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LAPORAN PROJEK SARJANA MUDA

PV GRID PARITY ANALYSIS FOR RESIDENTIAL SECTOR IN MALAYSIA

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Bachelor of Electrical Engineering (Industrial Power)

June 2014

“I hereby declare that I have read through this report entitle “*PV Grid Parity Analysis for Residential Sector in Malaysia”* and found that it has comply the partial fulfilment for awarding the degree of *Bachelor of Electrical Engineering (Industrial Power)*”

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Supervisor’s Name	:	………………………………
Date	:	………………………………

PV GRID PARITY ANALYSIS FOR RESIDENTIAL SECTOR IN MALAYSIA

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "*PV Grid Parity Analysis for Residential Sector in Malaysia"* 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.

Signature : ……..……………………………

Name : ….…………………………………

Date : ….…………………………………

To my beloved mother and father

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Below is the published work as a result of my Final Year Project.

[1] C. Y. Lau, C. K. Gan, and P. H. Tan, “PV Grid Parity Analysis for Residential Sector in Malaysia,” in *Power and energy conversion symposium (PECS) 2014*, 2014, pp. 111–117.

ABSTRACT

Solar Photovoltaic (PV) system has been identified as one of the promising renewable resources that could generate ‘green’ electricity for the consumers in Malaysia. The Malaysia Renewable Energy Act 2011 and the Feed-in Tariff (FiT) that have been introduced in 2011 have aimed to facilitate the increasing use of renewable energy in Malaysian energy mix. This is to reduce the dependency on fossil fuels and more importantly, to tackle the climate change challenge. In this regard, achieving grid parity is the main priority for the policy makers. When the cost of PV system generation is equal to or lower than the cost of conventional fossil fuel generation; grid parity is achieved. This project presents the detailed PV grid parity analysis for a 4 kW residential grid-connected PV system based on the calculation of the Levelized Cost of Electricity (LCOE). The research is carried out based on three key parameters that drive grid parity, namely: the PV system price, electricity tariff, and discount rate. The degradation FiT rate of solar PV system also taken into consideration. By using an annual energy yield of 1450 kWh/kWp, 21 years of system lifetime, 7.5% discount rate, 3.0% inflation rate, and 0.90% operation and maintenance (O&M) cost, the LCOE is calculated for a 4 kWp system to be RM 0.9170/kWh in 2014. With this, it may take up to 16 years for Malaysia to achieve PV grid parity. In contrast, with an assumption of 1.0%/year degradation rate of LCOE, results suggest that Malaysia will achieve grid parity in 2026. Various scenarios gave different number of years to reach grid parity in Malaysia. For both 8% and 10% degradation rate of FiT, the incomes after the grid parity is reached will be reduced for about RM 2,010.00 and RM 2,486.73 for year 2026 and 2029 respectively.

ABSTRAK

Sistem solar fotovoltaik (PV) telah dikenal pasti sebagai salah satu sumber yang boleh diperbaharui dapat menjana tenaga elektrik 'hijau' bagi pengguna di Malaysia. Apabila *The Malaysia Renewable Energy Act* dan *Feed-in Tariff* (FiT) telah diperkenalkan pada tahun 2011 dengan memudahkan pertambahan pengguna sumber yang boleh diperbaharui antara campuran tenaga di Malaysia. Tujuan tersebut untuk mengurangkan pergantungan terhadap bahan api fosil dan yang pentingnya dapat menangani masalah perubahan iklim. Dalam hal ini, pencapaian pariti grid adalah keutamaan bagi pembuat dasar. Apabila kos penjanaan PV sama atau kurang daripada tarif elektrik konventional; maka pariti grid tercapai. Projek ini telah menunjukkan analisis pariti grid PV bagi 4 kW kapasiti bagi kediaman perumahan dengan pengiraan kos levelized elektrik (LCOE). Penyelidikan ini dijalankan dengan berdasarkan tiga factor utama bagi mencapai pariti grid iaitu harga sistem PV, tarif elektrik dan kadar faedah. Selain itu, degradasi bagi kadar FiT bagi sistem solar PV juga dipertimbangkan. Dengan menggunakan hasil tenaga tahunan 1450 kWh/kWp, 21 tahun umur sistem, 7.5% kadar diskaun, 3.0% kadar inflasi dan 0.90% kos operasi dan penyelenggaraan (O&M); LCOE dapat dikirakan bagi sistem 4 kWp adalah sebanyak RM 0.9170/kWh pada tahun 2014. Dengan ini, pariti grid dapat dicapai dalam tahun yang ke-16 di Malaysia. Manakala, bagi 1.0% kadar degradasi tahunan LCOE menyebabkan pencapaian pariti grid pada tahun 2026. Senario yang berbeza membawa kesan yang berbeza bagi pencapaian pariti grid. Bagi kedua-dua 8% dan 10% kadar degradasi FiT, pendapatan selepas pariti grid mencapai akan berkurang sebanyak RM 2,010.00 dan RM 2,486.73 bagi tahun 2026 dan 2029 masing-masing.

