TECHNO-ECONOMIC ANALYSIS OF HYBRID PHOTOVOLTAIC-GENERATOR-BATTERY SYSTEM IN BARIO SARAWAK

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DEDICATION

"My dearest wife and family"

This is for all of you

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ABSTRACT

Solar energy is growing rapidly in recent years because of reduction of capital cost and ease of installation compared to other renewable energy. However, due to the intermittent characteristic, solar energy always combined with diesel generator and energy storage to provide reliable supply. Even though, the hybrid Photovoltaic (PV)-Diesel Generator-Lead Acid Battery system is having high operation cost in term of high diesel fuel transportation cost because of difficult fuel transportation and high replacement cost for lead acid battery. This study considered the hybrid PV-Diesel Generator-Lead Acid Battery power station in Bario, Sarawak, Malaysia. The Bario's solar hybrid power station was built upon previous related site surveys and it had been operational since January 2017. This study considered the validation of the collected data from Bario's solar hybrid power station, simulation of actual system configuration, PV-Lead Acid Battery system and PV-Vanadium Battery system. The comparison of actual system, PV-Lead Acid Battery system and PV-Vanadium Battery system based on different load demand were performed. The performance of different system were analyzed based on technical and economic constraints, including net present cost, levelized cost of energy, and analysis taking into account of operational aspects using Hybrid Optimization Model for Electric Renewable (HOMER). Vanadium battery is proposed to replace the diesel generator and lead acid battery because of the promising outcomes in long life cycle and lower operation cost from previous researchers. Sensitivity analysis were also carried out to analyze the effects of system performance and economic by changing main parameters such as load demand, photovoltaic and battery prices. The findings show that PV-Generator-Lead Acid Battery system has lower Cost of Electricity but higher carbon emissions. PV-Vanadium Battery system is technically feasible and financially competitive to used in Off-Grid Electrification.

ABSTRAK

Tenaga solar telah berkembang dengan pesat sejak kebelakangan tahun ini disebabkan pengurangan kos modal dan pemasangan jika dibandingkan dengan tenaga boleh diperbaharui yang lain. Walaubagaimanapun, disebabkan ketidakstabilan tenaga solar, ianya sering digabungkan bersama penjana kuasa diesel dan bateri bagi tujuan penyimpanan kuasa. Walaupun begitu, sistem hibrid Solar PV-Penjana Diesel-Bateri Asid Plumbum mempunyai kos operasi yang tinggi, terutamanya dari aspek kos penghantaran bahan api yang disebabkan oleh pengangkutan bahan api ke lokasi yang sukar serta kos pengantian bateri asid plumbum yang tinggi. Kajian ini berdasarkan stesen janakuasa hibrid Solar PV-Penjana Diesel-Bateri Asid Plumbum di Bario, Sarawak, Malaysia. Stesen jankuasa Bario telah dibina berasaskan kaji selidik tapak yang telah dibuat sebelumnya dan stesen tersebut telahpun beroperasi sejak Januari 2017. Kajian ini menganggap pengesahan data yang dikumpulkan dari stesen janakuasa hibrid solar Bario, simulasi konfigurasi sistem sebenar, sistem PV-Lead Acid Battery dan sistem Bateri PV-Vanadium. Perbandingan sistem sebenar dibuat antara Sistem PV-Bateri Asid Plumbum dan Sistem PV-Bateri Vanadium berdasarkan pemintaan beban yang pelbagai. Prestasi sistem dinilai dan dianaliasis berdasarkan kekangan teknikal dan ekonomi, termasuk nilai bersih semasa, kos tenaga bertingkat, dan analisis dengan mengambil kira aspek operasi menggunakan Hybrid Optimization Model for Electric Renewable (HOMER). Bateri Vanadium telah dicadang untuk menggantikan penjanakuasa diesel dan bateri asid plumbum kerana jangka hayat yang lebih panjang dan kos penyelenggaraan yang rendah berdasarkan pengkaji terdahulu. Analisis sensitiviti juga dibuat untuk mengetahui kesan terhadap prestasi dan ekonomi sistem dengan menukar paremeter utama seperti beban permintaan, harga photovoltaic dan bateri. Penemuan menunjukkan bahawa sistem PV-Generator-Lead Acid Battery mempunyai kos elektrik yang lebih rendah tetapi sitsem ini didapati melelepakan karbon pada kadar yang lebih tinggi. secara teknikal, sistem Bateri PV-Vanadium boleh dilaksanakan dan lebih berdaya saing dari segi kewangan untuk digunakan dalam sistem elektrik luar talian.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
COE	-	Cost of Energy
DC	-	Direct Current
NPC	-	Net Present Cost
PV	-	Photovoltaics
VRFB	-	Vanadium Redox Flow Battery

