



**Faculty of Mechanical Engineering**

**DESIGN OF A PV-DIESEL HYBRID SYSTEM WITH UNRELIABLE  
GRID CONNECTION IN KAMPUNG LB JOHNSON VILLAGE,  
MALAYSIA**

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**Master of Mechanical Engineering  
(Energy Engineering)**

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**DESIGN OF A PV-DIESEL HYBRID SYSTEM WITH UNRELIABLE GRID  
CONNECTION IN KAMPUNG LB JOHNSON VILLAGE, MALAYSIA**

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**A thesis submitted  
in fulfilment of the requirements for the degree of Master of Science  
in Mechanical Engineering (Energy Engineering)**

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## DECLARATION

I declared that this thesis entitled “Design of a pv-diesel hybrid system with unreliable grid connection in Kampung Lb Johnson Village, Malaysia” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

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Name : SALEH A. A. ALMAJDUP


Date : 26/04/2018.....

## APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfilment of Master of Mechanical Engineering (Energy Engineering).

Signature

:



Supervisor Name

:

Dr. MOHD ZAID BIN AKOP

Date

:

26.1.2018

## **DEDICATION**

At the first, I would like to express my sincere gratitude to all the members of my beloved family, parents, wife, sons, daughters, brother, sister and all other relatives. Their moral support, kindness, generosity, and patience have made my work and my life very rewarding. To all of them, I dedicate this project.

## ABSTRACT

The development of the current, existing and unreliable source of energy became necessary in the last decade, due to the huge demand on the electrical energy that caused by the developed technologies and electrical applications. In this study the integration of the renewable energy resources – solar Photovoltaic (PV) generators into an existing diesel generator and unreliable grid connection system is discussed and explained. The proposed location is Kampung LB Johnson villages, Negeri Sembilan, Malaysia. The main objective of this work is to develop, improve, and implement the optimal hybrid PV/diesel generator/battery hybrid system over the current unreliable grid connection. Firstly, the inclusion of the site location and metrological data is carried out, then the estimation of the load profile is performed for 120 households that locate at the proposed location. Secondly, the choosing of the proposed components of the system parts are also performed which includes PV arrays, diesel generators, fuel prices, battery banks and system power convertor. Thirdly, the pre-design step which includes finding all possible, existing and prospective scenarios are designed and prepared. Finally, the simulation of all of the proposed designs are carried out in deep details using HOMER software. The performance of all systems is driven based on deep analysis of all technical, economical, and environmental aspects. In addition, each system is compared to all other systems in order to find the optimal design with respect to the current existing diesel generator/grid system. Meanwhile, four different systems were choosing which includes. The existing diesel generator/grid, PV/battery/grid, PV/diesel generator/ battery, PV/ battery, and PV/diesel generator/battery/grid hybrid system. The result indicates that the PV/ diesel generator/battery/grid hybrid system shows the best behaviour, sizing efforts, techno-economic, and a very good environmental performance over all systems. This system is choosing to be the optimal system by including the best Net Present Cost (NPC) RM 6341312.46 and a very good Cost of Energy (COE) 1.226 RM/kWh, and seem to be promising for updating the current standalone (unreliable) systems. However, although the PV/diesel generator/battery/grid scenario shows a very good environmental performance, the 100% renewable energy system (PV/battery) trends to have the best environmental effects towards the surrounding environment by realising zero CO<sub>2</sub> emissions. Unfortunately, the PV/battery scenario have the highest NPC and COE. The results also informed that using hybrid system in power generation and updating the unreliable standalone mini-grid system would result in improving the general performance of the system, reducing the fuel consummation, fuel cost, and harmful CO<sub>2</sub> emissions. However, due to the current high prices of the renewable energy systems such as PV and batteries, the total replacement of the existing system seems to be economically impractical. But, the current developed technology seems to be promising to reduce these prices in the near future.



