MODELING AND SIMULATION OF HYBRID SYSTEM FOR ELECTRICITY GENERATION IN RURAL AREA (MICROTURBINE, BIODIESEL, SOLAR PHOTOVOLTAIC AND BATTERY/MTBDSPB)

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Dedicated

To

My beloved parents, wife, daughter, and son

A tribute

To

My country Iraq & all those who contributed to this project

Finally

To

My sources of inspiration and strength, who have dedicated their years supporting my study that make me feel proud and fortunate, always been great sources of encouragement.

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ABSTRACT

Design and implementation of an efficient yet techno-economic hybrid generator for off-grid electric supply is challenging. The cost-effectiveness and convenience offered by off-grid rural electrification system that integrates various renewable energy sources (RESs) became inevitable for areas where grid connection is neither available nor feasible. A hybrid combination of renewable energy technologies (RETs) is proven to be a suitable alternative over expensive grid extension for remote areas worldwide. This study proposes a hybrid model for electricity generation by assimilating renewable resources such as solar photovoltaic (SPV) and microturbine (MT) together with biodiesel generator (BDG) to fulfill the electricity demand of an off-grid remote village Perkampungan Orang Asli Sungai Jahai, Perak in Malaysia. The suitable renewable energy resources for the proposed hybrid system are identified to determine the daily load profile and cost-effectiveness that can be afforded by the villagers. The model is further simulated using HOMER software to evaluate the optimum performance of the hybrid system where the abovementioned village is taken for case study. The simulated results are analyzed, compared, and understood. The load demand pattern of the village over different months is accurately computed. The sizes of MT, SPV, and BD systems are optimized to achieve the minimized cost of energy (COE) generation. It is demonstrated that the use of decentralized RETs at an off-grid location is indeed the best alternative towards grid extension. Furthermore, HOMER data reveals the sustainability, techno-economic viability, and environmental friendliness of the proposed model based energy solution. The sensitivity analysis by combining MT, SPV, and BD is found to achieve the COE generation of $0.309 kWh which is much more than the present heavily subsidized electricity tariff of rural area in Malaysia (3.3 cent/kWh). Although, the COE obtained from the proposed hybrid system is nearly 10 times higher but it is significantly lower than a diesel generator alone ($0.70/kWh). The admirable features of the results suggest that the proposed hybrid generator may be beneficial for off-grid electricity generation and supply in remote rural regions.

ABSTRAK

Reka bentuk dan pelaksanaan penjana hibrid berkesan lagi tekno-ekonomi untuk bekalan elektrik luar grid adalah mencabar. Keberkesanan kos dan kemudahan yang ditawarkan oleh sistem pembekalan elektrik luar grid luar bandar yang mengintegrasikan pelbagai sumber tenaga yang boleh diperbaharu (RESs) menjadi tidak dapat dielakkan bagi kawasan yang mana sambungan grid adalah tidak tersedia atau tidak dilaksanakan. Gabungan hibrid teknologi tenaga boleh diperbaharu (RETs) terbukti menjadi alternatif yang sesuai kepada pelanjutan grid yang mahal bagi kawasan terpencil di seluruh dunia. Kajian ini mencadangkan satu model hibrid bagi penjanaan elektrik melalui asimilasi sumber boleh diperbaharu seperti fotovolta solar (SPV) dan mikroturbin (MT) bersama-sama dengan penjana biodiesel (BDG) bagi memenuhi permintaan elektrik daripada kampung terpecil luar grid iaitu Perkampungan Orang Asli Sungai Jahai, Perak di Malaysia. Sumber tenaga boleh diperbaharu yang sesuai untuk sistem hibrid yang dicadangkan telah dikenal pasti bagi menentukan profil beban harian dan keberkesanan kos yang dapat diberikan oleh penduduk kampung. Model ini selanjutnya disimulasi menggunakan perisian HOMER untuk menilai prestasi optimum sistem hibrid yang mana kampung dinyatakan di atas diambil untuk kajian kes. Keputusan simulasi dianalisis, dibandingkan, dan difahami. Corak permintaan beban kampung ini ke atas bulan yang berbeza dikira dengan tepat. Saiz sistem MT, SPV, dan BD dioptimumkan bagi mencapai kos yang diminimumkan tenaga (COE) generasi. Ia menunjukkan bahawa penggunaan RETs terpencar pada lokasi luar grid sememangnya adalah alternatif terbaik terhadap pelanjutan grid. Tambahan pula, data HOMER mendedahkan kelestarian, tekno-ekonomi daya maju, dan mesra alam sekitar bagi model yang dicadangkan berasaskan penyelesaian tenaga. Analisis kepekaan dengan menggabungkan MT, SPV, dan BD didapati mencapai penjanaan COE bagi $ 0.309 kWh yang jauh melebihi tarif elektrik yang disubsidi dengan banyak sekarang bagi kawasan luar bandar di Malaysia (3.3 sen/kWj). Walaupun, COE yang diperolehi daripada sistem hibrid yang dicadangkan adalah hampir 10 kali ganda lebih tinggi tetapi ianya adalah jauh lebih rendah berbanding penjana diesel sahaja ($ 0.70/kWj). Ciri-ciri yang mengagumkan daripada hasil kajian mencadangkan bahawa penjana hibrid yang dicadangkan boleh memberi manfaat bagi penjanaan elektrik luar grid dan bekalan di kawasan-kawasan terpencil luar bandar.

