CONTROL STRATEGY FOR DISTRIBUTED INTEGRATION OF PHOTOVOLTAIC AND BATTERY ENERGY STORAGE SYSTEM IN MICRO-GRID

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B011110067

920826-07-5773

A report submitted in partial fulfillment of the requirement for the Bachelor Degree of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

2015/2016

“ I hereby declare that I have read through this report entitle “Control Strategy For Distributed Integration of Photovoltaic and Battery Energy Storage System in Micro-grid” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature : ……..

Supervisor’s Name : ……..

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I declare that this report entitle "*Control Strategy For Distributed Integration of Photovoltaic and Battery Energy Storage System in Micro-grid*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

The micro-grid deployments are growing with independently, power system designers, manufacturers and researchers for the applications where the loads are more efficient association with extra output sources such as Battery Energy Storage System (BESS), and Photovoltaic (PV) systems. Using renewable source as main sources for micro-grid system also can avoid from the pollution to occur. Energy storage when combined with PV system can provide a stronger economic performance, as well as an added benefit of backup power for critical loads. This project proposed control strategies for integration of BESS and PV in a micro-grid. The operation enables the maximum PV and BESS utilization during different operating condition of the micro-grid, grid connected, islanded mode or a process between these two operations. For this PSM (Projek Sarjana Muda), the project will focus on analyzing the performance between photovoltaic system and battery in the simulations of micro-grids system and validate the simulation result using MATLAB/SIMULINK software. After the simulation was analyzed, the understanding of benefit in using renewable energy source as main power supply with support from battery energy storage to supply the power to the loads and power managements is realized in the different modes on micro-grid which is grid connected or islanded states. When the power generation from PV system was not enough to accommodate electric loads, the BESS or from secondary side of transformer will supply the insufficient power.

ABSTRAK

Penggunaan mikrogrid semakin berkembang dengan bebas, pereka sistem kuasa, pengeluar dan penyelidik untuk aplikasi dimana penyatuan beban elektrik lebih cekap dengan sumber pengeluaran tambahan seperti sistem bateri simpanan tenaga(BESS) dan sistem fotovoltan (PV). Dengan menggunakan sumber yang boleh diperbaharui sebagai sumber utama untuk sistem mikrogrid juga boleh mengelakkan dari berlakunya pencemaran. Bateri simpanan tenaga apabila digabungkan dengan sistem PV boleh memberikan prestasi ekonomi yang lebih baik serta keuntungan tambahan dari kuasa simpanan untuk beban elektrik yang kritikal. Tujuan projek ini dilaksanakan ialah untuk strategi kawalan integrasi sistem PV dan sistem bateri simpanan tenaga di dalam operasi mikrogrid. Operasi ini membolehkan sistem PV di kadar keluaran maksimum dan penggunaan sistem bateri semasa keadaan yang berbeza sama-ada semasa disambungkan ke grid utama, mod pulau atau proses antara kedua-dua operasi. Untuk PSM ini, projek akan memberikan tumpuan kepada menganalisis prestasi sistem fotovoltan dan bateri dalam simulasi sistem mikrogrid dengan menggunakan perisian MATLAB/SIMULINK. Selepas keputusan simulasi dianalisis, pemahaman manfaat dalam menggunakan sumber tenaga yang boleh diperbaharui sebagai bekalan kuasa utama dengan sokongan daripada penyimpanan tenaga bateri untuk membekalkan kuasa kepada beban dan pengurusan kuasa disedari dalam mod mikrogrid yang telah disambungkan ke grid utama atau mod pulau. Apabila penjanaan tenaga dari sitem PV tidak mencukupi untuk menampung beban elektrik, BESS atau bahagian skunder pengubah akan membekalkan kuasa tambahan untuk menampung beban.

ACKNOWLEDGEMENT

Assalamualaikum W.B.T.