## ABSTRAK

Perkembangan sumber tenaga semasa, sedia ada menjadi perlu dalam dekad terakhir ini, disebabkan permintaan tinggi terhadap kuasa elektrik yang disebabkan terbuka dan aplikasi elektrik yang maiu. Dalam kajian ini integrasi sumber tenaga boleh diperbaharui - penjana fotovoltaiik solar (PV) ke penjana diesel sedia ada dan sistem sambungan grid yang tidak boleh dipercayai dibincangkan dan dijelaskan. Lokasi yang dicadangkan dan di terangkan adalah Kampung LB Johnson, Negeri Sembilan, Malaysia. Objektif utama penyelidikan ini adalah untuk membangunkan, meningkatkan, dan melaksanakan sistem hibrid PV / diesel penjana / bateri hibrid yang optimum melalui sambungan grid semasa yang tidak cekap. Pertama, kemasukan lokasi dan data meteorologi telah diambil kira, kemudian anggaran profil muatan telah dilakukan untuk 120 buah rumah yang dicadangkan bagi bahagian-bahagian sistem juga dilakukan yang termasuk merangkumi lapisan PV, penjana diesel, harga minyak api, kuasa bateri dan penukar kuasa sistem. setrusnya, langkah pra-rangka yang termasuk sebarang kemungkinan, scenario yang ada dan prospektif dirancang dan disiapkan. Akhir sekali, penyelakuan semua reka bentuk yang dicadangkan dijalankan dengan terperinci- menggunakan perisian HOMER. Prestasi semua sistem didorong berdasarkan analisis mendalam semua aspek teknikal, ekonomi, dan alam sekitar. Di samping itu, setiap sistem dibandingkan dengan semua sistem lain untuk mencari reka bentuk yang optimum berkenaan sistem penjana diesel / grid sedia ada sekarang. Sementara itu, empat sistem yang berbeza dipilih termasuk; Penjana diesel / grid sedia ada, PV / bateri / grid, penjana PV / diesel / bateri, PV / bateri, dan penjana PV / diesel / bateri / sistem hibrid grid. Hasilnya menunjukkan bahawa sistem penjana PV / diesel / bateri / grid hibrid menunjukkan tingkah laku terrain, usaha ukuran, tekno-ekonomi, dan prestasi alam sekitar yang sangat baik terhadap semua sistem. Sistem ini memilih untuk menjadi sistem yang optimum dengan memasukkan Kos Had Semasa Bersih (NPC) RM6341312.46 yang terbaik dan Kos tenaga (COE) 1.226RM/kWh yang sangat baik. Walaupun senario penjana PV / diesel / bateri / grid menunjukkan prestasi alam sekitar yang sangat baik, sistem tenaga 100% boleh diperbaharui (PV / bateri) mempunyai kesan alam sekitar yang terbaik ke arah persekitaran dengan merealisasikan pelepasan CO<sub>2</sub> sifar. Malangnya, senario PV / bateri mempunyai NPC dan COE tertinggi. Hasilnya juga memaklumkan bahawa menggunakan sistem hibrid dalam penjaanan kuasa dan mengemas kini sistem grid mini yang tidak boleh dipercayai akan menghasilkan peningkatan prestasi umum sistem, mengurangkan pemakaian bahan bakar, kos bahan api, dan pelepasan CO<sub>2</sub> yang berbahaya. Bagaimanapun, disebabkan oleh harga tinggi semasa sistem tenaga boleh diperbaharui seperti PV dan bateri, jumlah penggantian sistem sedia ada seolah-olah tidak praktikal dari segi ekonomi. Namum, teknologi maju sekarang nampaknya menjanjikan untuk mengurangkan harga ini dalam masa terdekat.

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.0 Background**

In the last century many research has been implemented to find a sustainable source of energy to cover the loads adequately and perfectly. Renewable energy is considered as one of the best solution to generate sustainable energy, where renewable global status report shows renewable energy sources contribute 22.8% of global electricity, whereas, the remaining 77.2% comes from fossil fuels and nuclear power plant ("Renewables 2016: Global Status Report," 2016). Also, it is reported that 1.1 billion people around the world is living without any excess to the electrical grid. On the other hand, most of generation plants around the world use fossil fuels generators to generate electrical energy, which cause releasing harmful CO<sub>2</sub> emissions to the world. in addition to the associated high maintenance and fuel costs (Ashourian et al., 2013; Fadaeenejad, et al., 2014). Solar energy and photovoltaics (PV) arrays have the widest usage around the word compared to all other renewable energy resources (Halabi, et al., 2017). Where at the end of 2014 there were more than 178 GW of the installed PV generation system around the world (Diab, et al., 2016).