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8MP	-	Eighth Malaysian Plan
Bat	-	Battery
BD	-	Biodiesel
BDG	-	Biodiesel Generator
CHP	-	Combine Heat and Power or Cogeneration System
CO2	-	Carbon Dioxide
CNG	-	Compressor natural gas
COE	-	Cost of Energy
DOD	-	Depth of Discharge
EDL	-	Economical Distance Limit
GHG	-	Green House Gases
GoM's	-	Government of Malaysia
HOMER	-	Hybrid Optimization Model for Electric Renewables
HPSs	-	Hybrid Power Systems
HSMBPB	-	Hybrid Microturbine, Biodiesel Generator, Photo-voltaic and Battery System
LCA	-	Life Cycle Assessment
LCC	-	Life Cycle Cost
LCOE	-	Levelized Cost of Energy
MPPT	-	Maximum Power Point Tracker
MT	-	Microturbine
NOx	-	Nitrogen oxide
NPC	-	Net Present Cost
NREL	-	National Renewable Energy Laboratory
O&M	-	Operation and Maintenance

NREPAP	-	National. Renewable Energy Policy and Action Plan (Malaysia)
RAPS	-	Remote Area Power Supply System
RES	-	Renewable Energy Sources
RET	-	Renewable Energy Technology
RM	-	Ringgit Malaysia
PM	-	Particulate Matter
RPM	-	Revolution Per Minute
PV	-	Photovoltaic
PWM	-	Pulse Width Modulation
SO2	-	Sulfur Dioxide
SOD	-	State of Discharge
SOC	-	State of Charge
THD	-	Total Harmonic Distortion

CHAPTER 1

INTRODUCTION

1.1 Introduction

Lately, the demand of renewable energy technologies (RETs) for rural electric power supply is constantly increasing. The large fluctuations and the intermittent nature of RETs make them somewhat costly. Moreover, often long term storage is required due to their seasonal variations. Thus, hybrid systems emerged as suitable substitute by providing cost-effective and reliable electricity supply in remote areas [1].

This chapter develops a rationale of the research topic and attempt to argue why intensive research in the cited dissertation topic is absolutely necessary. The problem statement, objectives, scope of studies and research significance are underscored.

