PV meter to record the generation from the indirect PV generation system [3].

However, periodically, during low household power consumption period and high solar PV generation, the excess power is to flow into the grid. Nevertheless, no export excess power is allowed, therefore self-consumption consumer must be using all PV power for their own load. Self-consumption means that the generated power is fully consumed within the residential. Therefore, to optimise efficiency and consequent loss from residential PV installations, Energy Management System (EMS) needs to be introduced to manage Battery Energy Storage System (BESS) which commonly used worldwide [4]. Optimum BESS transmission is important in such a system to optimise renewable energy usage to save energy consumption from grid connections. The EMS are monitors and control the generated PV power, BESS cycle, the load power and energy consumed from the grid connected.

1.2 Problem Statement

The worldwide implementation of PV as DG in the system is escalated. In specific, the PV system is clean energy which can be installed at residences. The performance of the PV system varies significantly due to of nature or weather conditions. As the sources are irregular, the residential PV generation on grid-connected are not fully utilized when the load is at the minimum (off-peak load). In other words, most of the PV energy is generated during the day but residential areas consume more energy at night and early morning. Most of the residential areas use sources from the grid power while only a small fraction use energy provided by PV system. Therefore, due to PV excess generation during off peak load, the waste of power occurs. Power wastage from the PV excess has caused an increase in costs of electricity consumption on grid connected. Moreover, there is a power outage on the grid and there are no alternative sources for residential consumer. Hence, a residential PV system was implemented to minimise the use of electricity from grid power to renewable energy by proposing a technique for integrating the BESS in the EMS of the grid connection. The purpose of this project is to provide quality framework for EMS which is essential in maximising proper use of limited resources as PV generation.

1.3 Objective

The objective of this project are :

i. To design the EMS strategy for the network that cooperating PV and BESS.
ii. To optimize the PV size to minimize the electricity consumption from the main grid using Particle Swarm Optimization (PSO).
iii. To analyze PV configuration of EMS strategy for grid connected residential application.

1.4 Scope of Work

In order to achieve above-mentioned objective, there are several scopes in this project :

i. The BESS size of 780 Ah is chosen.
ii. The real historical data analysis for 24 hours is conducted.
iii. Average energy consumption for single house is 45 kWh per day.

1.5 Report Organization

This study has five chapters. The overview of the project is outlined in Chapter 1 including project background, problem statement, objectives and scope of work. Chapter 2 explores the literature on grid connected of residential, which discuss EMS for PV generation with BESS. Then, the type of BESS and a load profile for residential was studied. The metaheuristic optimization technique to be used in EMS is also discussed in Chapter 2. Chapter 3 details the proposed EMS approach, which is implemented using PSO in the MATLAB software. Besides that, it describes methods for determining BESS, State of Charge (SOC), and residential load requirements in accordance with the applied EMS. The analysis of EMS strategy is conducted based on three weather conditions in Malaysia. In Chapter 4, the results of the simulation are presented and discussed in detail. Strategic EMS on sunny days, cloudy days, and rainy days is analysed, and the effects of SOC and the power grid are discussed. Then, the PSO evaluated the PV size, grid power connection and PV configuration. Chapter 5 summarizes the findings and analysis. This chapter also includes some suggestion for future works. The appendix is presented after chapter 5.

1.6 Significant Contribution

A small contribution is made by this project toward the design of a more optimal and systematic PV configuration in order to reduce the power grid cost while increasing the use of renewable energy. Besides, the power grid connection for residential purposes can be estimated using the appropriate PV size measurement, BESS capacity, and SOC limit of the system based on strategic EMS.

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```
            particle(i).Best.gen = particle(i).gen;

            % Update Global Best
            if particle(i).Best.gen < GlobalBest.gen
                GlobalBest = particle(i).Best;
            end
        end
    end

    % Store the Best Pgrid Value
    Bestgen(it) = min(GlobalBest.gen);

    % Display Iteration Information
    disp(['Iteration ' num2str(it) ': Best Pgrid = '
num2str(Bestgen(it))]);

    %%display the best Pgrid of each iteration
    out.pop = particle;
    out.BestSol = GlobalBest;
    out.Bestgen = Bestgen;
    bestsize = GlobalBest.size;
   %display(bestsize);


end

%% Results

figure;
semilogy(Bestgen,'LineWidth',2);
xlabel('Iteration');
ylabel('Best Pgrid');
```