TECHNO ECONOMIC ANALYSIS OF RESIDENTIAL GRID-CONNECTED PHOTOVOLTAIC SYSTEM

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DEDICATION

This project report is dedicated to myself that being able to go through the part time study even though have a lot of commitment for small family and to entertain the work as full-time private worker. The challenge to complete this research study project is difficult but need to face until success. Things will not come easy if people have determination to go through it and complete until the times come. Slowly but surely end.

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ABSTRACT

The aim of the study is to investigate the optimization design of residential grid connected photovoltaic system based on the result of techno economic in HOMER. Malaysia have experienced the scheme of Net Energy Metering for those who participate in the grid connected photovoltaic system, that capable to reduce monthly electricity bills compared to the grid only system that fully depends on the grid energy. Malaysia scheme for renewable energy is change follow the scheme incentive by the government starting with Fit in tariff scheme until net energy metering scheme. The scheme also has the own requirement and several benefit for market player and end user. The scheme is not promising the same rules and requirement for every offer and quota, it is following the incentive by the government at that moment. Latest news the government launched the net energy metering 3.0 after the successful of net energy metering 2.0. this scheme allows customers to sell back their excess energy to grid but on "one on one" offset basis. The priority of this scheme is self-consumption and then excess energy should be sold back to grid. The main objective of this study is to be able to recommended the optimum configuration design of photovoltaic system for every category of household in Malaysia. Involve in this study the effect of electricity tariff since Malaysia tariff divided into fifth block tariff based on the power consumption of end user. This study location selection is in Taman Molek, Johor Bahru. The location of studies also has the own average scale of solar irradiance that will affect the residential grid connected photovoltaic system in Malaysia. Techno economic analysis in this HOMER can help to give the best result for optimization configuration circuit of photovoltaic system. Four factors of Techno-economic analysis to simulate which first is Net Present cost. NPC is the overall cost from the capital itself, operation and maintenance cost, Cost of energy, replacement cost and the revenue total sum up. the second is cost of energy that can offset between the selling energy and the buying energy. The third is payback period which is the time frame for end user get their early stage investment or capital investment. Last factor is the return of investment that can help end user receive profit from grid connected photovoltaic system. All the result is based on the 25 years Lifecyle.

ABSTRAK

Tujuan kajian ini adalah untuk mengkaji rekabentuk yang paling sesuai bagi sistem photovoltaic bersambung dengan grid berdasarkan keputusan tekno-ekonomik software HOMER. Malaysia telah berpengalaman dengan skim Net Energy Metering untuk yang terlibat dengan sistem photovoltaic bersambung dengan grid, ia mampu menrunkan bill bulanan elektrik berbanding dengan sistem grid sahaja yang bergantung sacara sepeunhnya dengan sistem grid. Skim bagi tenaga boleh diperbaharui adalah berubah mengikut insentif dari kerajaan bermula dengan Fit In Tariff sehingga Net Energy Metering. Skin ini juga mempunyai kehendak and keuntungan kepada pemain industri dan untuk pengguna. Skim ini tidak menajamin peraturan dan kehendak yang sama untuk settiap tawaran dan koata, ia mengikut insentif kerjaan pada waktu itu. Terkini, kerajaan telah melancarakan Net Energy Metering 3.0 selepas kejayaan Net Enrgy Metering 2.0, Skim ini membolehkan pengguna menjual elektrik jika tedapat lebihan tenaga kepada grid tetapi dengan satu kepada satu unit pembayaran. Keutamaan skim ini adalah guna sendiri dan jika terdapat lebihan boleh menjual kepada grid. Objektif utama kajian ini adalah boleh mencadangkan sistem pemasanagan yang paling baik untuk pemasanagn photovoltaic system bagi semua jenis pengguna di Malaysia. Kajian ini juga meibatkan penggunaan tariff yang sesuai berdasarkan pecahan lima blok tariff mengikut kadar penggunaan tenaga. Kajian ini dijalankan di Taman Molek, Johro Bahru. Lokasi kajian juga mepunyai data skala tenaga solar sendiri yang akan memberi kesan kepada kediaman yang mempunya sistem PV bersambung dengan grid. Analisa Tekno-ekonomi di dalam HOMER dapat menbantu memberi kan keputusan bagi rekabentuk litar yang terbaik. Empat factor Analisa tekno-ekonomi yang diambil kira, pertama kos semasa bersih. Kos ini adalah kos kesluruhan yang melibatkan modal, kos operasi dan penyelenggaran, kos penggantian dan keunutngan. Kedua ialah kos Tenaga yang akan memberikan keseimbangan di anatar harga jualan tenaga dana harga pembelin tenaga. Faktor ketiga ialah tempoh bayaran balik iaitu masa bagi pengguna mendapatkan semula modal yang telah dikeluarkan. Terkahir sekali pulangan pelaburan yang menbantu pengguna mendapatkn keuntungan. Keputusan adalah merujuk kepada 25 tahun jangka hayat