Alhamdulillah, I currently finished my final report for PSM. To begin with, i would like to express my own gratitude to Allah The Almighty for giving me the health and strength to complete my Projek Sarjana Muda successfully. I would like to show my special thanks for both my parents for their continuous support and help in order to complete my research. I would also like to express my deepest gratefulness and thank to my supervisor, En. Alias bin Khamis who willing to spare his time in guiding and share his experience for me to complete this research. I would also like to thank all my friends who have support and willing to help me in completing the research and the report. Finally, I would like to thank the entire member in matlab forums for all their help for teaching me and completing this project and once again, I wish to express my thanks to all those involved, either directly or in directly.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Renewable energy rise as an alternative energy that will not run out and can prevent pollution from occurring. Many researchers became interested in the field of power system from current conventional power system which has been long used into smart grids involving micro-grids [1].

The technologies for renewable energy source such as photovoltaic and wind have a fast development uses in integration grid to less the operational cost for loads in using the energy either to generate a DC or an AC power source [2].

Microgrids increase dependability locally through the establishment of a reliability development plan that integrates redundant distribution, smart switches, power generation and energy storage. Local power generation and storage let portions of the grid and critical facilities to function independent of the larger grid when needed and thus eliminate blackouts.

The engagement of PV generation and energy storage system use in micro-grid system get more attention between researchers for studying in micro-grid system. In grid integration, PV supposed to work in Maximum Power Point Tracking (MPPT) to supply the accessible power and the Battery Energy Storage System (BESS) necessary to deliver the difference power in case the PV system did not meet the requirement of total load. The main grid is likely to support the balance of power and regulate the voltage.

1.2 Problem Statement

In micro-grid system, the customer demanding domestic and industrial is all about the lesser operational cost and electrical energy uses. Other than that, conventional distribution networks that accept distributed generation connections may face serious difficulty when its control and protection functions become more complicated. This incurs a burden to the network operation and some technical limitations will appear when a great number of distributed generations are installed [3]. A normal power system usually full supported from main grid power for a factory or house to operate. To avoid this problem, the research about the benefit and performance of PV system and battery energy storage micro-grid must be finding and new innovation must be made to settle the problem.

1.3 Objectives

The following are the objectives of this project:

1. To study the control strategy for distributed integration of Photovoltaic and Battery Energy Storage System in micro-grids.
2. To analyze the power management between Photovoltaic system and battery in the simulations of micro-grids system in grid connected or islanded mode.

1.4 Scopes

The scopes of this project are:

1. To study the strategy for distributed integration of Photovoltaic and Battery Energy Storage System in the micro-grid system.
2. To analyze the power management of the micro-grid in grid connected or islanded mode using MATLAB/SIMULINK software.

1.5 Structure of Report

In this report, there are five chapters that will be explaining the details of this project. Firstly, all about the introduction of this project consist of project background, problem statement, objectives and scope are covered in first chapter. For chapter two, the literature review on former researches about micro-grids, photovoltaic system and battery energy storage are included. Next, the methodology of this project will be illustrated using flow chart, methodology in details is in chapter three. For chapter four, the analysis of the data which is obtain from the simulation result and discussion of the result will be verified and discussed. Finally, the finding that was concluded from final result in chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the overall project theory as well as the concept. The aim of this section is to discuss the theory and process which is used in past or recent project. On top of that, this chapter will bring on the idea and theory used to solve the project problem. Theoretical is essential for a guide during doing in any of study or research

2.2 Micro-grids

Micro-grid that is a local grid which can connect and disconnect from the conventional grid to function autonomously and also help minimize the grid disturbances to reinforce the grid resilences. In micro-grids which are low-voltage AC grids, often use diesel generators, and are installed by the community. It also can become as an essential purpose in changing the local electricity grid system. The different between traditional electricity grid (macro-grid) and micro-grid is the scale of the grids. Micro-grid is more like a small-scale grids compare to macro-grids. Micro-grids utilize with combination of the different energy resources, such as solar hybrid or using smart wind turbine power systems which can decrease the cause of the pollution [4].

