UNIVERSITI PUTRA MALAYSIA

SIZING OF BIOMASS AND SOLAR PHOTOVOLTAIC HYBRID RENEWABLE ENERGY SYSTEM FOR TROPICAL CLIMATE

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SIZING OF BIOMASS AND SOLAR PHOTOVOLTAIC HYBRID RENEWABLE ENERGY SYSTEM FOR TROPICAL CLIMATE

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

April 2016

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

SIZING OF BIOMASS AND SOLAR PHOTOVOLTAIC HYBRID RENEWABLE ENERGY SYSTEM FOR TROPICAL CLIMATE

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Chairman : Mohd Amran Mohd Radzi, PhD
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Nowadays, the electricity utility provider has started to consider a green power generation due to rapid depletion of fossil fuel reserves as well as world climate change. Among potential green and renewable resources are solar, wind and biomass which are environmental friendly, less cost and sustainable energy alternatives. However, all these resources are not available all the time throughout the year which lead to wide research works on Hybrid Renewable Energy System (HRES) by combining multiple energy resources. In addition, energy generated from the HRES is proven to have better quality and more reliable to end users rather than a system with only a single resource. Malaysia is located in tropical region which receives solar energy from sunlight consistently throughout the year. Besides that, Malaysia is also rich with biomass resources. The prospect of biomass energy resource especially from the oil palm industry is bright as it has become major sustainable energy in Malaysia.

The previous renewable energy system (RES) shows significant disadvantages such as reliability of supply, difficult to generate energy in large quantity, increasing cost of the diesel oil for diesel generator and CO2 emission. When the system combines a few resources, the energy generated will be flexible based on availability of the resources. Combining solar and biomass will be a unique work as firstly explored. However, without the dispatch strategy, the total cost of the system is much higher. Besides that, CO2 emission, total net present cost (TNPC) and cost of energy (COE) can be reduced by the HRES as compared to the RES.

Therefore, this research works is aimed to develop the best configuration of HRES mainly combining biomass and solar as renewable energy resources, in terms of sizing and strategy of operational aspect, with minimum amount of excess energy and CO2 emission.

The pilot area, where the system was planned to be considered for the optimization work is the Halal Products Research Institute (IPPH), located in Universiti Putra Malaysia. The IPPH's building is operating with a lot of research high-end equipment which consumes a very high power. The research started with development of HRES by considering sizing and strategy of operational aspect with biomass and solar resources either as standalone or grid-connected systems. The proposed HRES was evaluated by considering TNPC, COE, CO2 emissions and excess energy.

The evaluation of the energy potential from solar and biomass resources in Malaysia is presented. The best configuration of hybrid renewable energy system in terms of sizing and operational strategy by combining solar and biomass resources for stand-alone and grid-connected, have been modeled. The results presented for both HRESs are based on adjustment to capacity (or size) and price of components. The HRES with possible dispatch strategy has been determined to produce energy to meet the load demand. The performance of the stand-alone and grid-connected HRES has also been compared in terms of TNPC and COE. The HOMER is found to be widely used. Many researchers highlighted the usefulness of the HOMER as compared to other tools. The analysis can easily be done to evaluate the feasible and optimal configuration of the system. From the review, HOMER is chosen to be used to perform simulation and analysis in this research.

Finally, it shows that the stand-alone configuration of HRES with load following dispatch strategy shows the lowest of producing CO2 emissions and excess energy.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Iazah Master Sains

