MODELING AND SIMULATION OF GRID CONNECTED PHOTOVOLTAIC SYSTEM USING MATLAB / SIMULINK

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Dedicated with deep gratitude feeling to Paramahamsa Nithyananda
The embodiment of all the existential and non-existential energy
That ever guiding the path towards enlightenment in blissful

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In the name of God, the world begins and so this master project, hence to HIM the Most Blissful I would like to extend my gratitude. With HIS help, guidance and permission this master project came to existence. Thank you again *Nithyananda* (Eternal Bliss). I also would like to use this space to extend my gratitude to those that had rendered help, guidance, moral support and prayers in championing this project.

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ABSTRACT

Photovoltaic System is a huge topic that can be researched and studied on such as the arrangement of PV array is one of the issues that can be studied. Besides that, the control techniques can as well be delved into. Another important area that makes concern to the PV world would be the maximum power point tracker (MPPT) for PV to maximize the sun energy, and so many more can be said in these advanced millennia. Yet in this research work, the scope has to be scaled down in appreciation to the given time. This research project would mainly concern on the different PV technologies (amorphous silicon, polycrystalline) and their effect to the system in terms of energy output. Besides that, this project work would be designed nearly to the BIPV-PTM projects that have been implemented in Malaysia in order to verify the energy output results from the modeling and simulation activities. The project works will emphasis on Malaysia's temperature and solar radiation. On the other hand, having so much respect to the given time, the grid connected PV system modeling may not have protection system to be included in the design and only the best inverter model would be chosen for the simulation purpose. Overall findings indicate that the modeling using MATLAB / SIMULINK can be further used for investigation and make improvement in order to identify which best technologies to be implemented. The polycrystalline PV System yields higher energy output compared to the amorphous silicon technology is another finding thru this project.

ABSTRAK

Sistem Fotovoltaik merupakan satu tajuk besar yang boleh dikaji dan dipelajari dari pelbagai aspek seperti jenis susunan panel, cara pengawalan dan sebagainya. Disamping itu, penemuan dalam sistem penjejakan titik operasi maksima (*MPPT)* turut menyumbang kepada perkembangan sistem fotovoltaik ini. Namun begitu, projek ini hanya membincangkan perbezaan teknologi fotovoltaik *(amorphous silicon, polycrystalline)* dan impaknya terhadap penghasilan tenaga elektrik. Projek ini juga dimodelkan serupa dengan projek yang telah dibangunkan oleh Pusat Tenaga Malaysia (PTM) secara praktikal melalui projek Sistem Bangunan Berintegrasikan Sistem Fotovoltaik.*(BIPV).* Tujuan pemodelan sebegini adalah untuk menentusahkan tenaga elektrik yang dijana melalui pemodelan sistem. Projek ini memberi penekanan kepada suhu dan radiasi solar Malaysia. Sistem perlindungan tidak diberi penekanan dalam projek ini dan penyongsang terbaik dipilih dalam aktiviti pemodelan ini. Secara amnya, melalui projek ini, didapati pemodelan menggunakan perisian MATLAB / SIMULINK, amat relevan dan boleh diguna pakai serta ditambah baik untuk mengenalpasti teknologi fotovoltaik yang sesuai diimplemen di Malaysia. Melalui projek ini juga, didapati teknologi *polycrystalline* menjana tenaga elektrik yang tinggi berbanding dengan teknologi *amorphous silicon.*

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LIST OF SYMBOLS

PV	-	Photovoltaic
TNB	-	Tenaga Nasional Berhad
PTM	-	Pusat Tenaga Malaysia
BIPV	-	Building Integrated Photovoltaic System
kWp	-	kilowatt peak
kWh	-	kilowatt hour
d.c	-	direct current
a.c	-	alternating current
η_r	-	PV module efficiency at reference temperature (T_r = 25 ^oC)
β_p	-	Temperature coefficient for module efficiency (% / ^oC)
T_c	-	Surrounding Temperature
T_r	-	Reference Temperature (25 ^oC)
T_r	-	Reference Temperature (25 ^oC)