1.2 Background and Motivation

Undeniably, more than billion people living in rural Asia alone are not privileged to be benefited from electricity even though the worldwide electricity generation and transmission has apparently reached to a saturation point. Consequently, the socio-economic developments of these rural communities are always hindered due to unavailability of electric power in those areas. These energy deprived rural communities are always struggling for betterment in life styles. Education is severely suffered and various inconveniences of storing fresh food and medicine have significantly reduced their overall efficiency. Furthermore, the working hours are also slashed due to poor lighting conditions. The economic growth in these remote communities is limited by the accessibility of electricity grid [2].

Advancement in the power production based on RETs has opened up new avenue for providing electricity in remote rural areas. Largely, the remote communities over the globe are not in access of electricity because of the absence of national grid nearby. This is majorly due to the high cost involved in the extension of the transmitting and distributing infrastructure in these remote areas. However, in some developed nations rural inhabitants generate their own electricity via diesel generators. The cost of kWh generated by the diesel generator is considerably higher than the one from the utility grid and remains unaffordable for those remote communities. Simultaneously, the involvement of high cost in extending the national grid over remote areas makes it uneconomical for utility companies to expand it. Currently, RETs compared to that of grid expansion renders cost-effective solution for remote communities in supplying electric power [3].

Interestingly, PV systems can be installed in almost any location due to the availability of sufficient sunlight on almost every part of the earth surface. Conversely, other energy sources and related technologies are highly accessible location dependent. For instance, a mini hydro plant requires a river with sufficient

flow rate and a bio energy plant needs an adequate amount of biomass plantation. Thus, an appropriate energy system in a certain geographical location is chosen by considering the resources availability throughout the year. Fascinatingly, using multiple options of renewable energy resources more reliable electricity can be generated compared to a single renewable energy source. Combination of a conventional energy source together with renewable sources produces cost effective and more reliable energy solution. Assimilations of these complementary energy generation resources based on renewable or mixed energy (renewable energy with a backup bio-fuel/diesel generator) are termed as hybrid system or hybrid generator. Accordingly, the achieved grid is called off grid due to its size when compared to the main grid [1, 4].

The effective operation and implementation of HPSs require careful consideration of several factors including complex cultural background, political issues, economic environment, and energy related concerns. The suitability of installing HPSs at different regions of Malaysia must consider the availability of RESs in those areas. It is acknowledged that Malaysia receives an average of 12 hours solar radiation per day. Therefore, by combining PV with biodiesel and microturbine, the shortage of electricity in the rural areas can be overcome [5].

1.3 Problem Statement

In the rural area of Malaysia the access to electricity seems to be ever-demanding. Meanwhile, the urban communities are yet to achieve reliable electricity services. Truly, people in rural areas are still dreaming for connecting to an electricity supply. In 2009, over one million dwellings in Malaysia are still not electrified those are mostly in rural villages located on large riverbank. Despite country's strong economy, the lack of electricity supply has contributed to social

issues such as poverty, poor health services, deprived education, and gender inequality.

Recently, the environmental concerns are cropped up regarding the greenhouse gas (GHG) emissions from fossil fuel burning in diesel power stations. These are known to be the main power generators in Perak state of Malaysia. People are highly dependent on fossil fuel based electricity production due to its cost effectiveness and simple combustion process. Although, this source is capable of generating huge amount of electricity but the environmental pollution due to emission of carbon dioxide will contribute enormously to global warming and may lead to acid rain. To overcome this problem the use of hybrid electric generator is advocated. It must be admitted that the difficulty of supplying electricity to remote and inaccessible areas are the reason for obvious use of fossil fuel. There are certain areas where the implementation of grid extension involves high cost and technically infeasible. Due to this reason stand-alone hybrid system is an ideal option [6].

Finally, the rural electrification programs in Malaysia are always lacked by insufficient studies, expertise, and experiences. The obstacle among Government agencies to optimize REP implementations in Perak state aggravated the situation. Alternatively, Perak state has potential to build a mixed power development strategy by introducing RE to the existing power generation systems. This work intends to harness the promising RERs such as BDG, SPV, MT, battery and bio-directional inverter in Perak. It will make valuable contribution in understanding the possibility of electricity supply at cheaper rate in Perkampungan Orang Asli Jahai, Perak, Malaysia.