SAIZ BIOMAS DAN FOTOVOLTAN SOLAR SISTEM TENAGA BOLEH DIPERBAHARU HIBRID UNTUK IKLIM TROPIKA

Oleh

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Pada masa kini, pembekal utiliti elektrik telah mula mempertimbangkan penjanaan tenaga hijau kerana pengurangan pesat rizab bahan api fosil dan perubahan iklim dunia. Antara potensi sumber hijau dan boleh diperbaharui adalah solar, angin dan biomass; mereka adalah mesra alam, kos yang kurang dan alternatif tenaga yang mapan. Walau bagaimanapun, semua sumber-sumber ini tidak boleh didapati sepanjang masa sepanjang tahun yang membawa kepada kerja-kerja penyelidikan luas pada sistem tenaga boleh diperbaharui hybrid (HRES) dengan menggabungkan pelbagai sumber tenaga. Di samping itu, tenaga yang dijana daripada HRES terbukti mempunyai kualiti yang lebih baik dan lebih dipercayai berbanding sistem tenaga dari satu sumber sahaja. Malaysia yang terletak di rantau tropika menerima tenaga solar daripada cahaya matahari secara konsisten sepanjang tahun. Selain itu, Malaysia juga kaya dengan sumber biomas. Prospek sumber tenaga biomas terutamanya daripada industri kelapa sawit adalah cerah kerana ia boleh menjanjikan bekalan tenaga yang lebih lestari dan utama di Malaysia.

Sistem tenaga boleh diperbaharui (RES) menunjukkan kelemahan ketara seperti kebolehpercayaan bekalan, sukar untuk menjana tenaga dalam kuantiti yang banyak, meningkatkan kos minyak diesel untuk generator diesel dan pelepasan CO2. Apabila sistem menggabungkan beberapa sumber, tenaga yang dihasilkan akan menjadi fleksibel berdasarkan ketersediaan sumber. Menggabungkan biomas dan solar dan akan menjadi kerja yang unik kerana pertama diterokai. Tanpa strategi penghantaran, jumlah kos sistem adalah lebih tinggi. Selain itu, pelepasan CO2, jumlah kos terkini bersih (TNPC) dan kos tenaga (COE) boleh dikurangkan dengan pembangunan HRES berbanding dengan RES.

Oleh itu, kajian ini diadakan bertujuan untuk membangunkan konfigurasi terbaik bagi HRES terutamanya menggabungkan biomas dan solar sebagai

sumber tenaga boleh diperbaharui, dari segi aspek saiz dan strategi operasi, dengan jumlah tenaga yang berlebihan dan pelepasan CO2 dipastikan pada tahap yang minimum.

Kawasan terpilih di mana sistem itu telah dirancang untuk dipertimbangkan bagi kerja penyelidikan ini adalah Institut Penyelidikan Produk Halal (IPPH), bertempat di Universiti Putra Malaysia. Bangunan IPPH ini beroperasi dengan banyak peralatan penyelidikan berteknologi menggunakan kuasa yang sangat tinggi. Kajian ini bermula dengan pembangunan HRES dengan mempertimbangkan saiz dan strategi operasi dengan gabungan sumber biomas dan solar untuk sistem yang berdiri sendiri atau yang bersambung dengan grid. HRES yang dibangunkan dinilai dari segi aspek TNPC, COE, tahap pelepasan CO2 dan jumlah tenaga yang berlebihan.

Penilaian potensi tenaga daripada sumber solar dan biomas di Malaysia juga dibentangkan. Konfigurasi terbaik daripada sistem tenaga boleh diperbaharui hibrid (HRES) dari segi saiz dan strategi operasi dengan menggabungkan sumber solar dan biomas bagi sistem berdiri sendiri dan yang bersambung dengan grid telah dimodelkan. Keputusan yang dibentangkan untuk kedua-dua HRES adalah berdasarkan kepada pelarasan kepada kapasiti atau saiz dan harga komponen. Strategi operasi HRES juga telah ditentukan untuk menghasilkan tenaga untuk memenuhi permintaan beban. Prestasi sistem HRES berdiri sendiri dan yang bersambung dengan grid yang berkaitan juga telah dibandingkan dari segi aspek TNPC dan COE.

Akhir sekali, ianya menunjukkan bahawa konfigurasi sistem berdiri sendiri HRES dengan strategi penghantaran mengikut beban telah menunjukkan pengeluaran CO2 dan tenaga yang berlebihan pada tahap terendah.