CHAPTER I

INTRODUCTION

1.1 Project Background

Photovoltaic System (PV) is getting popular by day as the crude oil price increases and unstable in the global market. Furthermore with green peace movement, and the consciousness of mankind has heightened up regarding green energy, photovoltaic maybe one of the solution for better as well cleaner energy as it is naturally harness from the Sun energy. Although the technology is mainly well known in the space mission, yet it's still an alien for domestic usages. This is due to the high initial cost, generation efficiency and reliability [1]. On the other hand, to answer the cry for alternative energy has made the PV system again popular among the researchers. Having said so, the rural areas where the grid connection is extremely expensive, PV Systems have been implied to give hope to these areas, while for the urban life, the PV Water Heater is common and can be found on the roof of the houses.

Currently, more than 3500MW of photovoltaic system have been installed all over the world [2]. Referring to the results from Earth Policy Institute (EPI), the

world production of solar PV cells increased 32% in 2003, compared to the most recent 5-year average of 27% a year. Production increased to 742 MW, with cumulative global production at 3145 MW at the end of year 2003, enough to meet the electricity niche of one million homes. Referring to the EPI, this extraordinary growth is driven to some degree by improvements in materials and technology, but primarily by market introduction programs and government incentives [2].This fact can clearly conclude that this solar energy (photovoltaic) is a very promising as next generation energy source.

On the other hand, in Malaysia there are plenty of sectors join hands in promoting the photovoltaic including the government as well with the private sectors. Some of the projects are pilot project by TNB (Tenaga Nasional Berhad) whereby 6 pilot plants was installed during 1998 – 2001 in various places in Malaysia such as in Uniten, Port Dickson and Subang Jaya [3]. Pusat Tenaga Malaysia (PTM) is another building integrated with photovoltaics, using polycrystalline (47.28kWh) and amorphous (6.08kWh) [3]. This is inevitable evidence that shows solar energy is one of the practical renewable energy sources for Malaysia.

In this context, lots of research needs to be done in order to achieve a reliable and efficient energy. Looking at the grid connected system, whereby the system mainly consists of photovoltaic (PV) modules, inverter, battery, and switching point for the utility [4]. Different types of photovoltaic cell will yield different energy output, meanwhile the controlling technique of inverter is very crucial in championing the PV system. Inverter design should consider the size and capacity of the plant, on the other hand choosing the right controlling technique is needed as well in order to achieve an efficient renewable energy system.

There are many types of inverter used in converting the direct current (d.c) produced by the PV to alternating current (a.c). The conversion is a must in order to suit the AC grid system that have been implemented and practiced for so long. Some of the types that can be used are multilevel inverters such as flyback capacitor, neutral

point clamped multilevel inverter, diode clamped inverter and many more. Each topology has its own plus point and drawbacks depending on the usage of it. Applying certain controlling techniques to the inverters' such as Pulse Width Modulation (PWM), Space Vector Pulse Width Modulation (SVPWM), Step Modulation etc, the efficiency of the conversion can be obtain up to an optimum level. Hence this is another part for research in the PV Grid-Connected system.

On the other hand, there are many types of technology used in producing the photovoltaic cell, such as using the Silicon Photovoltaic (crystalline silicon, nanocrystalline), Thin Film solar cells (amorphous silicon, cadmium telluride, gallium arsenide, copper indium gallium deselenide) and Concentrating Photovoltaic (multijunction cells) [5]. As said above, the different types and topologies of photovoltaic gives different energy output, such as the amorphous silicon typically efficiency is 6%-8%, while multicrystalline is 11% - 14%, and mono-crystalline is 12% - 17%, etc [6]. Hence in this work, the major part of research will be a study on the impact of the different topologies of PV cells on the energy output generated.

Besides that, it's a common knowledge that, the PV system has different seasonal pattern behavior depending on the temperature as well as the solar irradiation. Due to the different temperature co-efficient of voltage and current the PV system has different output. Yet, to simplify the work of manufacturer mostly, the PV modules are rated at STC (standard test conditions) of solar irradiation as 1000 Wm^{-2}, while the spectrum is fixed and related to a sun-spectrum at air mass of 1.5 (AM = 1.5). The STC temperature operating for the PV cell is at $25^{o}C$ which does not relate to the practical world especially to Malaysia. Hence this project aims to have some practical simulation work to suit to Malaysian tropical weather and climate.