Micro-grids can supply the thermal and electricity power plus supporting and reducing the voltage sag will improve the quality of the power. From the utility's perspective, utilization of distributed energy sources can likely lower the appeal for distribution and

transmission facilities. The loads will decreases the flows in transmission and circuit of distribution with important effect which is capability to possibly substitute for network assets if distributed generation positioned close to loads. Furthermore, the service quality will be increased if the existences of the generation meet the demand of the customers. By reducing congestion and aiding restoration after faults, micro-grids can deliver the network support in times of stress. The mitigation of climate changes and the decreasing of emissions may be provided by development of micro-grids. This is because existing and emerging technologies for distributed generation units derived from renewable sources and micro source that are categorized by very low emissions.

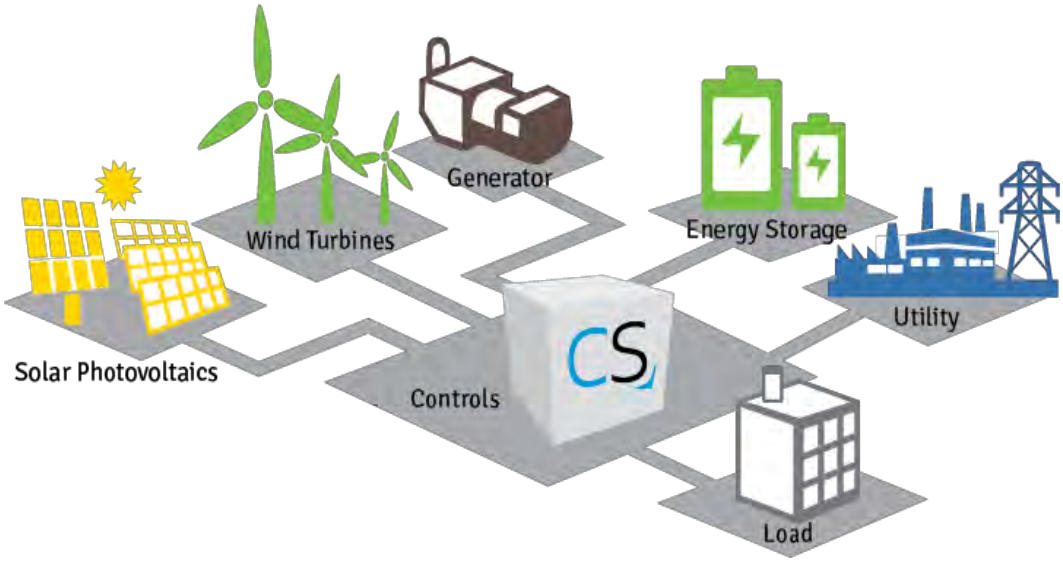

Figure 2.1 : The Microgrids system with variable source and connection or interconnection directly from local electricity grid.

2.3 Photovoltaic System

Solar photovoltaic is the method where the electricity formed from sunlight radiation. A semi conducting materials are used to make the photovoltaic cell where the sunlight strikes the cells, it is transformed into electricity. The solar cells are constructed from some thin layers of silicon. The electrons inside the cell are knocked loose when the PV panels were

strikes by sunlight radiation. The negative electron gets pushed away from silicon atom by the immersion of photon and positive hole remains. The positive hole and the unbound electron together are neutral.

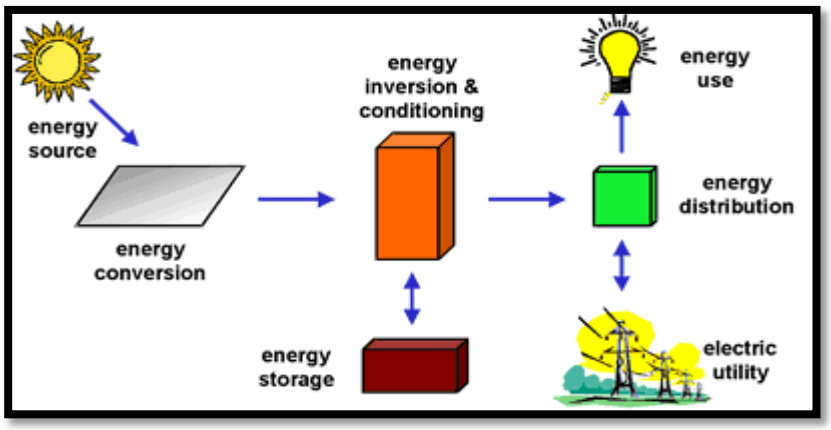

Figure 2.2 : The component of Photovoltaic system

So, the greater the solar radiation, the flow of electricity will become much more. The electricity was produce and delivered to energy distribution station thus to load or utility as shown in Figure 2.2.