ACKNOWLEDGEMENTS

It would not have been possible to write this thesis without the help and support of some people around me. First and foremost, my greatest gratitude goes to my supervisor, Associate Professor Dr. Mohd Amran Mohd Radzi who has supported me throughout my hard time doing the research and writing my thesis part time, with his patience and knowledge. He is very helpful and punctual person that I ever met.

Moreover, I would like to thank the other members of supervisory committee, Associate Prof. Dr. Hashim Hizam and Dr. Noor Izzri Abdul Wahab for their advice, comments and guidance.

My greatest gratitude also goes to my father, my mother and my siblings, my lovely wife and my little princess, for your endless support and encouragement towards myself and career development. Last but not least, to all my department academicians for inspiring me to pursue my dreams.

I certify that a Thesis Examination Committee has met on 08 April 2016 to conduct the final examination of Mohd Izhwan bin Muhamad on his thesis entitled "Sizing of Biomass and Solar Photovoltaic Hybrid Renewable Energy System for Tropical Climate" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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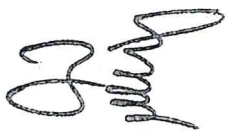

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I hereby confirm that:

- this thesis is my original work;
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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
PV	Photovoltaic
FiT	Feed-in –Tariff Scheme in Malaysia
TNB	Tenaga Nasional Berhad
CO2	Carbon Dioxide
HRES	Hybrid Renewable Energy System
HOMER	Hybrid Optimization Model for Electric Renewables
COE	Cost of Energy
NASA	National Aeronautics and Space Administration
UPM	Universiti Putra Malaysia
IPPH	Halal Product Research Institute
MPOB	Malaysia Palm Oil Board
US	United States
SEDA	Sustainable Energy Development Authority Malaysia
kWh	kilo watt hour
ICT	Information and Communication Technology
TNPC	Total Net Present Cost
SAHPPA	Stand-alone hybrid system power pinch analysis
IPF	Iterative-Pareto-Fuzzy
TED	Total energy deficit
LF	Load Following
CC	Cycle Charging

SAC	State of charge
MSW	municipal solid waste
RM	Ringgit Malaysia
EFB	empty fruit bunches
POME	Palm Oil Mill Effluent
NREL	National Renewable Energy Laboratory
iHOGA	Improved Hybrid Optimization by Genetic Algorithm
LAPSAH	Laboratory of Halal Science Research
LHV	low heating value
MF	mesocarp fiber
FFB	fresh fruit bunch
MC	moisture content
kJ/kg	kilojoule per kilogram

CHAPTER 1

INTRODUCTION

1.1 Background

There is an increasing development of various renewable energy systems due to rapid depletion of fossil fuel reserves as well as climate changes recently. In Malaysia specifically, the renewable energy is a significant agenda focused by the government through Green Technology Policy (Ministry of Energy, Green Technology and Water, 2009). As the world oil prices and the cost of developing the transmission lines increased dramatically with existence of various programs to reduce carbon dioxide emissions, renewable energy has become the most important alternative for the supply of power. The cost of energy produced from a renewable energy source is slightly high but when several renewable energy sources are combined, cost of energy generated is less than the conventional sources. The system which consists of a number of renewable energy sources is known as a Hybrid Renewable Energy System (HRES). Hybrid renewable energy systems have tremendous potential in generating more quality and reliable energy than a system based on a single source. Hybrid renewable energy system can be operated either stand-alone or grid-connected.

A stand-alone system needs to have sufficient storage capacity to handle power variations from the renewable energy sources involved. This type of system can also be considered as a micro-grid since it has its own generation sources and loads. In a grid-connected system, the alternative energy generated can supply the power to the local loads either to sell to the utility grid. The capacity of the storage for this system can be smaller if it is grid-connected since the grid can be used as a backup system (Balamurugan, et.al., 2009).

In this work, the hybrid renewable energy system consisting of biomass and solar energy sources is proposed. The main contributor of the system is biomass generator, whereas solar panels and diesel generators are the supported additional sources. These hybrid systems can provide electricity at a comparatively economic price and sell it to the grid. In order to obtain electricity from a hybrid system reliably and economically, its design must be optimal in terms of sizing and operation (Azah et.al., 2012).