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

By the year of 2018, Malaysia, while moving rapidly towards a delveloped nation, still consists of considerable number of rural areas which are under developed. Most of these rural areas are small villages, scattered across large areas of East Malysia (Sarawak and Sabah). In general, basic infrastructures are inadequate including proper roads, electiricty supply and water supply [1]. Some 400 villlages in the remote rural heartlands of Sarawak are difficult to connect to the main electricity grid. The extremely rugged and challenging terrain, mostly include hilly terrain means these communities are economically impossible to be supplied with electricity by extending distribution poles and power lines. At the year of 2018, over 8,700 households in the 300 isolated villages in Sarawak area still without 24-hours supply, but 2,000 households such as Batang Ai, Murum Resettlement in Belaga, Pelagus and Katibas in Central Region, Baram, Bario and Bakelalan in the North are already connected with 24-hour electricity through Off-Grid Solar Hybrid System funded either by Malaysia’s federal government or local Sarawak government [2].

Sarawak’s major generation plants and transmission grid is exteremely far from most of the remote rural areas such as Bario as shown in Figure 1.1. Bario is located 180km from Miri, the second largest town in Sarawak. Bario, lying an altitude of about 1,000 meters above sea level in the Northern region of Sarawak can be reached either by 45 mins flight of Twin Otter from Miri or 10-14 hours of four wheel drive on rugged and challenging logging road from Miri to Bario [3].

