Faculty of Mechanical Engineering

STREAMFLOW PREDICTIVE MODEL USING RELIABLE DISTRIBUTION METHOD TO ENHANCE SMALL HYDROPOWER SYSTEM PERFORMANCE

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A thesis submitted
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DECLARATION

I declare that this thesis entitled "Streamflow Predictive Model using Reliable Distribution Method to Enhance Small Hydropower System Performance" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	Mashitah binti Razi
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature	:……………………………
Supervisor Name	: Dr. Mohd Asri bin Yusuff
Date	:…………………………….

DEDICATION

This thesis is dedicated to my beloved mother and father, families, my supervisor and friends for support me with affections love and their companionship for success in my life. Thank you Almighty.

ABSTRACT

Nowadays, increasing electricity demand and rural electrification upgrading make renewable energy becomes more popular. Some examples of renewable energy applied in Malaysia are solar, biomass and hydropower. For hydropower, it can be classified into several types and schemes. For types, it depends on the power generated by the system, while schemes, it related to its operating mechanism. In Malaysia, generally, the small-hydropower system tied with 21 years Feed-In-Tariff (FiT) policy offered by Sustainable Energy Development Authority (SEDA) and for rural electrification, small-hydropower system based on run-of-river schemes is much better in terms of total electricity generated, sustainability, reliability and environmental friendly. Therefore, to make sure the sustainability and reliability of the system, understanding the character of the streamflow is a must. In this research, average daily streamflow data from January to December 2016 from Sungai Perting, Bentong, Pahang small hydropower system were used as data analysis. Statistical analysis in boxplot using R-Software provides first statistical order characteristic of the streamflow in terms of maximum, minimum, mean, median, first quartile and third quartile of the data. While, for distribution analysis, Probability Distribution Function (PDF) model of Gumbel, Weibull 2-parameter, Lognormal and GEV are used to represent the data. Most researchers used Lognormal, Gumbel and Weibull and less study on GEV distribution. Therefore, the GEV is introduced to increase the reliable method applied. Best fit distribution is finding by the help of MATLAB Software based on MLE value. To obtain the performance of the system, the study will focus on the turbine power generated related to the streamflow. From the results, 8 out of 12 months of the streamflow distribution exhibit GEV function and have maximum MLE values compared to the others. As for the performance of the system, streamflow is directly proportional to the power generated by the turbine.

ABSTRAK

Dewasa ini,terdapat peningkatan dalam penggunaan elektrik termasuk menaik taraf kehidupan masyarakat luar bandar menjadikan sumber tenaga semulajadi semakin popular. Antara contoh sumber tenaga asli yang terdapat di Malaysia adalah tenaga suria, bio jisim dan hidro. Bagi sumber tenaga hidro, ia boleh diklasifikasikan kepada beberapa jenis mengikut jumlah kuasa elektrik yang dihasilkan dan juga cara sistem itu berfungsi. Di Malaysia, aplikasi penggunaan tenaga hidro terikat dibawah bidang kuasa pihak berkuasa Pembangunan Tenaga Lestari Malaysia (SEDA) di bawah program Tariff Galakan selama 21 tahun perjanjian konsesi. Bagi sistem elektrik luar bandar, sistem tenaga hidro kecil yang berasaskan skim aliran sungai mempunyai kelebihan yang baik dari segi jumlah tenaga elektrik yang dihasilkan, kemampanan, kebolehpercayaan dan mesra alam sekitar. Oleh itu, untuk memastikan kelestarian dan kebolehpercayaan sistem tersebut, kefahaman tentang sifat aliran sungai amatlah penting. Data aliran sungai yang dikaji adalah purata harian dari Januari sehingga Disember 2016 di Sungai Perting, Bentong, Pahang. Analisis statistik melalui aplikasi boxplot yang terdapat didalam perisian-R diguna pakai untuk memberikan ciri-ciri kadar aliran air dari segi, nilai aliran yang paling tinggi, rendah, purata, pertengahan, kuartil pertama dan kuartil ketiga. Bagi analisis taburan, perisian MATLAB pula digunakan bagi mendapatkan fungsi taburan kebarangkalian yang paling sesuai berdasarkan nilai MLE yang paling maksima bagi mewakili fungsi kebarangkalian data aliran sungai dari bulan Januari-Disember 2016. Kebanyakan penyelidik lebih memfokuskan fungsi taburan Lognormal, Gumbel, dan juga Weibull dua parameter berbanding taburan GEV, oleh itu, fungsi GEV diperkenalkan bagi memberikan kaedah kajian yang lebih mampan. Hasil kajian mendapati, 8 dari 12 bulan data aliran kajian yang dikaji menjurus ke arah fungsi taburan kebarangkalian GEV dengan nilai MLE yang paling maksima berbanding fungsi kebarangkalian yang lain dan aliran sungai berkadar terus dengan tenaga yang dihasilkan oleh turbin yang diguna pakai iaitu Turgo Turbin.