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LIST OF ABBREVIATIONS

NEM	-	Net Energy Metering
NPC	-	Net Present Cost
COE		Cost of Energy
ROI	-	Return of Investment
PV	-	Photovoltaic
HOMER	-	Hybrid Optimization of Multiple Energy Resources
DC	-	Direct Current
UTM	-	Universiti Teknologi Malaysia
AC	-	Alternating Current
SEDA	-	Sustainable Energy Development Authority
ST	-	Suruhanjaya Tenaga

LIST OF SYMBOLS

λ	-	Temperature Co efficient
$	-	Dollar
RM	-	Ringgit Malaysia
%	-	Percentage
β	-	Optimal tilt angle(deg)
Φ	-	Latitude of the site(deg)

CHAPTER 1

INTRODUCTION

1.1 Overview

Worldwide trend shows an increasing number of photovoltaic (PV) installations due to the potential depletion of non-renewable energy resources and the huge gas emission from non-renewable energy resources that can cause global warming. Malaysia benefits largely from solar energy due to its strategic location that receives abundant sunshine. Monthly average sunshine hours in Malaysia range about 4 hours to 8 hours and can be considered consistent throughout the year. Since 1998, Malaysian government started to educate Malaysian citizen about the renewable energy sector, with the first grid connected PV system project installed in January 1998[1]. The growth of grid connected PV installation can been seen after the program created by the Malaysian government to encourage the renewable energy in Malaysia. Fit in tariff is the first initiative by the government that give more profit to Malaysian that registered under this program. Up to 2020 Malaysia introduce the Net Energy Metering with one-on-one basis system.

Previous work on the residential grid connected PV system in Malaysia had been carried out by many researcher [1-20]. Among the issue studied areas the effect of Net Energy Metering Scheme or Fit in Tariff towards the residential grid connected PV system [3-5]. Another issue studied are the component cost and the selectivity of PV system will give effect to the residential grid connected PV system [8-10]

However, what the best configuration design or the optimize design that suitable for residential grid connected PV system to use in order to saving their cost are not widely discussed. The configuration design of residential grid connected photovoltaic system

for 1-unit house need to identify to meet the rules and regulation of renewable scheme in Malaysia.

1.2 Problem Statement

Photovoltaic (PV) is one of the current technology developments by the global trend to encourage green technology industry. Nowadays, Malaysia starts to develop large scale solar PV projects involving government and private agency to fulfil the load demand in Malaysia as one of the alternatives to reduce harmful gas emissions. However, the number of residential grid-connected PV installations in Malaysia is minimal compared to the worldwide residential PV system installation trend. The low PV application rates from the residential renewable energy programme shows the lack of awareness among residential grid-connected PV systems. This paper will analyse the techno economic feasibility of net energy metering (NEM) for grid-connected PV systems at residential area through several configuration of PV installations. The result will determine the effectiveness of residential grid-connected PV installations from technical and economic aspects

1.3 Research Objective

The objectives of the study are:

1. To formulate several configurations and topologies of grid-connected photovoltaic systems at residential area

2. To determine the optimal system that can be used in residential area as residential grid-connected photovoltaic systems in terms of economic and technical evaluations of PV systems

3. To analyse the feasibility of installation of residential grid-connected photovoltaic systems in residential area based on the

1.4 Scope of Project

The scope of project for this paper is:

1. Design several configurations and topologies of residential grid connected PV system by using HOMER
2. Find the optimal design system of Residential Grid-Connected PV system using HOMERS in term of economical evaluation and technical specifications of photovoltaic system for residential installations

3. The results will determine the effectiveness of residential grid –connected PV installation based on the net energy metering (NEM) scheme.

1.5 Expected Contribution

The work is expected to give the following contributions:

1. Data characteristic of power consumption of a residential in Malaysia.

2. Data of PV installation based on Net Energy Metering requirement of grid connected photovoltaic system installation. Inverter size ≤ 4kWac for single phase and ≤10kWac for three phase residential type. While for photovoltaic size is ≤72 kWp for photovoltaic.

3. Improve understanding of effect of various configuration or combination PV Installation (PV Array capacity and Inverter size) towards the Net Present Cost and Net Energy metering tariff.

north Malaysia, west Malaysia and East Malaysia. This is because the solar irradiance is varying for specific location in Malaysia. This study is fully simulation base and in future the practical studies can be extend to received actual data from site. This studies also can be extended for Commercial and Industrial sector because the Net Energy Metering requirement of the photovoltaic installation in this sector is higher compare to domestic sector. The photovoltaic panel capacity installation can be more than 72kWp for commercial and industrial grid connected photovoltaic system. The topic research has potential for renewable energy sector in Malaysia. The Future recommendation studies will benefit every unit of residential and commercial building to create the green environment for Malaysia

REFERENCE

1. Solar PV installation: Getting started. Solar panel Malaysia

2. Net Energy Metering SEDA Malaysia,http://www.seda.gov.my/reportal/nem/

3. TNB tariff - https://www.tnb.com.my/residential/pricing-tariffs

4. Li Z., Ma T. Peer-to-peer electricity trading in grid-connected residential communities with household distributed photovoltaic 2020, Applied Energy Article

5. Rodney H.G. Tan, T.L. Chow. A Comparative Study of Feed in Tariff and Net Metering, 2016, UCSI University North Wing Campus with 100 kW Solar Photovoltaic System.