2.3.1 Photovoltaic Array Model

Photovoltaic cells contains of p-n junction made up in a thin layer of semiconductor. Monocrystalline and polycrystalline are the common material for PV cells. The ideal solar cell is the one in which a current supply is connected in antiparallel with a diode. When the cell is exposed to sunlight, the direct current generated which varies linearly with solar radiation. The model can be improved, including the effect of a shunt resistance and series resistance. The single-diode model for PV cells equivalent circuit is presented in Figure 2.2.

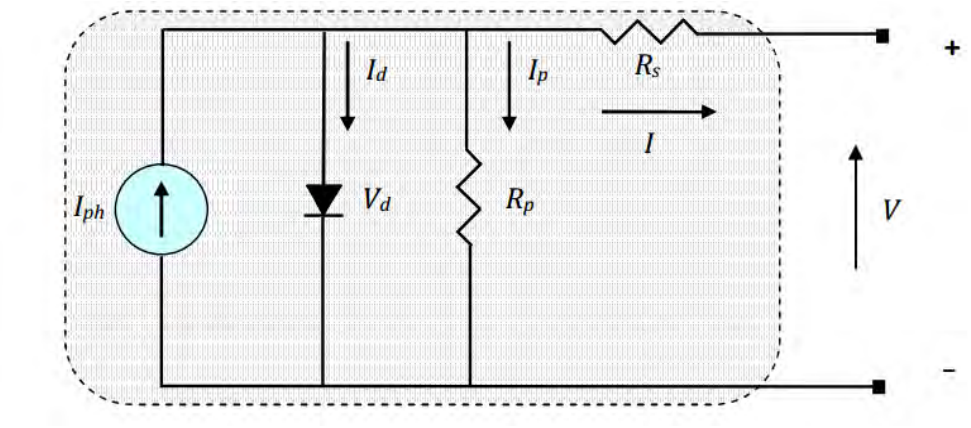

Figure 2.3 : The model for equivalent circuit of a photovoltaic cell

2.3.2 Maximum Power Point Tracking Control Algorithm

A maximum power point tracker is an electronic DC to DC converter that optimizes the match between PV panels and the battery storage or conventional grid to maximize the output power [13].

The solar radiation and temperature have an impact on the output power characteristic of the photovoltaic system where the purpose of irradiance and temperature curves are nonlinear. Moreover, during the day, the solar radiation has unexpected variation. For these circumstances, the photovoltaic systems operating point need to shift to maximize the generated energy when the maximum power point of the photovoltaic shifts continuously. Thus, to maintain the photovoltaic array's operating point at its maximum power point, the maximum power point tracking techniques was used.

2.3.2.1 Constant Voltage Method

A constant voltage method is the steady voltage of MPP algorithm that spontaneously regulated the reference voltage for unpredictable environmental conditions. The concept of this method was shown in Figure 2.4. A simple analog feed forward pulsewidth modulation

controller is creating as the weather conditions differ to track the maximum power point of a solar cell array. The open circuit voltage is tested while not busting the entire source from the load since the circumstance with other constant voltage MPPT methods was configured by solar array source [16].

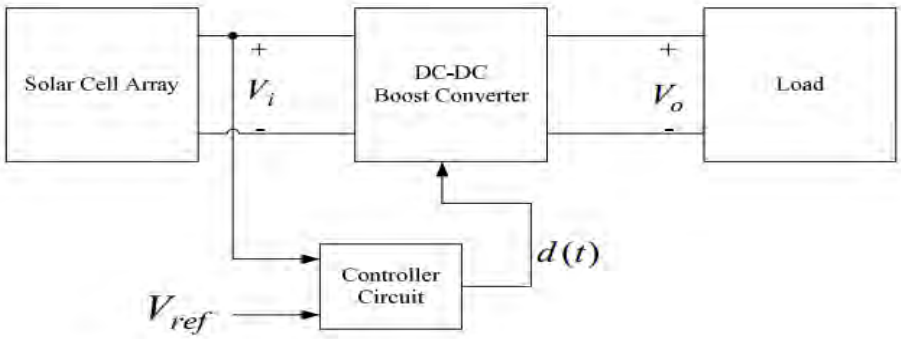

Figure 2.4 : Solar Powered System Model.

