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Faculty of Engineering

DESIGN AND DEVELOPMENT OF ENERGY HARVESTING SYSTEM FROM USELESS WATER AT AN URBAN SCALE

Gabriel Koh Cheo Jun

Bachelor of Engineering

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DESIGN AND DEVELOPMENT OF ENERGY HARVESTING SYSTEM FROM USELESS WATER AT AN URBAN SCALE

GABRIEL KOH CHEO JUN

A dissertation submitted in partial fulfilment

Of the requirement for the degree of

Bachelor of Engineering

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ABSTRACT

This project discusses the design and development of a energy harvesting system at the urban scale that can provide sufficient energy to all residents of Malaysia while also making use of the country's water resources. The system is intended to be implemented in the urban area. This control system is based on four distinct sensors: an ultrasonic sensor, a water flow sensor, a voltage sensor, and a current sensor. Each of these sensors monitors a different variable. The Arduino MEGA2560 board is the primary control unit or microcontroller, and the ESP8266 Wi-Fi module is responsible for the communication protocol. Users can monitor the minuscule hydropower harvesting equipment using the Internet of things (IoT).

These systems are easy to operate and can be monitored using an application on a mobile device. This project uses a harvesting system based on the Internet of Things (IoT), and the hydropower harvesting energy system can be monitored using mobile phones with Internet connectivity. The system also includes a component that, when implemented, will improve the hydropower device. Users can monitor and observe the operation of the equipment in three primary areas through mobile applications: the water flow rate, the voltage, and the current generated. The residents of the hamlet receive a warning notification on their smartphones if the water level reaches a point that could be considered hazardous. Users receive a warning from this notification, which helps to prevent flooding and saves lives. The portability, small size, low price, and ease of assembly of this micro hydropower energy harvesting system are among its most significant advantages. Additionally, it lowers emissions of greenhouse gases while simultaneously providing clean energy. As a direct consequence of this, every objective has been accomplished.

ABSTRAK

Projek ini membincangkan reka bentuk dan pembangunan sistem tenaga penuaian kuasa hidro mikro pada skala bandar yang boleh menawarkan tenaga yang mencukupi kepada semua penduduk Malaysia di samping memanfaatkan sumber air negara. Sistem kawalan ini dibina di sekitar empat penderia berbeza: penderia ultrasonik, penderia aliran air, penderia voltan dan penderia arus. Unit kawalan utama atau mikropengawal ialah papan Arduino MEGA2560, dan protokol komunikasi ialah modul Wi-Fi ESP8266. Pengguna boleh menggunakan internet untuk memantau peralatan tenaga penuaian kuasa hidro (IOT) yang kecil.

Sistem ini mudah dikendalikan dan mungkin dipantau menggunakan aplikasi telefon pintar. Dalam projek ini, sistem penuaian berasaskan IoT digunakan, dan sistem tenaga penuaian kuasa hidro boleh dipantau melalui telefon mudah alih dengan sambungan Internet. Di samping itu, ciri yang menambah baik peranti kuasa hidro diperkenalkan kepada sistem. Aplikasi mudah alih membolehkan pengguna memantau dan memerhati operasi peralatan dalam tiga bidang utama: kadar aliran air, voltan dan arus yang dijana. Apabila paras air naik ke paras berbahaya, mesej penggera dihantar ke telefon pintar untuk memberi amaran kepada penduduk di dusun itu. Pemberitahuan ini memberi amaran kepada pengguna, mencegah banjir dan menyelamatkan nyawa. Faedah utama sistem tenaga penuaian kuasa hidro mikro ini ialah ia mudah alih, kecil, kos rendah dan mudah untuk disediakan. Ia juga membekalkan tenaga bersih dan mengurangkan pelepasan gas rumah hijau. Hasilnya, semua objektif tercapai.