1.4 Research Objectives

The main aim is to propose an optimal off grid techno-economic hybrid system design by combining microturbine-biodiesel generator-solar PV to provide affordable and reliable electricity for a rural community in Perak, Malaysia. To achieve this goal the following objectives are cited:

1. To identify the suitable renewable energy resources for the proposed hybrid system.
2. To characterize the physical properties of biodiesel fuel.
3. To model and simulate of the hybrid system using the HOMER software package.
4. To evaluate the performance of the optimal hybrid system in the context of Perkampungan Orang Asli Jahai, Perak, Malaysia.
5. To determine the daily load profile by selecting component and make cost analysis of the rural community.
6. To compare the proposed hybrid model generated results with the conventional resources.

1.5 Scope of the Study

The scopes of the present research are:

1. Examine different type of renewable energy sources, storage devices and conversion system involved in hybrid energy generation system.
2. Simulate the impact of different renewable energy sources on the climate change.
3. Inspect the fuel local supply to explain how the selected available gas and biodiesel can be fed into the combustion system of an externally fired

microturbine and biodiesel generator. It takes into account the composition of combustion gases in relation to heat exchangers and chimney downstream the combustion.

4. Model the entire design and optimize the off grid hybrid system by combining microturbine-biodiesel and generator-solar PV with battery.
5. Make a techno-economic estimate to identify the feasibility of affordable and reliable electricity to rural people.
6. Simulate the model using HOMER software for further techno-economic analysis.
7. Analyze the simulation results of electricity power generation using different fuels (B100+CNG) and compare them with the results of electricity generation using (B20 + CNG).
8. Optimize the hybrid system in HOMER to check the sensitivity.
9. Evaluate the proposed model performance in terms of cost and benefit.

1.6 Benefit of Renewable Energy

Indeed, the renewable resources not only provide environmental friendly clean electrical energy but also play significant role in ecological benefits. The supply of electricity via hybrid energy technology in the rural areas of developing nations can substitute relatively a small amount of fossil fuel. The future fossil fuel based energy demand seems alarming because this resource is exponentially depleting. Furthermore, the rapid industrializations and subsequent deforestation through over-exploitation of wood and charcoal resources will lead to environmental catastrophe. Thus, the search for alternative route for the electrification of rural areas is inevitable. The renewable energy resources emerged as new stars in the horizon due to its natural compatibility and environmental safety in terms of de-pollution effects and climate protection [7]. To this end, the renewable system distributed generation of electricity has several added advantages as illustrated in figure 1.1.

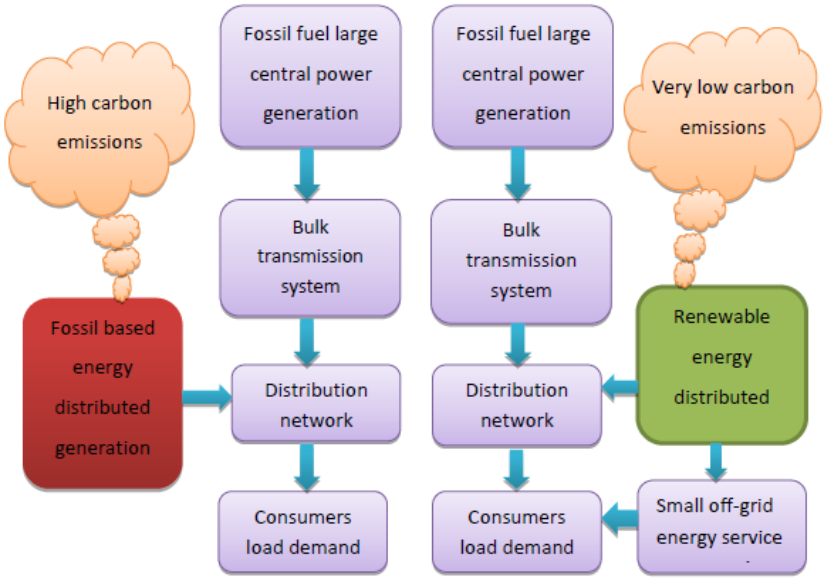

Figure 1.1 Comparison between the present and future electricity supply structure [7]