Finding the optimum combination of the different hybrid renewable energy systems around the world has played a vital role in both developed and developing countries in the last two decades. Hybrid systems are associated with many benefits by using more than one source of energy which reduce the shortage, minimizing the global harmful emissions, and grantee an effective generation of energy. Also, it increases the reliability, as in the case of

using only one renewable source of energy it may not grantee sufficient reliability and stability due to non-linear characteristics of some components. For example, solar Photovoltaics (PV) exhibits low performance in cloudy weather, thus using enhancement technology such as emerging the PV arrays with another source of energy (M. Deshmukh & Deshmukh, 2008).

Hybrid renewable energy systems plays an important role in rural electrification systems (Mohammed, et al., 2013). Besides, its positive impact on the developments of advance power electronics and interfacing technologies (Chakraborty, 2011). As it involves configuration of different renewable energy systems for maximum power output. Therefore, developing such technologies would create a suitable solution for the uncertainty and variability characteristics. However, the modelling and optimization of such systems is very important, where many approaches were used to analyse and investigate the performance of the hybrid systems such as; linear programming model (LPM) (Kanase-Patil, et al., 2010), dynamic programming (DP) (Das, et al., 1990), non-linear programming (NLP) (Ashok, 2007), multi-objective goal programming (S. Deshmukh & Deshmukh, 2009), multi-input linear programming (MILP) (Ferrer-Martí,et al., 2013), and software and optimization tools (Sinha & Chandel, 2014).

In these regards, hybrid renewable energy systems are recognized as a feasible solution, cost effective, and proved their efficient energy generation. Hybrid renewable energy systems are proof the capability to meet the local load demands in rural, remote, and special urban regions. Thus, determining the optimal sizes of the proposed systems performs a major step in the preparation of the hybrid systems. Furthermore, with the development of new technologies in this field, new problems arise, which become much more fascinating to be solved. Meanwhile, the interest for hybrid renewable energy systems is increasing in the

world as a way to developed sustainable, reliable, and independent source of energy for both new systems or upgrading the existing systems.

### 1.1 Problem statement

Hybrid energy systems has got the intention in the recent years as an effective power system mainly for electrifying remote areas. These systems have been widely designed and implemented in different parts of the world. Where, the main focused of these studies was reported in designing new standalone hybrid systems, in examining the potential of implanting such systems, and in investigating the techno-economic feasibility. Different topologies were considered based on the proposed site location for implementing hybrid renewable energy projects such as; PV\diesel generators\battery banks (Rezzouk & Mellit, 2015), PV\wind\diesel generators\battery banks (Baneshi & Hadianfard, 2016), Hydro\PV\wind (Bekele & Tadesse, 2012), and PV\fuel cell\battery banks (Isa, , et al., 2016). In general, using hybrid renewable energy systems has showed high potential in terms of the technical, and economical aspects. However, investigating the systems performance over an unreliable grid connection has not been taken into consideration despite its high importance mainly in developing and improving the micro-grid system.

In these regards, the among the different investigated works, it could be concluded that there is no comprehensive study has been developed to investigate the real operational system by considering unreliable grid connection alongside with the optimal hybrid renewable\conventional energy systems. Furthermore, this work is proposed to analyse all possible and current scenarios of hybrid PV\diesel generator\battery\grid banks energy system for a specific location in Malaysia called FELDA LB Johnson or Kampung LB Johnson at Negeri Sembilan. The existing system at this location includes diesel generator \ grid connection system. Meanwhile, the existing system suffers from unreliable grid



connection and un-continuous power supply to the loads, in which it needs to be analysed and optimized.