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LIST OF ABBREVIATIONS

AST	-	Archimedes Screw Turbine
DC	-	Direct Current
EPS	-	Electrical Power System
IG	-	Inductor Generator
IoT	-	Internet of Things
RE	-	Renewable Energy
Di	-	Inner Diameter
Do	-	Outer Diameter
L	-	Total Length of the AST
β	-	Inclination Angle of the AST
N	-	Number of Helical Planed Surface
S	-	Screw Pitch
f	-	Full Height of the Bucket
hu	-	Upper Inlet Water Level
hL	-	Lower Inlet Water Level

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CHAPTER 1

INTRODUCTION

1.1 Background

Humans are developing a global civilization since our earth cannot provide their energy needs. Access to clean energy enhances people's health, the standard of living, and economic, social, and political chances. To meet the energy demands of future generations, returning to renewable energy sources is a beautiful method for decreasing climate change[1]. Human engagement in the natural ecosystem and life cycle has harmful repercussions. Thus, the earth is embroiled in hostile environmental transformations and climate conditions that imperil future humanity. People from all areas of life are inventing and using clean, renewable energy sources because they know the consequences of burning fossil fuels. These energy sources include geothermal Energy, Tidal Energy, hydroelectric Energy, wave energy, solar photovoltaic energy, thermal energy, biomass, and biofuel. Due to their sophisticated technological capabilities and widespread economic acceptability, solar and hydropower have risen to the top of this list of potential energy sources [2]. Renewable energy originates from natural sources that replenish themselves fast. Sun and wind are never-ending sources. Renewable energy is abundant. To form, gas, coal, and oil require a very long time, up to hundreds of millions of years. When fossil fuels are used for energy, carbon dioxide is released. Energy-dependent economies are more likely to suffer economic losses from environmental degradation and unfavorable climatic conditions. Renewable Energy's clean energy benefits are disputed.

The global goal of providing access to clean energy is not yet within reach, despite significant advances in power generation technologies from wind and solar energies as well as intensive efforts by engineers and planners for overall improvements in worldwide electrification rates from 76% to 85% from 1990 to 2012 [3]. Hundreds of millions of households across several countries are currently without electricity. Like many other countries, Malaysia increasingly relies on generating energy from non-renewable sources.

Due to renewables' massive impact on economic and social well-being, authorities have become more concerned with constructing, sustaining, and upgrading renewable energy sources and innovating ways to protect them. A total of 29,000 MW of hydropower resources and potential are discovered. However, only 2,091 MW of it is being used [4]. The Malaysia Renewable Energy Roadmap (MyRER) report serves as a roadmap for the nation's transition to a low-carbon energy system for power distribution. The plan is concentrated on increasing the share of Malaysia's four primary renewable energy sources, which are solar, biomass, biogas, and hydropower, in its power delivery system, among other things [5]. Hydropower makes up 86% of Malaysia's renewable energy capacity and is responsible for most of the country's energy output, yet it only generates 15% of all energy. Even while just 20% of hydro's potential has been realized, more development will present difficulties in minimizing the environmental impact on the rivers, land, and even natural habitats of the nearby populations and wildlife [6]. Figure 1.1 shows the statistics for the Renewable energy consumption from the year 2012 to 2018.