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LIST OF ABBREVIATIONS AND SYMBOLS

ASCII	-	American Standard Code for Information Interchange
FDC	-	Flow duration curve
FiT	-	Feed-in-Tariff
$f(x)$	-	PDF function for Lognormal/Gumbel/Weibull/GEV
GDP	-	Gross Domestic Product
GEV	-	Generalize Extreme Values
GRACE	-	Gravity Recovery and Climate Experiment
IQR	-	Inter quartile range
ktoe	-	Thousands tonnes of oil equivalent
kW	-	Kilo Watt
kV	-	Kilo Volt
km	-	Kilometre
km^2	-	Kilometre per square
kWh	-	Kilo Watt hour
kg/m3	-	Kilogram per meter cubic
MLE	-	Maximum Likelihood Estimation
MW	-	Mega Watt
MWh	-	Mega Watt hour
m	-	Metre
m^3/s	-	Meter cube per second
m/s^2	-	Meter per second square
mm	-	Millimeter
mm/yr	-	Millimeter per year
PDF	-	Probability distribution function
Q1	-	First quartile
Q3	-	Third quartile

REPPA	-	Renewable Energy Power Purchase Agreement
ROI	-	Return of Investment
SCADA	-	Supervisor Control and Data Acquisition
SCORE	-	Special Commission on Renewable Energy
SEDA	-	Sustainable Energy Development Authority
SOFC	-	Solid Oxide Fuel Cell
SREP	-	Small and Renewable Energy Program
S	-	Standard deviation
TNB	-	Tenaga Nasional Berhad
TWh	-	Tera Watt hour
Whr/m^2	-	Watt hour per square meter
$\bar{x}$	-	Arithmetic mean
x_{md}	-	Median
%	-	Percentage
ξ	-	Shape parameter for GEV
β	-	Shape parameter for Weibull 2-parameter
η	-	Scale parameter for Weibull 2-parameter
μ	-	Mean for Lognormal and Location parameter for Gumbel and GEV
σ	-	Standard deviation for Lognormal and Scale parameter for Gumbel and GEV

LIST OF PUBLICATIONS

Razi, M., Yusuff, M. A., Zakaria, K. A. and Putra, A., 2018. Stream Flow Analysis for Small Hydropower System based on Run-of-River Schemes. *ARPN Journal of Engineering and Applied Sciences,* 13(3), pp. 1115-1118.

Razi, M., Yusuff, M. A., Tee, B. T. and Zakaria, K. A., 2017. A Significance Approach Between Patterns of Water River Flow Rate to the Exploitation of Power Generated in Small Hydropower System.. *International Review of Mechanical Engineering (IREME),* 11(11), pp. 831-835.

Razi, M., Yusuff, M. A., Tee, B. T. and Zakaria, K. A., 2017. Prediction of Available Power Being Generate in Small Hydropower System at Sungai Perting Bentong Pahang. Putrajaya, Malaysia, *MATEC Web Conference.*

CHAPTER 1

INTRODUCTION

1.1 Background

This chapter discussed on the background of the studies, problem statements, objectives aimed in this research and the scope. Renewable energy resources become one of the important key of global energy, environmental and sustainability. It also includes reduction of Greenhouse Gas emissions and safe energy provision in a hastily manner. There are several types of renewable energy applied such as solar, biomass, hydropower and geothermal (Kosa et. al., 2011). In Malaysia, there are three main most popular types of renewable energy resources which are solar, hydro and biomass (Shamsuddin, 2012). The application of biomass is due to abundant of the palm oil plantation industry in Malaysia with quantity of 38900tonnes/year and the maximum potential energy is 320 MW.

The use of solar energy is due to location of Malaysia at the Equatorial region with average solar radiation between 4000-5000 Whr/m^2 for 4-8 hours per day. Majority of it is in form of solar PV and individual used (Mekhilef, 2010). For hydro energy resources in Malaysia, potential of electrification came from the landscape of hilly topography and abundant numbers of flowing streams to foot hills with 150 river systems in Peninsular and 50 rivers in Sabah and Sarawak. As for then rainfall, the estimated average annualis2400 mm compared to world's average annual which is 750 mm (Raman et. al., 2009). Based on the facts, hydro energy resources can be considered as one of the most available renewable energy resources for rural electrification in Malaysia.

Basic principle of hydropower generation is, when the water can be conveyed into a pipe or flow from higher to a lower level, then it will produce water pressure that can performed work of the mechanical component. Then, the movement of the mechanical components will turn the conversion of the water energy flow into mechanical energy and it can be used to drive an electricity generator. This generation of energy needed suitable location as it required an adequate amount of water flow and effective head to maximize the utilization of the hydropower system itself (Basar et. al., 2011). Hydropower energy can be classified as one of the oldest energy forms that are economical, reliable, predictable and clean in generating electricity.

It is also known to be one of the best commercially viable on large scale and small scale application in Malaysia. As a long term application, it can store large amount of electricity at lower cost and can be adjusted accordingly to the customer demands (Ong et. al., 2011). Hydropower can be divided into two segments which are large scale and small scale technology. For large scale hydropower the capacity of electricity can be up to 100 MW and for small scale technology with range of capacity 1–15 MW it can be divided into more categories. In hydropower system, there are also several schemes applied which are run-off-river, dam and integrated water canal or water supply pipe. Table 1.1 shows the categories of the small hydropower scale system that can be applied.