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AEO	-	Annual energy outlook
BOS	-	Balance of system
CAPEX	-	Capital expenditures
CO_2	-	Carbon dioxide
C-Si	-	Crystalline Silicon
DC	-	Direct current
DLs	-	Distribution Licensees
E	-	Annual electricity production
EIA	-	Energy Information Administration
FIAHs	-	Feed-in Approval Holders
FiT	-	Feed-in Tariff
FKE	-	Faculty Electrical Engineering
HIT	-	Hetero-junction with intrinsic thin layer
JNNSM	-	Jawaharlal Nehru National Solar Mission
KWh	-	Kilo-Watt hour
KWp	-	kilo-watt peak
LCOE	-	Levelized cost of electricity
LMP	-	Locational marginal prices

MYR	-	Malaysian ringgit rates
NDRC	-	National development and reform commission
O&M	-	Operation and maintenance cost
PV	-	Photovoltaic
RE	-	Renewable Energy
RM	-	Ringgit Malaysia
SDE	-	Simulation Renewable Energy
SEDA	-	Sustainable Energy Development Authority
SESB	-	Sabah Electricity Sdn Bhd
SESCO	-	Sarawak Electricity Supply Corp
SMA	-	System advisor Model
SRECs	-	Solar renewable energy credits
ST	-	Suruhanjaya Tenaga
TF	-	Thin film
TNB	-	Tenaga National Berhad
UTeM	-	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 Research Background and Motivation

In these recent years, the use of non-renewable energy sources has brought a negative impact to the environment. Due to the high demand and long dependence of the world's energy consumption on fossil fuels, the non-renewable energy resources are gradually depleting over time. Therefore, solar Photovoltaic (PV) has emerged as an alternative energy resource. However, the PV has often been contemplated to be one of the most costly means for generating electricity, especially when compared with the much cheaper conventional fossil fuel power plant [1]. Therefore, the Malaysian government has encouraged the installation of PV system by introducing the incentives such as Feed-in Tariff (FiT) scheme began as early as 2004, and in 2011 [2]. Driven by the promise of PV installation, PV electricity generation cost is expected to decrease over the years. Hence, the degradation of PV generation price and the annual increment of electricity tariff will help to drive towards what is often called grid parity [3]. Grid parity, in many countries across the world, is referred as the intersection or breakeven point where the price of electricity for the end consumer equals to the PV electricity generation cost.

Many consumers in Malaysia have installed the PV system as an investment tool to take advantages of the FiT scheme. In light of this, the year when Malaysia will reach the solar PV grid parity is their great concern. This is due to the grid parity will bring many revenue on financial segment for investors. Investors should know the effect when grid parity reached either earlier or later to avoid the financial risk such as income losses. However, electricity tariff is expected to be increased in the future year which will fasten the year to reach grid parity. Electricity tariff will meet a breakeven point when the PV system Levelized Cost of Electricity (LCOE) equals to or lower than the electricity tariff.

This project is a case study which presents a detailed analysis of grid parity based on the calculation of LCOE for the residential sector in Malaysia. In addition, the sensitivity of key drivers toward grid parity, i.e., the projection of PV system LCOE compared to the forecasted conventional electricity tariff in Malaysia, is evaluated. As the result, Malaysia is expected to witness a significant growth in the PV market in the years to come.