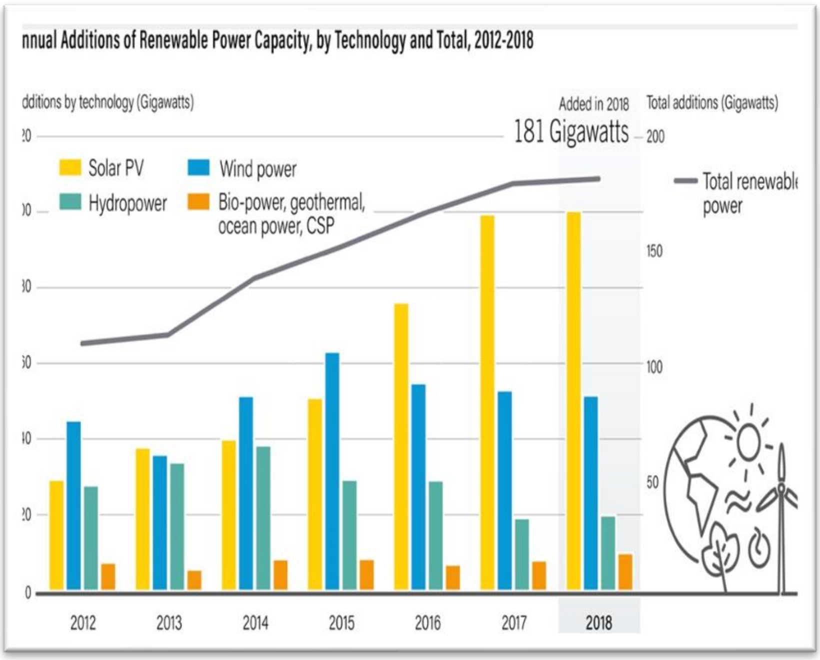

Figure 1.1 Renewable energy consumption from the year 2012 to 2018.

Malaysia has pioneered renewable energy since 1980. The Four Fuel Diversification Strategy included oil, gas, coal, and hydro. 1997's Kyoto Protocol and 1999's Fifth Fuel Policy. At COP 15, Malaysia pledged to reduce its carbon emissions by 40% and the share of GHG emissions in its GDP by 45% from 2005 to 2030 [7]. According to SCOPUS, the largest abstract and citation database, there is a notable increase in the number of research publications in Malaysia related to renewable energy production, as illustrated in figure 2 [8].

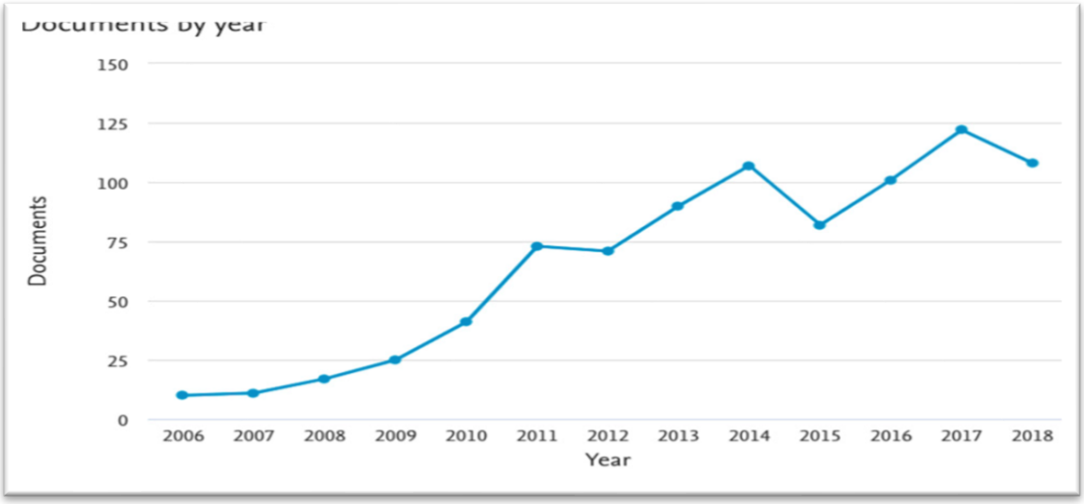

Figure 1.2 Research publications in Malaysia related to renewable energy

Hydroelectricity is generated from moving water, such as that found naturally in mountain streams and clear lakes throughout the winter and spring seasons. The use of falling water to turn turbines and generators is one method that may be utilized to produce electricity. Energy cannot be created nor destroyed, but it may transform into many other forms as it moves through the natural world. The production of electricity does not lead to an increase in total energy along its course. In its most basic form, the process includes the conversion of one kind of energy into another. This principle is also referred to as the law of the conservation of energy. Because the universe is an enclosed system, the total energy present has not altered.