In promoting, grid connected photovoltaic system by building integrated photovoltaic system (BIPV) the Malaysian government has been very supportive via Malaysian Industrial Development Authority (MIDA) in terms of tax holiday, industry park and many more incentives. Besides that competitive electricity tariff

(USD 4-6 cents / kWh) is another plus point in the blooming of PV system industry. Political and economic stability in Malaysia act as a catalyst for this new industry [7].

As a conclusion, it's worthwhile to research on this photovoltaic system as it is the next generation energy source, while it's green and promotes to cleaner world. On top of that, this research work is in line with the government aspiration on becoming a greener nation with a renewable energy source. This in return will mark Malaysia another step higher in the eyes of the world. Impact of different topologies and technology of PV will be the main concern on this research work. Although the single cell and multijunction solar types have different energy output in various technology, yet the research in terms of comparison have to be conduct in finding the advantages and disadvantages of the system as well the behavior of the system to the Malaysian climate. These are the issues pertaining to this research work.

1.2 Research Objective

Following are the objectives that hopefully to be achieved at the end of this project implementation. Those objectives are:-

- To study solar cell circuit model
- To model and simulate a single junction solar cell
- To determine energy output of different PV technologies.

1.3 Research Scopes

In accomplishing this research, the work has been divided into few parts. As for the beginning part, the literature review on the photovoltaic theory, topology and its operation as well grid-connected PV system will be glanced thru to have a better understanding on the system as a whole. On the second stage after the understanding of theory, modeling and building up the equivalent electrical circuit shall commence at once. As to mark the end of the work, the simulation result using the single junction cell will be used to determine the energy output (kWh) using the input parameters temperature and solar radiation obtained from Malaysian Meteorological Data (MMD).

As mention above the general scope and flow of this research work, the single cell PV shall be modeled first and simulated. Then it will be verified using the I-V curve of a manufacturer's data sheet. After all the verification process done, the modeling part for Malaysian context shall be done and analyzed.

In this work, PV cells from amorphous silicon and polycrystalline silicon types will be used. The first one represents the thin film technology and the later part the silicon technology. These technologies will the major research on this project. The simulation later part will be done to Malaysian solar irradiation and temperature value.

As for the accomplishment of this project, the project will be extended up to the verification thru actual monitored Malaysian Building Integrated Photovoltaic (MBIPV) system.

1.4 Methodology

The approach that has been applied in championing this project can be divided into two major segments. The first segment is the literature review and the second part is on the circuitry modeling and simulation. In the beginning, the literature review will help to understand the photovoltaic cell by understanding their types, and identifying all the PV system components. Then literature part will continue as the studies will be extended to different technology of single cell for amorphous and polycrystalline cells.

Later on the literature review continues up to grid components as well studies on the inverter models for the grid conducted concurrently. On the other hand, the meteorological data is also gathered in order to make this research work to be contextualized for Malaysian environment. Site visiting to MBIPV is also part of the literature review as well to gather data for the literature review on the simulation software also done in order to be able to use the software effectively.

On the second part, the single junction cell will be simulated and verified thru manufacturer data sheet using I-V curve. After all verification successfully done, the modeling and simulation part for inverter shall take place. After all the major components of grid connected PV successfully done, the component shall be interconnected and simulated to the Malaysian context. After completion of the system simulation, using few bench marks the results will be analyzed. Following are the summarized flow chart on this project.