Malaysia is a country blessed with a lot of biomass resources. This country has many types of trees and agriculture commodities, and all of them have widely been used as significant resources for biomass generator to generate an energy. Among them, palm oil is one of the largest agriculture commodities in Malaysia. The by-product from palm oil waste can be used for converting into biomass energy. The prospect of oil palm related biomass energy resource is bright as it has become major sustainable energy in Malaysia and worldwide market. In the development of renewable energy in Malaysia, biomass has

been among one of the most important and widely used. The National Biofuel Policy was launched in 2006 to promote the use of biomass energy sources that are environmentally friendly. Under the Five Fuel Policy, the Government of Malaysian has identified biomass as one of the highly potential renewable energy sources. In Malaysia, at least 168 million tons of biomass were produced in a year. The sources of biomass can be from oil palm waste, wood waste, sugar cane waste and municipal waste. Malaysia is the largest producer of agricultural commodities in the region. Malaysia is also among ASEAN countries that promote use of biomass as a renewable energy source (Bioenergy consult, 2013).

Meanwhile, solar energy from sunlight is very useful and it is a very sustainable energy. Malaysia is the country that gets solar energy from sunlight consistently throughout the year. Therefore, more reliable power can be generated from the solar energy based system. The solar panel with the various sizes, which is also known as solar photovoltaic (PV) panel, captures the solar energy using solar cells. The solar cells exposed to the solar energy will convert the sunlight to the electrical energy which can be used by the local loads. The solar PV panel can be used for a very long time such as 20-25 years with less maintenance and it also can still generate electrical energy during cloudy weather. Therefore, potential electrical energy can be generated with a great growth of PV system, can be seen clearly either as big and small PV plants or as building integrated PV system.

Feed-in-Tariff (FIT) program was introduced in Malaysia in 2011. The program is to promote renewable energy to consumers and its benefits by consumers using renewable energy systems. With the FIT program, the user can re-sell the additional electricity generated to the electricity provider, which is Tenaga Nasional Berhad (TNB).

In design of renewable energy system, optimized models need to be developed for the optimal operation of the system. The number of selected components, weather data, availability of energy resources, cost analysis and the best solutions of sizing must be considered for the optimal system. The best optimal system solution is also considered according to the lowest cost especially energy per kWh.

1.2 Problem Statement

The Renewable Energy Systems (RES) developed by the other researchers before shows the significant disadvantages such as reliability of supply, difficult to generate energy in large quantity, increasing cost of the diesel oil for diesel generator and CO2 emission. A strong motivation for development of HRES is to tackle down all disadvantages in RES. When the system combines a few resources, the energy generated will be flexible based on availability of the resources. Combining solar and biomass will be a unique work as firstly explored. However, proper selection of energy resources processed by HRES is another task which can be done by a dispatch strategy. Without the dispatch strategy, the total cost of the system is much higher. Thus, developing a HRES

with suitable dispatch strategy is another problem that should be solved. Besides that, the CO2 emission can be reduced by the HRES as compared to the RES. However, there are different levels of CO2 emission for HRES such as emissions from biomass generator, battery and also from grid if the HRES is a grid-connected system. Thus, managing CO2 emission to low level is one of the challenges. Finally, another challenge is to reduce cost when developing a HRES in terms of operation and maintenance cost, logistic cost and price of equipment involved which need to be minimized as much as possible.

1.3 Aim and Objectives

The main aim of this research is to obtain the best design of hybrid renewable energy system with solar and biomass resources.

The detailed objectives of this research are:

1) To evaluate the energy generation potential from biomass and solar PV resources in Malaysia.
2) To determine the best configuration of biomass and solar PV HRES in terms of sizing and operational dispatch strategies of load following (LF) and cycle charging (CC).
3) To compare performance of the biomass and solar PV HRES configurations in stand-alone and grid-connected operations in terms of total net present cost (TNPC), cost of energy (COE), excess electricity and pollutant emission.

