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Implementation of a Data Logging System for a Small Scale Hydrokinetic Turbine

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Implementation of a Data Logging System for a Small Scale Hydrokinetic Turbine

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

……………………………………

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ABSTRACT

A suitable data logger is needed for data collection to demonstrate the practicality of Hydrokinetic Turbine (HKT) in a rural area of Sarawak application. HKT is a technology that extracts kinetic energy from river currents of almost zero elevation. Currently, commercial data loggers are embedded with features that may not be usable for specific applications of the system. Additionally, they use excessive amounts of energy and are incompatible with certain transducers. Conventionally, Turbem software has been used for the HKT's numerical simulations. However, estimations of electrical power are usually higher than the experimental values obtained, which causes some difficulty in determining the right range of transducers. In this study, to cater to the problem, a prediction graph was produced by the combination of the BEM theory and laboratory experiments. The data logger was implemented with an automatic data-file creation capability, the energy consumption of which would be very low, and it would be easily customizable. Transducers such as a voltage divider showed 0.7% of error, and a current transducer performed at 5%. Whereas a propeller type current meter and rotational speed meter performed at 1% of inaccuracy. The data logger demonstrated an acceptable accuracy and behavior of the logging performance test. The real time operation of the data logger was also verified in a field test. The results showed that the terminal voltage suffered ±2% of error, while the output current, rotational speed of generator, river velocity and output power showed about ±4%, ±21%, ±16% and ±5% of error, respectively. Therefore, the ranges of the data logger's transducers are considered within the HKT system nominal and operational values, except the range of the current transducer. These readings demonstrated that the data logger could fulfill its function.

Keywords: Hydrokinetic turbine energy, data logger, power production

Membina Sistem Pengumpulan Data bagi Kegunaan Tenaga Hidrokinetik Berskala Kecil

ABSTRAK

Tenaga Hidrokinetik (HKT) merupakan satu teknologi tenaga hijau. HKT mengekstrak tenaga kinetik daripada aliran air sungai yang memiliki kecerunan menghampiri sifar. Bagi membuktikan bahawa HKT adalah penyelesaian praktik untuk kegunaan elektrik luar bandar, alat pencatat data yang bersesuaian diperlukan bagi membuat kutipan data. Masa kini, data logger komersial dimuatkan dengan ciri-ciri yang kurang bermanafaat untuk kegunaan sistem HKT, mengeksploitasi banyak tenaga dan kurang sesuai dengan sesetengah transduser. Kebiasaannya, perisian Turbem digunakan untuk simulasi bagi mengenalpasti kuasa keluaran pada sistem agar julat pada transduser dapat dikenalpasti. Namun, perisisan tersebut selalunya menghasilkan nilai kuasa keluaran yang jauh lebih besar daripada kaedah eksperimen. Maka penganggaran kuasa keluaran dibuat dengan menggabungkan teori BEM dan eksperimentasi. Alat pencatat data yang dihasilkan memiliki kebolehan membentuk fail data secara otomatik dan kurang penggunaan tenaga. Ia juga melalui kalibrasi dan diuji, di mana transduser seperti pembahagian voltan mengalami 0.7% kesilapan, transduser arus 5%, meter pengukur arus sungai dan meter pengukur kelajuan putaran masing-masing 1% ketidaktepatan. Keadaan ini menunjukkan bahawa alat pencatat data memiliki ketepatan yang berpatutan. Alat pencatat data juga diuji di lapangan sebenar dan didapati julat bagi voltan terminal adalah ±2% ketidaktepatan, manakala arus keluaran, laju putaran generator, arus sungai dan kuasa keluaran adalah ±4%, ±21%, ±16% dan ±5% ketidaktepatan. Ini menunjukkan ia memenuhi fungsi dan kebolehpercayaan.