1.7 Thesis Outline

This thesis deals with the optimal sizing of a hybrid renewable energy system for electrifying a rural community in Perak, Malaysia. The system design, optimization, implementation, and performance evaluation are the recurring theme. The thesis consisting of 5 chapters are organized as follows:

Chapter 1 provides a brief overview on the rationale for this study. It includes the energy situation in the rural areas of Malaysia. Electricity provision, background, objectives of the study, scope of the study, present status of electric supply for the selected village and most importantly the need to renewable energy is justified.

Chapter 2 deals with the review of relevant literatures on renewable energy sources. Various available technologies used for generating electricity and their advantages and disadvantages are emphasized

Chapter 3 describes the detailed methodology that is required to fulfill the proposed objectives. The main components of the designed hybrid system together with the relevant characteristics of the system components such as electrical characteristics, costs, operation, and maintenance issues are highlighted. The site meteorological and load data are also discussed. Finally, the modeling of the hybrid system using HOMER software and subsequent simulation processes are demonstrated.

The results obtained from the HOMER simulations are discussed in Chapter 4. The results of the optimization and sensitivity analysis, the selection of the optimal hybrid configuration and the performance of the selected system for varying conditions of load, solar, palm oil and natural gas resource are explained. The basic design of the hybrid system is illustrated.

Chapter 5 concludes the thesis with the notable contribution and future outlook. Due to time constrains is it not possible to give full justice on the topic. However, this research has bred new problems which are worth solving.

REFERENCES

1. Iromi, U. R. 2013. *Techno-Economic Optimum Sizing of Hybrid Renewable Energy System in Rural Electrification in Srilanka*. Msc Thesis, University of Agder, Srilanka.
2. Prasanthi, C. J. 2009. *Assessment of Technology Requirements for Off-grid Rural Electrification.* Msc Thesis, The University of Nottingham, UK
3. Sopian, K. Zaharim, A. Ali, Y. Nopiah, J. Razak, A. and Muhmmad, S. 2008. *Optimal Operational Strategy for Hybrid Renewable Energy System Using Genetic Algorithms*. WSEAS Transactions on Mathematics. 7(4), 130-140.
4. Bashir, M. and Sadeh, J. 2012. Optimal Sizing of Hybrid Wind/Photovoltaic/Battery Considering the Uncertainty of Wind And Photovoltaic Power Using Monte Carlo. Proceeding of the 2012 *Environment and Electrical Engineering (EEEIC), 2012th International Conference on,* 1081-1086.
5. Abdullah, H. b. S. 2013. *Feasibility Study of PV-Wind and PV-Diesel Hybrid Power System in Malaysia*. Msc Thesis, University Teknologi Malaysia, Malaysia.
6. Yang, H., Zhou, W., Lu, L. and Fang, Z. 2008. Optimal Sizing Method for Stand-Alone Hybrid Solar–Wind System with LPSP Technology by Using Genetic Algorithm. *Solar Energy,* 82(4), 354–367.
7. Mipoung, O. D., Pillay, P. and Lopes, L. 2011. Generator Selection for Rural Electrification from Renewable Energy. Proceeding of the *2011 Electric Machines & Drives Conference (IEMDC), 2011 IEEE International*, 306-311.
8. Paudel, S., Shrestha, J., Neto, F., J., Ferreira, J. A. and Adhikari, M. 2011. Optimization of hybrid PV/wind power system for remote telecom station.

Proceeding of the 2011 *Power and Energy Systems (ICPS), 2011 International Conference on*, 1-6.