1.4 Scope of Research

The research scope taken in this work starts with an overview of development done for HRES in recent years. Furthermore, many research articles about HRES using renewable sources are reviewed. Then, the preliminary study of energy generated from renewable energy resources in Malaysia is explained before the selection of combination of solar and biomass resources is made.

The development of the system started with load data profiling for the identified pilot building. After that, selection of components and a suitable dispatch strategy for the system was made. The simulation for the proposed HRES was done by using the Hybrid Optimization Model for Electric Renewables (HOMER) software tool. The simulation work is based on 2 operational approaches, which are stand-alone and grid-connected. From the output of simulation, the results are compared and analysis is conducted on techno-economic aspects. These techno-economic aspects are assessed with a suitable dispatch strategy used by the system, development cost, CO2 emission level and the system excess energy. Finally, the proposed HRES is expected to produce enough energy to meet load demand with minimum excess energy, low cost of energy (COE) and low effect of the greenhouse gas emissions from the system.

There are some limitations on this research work. It has only covered the weather data for Malaysia taken from The National Aeronautics and Space Administration (NASA) Atmospheric Science Data Center. In more specific, the data is for Latitude 2° 59'N and Longitude 101° 42'E, which represents UPM Serdang, Selangor where of the Halal Products Research Institute (IPPH) is selected as the pilot area. For solar PV development, data captured by Sustainable Energy Development Authority Malaysia (SEDA) Statistics and Monitoring website for year 2013 to 2015 has been used to study how much renewable energy generation from the solar PV in Malaysia. For biomass resource data, only palm oil production data maintained by Economic and Industry Development Division, Malaysia Palm Oil Board (MPOB) is covered. The data covered is from years 2013 - 2014 available at the website http://bepi.mpob.gov.my/. In term of techno-economics aspect, all analyses conducted are in US Dollar currency because HOMER is also using the similar currency for the simulation purposes.

1.5 Thesis Layout

In this thesis, the studies with objectives related to the research work are discussed in five chapters as follows:

Chapter one describes the background of research conducted, explanation of the problem statement, identifying the aims and objectives of research, followed by the scope of research works and organization of this thesis.

Chapter two describes literature review of the research conducted. The relevant published articles are reviewed comprehensively and critically. The main topic reviewed is development of HRES in Malaysia and also worldwide. Other than that, there are also some reviews on renewable energy resources especially solar and biomass to be covered. Design, sizing and optimization of HRES and dispatch strategy are also reviewed. Finally, review on economy analysis for HRES development is also presented.

In chapter three, the methodology of the research work conducted are provided. The tool used for simulation of the developed HRES is also described. The amount of load selected and used for the pilot plant is also surveyed and calculated in this chapter.

Chapter four covers the results and discussion of all the research findings. The potential study of energy generated from solar and biomass available in Malaysia is presented. Then, the results of simulation and analysis of stand-alone and grid-connected HRESs are explained separately. Furthermore, a brief discussion on the best design of the developed HRES is also provided in this chapter.

Chapter five, which is the final chapter, consists of research conclusion. The whole of research works is summarized and all findings for each listed objective are also explained. Some recommendations for future works related to this research work are suggested.

REFERENCES

Green Technology Policy (2009). Ministry of Energy, Green Technology and Water: Malaysia.

P.Balamurugan, S. Ashok and T. L Jose (2009). Optimal Operation of Biomass/Wind/PV Hybrid Energy System for Rural Areas. *International Journal of Green Energy*, vol. 6 (1): 104-116.

Azah Mohamad and Thamer Khatib (2012). *Proceedings from 2012 IEEE PES Transmission and Distribution Conference and Exposition (T&D)*. Design of Hybid PV/Diesel Generator Systems at Minimum Cost: Case study for Kuching, Malaysia. Orlando, Florida, USA.