1.2 Problem statement

In Malaysia, the government has encouraged people to increase the installation of PV systems among the residential and consequently introduced FiT scheme. The combustion of fossil fuels such as natural gas, oil and coal produce the carbon dioxide which can be lead to acid rain and global warming. Therefore, generation of PV system has beneficial to the environment which could be reduce the Green House Gas including carbon dioxide (CO_2) emissions are relatively clear [4]. By installing PV plant system, customers will become like an investor since install the PV system such an investment which could be earn the payback money from the generating power to the grid. Due to these various incentives will made grid-connected solar photovoltaic power systems to be a great financial investments for many consumers.

Payback period becomes a key investment decision indicator among the investors in global. It can affect the generation of PV system, system performance and PV system energy cost. However, all of these parameters have not been analysed in Malaysia since banker and other parties are still not familiar with the beneficial of PV installation. In addition, grid parity is important to be analysed due to economic crisis in a country such as inflation or the rise of the electricity price on grid utility. Other than that, policy in a country and tariff degeneration could also affect the grid parity. Indeed, the generation of photovoltaic systems to reach grid parity was become one of the most popular discussed topics in the world of renewable energy [1]. Thus, it is the most significant to have accurate information of local electricity costs pricing schemes and usage. Therefore, a thorough understanding and make clear on what is the exact coming for the future after grid parity is reached. All the factors should indicate and the financial risk can be avoided after predicted the year of grid parity.

1.3 Objectives

The main objectives of this project are as following:

- To investigate the key parameters that drive grid parity in Malaysia and their respective sensitivity.
- To estimate the breakeven year to reach grid parity in Malaysia under various scenarios.

1.4 Scope

This project covers the historical and projection of electricity tariff and solar PV generation cost in Peninsular Malaysia. The subsidies are included for the electricity prices utility (TNB stated tariff). The estimation of the breakeven point of the year is to achieve project bankability and grid parity in Malaysia.

This project is expected to determine the key parameters that drive grid parity in Malaysia. There are few key drivers which will affect the period of year to reach grid parity such as conventional electricity tariff, inflation rate, discount rate and LCOE. For financial section, the discount rate of the value of cost of PV installation will decreases in a range year by year which can bring a big effect on grid parity. Besides that, technical performances will affect the yield of the power generation of PV system. The performance of solar will strongly influences the period of reaching grid parity in a country. Government policy plays an important role in driving the grid parity in Malaysia. Feed-in tariff (FiT) and incentives are designed to encourage more installation of PV systems of the consumers in Malaysia. By analysing the different increment rate of electricity tariff in Malaysia and PV generation cost (LCOE) in different scenarios and conditions, it will give different ranges of the estimation of the year to reach of grid parity in Malaysia. The comparison of cumulative incomes was carried out by different year of grid parity reached.

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Energy

According to Sustainable Energy Development Authority (SEDA) [5], renewable energy (RE) is defined as any form of primary energy from recurring and non-depleting indigenous resources. In the first column of the Schedule of the RE Act 2011 [5] explained that renewable resources means the recurring and non-eliminate domestic resources or technology. Renewable energy is any energy source that naturally replenished such as sunlight, biomass, wind and hydro. These energy sources are environmentally friendly because it does not causing any pollution to the ecology whereas it can still help to reduce pollution such as carbon dioxide emission by solar energy. Non-renewable energy is simply the other way around, is the energy resource which is non-replenished such as fossil fuel, oil, natural gas and coal. These energy resources are harmful and hazard to the ecology. Recently, solar was chosen for one of the best renewable energy resources since there is a rapid growth demand in the world and cause the depletion of fossil fuel and coal for energy generation. Therefore, it pushes many studies towards the renewable energy especially solar energy.

Sun is a renewable source that can be harvested to generate electricity. The solar energy is an abundant and free resource of energy and it can help to improve the environment since it does not contribute to climate change. Today, the push of renewable energy sources is driven by a renewed concern for the environment. Solar energy is the example of an environmentally friendly energy since it is free from sun. The most wonderful point is the solar energy will not run out until the sun was goes out.

Solar energy has been divided into two categories which are solar photovoltaic and thermal solar. Solar photovoltaic usually referred to as PV. The word photovoltaic comes from “photo”, meaning light, while the “voltaic”, means to generate electricity power. Therefore, solar PV process is generates power electricity directly from sunlight. Solar PV offer customers the ability to produce electricity in a quiet, clean, secure and reliable way. Therefore, PV system is very encouraged by government because there is no release of pollutant, low maintenance, very long lifespan and high reliability to be used in future.