9. Kumar, A. Mohanty, P., Palit, D. and Chaurey, A. 2009. Approach for Standardization of Off-Grid Electrification Projects, Renewable and Sustainable Energy Reviews, 13, (8), 1946–1956.
10. Economic Planning Unit. 2013b. Economic Development-9th Malaysia Plan, Overview [online], available: http://www.epu.gov.my/ninth [accessed 15th May 2014].
11. Ghazali, M. and Azlina, S.N. 2013. *Renewable Energy in Malaysia: The Viability of Large Scale Introduction of Solar PV for both Grid-Connected and Stand-Alone Hybrid Systems*. Msc Thesis. University of Otago, Dunedin, New Zealand.
12. Kaundinya, D. P., Balachandra, P. and Ravindranath, N. 2009. Grid-Connected Versus Stand-Alone Energy Systems for Decentralized Power-A Review of Literature. *Renewable and Sustainable Energy Reviews*, 13(8), 2041–2050.
13. HUEI. N. S. 2012. *Hybrid Wind and Photovoltaic (PV) Power Generation System with Superconducting Magnetic Energy Storage (SMES).* Msc Thesis, Universiti Teknologi Malaysia, Malaysia.
14. Villalva, M. G. and Gazoli, J. R. 2009. Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays. *Power Electronic, IEEE Transactions on*, 24(5), 1198-1208.
15. Madhaiyan, V. and Subramaniam, V. 2014. Exprimental Verification of Photovoltaic- based- Three phase Four- wire series Hybrid Active Power Filter. *Electric Power Components and Systems*, 42(13), 1356-1370.
16. Moubayed, N., El.-Ali, A. and Outbib, R. 2009. Control of a Hybrid Solar-Wind System with Acid Battery for Storage. *WSEAS Transactions on Power Systems*, 4(9), 307-318.
17. Al-Rawahi, N., Zurigat, Y. and Al-Azri, N. 2011. Prediction of Hourly Solar Radiation on Horizontal and Inclined Surfaces for Muscat/Oman. *The Journal of Engineering Research*, 8(2), 19-31.
18. Shah, R. 2005. Compact Heat Exchangers for Microturbines. In Micro Gas Turbines. Educational Notes RTO-EN-AVT, 131(2), 2-18.

19. Guda, S. R. 2005. *Modeling and Power Management of a Hybrid Wind Microturbine Power Generation System*. Msc Thesis, Montana State University-Bozeman, College of Engineering, Bozeman, Montana.
20. Zhu, Y. and Tomsovic, K. 2002. Development of Models for Analyzing the Load-Following Performance of Microturbines and Fuel Cells. *Electric Power Systems Research*, 62(1), 1-11.
21. Smolen, S. and Budnik-Rodz, M. 2005. Economical Analysis of Energy Conversion and Use by Cogeneration Systems with Microturbines. *IASME Transactions*, 2(8), 1339-1342.
22. United State Environmental Protection Agency. 2008. Technology Characterization: Microturbines. Daft Technical Report, EPA420-P-02-001. Washington, DC.
23. Bakar, R. A. 2008. A Technical Review of Compressed Natural Gas as an Alternative Fuel for Internal Combustion Engines. *American Journal of Engineering and Applied Sciences,* 1(4), 302.
24. Srinivasan, K.K., Krishnan, S. R., Singh, S., Midkiff, K. C., Bell, S. R., et al. 2006. The Advanced Injection Low Pilot Ignited Natural Gas Engine: A Combustion Analysis. *Journal of engineering for gas turbines and power*, 128(1), 213-218.
25. Shasby, B.M. 2010. *Alternative Fuels: Incompletely Addressing the Problems of the Automobile*. MSc Thesis, Virginia Polytechnic Institute and State University, USA.
26. Cheah, S.L. 2004. *Analysis of Engine Performance using Palm Oil Methyl Ester*. Msc Thesis, University of Southern Queensland.
27. Aziz, A. A., Said, M.F. and Awang, M.A. 2005. Performance of Palm Oil-based Biodiesel Fuels in a Single Cylinder Direct Injection Engine. *Palm Oil Developments*, 42, 15-27.
28. Nagi, J. and Nagi, S. K. A. F. 2008. Palm Biodiesel an Alternative Green Renewable Energy for the Energy Demands of the Future. Proceeding of the 2008 *International Conference on Construction and Building Technology, ICCBT,* 79-94.
29. Ferreira, R. W. M., Guerra, D., Nogueira, M. and Lacava, P. T. 2011. Experimental Evaluation of Gas Turbine Emissions Fueled with Biodiesel and