## **1.2 Scope of the study**

As mention in the previous section, this study is performed to investigate all possible scenarios that are related to a current micro-grid system located at Negeri Sembilan, Malaysia. This system is examined over the current combinations and developed to examine the possible scenarios. Also, to spot the advantages\disadvantages that are associated with each scenario. Therefore, this work is proposed to include all optimization, improvement, techno-economic feasibility for each part in the system, in addition to an analytical comparison between all scenarios to specify the optimal topology among all other frames.

## **1.3 Objectives**

The general aim of this thesis is to find the optimum design and improve the current unreliable grid connection with diesel backup system for Kampung LB Johnson in Malaysia. Where the configuration of this system, includes diesel generators and grid connection components, and suffers from interrupted power supply to the loads due to having unreliable grid connection. In addition to introduce the renewable energy system solar generation (PV) system and examine it is effects on the system. the specific objectives are explained as follows:

1. To test the proposed PV systems in an existing unreliable hybrid diesel mini-grid system.
2. To find the optimal system design of the proposed hybrid renewable energy/conventional system and reducing the disadvantages of the existing unreliable system.



3. To validate the feasibility of the proposed hybrid PV/diesel generator/battery/grid system over a period of 25 years.

#### **1.4 Thesis outline**

This work includes five main chapters each are associated to sub-sections as follows: Chapter 1 includes the introduction of the study with a background, problems statement, scope of this study and the proposed objectives. Then Chapter 2 includes all necessary literature review, where, Chapter 3 includes the methodology that is used in this work with all needed site location, component configuration, load data, work procedure, and used software. Chapter 4 is the results and discussion chapter which includes all technical, economical, and environmental aspects, in addition to the comprehensive analytical comparisons. Finally, Chapter 5 includes the conclusion of the main findings in this work.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 Introduction**

Around the world, almost 20% of the world population are living without any electrical energy access. Many of the societies perform over 20% of their income on the energy sector, while the small societies are suffered from different constraints which include the small size, remote location, limited expert, resources and directly affected by the global environmental challenges (Neves, et al. , 2014). In these regards, the world struggling for finding a sustainable energy access for such communities. The renewable energy performs a suitable solution to generate suitable energy. However, the implementation of these systems is still considered as challenge and need several stages to earn the perspective advantages which are illustrated as follows:

#### **2.1 Development of hybrid renewable energy systems.**

Renewable energy resources have proved their efficiency in being an alternative source of energy to fossil fuels. However, many disadvantages are associated when they are used as an individual sources of energy, related to high capital costs and the unpredictable nature of these sources (Bahramara, et al., 2016). To overcome this problem, a creative solution of using a mix of renewable energy systems and conventional sources of energy (Erdinc & Uzunoglu, 2012). In most hybrid renewable energy systems, solar and wind systems are widely used to generate electrical energy in both off-grid and on-grid systems.

In fact, when the renewable energy systems are not available to supply the loads, the other part of the system (backup) would do this task. On the other hand, when the renewable energy sources supply excess energy, it would be delivered to the storage system.

The main advantages of meeting all criteria of sustainable development which includes economic, environmental, and social aspect. Some of the technical analysis that is associated with such systems in reducing the Cost of Energy (COE), harmful CO<sub>2</sub> emissions, and providing electrical energy access to the rural communities (Bahramara et al., 2016).

2.2 Solar energy

Solar energy is regarded as one of the main sources of energy that is used in power generation. Solar energy depends directly on the global solar radiation which is varied from zone to another (Mohammed, et al., 2014). Also, it could vary within the same region as shown in Figure 2-1.



Figure 2- 1 : Different Solar energy zones in Tibet, China (Mohammed et al., 2014)

Based on this difference the potential of using solar energy is subjected to the proposed site location and the intensity of the solar radiation. Therefore, an effective solar radiation data plays a vital role in the development and implementation of any solar radiation projects with respect to the proposed area (Zawilska & Brooks, 2011).

There are many applications are associated with the solar energy in different files of thermal and electrical applications such as; cockers, space and water heating, electrical Photovoltaics (PV), and etc. In particular, using the solar energy in the thermal application would help to reduce the deforestation rate and exhibit higher potential towards the sustainable developments (Liu, et al., 2008). In general, using the solar energy in different fields would ensure cost effective and user-friendly utilization. However, the potential of using the solar energy is related to the availability of the sun which is reduced during winter seasons. Thus, using hybrid systems with/without storage system would help to diminish this major drawback.