Nevertheless, energy's manifestations are always evolving [9]. The flow of water is an essential component in the generation of power. Kinetic Energy describes moving energy, which is exactly what we have here. Through the rotation of turbine blades, the energy of moving water may be turned into mechanical or mechanical energy. Mechanical energy transforms into electrical energy when the energy is transferred from the turbine to the generator rotor. Hydropower is an abbreviation for hydroelectric power, which is the term used to refer to the generation of electricity by utilizing water as the primary resource. Hydroelectric power plants are the structures that are responsible for the generation of hydroelectric electricity. Even if some power plants are located on rivers, streams, and canals, dams are still essential to provide a constant water supply. Dams are constructed to collect and store water for future use in various activities, including agriculture, industrial, domestic use, and power generation. The reservoir acts like a battery in that it stores water and then distributes it to power plants when required.

The growing importance of hydropower in global power grids is responsible for this opportunity. For hydropower to take advantage of new possibilities and overcome new problems, it must evolve from its current state as the principal energy storage technology and grid flexibility. Any new hydropower innovation should improve these areas and reduce the costs of setup, operation, and upkeep. Hydropower will be able to react to changes in electrical power systems (EPSs), markets, and weather thanks to technological advancements. Hydro facilities have issues with variable renewable energy generation. New hydropower development and facility modifications and restorations must comply with stringent environmental requirements [10].

Investment in hydropower sources benefits the economy, society, and the country's bottom line. Micro hydropower harvesting devices can collect clean energy from excess head pressure in urban and household water pipes, making them suitable for renewable energy integration in cities. These micro hydropower harvesting devices could aid pipeline management and maintenance while providing clean, continuous electricity to towns, energy-intensive businesses, and agricultural irrigation districts. Hydroelectricity is dependable, efficient, versatile, low-cost, and capable of producing large amounts of energy. Micro hydropower collecting devices make renewable energy sources like wind and solar power more adaptable by balancing fluctuations in supply and demand. Because there are numerous hydropower plants, this innovation could be used in large-scale centralized and small-scale urban distributed energy models. The development of micro hydro turbines for urban use has made waterpower capture possible for onsite energy generation, domestic manufacturing, industrial, and agricultural industries.

1.2 Problem Statement

The rising demand for energy in urban areas is evidence of the fast urbanization that is taking place in Sarawak. The geologist believes that Sarawak is situated in an advantageous location concerning the tropical rainforest. This indicates that the state of Sarawak has been receiving significant precipitation during the past few years. Despite this, the opportunity must be taken advantage of within our urban size—the rainy season in Sarawak results in a significant loss of a free water source for the state.

In remote places, there is a lack of access to a reliable and cost-effective power source. Many locations, particularly rural or mountainous areas, lack power infrastructure, making it difficult for residents to meet their energy needs. Due to high installation costs, maintenance needs, and environmental issues, traditional power producing technologies are frequently impracticable.

The primary explanation is that collecting rainwater, also known as stormwater drainage, is rare in this area. The estimates provided by the specialists demonstrated that rainwater is lost each year, and efforts need to be made to convert this lost precipitation into energy conservation.

The energy harvesting system for rainwater stormwater drainage that is presented in this project will provide the appropriate solution for the energy conversion required to generate electricity from rainwater on an urban scale.

1.3 Objectives

The principal objective of this final year project research is to design and develop a hydropower harvesting system with the Internet of things-based technology (IoT) at the urban scale

Its measurable objectives are as follows:

- To investigate the optimization of the voltage and current generated by hydropower with IOT-based technology
- To design a mini hydropower harvesting system at an urban scale and utilize the water flow, especially during raining season.
- To test the performance of the mini hydropower harvesting system by monitoring the various load, such as lighting at the urban scale.

1.4 Project Scope

The project consists of three main parts, which can be categorized into the generating system, types of turbines, and the IoT technology-based product. This project's scope is segregated into two parts, software and the development of the hardware part, or the prototype.

1. **Modeling and simulation**

The control algorithm is simulated with the Arduino board to study the energy generated by the hydropower and maximize the energy converted from mechanical energy into electrical energy.

2. **Hardware Implementation**

Design and implement the mini hydropower harvesting system prototype by using the Arduino board as its central control unit, the ac generator to convert the mechanical power into electrical power, the turbine design to maximize the water flow, and finally, the power distribution into various loads.