Biodiesel-Diesel Blend. Proceedings of the 2011 *8th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics*, 272-277.

30. Bazmi, A. A., Zahedi, G. and Hashim, H. 2011. Progress and Challenges in Utilization of Palm Oil Biomass as Fuel for Decentralized Electricity Generation. *Renewable and Sustainable Energy Reviews*, 15(1), 574-583.
31. Abdullah, A., Salamatinia, B., Mootabadi, H. and Bhatia, S. 2009. Current Status and Policies on Biodiesel Industry in Malaysia as the World's Leading Producer of Palm Oil. *Energy Policy*, 37 (12), 5440–5448.
32. Abdullah, A. Z., Razali, N. and Lee, K. T. 2009. Optimization of Mesoporous K/SBA-15 Catalyzed Transesterification of Palm Oil Using Response Surface Methodology. *Fuel Processing Technology*, 90(7), 958–964.
33. May, C.Y., Ngan, M. A., Yoo, C. K., Majid, R. A., Chung, A. Y. K., Nang, H. L. L. 2005. Palm Diesel: Green and Renewable Fuel from Palm Oil. *Palm Oil Developments*, 23, 3-7.
34. Al-hinai, A. and Feliachi, A. 2012. Dynamic Model of a Microturbine Used as a Distributed Generator. Proceedings of the 2012 *System Theory, 2012. Proceedings of the Thirty- Fourth Southeasterm Symposium on*, 209-2013.
35. Belfkira, R., Zhang, L. and Barakat, G. 2011. Optimal Sizing Study of Hybrid Wind/PV/Diesel Power Generation Unit. *Solar Energy*, 85(1), 100-110.
36. Abdel-Qader, M. S. I. 2008. *Simulation of a Hybrid Power System Consisting of Wind Turbine, PV, Storage Battery and Diesel Generator with Compensation Network: Design, Optimization and Economical Evaluation.* Msc Thesis, Najah National University, Palestine.
37. Mahmoud, M. M. and Ibrik, I. H. 2006. Techno-Economic Feasibility of Energy Supply of Remote Villages in Palestine by PV- Systems, Diesel Generators and Electric Grid. Renewable and Sustainable Energy Reviews, 10(2), 128-138.
38. Agajelu, B. O. 2012. *Life Cycle Cost Analysis of a Diesel/Photovoltaic Hybrid Power Generating System.* Msc Thesis, Nnamdi Azikiwe University, Nigeria.
39. Parvin, S. 2014. *Remote Area Electrification with Stand- alone Hybrid Renewable Energy using HOMER software: Optimization and Techno-economic Analysis*. Msc Thesis, Jadavpur University Kolkata, India.
40. Zahedi, A. and Kalam, A. 2000. Balancing Cost and Performance in a PV/Wind/Battery Hybrid Power System. Proceedings of the *2000 Proceedings*

of Australia Universities power engineering conference (AUPE'00), Brisbane, Australia, 280-283.