Kata kunci: *Tenaga hidrokinetik, alat pencatat data, kuasa keluaran*

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LIST OF ABBREVIATIONS

AC	Alternating Current
ADC	Analogue to Digital Converter
BEM	Blade Element Method
DC	Direct Current
ELC	Electronics Load Controller
HAHT	Horizontal Axis Hydrokinetic Turbine
HKT	Hydrokinetic Turbine
IC	Integrated Circuit
I^2C	Inter-Integrated Circuit
LED	Light Emitting Diode
MPPT	Maximum Point Power Tracking
PMDC	Permanent Magnet Direct Current
QFD	Quality Function Deployment
RTC	Real Time Clock
SD	Secure Digital
SDHC	Secure Digital High Capacity
SPI	Serial Peripheral Interface
TSR	Tip-speed Ratio
TTL	Transistor to Transistor Logic

CHAPTER 1

INTRODUCTION

1.1 Study Background

Sarawak is in East Malaysia and has a large geographical area of about 124,450 km^2 and a population of almost 2.79 million people (Department of Statistics Malaysia Official Portal, 2019). More than 48% of Sarawak's people live in rural areas, involving 6,235 villages and 200,000 households. The electrification progress for Sarawak is at about 90.4% coverage, which still leaves around 1,919 villages or approximately 41,004 households in the off grid connected power supply. 74.6% of rural communities consist of less than 50 families. These households are separated by a 5-10 km distance, and are widely dispersed all over the region. (Shiun, 2016).

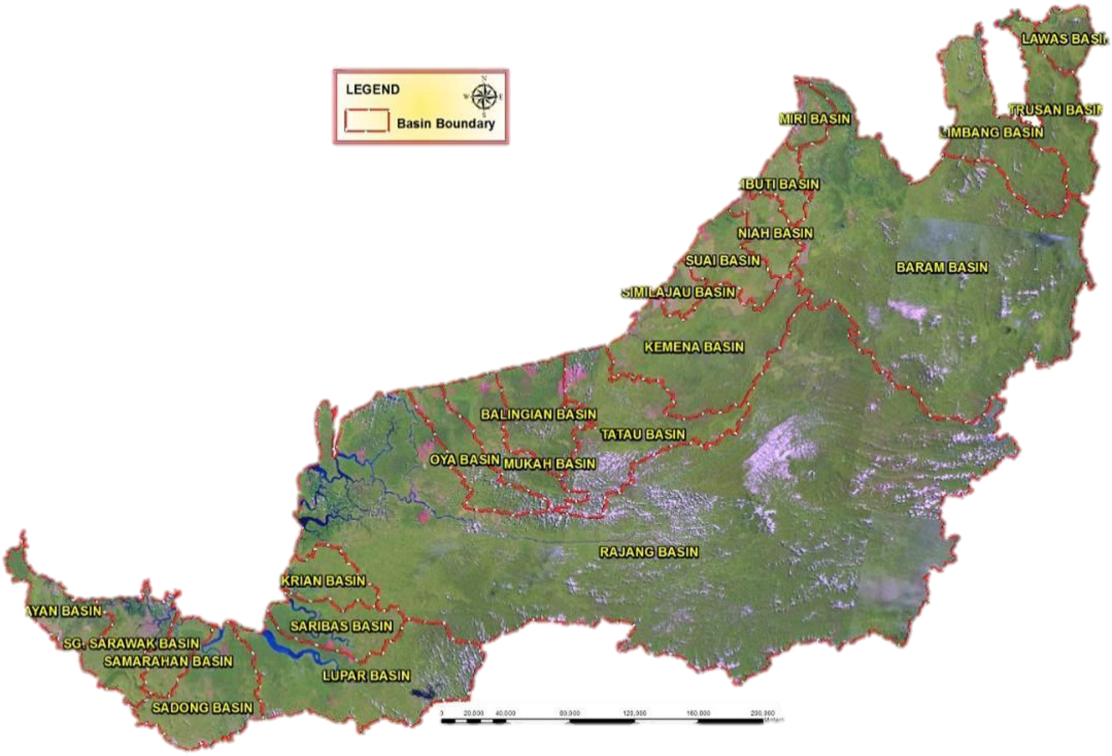

Figure 1.1: Sarawak Major River, copyright of Department of Irrigation & Drainage Sarawak

Sarawak is blessed with high rainfall, with an average of 3,300 mm and 4,600 mm annually, which brings regular streaming rivers that can be utilized to produce electricity. Figure 1.1 shows major rivers in Sarawak. It has more than 55 lowland rivers with a combined length of more than 3,300 km (Sarawak Goverment, 2018). Lowland rivers are categorized as having zero or little elevation or less than 3 m of static head. *Batang* Rajang for example, is the largest river in Malaysia, where the water depth is around 4.1 m and velocity, up to 1.1 m/s. This forms streams and its tributaries which are around 0.2 m – 1.3 m in depth, with a flow speed from 0.05 m/s – 1.35 m/s (Ling et al., 2017). Moreover, most of the rural communities live in *rumah panjang* or long houses that are situated by a river for water supply, food, and transportation. Thus, by manipulating Sarawak's geography and meteorology advantages, hydrokinetic turbine (HKT) energy should be considered as a potential solution for the off-grid rural community's electric power supply applications.