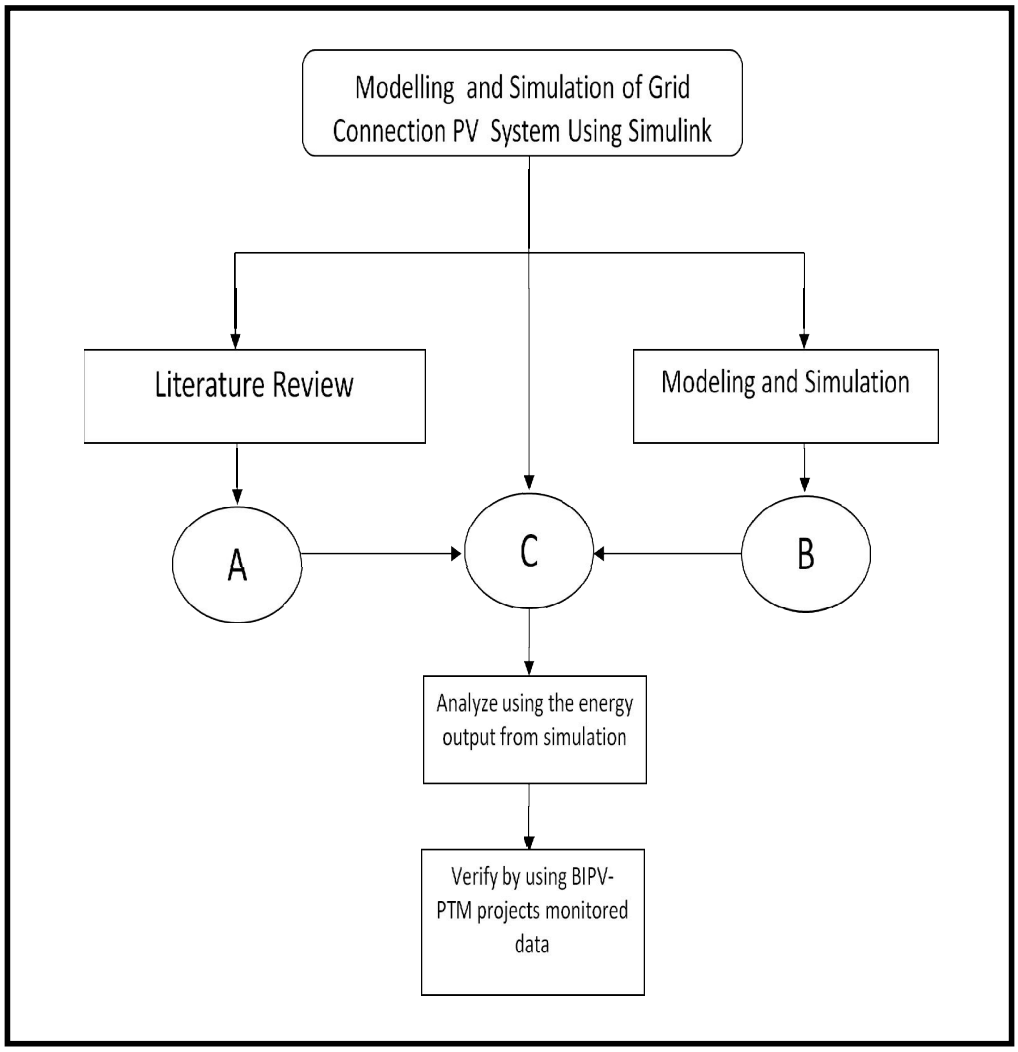

Figure 1.0: Methodology Flow Chart

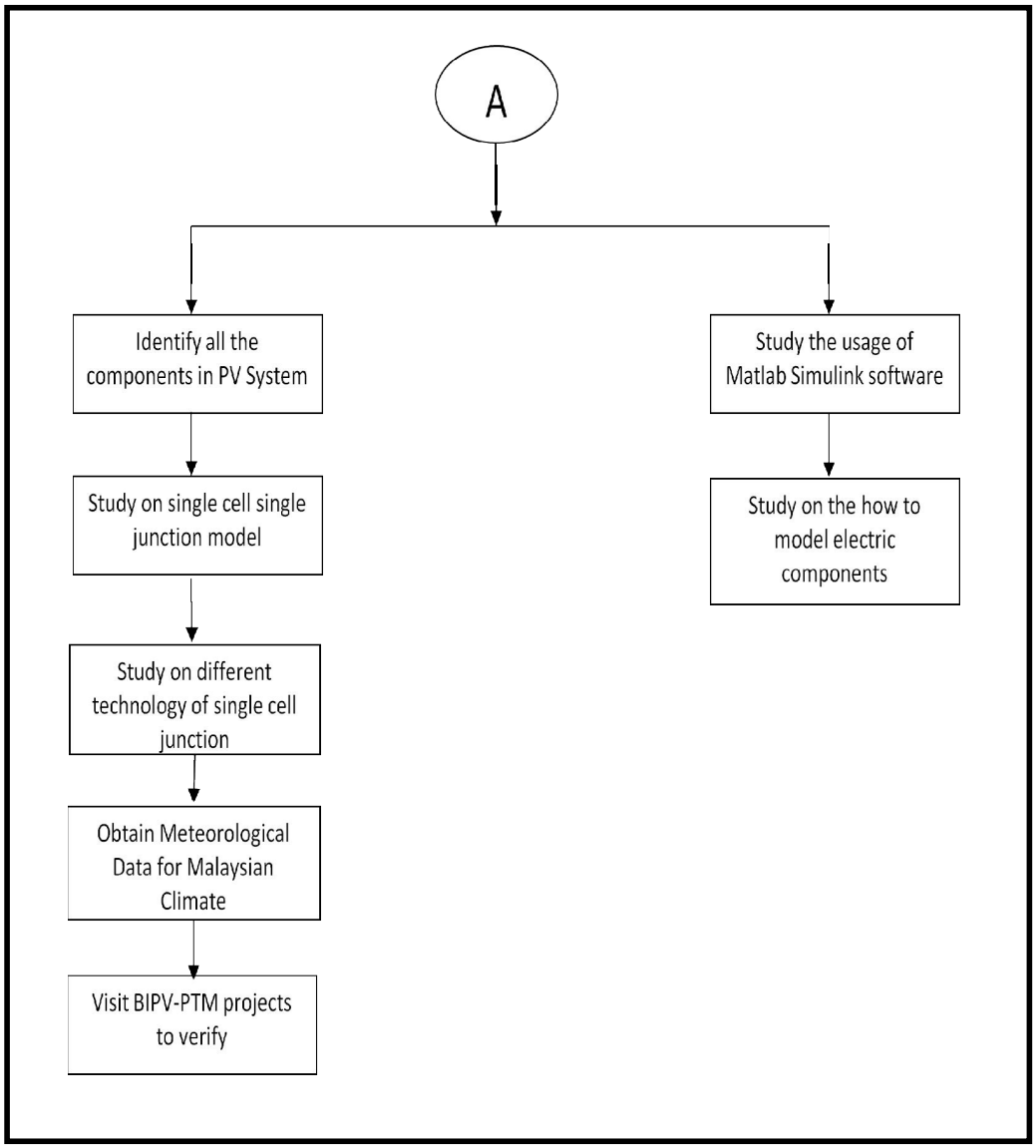

Figure 1.1: Flow Chart for Literature Review

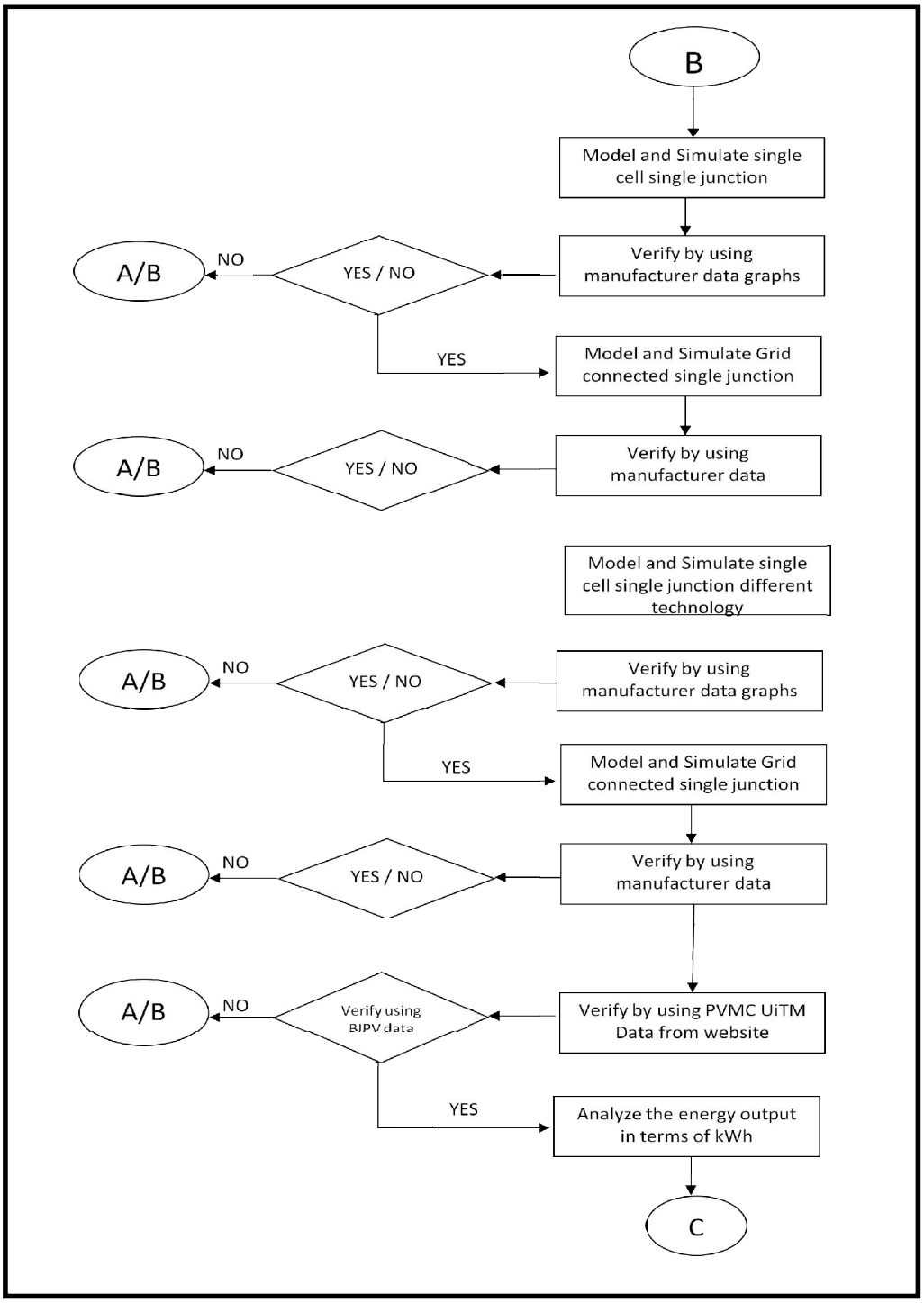

Figure 1.2: Flow Chart on Simulation

1.5 Thesis Outline

This theses will is a compilation of many chapters that will elaborate in stages the research work that have been carried out. As in general this theses mainly consist of five main chapters; introduction, literature review, circuitry buildings and simulation using MATLAB / SIMULINK software, simulation results analysis and conclusion.

In chapter I, this thesis will discuss the research project in collectively. This chapter explained the crucial aspect of the research work such as background studies, objectives, research scopes, and methodology as well the thesis outline will also be discussed finally.

Chapter II completely dedicated to literature review about the grid connected PV system. This chapter will be solely theoretical in detail discussing on the types photovoltaic cell, inverters, and the whole system about it. In this academic scribbling some of the controlling techniques for inverters will be discussed as well. In this section the related works also will be discussed.

Chapter III will be explaining on how the circuit modeling being development using the MATLAB / SIMULINK. The single cell for both amorphous and polycrystalline will be developed first. All the components used in building the models shall be included as well to add value in the academia world.

Chapter IV will be discussion in depth on the obtain simulation results. The result will be analyzed in terms of energy output and also verification using the online monitored data gathered from Malaysian Building Integrated Photovoltaic (MBPIV).

Conclusion and suggestion in improvising this research work shall be detailed out in Chapter V.

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