There are four different types of PV Solar systems were installed in the area of Faculty Electrical Engineering (FKE) in Universiti Teknikal Malaysia Melaka (UTeM) which are poly crystalline silicon (C-Si), mono crystalline silicon, thin film and heterojunction with intrinsic thin layer (HIT). The Figure 2.1 shows the various type of PV panel.

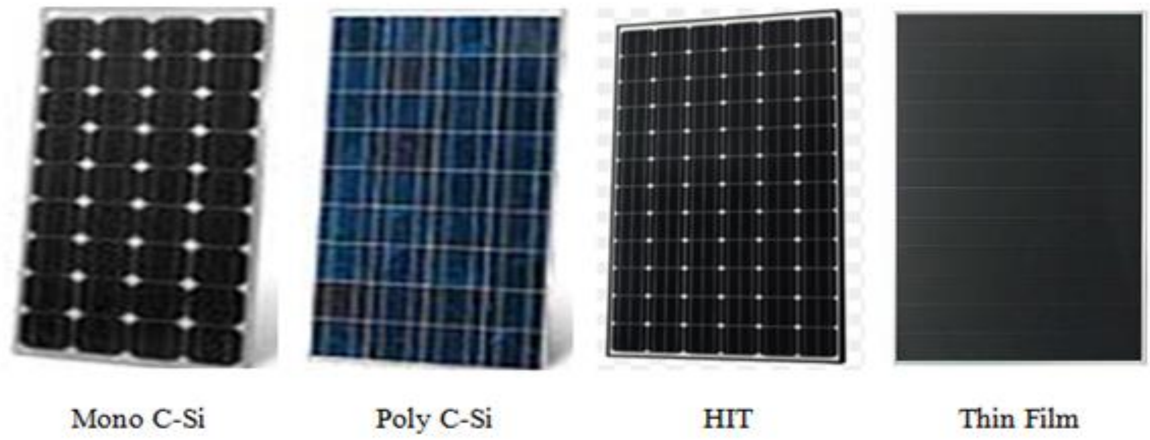

Figure 2.1: Various types of PV panels installed in FKE UTeM.

Malaysia is located at the equatorial region with an average solar radiation of 400-600MJ/m^2 per month [6]. However, due to the expensive of photovoltaic (PV) modules and solar electricity tariff rate which make solar energy is still at the initial stage in Malaysia. Malaysian government is keen to make solar energy as one of the important sources of energy in country to improve the production of power generation and reduce the used for gas and fossil fuel. Therefore, the Feed-in-Tariff (FiT) was designed for renewable energy to enable users to sell excess power to the power grid which could be encouraged more installation of PV panels in the country.

The installation of PV panels is still expensive in Malaysia compared with the electricity offered by utility companies in Malaysia such as, Tenaga Nasional Berhad (TNB) at Peninsular Malaysia, Sabah Electricity Sdn Bhd (SESB) and Sarawak Electricity Supply Corp (SESCO) since the PV modules are expensive of its manufactures cost [6]. This is the main reason why there are still less people install PV panels.

2.2 Feed-in Tariff (FiT)

2.2.1 FiT in Malaysia

The Cabinet had approved a policy in Malaysia on 2nd April 2010 which is improving the application of native renewable energy resources to contribute towards sustainable socio-economic development and national electricity supply security [5]. According to SEDA [7], FiT was introduced in Malaysia as early as 2004 and 2011, the years of effort finally success in the passing of two laws related to sustainable energy. This result is the dawn of a new era for Malaysia in a move toward mitigating climate change and achieving energy autonomy.

Malaysia’s FiT system obliges Distribution Licensees (DLs) to buy from feed-in Approval Holders (FIAHs) the electricity produced from RE and sets the FiT rate. The DLs will pay for RE supplied to the electricity utility for a specific time [8]. The FiT mechanism would ensure that RE becomes a viable and sound long-term investment for consumers by guaranteeing access to the grid and setting a reasonable price per unit of RE in Malaysia.

Advances of RE technology and deployment of RE will increase with FiT performance in Malaysia [9]. This situation helps in encouraging consumers to install the PV system. FiT is a program or tool that allows electricity that is produced from replenishment RE resources to be sold to grid utilities (e.g. TNB) at a fixed reasonable