Table 1.1: Categories and range of capacity applied in small hydropower system (Singh, 2009)

Categories of small hydropower scale system	**Capacity of the system**
Mini	100 kW-1 MW
Micro	5 kW-100kW
Pico	Watts up to 5 kW

For small hydropower technology, it can be one of the best alternatives solutions in providing electricity for rural communities and applications hence, improving the quality of life. Most of the small hydropower technology applied worldwide is based on run-of-river schemes where it can be standalone system in isolated areas or grid connected to local grids or national grid used. The run-of-river system is free CO_2 emissions and one of the oldest electricity generations. Total potential capacity in Malaysia is around 500 MW for the long run projects especially in run-of-river schemes. In 2013, total capacity installed was 26063 MW as 21628 MW in Peninsular Malaysia, 1303 MW in Sabah and 3132 MW in Sarawak. Besides, the hydroelectric production used was around 14.73% and the small hydropower contributed 0.17% (Abdullah et. al., 2016).

Small and Renewable Energy Program (SREP) was first launched in May 2001, with the coordinating and oversight Special Commission on Renewable Energy (SCORE). This program is to increase the development of renewable energy projects under SREP which allows renewable projects up to 10 MW to sell their output such as solar, hydro, biomass, biogas, municipal waste and wind at specific fixed premium price and duration to the utility, under 21-year license agreements Feed-in-Tariff (FiT).

To increase the utilization of the renewable energy resources towards national electricity supply and sustainable socioeconomic development, government of Malaysia has established the National Renewable Energy Policy and Action Plan on 2009 while Renewable Energy Act 2011 is more focused on the establishment and implementation of a special tariff system to catalyze the generation of renewable energy (Nasab, 2012). The duration of FiT is based on the characteristics of the renewable resources and technologies. For biomass and biogas resources are 16 years while 21 years for small hydropower and solar photovoltaic technologies (SEDA, 2019). Table 1.2 shows the annual power generation (MWh) of small hydropower system generated under FiT system in Malaysia from 2012 until 2017.

Table 1.2: Annual power generation by small hydropower system in Malaysia (seda.gov.my 2017)

Year	**Annual power generation (MWh)**
2017	58715.60
2016	47798.28
2015	55406.38
2014	64549.65
2013	79081.75
2012	25629.78

The run-of-river small hydropower plants have several key advantages over conventional dam storage application in terms of flexibility, suited for small head and have smaller social economics impact which are better for remote area application as it give better way for providing the electricity for the rural. Conventional method of the hydro generation relies on large area of dam which influences the change of the environment landscape as it permanently altered the downstream flow regime compared to run-or-river schemes. On the other hand, the run-of-river does not significantly induced in permanent alteration to environment and require low weir (Ramos et. al., 2000). Besides, the volume of the water flow diverted to the weir will be released back to the river of the intake and give less impact to the regulation of the river flow ecosystem. Thus, this scheme is considered as better technology for rural application and acceptable for social and environmental application such as the landscape of the flora and fauna of the ecosystem.

Streamflow is the volume of water flow passes through a specific point on a given period. Understanding the measurement of the streamflow analysis helps in monitoring the flood or even manages the water quality of aquatic habitat, pollution concentration and land erosion. Besides, it also important for a stream ecosystem and responsible for the physical characteristic of the river small hydropower system itself. Enough water river flow rate or streamflow and sufficient head are needed as it is the major key component in small hydropower installation in order to produce enough amount energy to the site to be utilized. As the head of the small hydropower systems are practically constant, the streamflow are crucial elements and the available flow is highly variable. Besides, the power generation of the system during its lifetime mainly depends and controlled by the availability of the streamflow of the system itself (Basso and Botter, 2012).

The streamflow analysis is also important as the performance of the hydro-turbine such as power produced by the turbine, rotational speed of the rotor (rpm), wear and capitations of the turbine blade are mainly depends on it (Acakpovi et. al., 2014). Besides, in the fields of hydrology application, feasibility and availability studies of the streamflow are necessary as it can be used in determine the efficiency and productivity of the projects itself. Streamflow observed at the intake of the river cross section system are strongly fluctuating in time at multiple timescales showing the complexity of the hydro climatic processes and volume of streamflow also affected by the climate change of the region.

1.2 Problem statement

In Malaysia, small hydropower system based on run-of-river schemes of sizes 1 MW to 10 MW is rarely being applied for community's purposes. Yet it can be one of the best alternative renewable energy in generating electricity especially in remote area application to fulfill the consumer demand. The natural topography of hilly running almost passes through the entire length of the country and abundant numbers of streams flowing to foothills increased the potential of application the small hydropower system (Hoskin et. al., 2013). To access the suitability of a potential site for a hydropower or small hydropower, feasibility study and statistical analysis in term of hydrology of the sites needs to be