41. http://en.wikipedia.org/wiki/Battery_charger
42. Abdullah, A. 2008. *Portable Solar Street Lamp*. Msc Thesis, Universiti Malaysia Pahang, Malaysia.
43. Ismail, M., Moghavvemi, M. Mahlia, T. 2013. Techno-Economic Analysis of an Optimized Photovoltaic and Diesel Generator Hybrid Power System for Remote Houses in a Tropical Climate. *Energy Conversion and Management,* 69, 163–173.
44. Ali, S., Pattanayal, P., Sanki, P. and Sabat, R. 2012. Modeling and Control of Grid-Connected Hybrid Photovoltaic Distributed Generation System. *International Journal of Engineering Sciences & Emerging Technologies,* 4(1), 125-132.
45. Esram, T. and Chapman, P.L. 2007. Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. *IEEE Transaction on Energy Conversion EC*, 22(2), 439.
46. Bernal-Agustı´n, J. L. and Dufo-lo′pez, R. 2009. Simulation and Optimization of Stand-Alone Hybrid Renewable Energy Systems. *Renewable and Sustainable Energy Reviews*, 13(8), 2111–2118.
47. Jacobus, H. S. 2010. *Solar-Diesel Hybrid Power System Optimization and Experimental Validation*. University of Maryland, College Park.
48. Sen, R. and Bhattacharyya, S. C. 2014. Off-Grid Electricity Generation with Renewable Energy Technologies in India: An application of HOMER. *Renewable Energy*, 62, 388-398.
49. Tan, C. W., Firdaus, M. Z. M. and Pauzi, M. K. M. 2014. System Investigation of a Hybrid Solar and Generator Set Power Supply for Rural Area in Perak Malaysia. *Advances in Energy*, 2(1).
50. Maps of World. Malaysia Latitude and Longitude. Can see, http://www.mapsofworld.com/lat_long/malaysia-lat-long.html
51. http://www.solarcellsales.com/techinfo/docs/bp-485.pdf.
52. Bank Negara Malaysia 2014. [Online] Available: http://www.bnm.gov.my/index.php?&lang=en. [Accessed: 30, OCT, 2014].
53. www.rollsbattery.com.

54. Lau, K. Y., Yousof, M., Arshad, S., Anwari, M. and Yatim, A. 2010. Performance Analysis of Hybrid Photovoltaic/Diesel Energy System under Malaysian Conditions. *Energy*, 35(8), 3245-3255.
55. Ismail, M., Moghavvemi, M. and Mahlia, T. 2013. Current Utilization of Microturbines as a Part of a Hybrid System in Distributed Generation Technology. *Renewable and Sustainable Energy Reviews,* 21, 142–152.
56. Shiroudi, A. and Taklimi, S. R. H. 2011. Demonstration Project of The Solar Hydrogen Energy System Located on Taleghan-Iran: Technical-economic assessments. *Volume 4 Fuel Cells*, 1, 1158.
57. Biodiesel Expedition, available in UTM market website: http://www.utm.my/biodiesel-expedition-2014/market-analysis/
58. Gas Malaysia Berhad, available in website: http://www.gasmalaysia.com/services/tariff_rates.php
59. Kunaifi 2009. *Options for the Electrification of Rural Villages in the Province of Riau, Indonesia.* Msc Thesis, Murdoch University, Perth, Australia.
60. http://www.delekenergy.co.il/?pg=calc&CategoryID=198
61. Tenaga Nasional Berhad 2013. 'Pricing & Tariff-Commercial Customer', Overview [online], available: http://www.tnb.com.my/investors-media/annual-reports.html [accessed 3rd sep 2014].
62. Shafie, S., Masjuki, H. and Mahlia, T. 2014. Life Cycle Assessment of Rice Straw-Based Power Generation in Malaysia. *Energy*, 70, 401-410.
63. Soimakallio, S., Kiviluoma, J. and Sakku, L. 2011. The Complexity and Challenges of Determining GHG Emission from Grid Electricity Consumption and Conservation in LCA (Life Cycle Assessment). *Amethodological Review. Energy*, 36(12), 6705-6713.
64. Shekarchina, M., Moghavvemi, M., Mahlia, T. and Mazandarani, A. 2011. A Review on the Pattern of Electricity Generation and Emission in Malaysia from 1976-2008. *Renewable and Sustainable Energy Review*, 15(6), 2629-2642.