6. Tie C.H., Gan C.K. Impact of grid-connected residential PV systems on the Malaysia low voltage distribution network, 2013.

7. Lau K.Y., Muhamad N.A., Arief Y.Z., Tan C.W., Yatim A.H.M. Grid-connected photovoltaic systems for Malaysian residential sector: Effects of component costs, feed-in tariffs, and carbon taxes 2016

8. Abd Wahid S.S., Nawawi Z., Jambak M.I., Sidik M.A.B., Arief Y.Z., Mustafa M.W. 2015., Adzis Z. Potential of residential grid-connected photovoltaic system as the future energy source in Malaysia

9. Yatim Y., Yahya M.W., Tajuddin M.F.N., Ismail B., Sulaiman S.I. 2018, Tecno-economic analysis of PV module selection for residential BIPV with net metering implementation in Malaysia.

10. Mohd Nordin A.H., Sulaiman S.I., Shaari S., Mustapa R.F. 2020. Life-cycle assessment of residential-scale grid-connected photovoltaic system in Malaysia based on monocrystalline silicon modules

11. Qusay Hasssan., 2020. Evaluation and optimization of off-grid and on-grid photovoltaic power system for typical household electrification

12. Normaazlina Mat Isa, Himadry Shekhar Das, Chee Wei Tan, A.H.M Yatim. 2016.A techno economic assessment of a combined heat and power photovoltaic / fuel cell/ battery energy system in Malaysia Hospital

13. Rafiza Abdul Rahman, Shahril Irwan Sulaiman, Ahmad Maliki Omar. 2011Performance analysis of 45.36kWp Grid connected Photovoltaic system at Malaysia Green Technology Cooperation.

14. Shing Chyi Chua, Tick Hui Oh Renewbale and sustainable energy review. 2011

15. Natalia Gava Gastaldo, Graciela Rediske What si the profile of investor in household solar Photovoltaic energy system 2019.

16. Sam KhiihiKamali, Sallehuddin Yusof, Jeyraj Selvaraj 2010. Impact of Grid connected PV system on the Steady state operation of Malaysia.

17. M.Z Hussin, N.Hasliza, A.Yaacob, M.Zain 2012.A development and challenge of Grid-Connected Photovoltaic system in Malaysia .

18. Chin Ho Tie, Chim Kim Gan. 2012. Impact of Grid connected residential PV system on the Malaysia Low Voltage Distribution Network.

19. HOMER- Hybrid Optimazation of Multiple Energy Sources. https://www.homerenergy.com/products/pro/index.html

20. Fit Handbook from KeTTHA Kementerian Tenaga dan sumber asli https://www.ketsa.gov.my/ms-my/Pages/default.aspx

21. Farahdilah Ghazali, Abdul Haseeb Ansan , 2018: The Renewable Energy Act 2011 : A Study On Renewable Energy Development in Malaysia.

22. Syed A.Malik, Abdul Rahman Ayop, Solar energy technology 2014: knowledge, awareness, and acceptance of B40 household in one district of Malaysia toward government initiatives.

23. H.O. Tijani, C.H Tan, N Bashir, 2014, Techno-econimic analysis of hybrid photovoltaic /diesel / battery off-grid system in Nother Nigeria.

24. Solar Resources Map of Malaysia , https://solargis.com/maps-and-gis-data/download/malaysia. Accessed 13th April 2020

25. H.Z.Lang, J Baeyens, J. Degreve, G.Caceres, .2013Concentrate Solar Power Plant : Review and design methodology.

26. Laith M Halabi, James Hazelton, 2017 Performance analysis of Hybrid PV/diesel / battery system using HOMER: A case study Sabah, Malaysia.

27. Himadry Shekhar Das, Chee Wei Tan, A.H.M Yatim, Kwan Yiew Lau Feasibility analysis of Hybrid photovoltaic / battery / fuel cell energy system for an indigenous residence in East Malaysia

28. Solar PV cell module, Array, https://www.samlexsolar.com/learning-center/solar-cell-module-array.aspx

29. PV Array https://openei.org/wiki/Definition:PV_array#:~:text=An%20interconnected%20system%20of%20PV,consist%20of%20a%20single%20module. Access 2012.

30. Inverter. leonics.com/support/article2_12j/articles2_12j_en.php