### **2.3 Wind energy**

Wind energy system is a mechanical (structural) system which transfer the kinetic energy of the wind into electrical energy form. Wind energy generators, are used to generate reliable energy at both large scale and small scale depending on the availability of higher potential of the wind speed. In this case, more strong and stable wind speed with high altitude regions are usually used to perform wind farms (Banos et al., 2011). Where the wind energy is integrated with the national grid to generate the power in different parts of the world such as in Denmark (Gipe, 1991), USA (Dvorak,et al., 2010), and Canada (Li & Li, 2005).



The developed and developing countries are working towards increasing the installed capacity of the wind energy where it is suitable due to its significant impact in power generation. However, the high cost associated with creating such systems forms a major drawback, thus using hybrid systems reduce this impact. In this regard, a sustainable site selection and ensuring the optimal sizing of the system in addition to enlightening the investors regarding the risk and benefits are highly needed to ensure an efficient system (Changliang & Zhanfeng, 2009).

#### **2.4 Feasibility of hybrid renewable energy systems**

To ensure an efficient utilization of hybrid renewable energy studies, prefeasibility studies are highly important and needed (Khare, et al., 2016). Such studies include the metrological parameters, the availability of the renewable energy resources and the load demand. It assesses the most suitable location and system combination. In this regards some studies are highly informative as shown in (Khan & Iqbal, 2005). The authors gave meticulous feasibility study for a wind/solar hybrid system. Within the study the authors analysed the sizing and the performance of the proposed system, where the results showed have a Net Present Cost (NPC) of \$ 36738 and a Cost of Energy (COE) of 0.492 \$/kWh for 4.73 kW peak load.

In the last decade, the feasibility of establishing hybrid systems was deeply investigated through different studies (Ismail, et al., 2013; Ohijeagbon & Ajayi, 2015; Palit, et al., 2011; Rahman, et al., 2016; Rajkumar, et al., 2011; Shaahid, et al., 2014). In (Shakya, et al., 2005), the authors studied standalone hybrid renewable energy system, which includes wind turbines, PV and hydrogen storage system. The result shows that the general COE is 2.52 AU\$/kWh, while the high cost is coming because of the hydrogen storage system as it forms 52% of the total cost of the system. Another study was considered to study hybrid



system contains wind turbines, diesel generator and air compressed storage energy system (Ibrahim, et al., 2010). The results show that the inclusion of wind turbine and unique storage system result in improving the total efficiency of the system, reduce the associated costs, fuel consumption, and harmful CO<sub>2</sub> emissions.

In the same manner, another study was conducted to examine the techno-economic feasibility of hybrid PV/diesel generator system (Mahmoud & Ibrik, 2006). The result demonstrates the using hybrid PV/diesel generator systems as the best solution where it shows better attitude and variability than standalone diesel generators or grid extension systems mainly for rural locations. Meanwhile, a study was carried out to investigate the effectiveness of using hybrid system around the world using Geographic Information System (GIS) software (Cader, et al., 2016). The results demonstrate the high feasibility of the proposed PV/battery/diesel hybrid system in reducing the COE and improve the general performance. Furthermore, a study was performed to examine introducing Fuel Cell (FC) in energy system along with PV, wind turbines, and battery banks (Rezk & Dousoky, 2016). Six different combinations were employed and tested using HOMER software and were compared to grid extension solution. The results have found that hybrid system of PV/FC offers the best COE and NPC over all solution including grid extension and standalone wind/battery systems.

A study was performed to find the optimum solution for a specific location in Malaysia using loss-of-load probability (LLP) to be less than 0.01 (Khatib, et al., 2011). The result shows that the hybrid combination of PV/diesel generator reduced the cost by 35% and being more viable than standalone PV arrays or diesel generators. Similarly, the PV/diesel generator system was investigated in (Rehman & Al-Hadhrami, 2010). HOMER software was used in the optimization were the results finds many configurations using four