Lazarov VD, Notton G, Zarkov Z, Bochev I. (2005). *Proceedings from ELMA 2005, Eleventh International Conference on Electrical Machines, Drives and Power Systems*. Hybrid Power Systems with Renewable Energy Sources Types, Structures, Trends for Research and Development. Sofia, Bulgaria.

Sumathi S, Chai SP, Mohamed AR. (2005). Utilization of oil palm as a source of renewable energy in Malaysia. *Renewable and Sustainable Energy Reviews,* vol. 12(9): 2404-2421.

Kaldellis, J.K., Kondili, E. & Filios, A. (2006). Sizing a Hybrid Wind-Diesel Stand-Alone System on the Basis of Minimum Long-Term, Electricity Production Cost. *Applied Energy*, vol. 83: 1384-1403.

Borowy, B. S. & Salameh, Z.M. (1994). Optimum Photovoltaic Array Size for a Hybrid Wind/PV System. *IEEE Transaction on Energy Conversion*, vol.9 (3): 482-488.

Dufo-Lopez, R., Bernal-Augustin, J. L. (2005). Design and Control Strategies of PV-Diesel Systems Using Genetic Algorithm. *Solar Energy*, vol. 79 (1): 33-46.

Celik, A. N. (2003). Techno-Economic Analysis of Autonomous PF-Wind Hybrid Energy Systems Using Different Sizing Methods. *Energy Conversion and Management*, vol. 44: 1951-1968.

Ashok, S. (2007). Optimised Model for Community-Based Hybrid Energy System. *Renewable Energy*, vol.32 (7): 1155-1164.

Zuhairuse Md Darus, Nor Atikah Hashim, Siti Nurhudayah Abdul Manan, Mohd Azhar Abdul Rahman, Khairul Nizam Abdul Maulud and Othman Abdul Karim (2009). The Development of Hybrid Integrated Renewable Energy System (Wind and Solar) for Sustainable Living at Perhentian Island, Malaysia. *European Journal of Social Sciences*, vol.9 (4): 557-563.

Juhari Ab. Razak, Kamaruzzaman Sopian, Yusoff Ali (2007). Optimization of Renewable Energy Hybrid System by Minimizing Excess Capacity. *International Journal of Energy*, Issue 3, vol.1: 77-81.

Kamaruzzaman Sopian, Mohd Yusof Othman, Mohd Azhar Abd. Rahman (2005). Performance of a Photovoltaic Diesel Hybrid System in Malaysia. *ISESCO Science and Technology Vision*, vol. 1: 37-39.

M. O. Abdullah, V. C. Yung, M. Anyi, A. K. Othman, K.B. Ab. Hamid, J. Tarawe (2010). Review and comparison study of hybrid diesel/solar/hydro/fuel cell energy schemes for a rural ICT Telecenter. *Energy*, vol. 35: 639-646.

Nurul Arina bte Abdull Razak, Muhammad Murtadha bin Othman, Ismail Musirin (2010). Proceedings from the *4th International Power Engineering and Optimization Conference (PEOCO).* Optimal Sizing and Operational Strategy of Hybrid Renewable Energy System using HOMER. Shah Alam, Selangor, Malaysia.

Tamer Khatib, A. Mohamed, K. Sopian, M. Mahmoud (2011). Optimal sizing of building integrated hybrid PV/diesel generator system for zero load rejection for Malaysia. *Energy and Buildings*, vol. 43: 3430-3435.

Tamer Khatib, Azah Mohamed, K.Sopian (2012). Optimization of a PV/wind micro-grid for rural housing electrification using a hybrid iterative/genetic algorithm: Case study of Kuala Terengganu, Malaysia. *Energy and Buildings*, vol.47: 321-331.

Tamer Khatib, Azah Mohamed, K.Sopian, M. Mahmoud (2013). Optimal sizing of the energy sources in hybrid PV/diesel systems: A case study for Malaysia. *International Journal of Green Energy*, vol. 10: 41-52.