2.3.2.2 Incremental Conductance Methods

Based on the observation that using formula holds at the MPPT for incremental conductance methods [18];

$$\left(\frac{dI_{PV}}{dV_{PV}}\right)+\left(\frac{I_{PV}}{V_{PV}}\right)=0 \qquad \text{.....eq. 2.1}$$

where IPV and VPV are the PV array current and voltage, respectively.

When the ideal operating point in the P-V plane would be to the right of the MPP, we have (dIPV/dVPV) + (IPV/VPV) < 0, while the ideal operating would be to the left of the maximum power point, we have (dIPV/dVPV) + (IPV/VPV) > 0. The maximum power point will be followed by differentiating the immediate conductance (IPV/VPV) to incremental conductance (dIPV/dVPV). Hence the mark of the quantity (dIPv/dVPV) + (IPV/VPV) shows

the appropriate direction of perturbation causing to the MPPT. The operation of photovoltaic array is retain at this point and the perturbation ended unless a change in dIPV is noted once maximum power point was achieve. In this instance, the algorithm decrement or increment of Vref to track the new maximum power point [18].

When the MPPT has been achieved, it is theoretically likely to discover when the perturbation can be stopped by the incremental algorithm. The incremental algorithm provides a great performance under quickly shifting atmospheric conditions.

The advantages for incremental conductance techniques are the efficiency is high which is about 98% and the reliability is accurate. While for disadvantages, the design complexity is more difficult. The cost for this design also expensive and more complex compare to other technique [19].

2.4 Battery Energy Storage System

Energy storage can provide much more versatility as well as balancing to the grid, offering an important backup in order to intermittent renewable energy. It may enhance the controlling regarding to distribution networks, increasing efficiency and reducing the cost. By doing this, it could convenience the market benefit of renewable energy, ensuring higher security for energy supply, speed up the decarbonization of utility grid, and also enhance the protection and efficiency for transmission and distribution of electricity.

For distribution area, BESS can regulate the electricity source from variable renewable energy sources to the low or medium voltage of utility grid to match up with load demand. This also happen by managing the power flow and keeping voltage in suitable range and mitigating blockage.

2.4.1 Photovoltaic Output Smoothing with Energy Storage

The battery was functional as to increase the power to the photovoltaic output or decrease which is to smooth out the excessive frequency of the photovoltaic power that happen through interval with passing cloud shadows over the photovoltaic panels. While preventing overworking the electrical battery when it comes to capacity and ramp functionality, the control system is pushed with the challenge to decreasing temporary photovoltaic output variability. The control framework provides two extra inputs in order for battery to respond. For instance, the actual battery might react to photovoltaic variability, load variability or area control error or a mix of the three [6].

The system parameter supposed to be fixed photovoltaic system rating, the rating of converters and size of the battery capacity. A modify in the nominal parameter values needed to generate continued adequate overall performance should be effected with different battery parameter values. The result of temperature, charge or discharge rating, equalization and efficiency charging wasn't regarded. This kind of improvement might be included into the model. However, their effect on the entire controller functionality is just not likely to be very considerate [6].

2.4.2 Control of BESS in Microgrids for Islanded Operation.

The actual microgrids works in grid connected mode, however when fault happen in the upstream grid, it will detach as well as change into islanded mode. For grid connected mode, the managing power at the point of common coupling is essential management operation as opposed to the frequency and voltage. The harmonized control strategy involving diesel generator and battery energy storage system is required for the controlling the frequency and voltage when inquired in islanded mode. Almost all Plus Integral Controller (PIC) own set Plus Integral (PI) gains however, real time current gains are usually applied to PI controller applying Fuzzy logic. Therefore, output feature of battery energy storage system utilized real

time current gains to PI controller by applying fuzzy logic is quicker and much more precise that using fixed gains [7].