HKT is a potential technology that can be used to extract kinetic energy from river currents of almost zero elevation, also known as lowland rivers (Izadyar, Ong, Chong, Mojumder, & Leong, 2016).

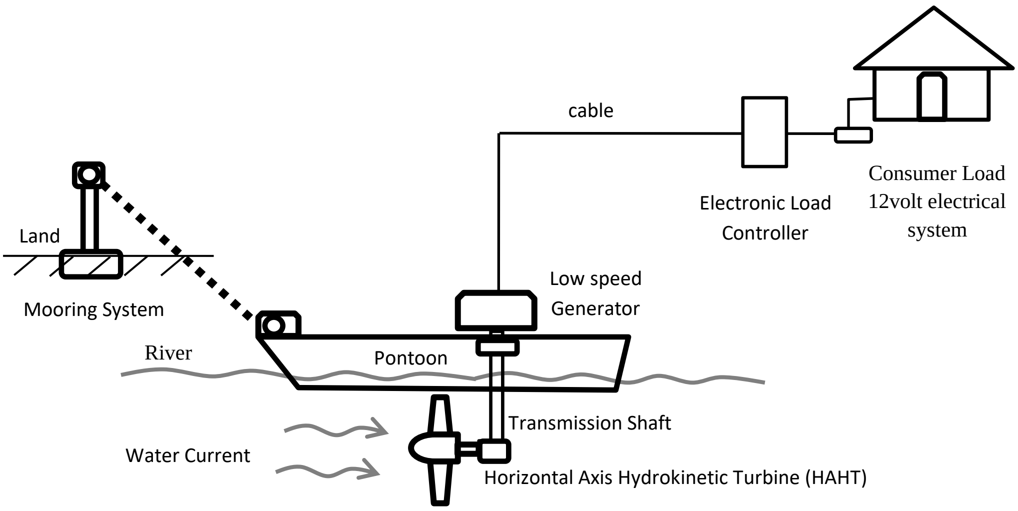

Figure 1.2: The concept of Hydrokinetic Turbine System

The flowing rivers which have insufficient elevation for conventional micro-hydropower energy, but have ample kinetic energy may offer many potential sites for HKT to produce electricity (Vermaak, Kusakana, & Koko, 2014). The concept of a hydrokinetic turbine system is shown in Figure 1.2. The system requires no civil work, nor any pipe work, and a small conducive area. This system is very simple with minimum equipment needed for installation and can be easily moved from one stream to another if required (Anyi, 2013). A small scale HKT has the capacity to produce electricity of around 15 W to 1,000 W of power (Shiun, 2016), and the operation can practically be fabricated (Riglin, 2016) according to the number of households, which can maintained and repaired by the rural community. Thus, such a simple-to-operate concept based on standardized or modularized designs of technology is needed for rural communities.

However, there are limited or no recorded studies to justify the potential of HKT for electrification in the rural areas of Sarawak. A large data collection of the system's electricity power production is compulsory for technical analysis. Besides, statistical data of the HKT system can be used to gain attention and trust from the stakeholders that might be interested in the development of the system. Based on statistics, intelligent judgments and decisions can be derived in the presence of uncertainty and variation. Therefore, to provide statistics or technical analyses, a suitable data logger plays an important role as a tool to perform proper and extensive data collection.

The degree of utilization, also known as the capacity factor (Lalander, 2010), is a study to estimate the competitiveness of different renewable energy sources that have been applied, in this case, in the rural electrification of Sarawak (Abdullah et al., 2010). The study is required to have at least a one-year-series of power production and optimal operating data.

Relying on multi meters and current clampers to measure electric energy production is inconvenient when the data collection is carried out for a long period of time (Riglin & Schleicher, 2016). Besides, it is also a tedious job and requires manpower. Consequently, the length of the recorded series of data will be limited. Thus, an experimental investigation of the operation and performance study of HKT may not be comprehensive. All the recorded data will not be timely synchronized (Kjellin, 2012). Even though this research does not focus on estimating the competitiveness of different renewable energy sources, it shows that a data logger is an important tool to record a long series of data, perform measurement tasks accurately and achieve timely synchronization.