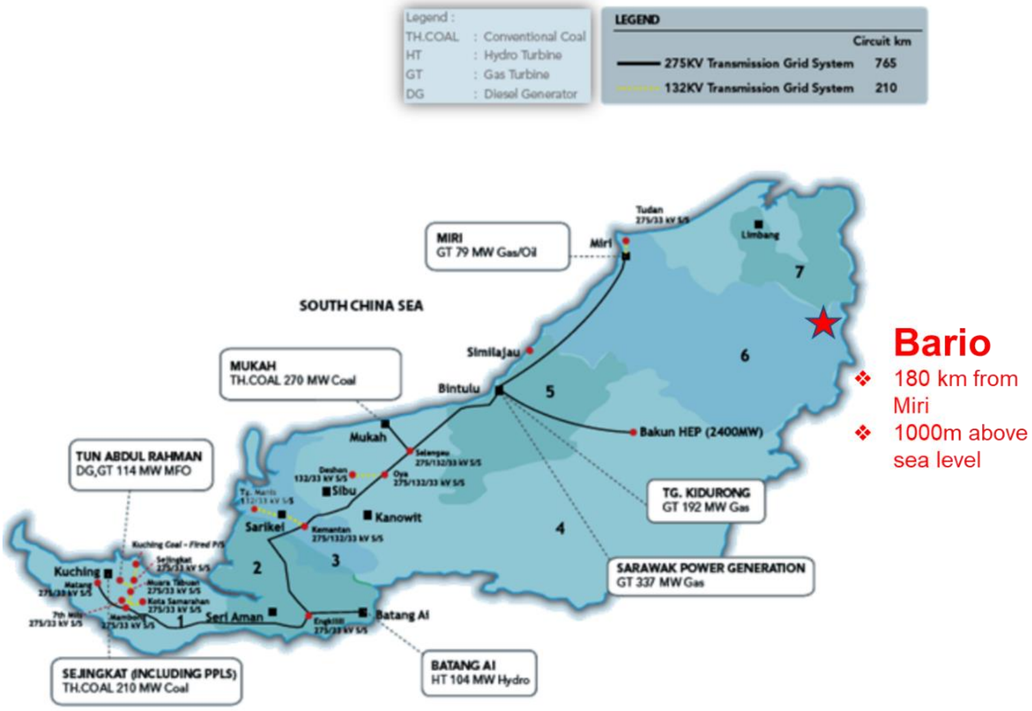

Figure 1.1 Sarawak Major Generation Plants and Transmission Grid [4]

Since year 2016, Bario community enjoys 24-hour electricity supply of a 887 kilowatt peak solar hybrid system. This solar hybrid system has the capital cost of RM27 Million and is currently operaated and maintaned by Sarawak Energy, the only electricity utility company in Sarawak [5]. The detail design of Bario Solar Hybrid System will be discussed in Chapter 2. Figure 1.2 shows the view of Bario highland.

Figure 1.2 View of Bario

1.2 Problem Statement

Solar hybrid system proven to be feasible and suitable solution for rural electrification in Sarawak because of difficulty to construct transmission grid to rural villages that is situated at interior of Sarawak. Previous researcher concluded that hybrid PV-Lead Acid Battery-Diesel Generator system perform best technically while also provide good economic and environmental performance [6]. Other research also showed that PV-Battery-Diesel Generator system is more economical [7] compared to PV-Wind-Battery-Diesel Generator system and Wind-Battery-Diesel Generator system [8]. However, maintenance cost especially replacement cost for lead-acid batteries was not realistically considered during desing stage. Lead Acid Battery has design life cycle of about 3000 cycles but can only last less than 5 years in practical considering temperature factor and also influenced by the depth of discharge. The challenges also include the transportation of bulky Lead Acid Battery to the rural villages that can be 10 of hours logging roads drive from nearest town.

Figure 1.3 Journey to Bario

Figure 1.4 Transportation of Components to Rural Area

1.3 Motivations

Due to technology advancement, Vanadium Redox Flow Battery (VRFB) was commercialized and used in Photovoltaic (PV) power system application in other country such as China. Compared to other storage technologies, VRFB has advantages including longer lifecycle, lower operation and maintenance cost, higher storage efficiency, faster response, and can operate over a wide range of power outputs. Simulation results from previous researcher show that VRFB was better and fitter as long term energy storage solution compared to lead acid battery in term of physical characteristics and financial feasibility [9]. Other researcher salso proved that VRFB can be promising energy storage for reliability, quality, secure, scalability and deep discharge capacity for renewable energy system especially PV system [10]. VRFB is also believe to have competitive capital cost according to researcher in paper [11], and claimed to be half of the lithium battery cost.

1.4 Project Objectives

The objectives of the project are :

(a) To evaluate the feasibility of Vanadium Redox Flow Battery (VRFB) as energy storage system for actual medium scale hybrid PV system (887 kWp) at rural villages in Bario, Sarawak, Malaysia

(b) To optimize the size of hybrid PV system using HOMER with minimum total net present cost (NPC) and cost of energy (COE) by satisfying real load demand in Bario, Sarawak

(c) To perform techno-economic analysis on simulation result of the (i) PV-Generator-Battery, (ii) PV-Battery, and (iii) PV-VRFB system by using HOMER

1.5 Scope of Study

1.6 Report Outline

Chapter 1 describes the introduction of Bario, Sarawak and Solar Hybrid System initiatives in Sarawak. This chapter also includes the problem statement, motivation, research objectives, and scope of this study.

Chapter 2 presents the previous literature and studies relevant to this project. It also reviews the Solar Hybrid System of Bario and various type of energy storage system used in Photovoltaic system.

In Chapter 3, the methodology of the project is described. The economical analysis is described.

Chapter 4 discusses about the results and analysis for different configuration. The technical performance and economical studies were presented and discussed.

Chapter 5 concludes the study and recommend future work to be performed.

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