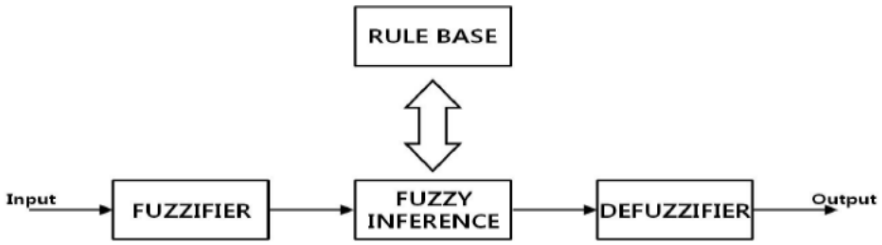

Figure 2.5 : Overall configuration of fuzzy logic controller.

Fuzzy logic offers strength to nonlinear design evaluation as well as don't have to use mathematical model when comparing to general PI controller. Therefore, utilizing Fuzzy PI controller at battery energy battery storage system will be much more precise and faster than PI controller at battery energy storage system. Beside to robustness is much more outstanding than PI controller [7]

2.5 Review of Previous Related Works

The management strategy for distributed regarding of renewable sources as backup sources in micro-grids was study by Amjad Anvari Moghaddam, Alireza Seifi from Department of Power & Control, School of Electrical and Computer engineering, Shiraz University, Taher Niknam from Department of Electrical and Electronics Engineering, Shiraz University of Technology and Mohammad Reza Alizadeh Pahlavani from the Department of Electrical Engineering, Iran University of Science Technology (IUST), Tehran. Their paper proposes for optimal operation of a typical micro-grid with RES accompanied by a back-up Micro-Turbine/Fuel Cell/Battery hybrid power source to level the power mismatch or to store the surplus of energy when it's needed. The suggested management allows the maximum renewable energy use through various operating modes of the system where grid is connected

to micro-grids, islanded mode or changeover among both modes while generating an allowance for the direct current voltage control and loads source [17].

There also a researches using four type of renewable energy source (RES) which is wind turbine, fuel cell, PV and energy storage (ES) in micro-grids system. The function of an isolated direct current micro-grid that involves of the turbine of wind, ES, PV system and direct current loads was researched which is to integrate the alternating current supply with other RES and the controller can be designed for an effective power management that will be used as hybrid power supply with utilization of green energy than conventional grid energy [22].

2.6 Summary

This chapter discuss on the overall project theory and concept. The purpose of this is to explain the perspective and method that is used in previous research or projects and to classify how much this project relate with those research and theory. Moreover, this chapter will show the theory and concept used to solve the project problem. Theoretical is very important as a guide in doing any kind of research. This chapter provided to six subtopic. First, it was about the details of micro-grid then follow by a PV system. Then, there's about BESS follow by the review of previous related works.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The research strategy is inevitable to obtain a great result in study and solving the problem. In order to study the data effectively, it's really essential to acquire the best understanding and also seeing regarding the flow strategy of the statistical solution to be used. Through this chapter, the process flow will be presented to indicate the experimental procedure of the project. After that, it is pursued by much more details in the assessment of factors of defect design by utilizing the flow chart of methodology for this project. The strategies are concentrate on the actual factorial design experimental which have been choose this specific task and also already been research in Literature review. For methodology section, the chapter will concentrating on the process that been done to achieved the objective and fulfill the research target in Chapter 1, which is to study the management strategy for distributed regarding of PV and energy storage in micro-grids, to design the PV system and BESS.

3.2 Flow Chart of Methodology

The methodology is planned by using the flow chart for conveying the method from the beginning until the end of the project. The task that carried out will be more systematics and acceptable using the flow charts. By following the flow charts, any mistake or problem will be easy to locate and solve. For this research, the corresponding flow charts are organized will be displayed in Figure 3.1.