Ahmed M.A. Haidar, Priscilla N. John, Mohd Shawal (2011). Optimal configuration assessment of renewable energy in Malaysia. *Renewable Energy*, vol.36: 881-888.

M. H. Ashourian, S.M. Cherati, A.A. Mohd Zin, N. Niknam, A.S. Mohktar, M. Anwari (2013). Optimal green energy management for island resorts in Malaysia. *Renewable Energy*, vol. 51: 36-45.

Nahidul Hoque Sanmrat, Norhafizan Bin Ahmad, Imtiaz Ahmad Choudhury, Zahari bin Taha (2014). Modeling, Control, and Simulation of Battery Storage Photovoltaic-Wave Energy Hybrid Renewable Power Generation Systems for Island Electrification in Malaysia. *The Scientific World Journal*, vol. 2014: 1-21.

M. Fadaeenejad, M. A. M. Radzi, M. Z. A. AbKadir, H. Hizam (2014). Assesstment of hybrid renewable power sources for rural electrification in Malaysia. *Renewable and Sustainable Energy Reviews*, vol. 30: 299-305.

Wai Shin Ho, Cheng Seong Khor, Haslenda Hashim, Sandro Macchietto, Jiri Jaromir Klemes (2014). SAHPPA: A novel pinch analysis approach for the design of off-grid hybrid energy systems. *Clean Technology Environmental Policy,* vol. 16: 957-970.

R.N.S.R. Mukhtaruddin, H.A. Rahman, M. Y. Hassan, J.J. Jamian (2015). Optimal hybrid renewable energy design in autonomous system using Iterative-Pareto-Fuzzy technique. *Electrical Power and Energy Systems*, vol. 64: 242-249.

Christopher W. Ajan, S. Shahnawaz Ahmed, Hussein B. Ahmad, Faridah Taha, Abdullah Asuhaimi B. Mohd Zin (2003). On the policy of photovoltaic and diesel generation mix for an off-grid site: East Malaysian perspectives. *Solar Energy*, vol.74: 453-467.

K.Y. Lau, M. F. M. Yousof, S. N. M. Arshad, M. Anwari, A. H. M. Yatim (2010). Performance analysis of hybrid photovoltaic/diesel energy system under Malaysian conditions. *Energy*, vol.35: 3245-3255.

Mei Shan Ngan, Chee Wei Tan (2012). Assessment of economic viability for PV/wind/diesel hybrid energy system in southern Peninsular Malaysia. *Renewable and Sustainable Energy Reviews*, vol. 16: 634-647.

SK. A. Shezan, R. Saidur, K. R. Ullah, A. Hossain, W. T. Chong, S. Julai (2015). Feasibility analysis of a hybrid off-grid wind-DG-battery energy system for the eco-tourism remote areas. *Clean Technology Environmental Policy*, vol. 17: 2417-2430.

Ayong Hiendro, Rudi Kurnianto, Managam Rajagukguk, Yohannes M. Simanjuntak, Junaidi (2013). Techno-economic analysis of photovoltaic/wind/hybrid system for onshore/remote area in Indonesia. *Energy*, vol. 59: 652-657.

Abolfazl Ghasemi, Arash Asrari, Mahdi Zarif, Sherif Abdelwahed (2013). Techno-economic analysis of stand-alone hybrid photovoltaic-diesel-battery systems for rural electrification in eastern part of Iran –a step towards sustainable rural development. *Renewable and Sustainable Energy Reviews*, vol. 28: 456-462.

Kanzumba Kusakana (2014). Techno-economic analysis of off-grid hydrokinetic-based hybrid energy systems for onshore/remote area in South Africa. *Energy*, vol. 68: 947-957.

Abdelhamid Kaabeche, Rachid Ibtiouen (2014). Techno-economic optimization of hybrid photovoltaic/wind/diesel/battery generation in a stand-alone power system. *Solar Energy*, vol.103: 171-182.

Golbarg Rohani, Mutasim Nour (2014). Techno-economic analysis of stand-alone hybrid renewable power system for Ras Musherib in United Arab Emirates. *Energy*, vol.64: 828-841.