3. **Overall testing of the developed system**

To determine the efficiency of the harvesting system by using hydropower on an urban scale, measure the power generated from the prototype, and reduce energy consumption.

1.5 Project Outline

The five chapters that make up this paper are an introduction, a literature review, a methodology, a result and discussion, and a conclusion and recommendation chapter. Detailed descriptions of each chapter can be found further down the page.

1.5.1 Chapter 1: General Framework

Chapter 1 included the introduction of renewable energy, the demand for the power needed, a description of hydropower, and the uses of hydropower at the urban scale. The objective, problem statement, scope, and project have consisted in chapter 1 as well.

1.5.2 Chapter 2: Literature Review

The project's first goal, which concerned the method of investigating how the system was used, is covered in detail in Chapter 2. This chapter also gives an overview of the studies associated with the project and required to complete it. In addition, a research void has been produced to compare the methodology, outcomes, and limitations based on the literature review.

1.5.3 Chapter 3: Methodology

The methodology section describes the approach and procedures that were used to carry out the study or research. The methods required to accomplish the second goal are presented in Chapter 3, which may be found here. This chapter will also discuss the model design, the type of turbine implements, and the Internet of Things (IoT) based product that will be used to monitor the micro hydropower harvesting system. Describe the characteristics of the study's subjects or sample. Describe the data collection procedures employed. Surveys, interviews, observations, experiments, archival research, and other data collection methods may be used. Describe the processes that were performed, any instruments or tools that were used, and how data was recorded. The analytical procedures or statistical approaches used to analyse the data that was obtained.

1.5.4 Chapter 4: Result and Discussion

In Chapter 4, the results of the project are discussed. One of these results is the finished design of a micro hydropower harvesting system that incorporates an IOT-based product. This chapter illustrates each finding that was gleaned from the project's prototype as well as its simulation. In other words, the purpose of the results section is to provide the findings of your research or analysis. It usually entails organising and presenting data or information in an understandable and clear manner.

1.5.5 Chapter 5: Conclusion and Recommendations

The overall project is ended in Chapter 5, which also provides a summary of the accomplishments made once the project was over. It also includes recommendations and suggestions for further research in hydropower harvesting systems. Recommendations are acts or ideas that are suggested based on what the analysis showed. It deal with the problems or chances that have been found and give advice on how to move forward. Recommendations should be useful, detailed, and possible, given the situation's resources and limitations. It is used to back up by the study or investigation's evidence or analysis.

Chapter 2

LITERATURE REVIEW

2.1 Technology Developments

In the research [11], the authors developed urban and building hydropower system hardware. Internal and external systems make up the prototype. The internal system, where only the generator protrudes from the conduit and the turbine is inside the pipe. The runner's external system is in a bypass conduit. Small turbines power off-grid water metering and control stations. These generators outperform wind turbines and solar panels due to their low water loss and constant output. These are difficult to operate and maintain (backup batteries required), polluting (gas-powered), and have fueling and maintenance issues. Many self-sufficient control units strategically placed across the water grid enable system health monitoring and management.

In water-scarce countries with aging infrastructure, spills and leaks are especially problematic. These technologies could extend renewable energy sources at an urban scale for a distributed energy model or work with other discontinuous renewable systems to provide massive amounts of renewable electric power at the building scale. In-pipe hydro systems can generate electricity regardless of latitude and location if water pipes have enough pressure. The research shows that in-pipe systems can generate and supply a lot of energy without the architectural integration and weather sensitivity of photovoltaic and wind systems. If the local water distribution network supports them, in-pipe systems are great. These devices provide renewable energy and control water flow and pressure in distribution networks. Any gravity-fed pipeline upstream of a pressure-transient zone can have one of these devices. They operate without pump back-pressure or speed adjustments in many flow conditions.

From the research [12], the authors investigated how turbine design might affect in-pipe energy extraction. This study examines the spherical, three, four, and five-bladed helical turbines. A working prototype of the turbines has been designed. SolidWorks helped 3D print six turbine designs. The authors optimized the blade number, angle of