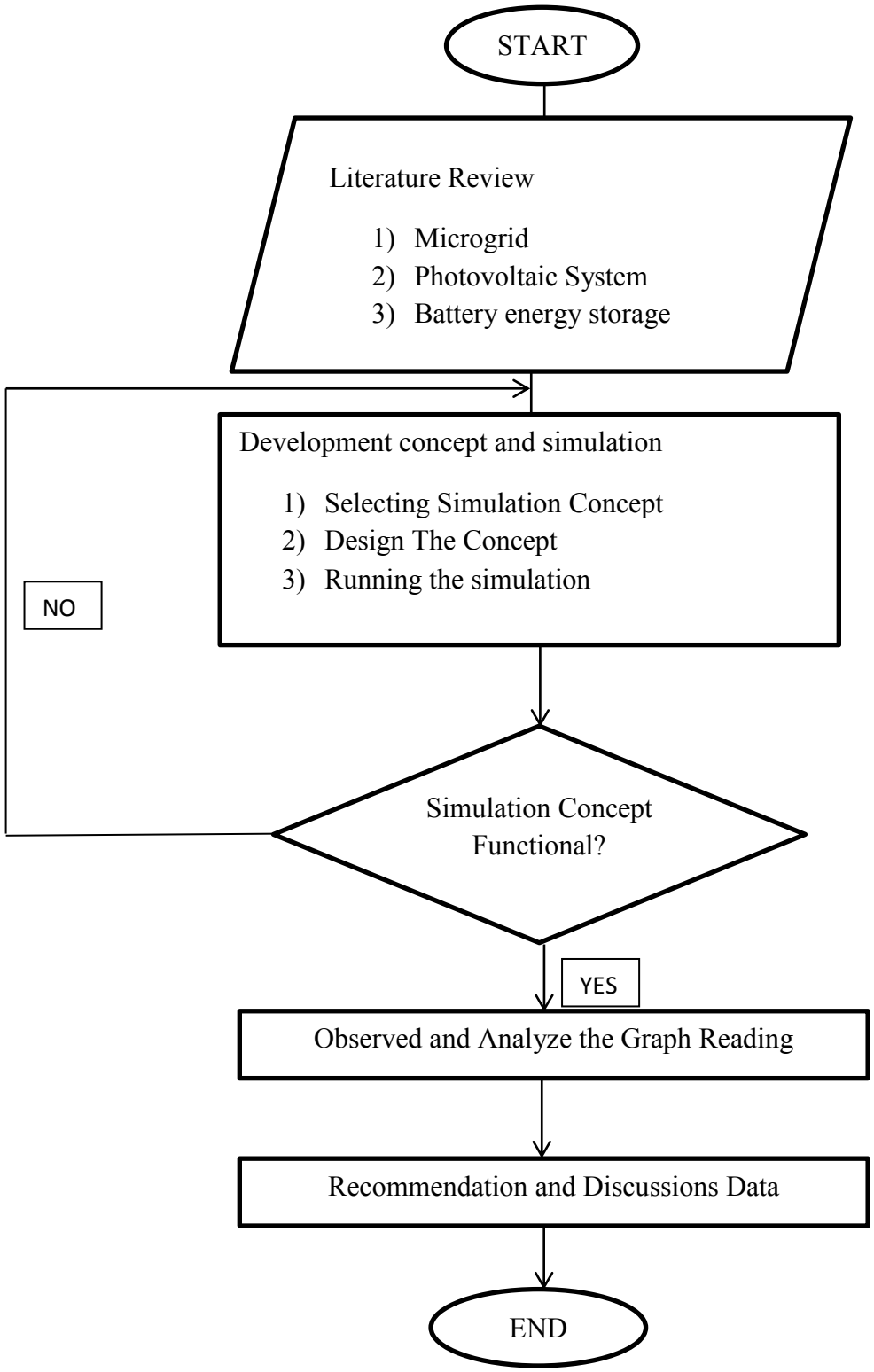

Figure 3.1 : Flow chart of Methodology from beginning of project until submit the report.