Amir Norat, Joshua M. Pearce (2011). Dispatch strategy and model for hybrid photovoltaic and trigeneration power systems. *Applied Energy*, vol.88: 3270-3276.

Juan M. Lujano-Rojas, Claudio Monteiro, RodolfoDufo-Lopez, Jose L. Bernal-Agustin (2012). Optimum load management strategy for wind/diesel/battery hybrid power systems. *Renewable Energy*, vol. 44: 288-295.

Maria Stefania Carmeli, Francesco Castelli-Dezza, Marco Mauri, Gabriele Marchegiani, Daniele Rosati (2012). Control strategies and configurations of hybrid distributed generation systems. *Renewable Energy*, vol. 41: 294-305.

A.Nottrott, J. Kleissl, B. Washom (2013). Energy dispatch schedule optimization and cost benefit analysis for grid-connected, photovoltaic-battery storage systems. *Renewable Energy*, vol. 55: 230-240.

Mekhilef, S., Safari, A., Mustaffa, W. E. S., Saidur, R., Omar, R., & Younis, M. A A. (2012). Solar energy in Malaysia: Current state and prospects. *Renewable and Sustainable Energy Reviews*, vol.*16* (1): 386–396.

Ashnani, M. H. M., Johari, A., Hashim, H., & Hasani, E. (2014). A source of renewable energy in Malaysia, why biodiesel?. *Renewable and Sustainable Energy Reviews*, vol. *35*: 244–257.

Ali R, Daut I, Taib S. (2012). A review on existing and future energy sources for electrical power generation in Malaysia. *Renewable and Sustainable Energy Reviews,* vol.16 (1): 4047-4055.

Bernal-Agustin JL, Dufo-Lopez R. (2009). Simulation and optimization of stand-alone hybrid renewable energy systems. *Renewable and Sustainable Energy Reviews,* vol.13 (1): 2111-2118.

Zhou W, Lou C, Li Z, Lu L, Yan H (2010). Current status of research an optimum sizing of stand-alone hybrid solar-wind power generation systems. *Applied Energy*, vol. 87: 380-389.

Sunanda Sinha, S.S. Chandel (2014). Review of software tools for hybrid renewable energy systems. *Renewable and Sustainable Energy Reviews,* vol*.* 32 (1): 192-205.

Azhari AW, Sopian K, Zaharim A, Ghoul M (2008). A new approach for predicting solar radiation in tropical environment using satellite images-case study of Malaysia. *WSEAS Transactions on Environment and Development,* vol.4 (4): 373- 378.

NASA Surface meteorology and Solar Energy – Location. (2013). Weather and Solar Data. Retrieved from https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip@larc.nasa.gov

Malaysia Palm Oil Board (MPOB) (2013-2015). Palm Oil Production Data for Malaysia. Retrieved from http://bepi.mpob.gov.my/index.php/component/content/category/46.html

Bioenergy consult. (2013, Sept. 3). Biomass Resources in Malaysia, Retrieved from http://www.bioenergyconsult.com/tag/biomass-energy-in-malaysia/

HOMER Website. (2014, December 30). HOMER Software Introduction. Retrieved 30 from www.homerenergy.com

RETScreen Website. (2014, December 30). RETScreen Software Introduction, Retrieved from http://en.openei.org/wiki/RETScreen_Clean_Energy_Project_Analysis_Software

iHOGA Website. (2014, December 30). iHOGA Software Manual, Retrieved from www.unizar.es/rdufo/user%20manual.pdf

iHOGA Website. (2014, December 30). iHOGA Software Introduction. Retrieved from www.unizar.es/rdufo/hoga-eng.htm

SEDA Website. (2015, March 3). Renewable Energy Generation Data. Retrieved from http://seda.gov.my/

Bioenergy consult. (2015, June 9). Biomass Wastes from Palm Oil Mills. Retrieved from http://www.bioenergyconsult.com/tag/biomass-energy-in-malaysia/