A data logger should be built based on Quality Function Deployment (QFD) and should be specific for an HKT system in rural areas. Thus, the proposed data logger should consider factors such as the crucial features in the HKT system for a small number of households, off-grid connections that use 12 V electrical systems, a harsh rainforest environment and the condition of lowland rivers. Therefore, modifying a commercial data logger to suit these needs will prove more difficult than fabricating a new one. A fabricated data logger could be easily customized according to the requirements, would be cost effective, be more practical and perform reliable data collection.

1.2 Problem Statement

Horizontal Axis Hydrokinetic Turbine (HAHT) is likely to become a technically practical solution in off-grid small applications (Anyi & Kirke, 2010). In many research studies from around the world relating to hydrokinetic energy, the focus has been mainly on the development of HAHT blades (Azrulhisham, 2018; Chica, Torres, & Arbeláez, 2018; Tian et al., 2018), while only a few studies have looked into the operations and performance study of an overall system (Riglin & Schleicher, 2016). Majority of the researchers have focused on the potential of a studied site (Aling, Atan, Fahies, & Ismail, 2018; Saupi et al., 2018; Riglin, 2016; Döll, Fiedler, & Zhang, 2009) and one study about collecting resource data for a selected rural area in Sarawak (Saupi et al., 2018). However, there is limited literature that justifies the potential of HKT for electrification in rural areas of Sarawak. Thus, it can be said that an estimated power production and optimal operation study has not been conducted yet. Estimated power production and optimal operation study provides crucial information in determining the range of the data logger's transducers.

In conventional HKT systems, a software and simulation design tool such as Turbem and Computational Fluid Dynamics (CFD) are used for the numerical simulation of the system. The software utilizes the Blade Element Momentum (BEM) theory. However, the software estimation is usually higher than experimental power or output speed, and hence it tends to overestimate the operating point where the maximum power is extracted (Tian et al., 2018; Izadyar et al., 2016). The overestimation of the operating point occurs because mechanical friction and misalignment effects are not included in the BEM model used by the software. Besides the software and simulation tools, an HAHT is usually tested in the towing tank or by recirculating current flume facilities. The aim of this test is to identify the performance curves of the turbine and to obtain the rotational speed of the rotor in relation to flow velocity (Murray et al., 2018). However, these facilities are not yet available in local universities and industrial research centers. Therefore, an alternative experimental design is needed to cater the gap between numerical simulations and the limited facilities in order to perform such an experiment, so that the HKT estimated power production and optimal operation value could be determined.

Several commercial data loggers only cover general parameters (Onset Computer Corporation, 2015; Fuentes, Vivar, Burgos, Aguilera, & Vacas, 2014; Siew, Wong, Tan, Yoong, & Kin Teo, 2012). Sometimes, there are some parameters embedded together with the standard data logger which are not related with specific technology (Pattanaik, Leo, Narasimha Rao, & Jalihal, 2017; Filizola, Melo, Armijos, & McGlynn, 2015); like a built-in temperature sensor which may not be entirely usable for certain applications. In HKT systems, a tool is needed to measure the resource of kinetic energy of the flowing river. Most of the research works refer to an Acoustic Doppler Current Profiler (ADCP) (Ling et al., 2017; Yuen, Apelfröjd, & Leijon, 2013). However, the output signals of an ADCP or a well-established propeller type current meter are usually incompatible with the commercial data logger. They always come with manufacture protected layout-designs which are not authorize for commercial uses (Shen, 2013) and do not provide a standardized signal output. Moreover, a researcher (Saupi et al., 2018) claimed that, while ADCP is accurate, the price is very expensive and it needs to be handled by relevant expertise. A study had been conducted by the researcher to estimate the resource data at *Batang* Balleh; it found that the comparison between Surface Floating Method (SFM) and ADPC is not significant. Although the ADCP is based on Doppler technology that allows for faster sampling and measurement of discharge and downstream/upstream weir characterizations, these extra features are not compulsory (Schubauer & Mason, 1937) to determine the optimal operational value in a hydrokinetic turbine. Consequently these features may not be usable for specific needs or applications, and may result in unnecessarily expensive setups, and may thus increase the cost of research (Fuentes et al., 2014). A data logger device and its transducers usually account for about 10% to 40% of the system’s overall cost.