Faculty of Electrical Technology and Engineering

DEVELOPMENT OF ENERGY GENERATION AND STORAGE USING DYNAMO FOR CRANE GAME

MICHELLE YAP HUI LIN

Bachelor of Electrical Engineering Technology with Honours

2024

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**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology with Honours**

Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this thesis entitled "DEVELOPMENT OF ENERGY GENERATION AND STORAGE USING DYNAMO FOR CRANE GAME" 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 the candidature of any other degree.

Signature	:	
Student Name	:	MICHELLE YAP HUI LIN
Date	:	3/1/2025

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature :

Supervisor Name : MADAM HALYANI BINTI MOHD YASSIM

Date : 3/1/2025

DEDICATION

This report is dedicated to my family, friends and lecturers who have helped me through thick and thin. They have been helping me emotionally and mentally by being there for me to complete this project. Without their guidance and encouragement, I would not have been able to complete this project smoothly.

I would also like to dedicate this project to my supervisors, who guided me through challenges and showed incredible patience with me in this project. I would like to show my gratitude for his willingness to share his knowledge and experience to help with this project.

Finally, this report is dedicated to those who believed in me and had faith in my abilities. Their continuous support had been part of this success.

ABSTRACT

People are encouraged to install solar PV as the power supply to power the household by implementing a programme called NEM by the SEDA that allows users to consume the energy generated first and the excess energy will be transferred to the grid. The excess energy price will be cut in the next monthly electricity bill. This programme helps to reduce the dependency on fossil fuels and to improve the environment. This research focuses on the creation and design of an alternative energy such as bicycle generator by using a dynamo that can generate power to supply low-powered appliances. This project aims to find a low-cost alternative energy source by converting mechanical energy to electrical energy. Therefore, the performance of the bicycle generator needs to be analysed. It is important to have alternative energy resources because there are times when renewable energy is unable to produce optimum power due to intermittency. For example, solar PV will not generate any power during the night-time or rainy season. Therefore, it is vital to have an alternative energy to overcome that situation instead of depending on fossil fuels. Fossil fuels is one of the major causes of the greenhouse effect and climate change due to the emission of carbon gas which causes the thinning of the ozone layer in the atmosphere. By using alternative energy resources, the emission of carbon gas can be reduced. Therefore, to achieve this, an alternative energy such as a bicycle generator is studied. It was found that it could generate a high power depending on the generator used and the speed of rotation of the bicycle wheel. The more the rotation of the wheel, the higher the voltage and current generated and thus, producing higher power. This can be achieved using a dynamo to convert the mechanical energy from the rotation of the wheel to electrical energy that produces an AC current. The current is converted into DC using a rectifier to power the claw machine that uses DC supply. To ensure a continuous flow of energy, a lead acid battery is used to store energy. In conclusion, it is possible to generate energy using a bicycle and dynamo to power low-powered appliances and to power a high-powered appliance, a different generator such as an alternator is used.

ABSTRAK

SEDA telah melaksanakan program NEM bagi mengalakkan masyarakat memasang PV solar sebagai bekalan kuasa untuk membekalkan tenaga kepada isi rumah dengan menggunakan tenaga yang dijana terlebih dahulu dan yang berlebihan akan dipindahkan ke grid. Lebihan harga tenaga akan dipotong dalam bil elektrik bulanan. Program ini membantu mengurangkan pergantungan kepada bahan api fosil dan menambah baik alam sekitar. Penyelidikan ini memberi tumpuan kepada penciptaan dan reka bentuk tenaga alternatif seperti penjana basikal dengan menggunakan dinamo untuk menjana kuasa bagi peralatan berkuasa rendah. Projek ini bertujuan untuk mencari sumber tenaga alternatif kos rendah dengan menukar tenaga mekanikal kepada tenaga elektrik. Oleh sebab itu, analisis prestasi dinamo penting untuk mengenalpastikan tenaga yang dijana mencukupi. Sumber tenaga alternatif penting untuk digunakan semasa tenaga boleh diperbaharui tidak dapat menghasilkan kuasa optimum. Sebagai contoh, PV solar tidak dapat menjana kuasa pada waktu malam atau musim hujan. Oleh itu, tenaga alternatif penting untuk mengatasi keadaan tersebut dan tidak bergantung kepada bahan api fosil sepenuhnya. Bahan api fosil merupakan salah satu punca utama kesan rumah hijau dan perubahan iklim akibat pelepasan gas karbon yang menyebabkan penipisan lapisan ozon di atmosfera. Penggunaan sumber tenaga alternatif dapat mengurangkan pelepasan gas karbon. Oleh itu, tenaga alternatif seperti penjana basikal dikaji. Hal ini kerana, penjana basikal dapat menjana kuasa yang tinggi bergantung kepada alat penjana yang digunakan dan kelajuan putaran roda basikal. Semakin banyak putaran roda, semakin tinggi voltan dan arus yang dihasilkan. Dengan itu, ia dapat menghasilkan kuasa yang lebih tinggi. Ini boleh dicapai dengan menggunakan dinamo untuk menukar tenaga mekanikal daripada putaran roda kepada tenaga elektrik yang menghasilkan arus ulang-alik. Arus tersebut ditukar kepada arus terus dengan menggunakan penerus untuk menggerakkan mesin cekau yang menggunakan bekalan arus terus. Untuk memastikan aliran tenaga yang berterusan, bateri asid plumbum digunakan untuk menyimpan tenaga. Kesimpulannya, basikal dapat menjana tenaga dengan menggunakan dinamo untuk menggerakkan perkakas berkuasa rendah dan untuk menggerakkan perkakas berkuasa tinggi, penjana yang berbeza seperti alternator digunakan.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Madam Halyani binti Mohd Yassin and co-supervisor, Sir Arman Hadi bin Azahar for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support through funding the component needed which enables me to accomplish the project. Not forgetting my fellow colleague, for the willingness of sharing his thoughts and ideas regarding the project.

My highest appreciation goes to my parents and family members for their love and prayer during the period of my study. An honourable mention also goes to my best friend for all the motivation and support that had encouraged me.

Finally, I would like to thank all the staffs at Universiti Teknikal Malaysia Melaka, fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

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LIST OF SYMBOLS

δ	-	Voltage angle
°C	-	Degree Celsius
$E_{consumption}$	-	Energy consumption
E_{PV}	-	Energy generated from PV
$Tariff$	-	Tariff
$P_{consumption}$	-	Price consumption
$E_{consumption}$	-	Energy consumption
P_{PV}	-	Price of energy produced by PV
E_{Bill}	-	Electricity monthly bill
E_{Import}	-	Net energy imported
$E_{Exported}$	-	Net energy exported
E_{net_total}	-	Total net energy
KeTSA	-	Kementerian Tenaga dan Sumber Asli
E_g	-	Induced emf
Z	-	Total number of conductors
P	-	Number of poles
ϕ	-	Flux per pole
A	-	Number of parallel paths in the armature
N	-	Armature speed in RPM
P	-	Power generated
I	-	Current generated
V	-	Voltage generated
P_{load}	-	Power generated by load
$P_{supplied}$	-	Power supplied to the load
$P_{generated}$	-	Power generated by the generator

LIST OF ABBREVIATIONS

V	-	Voltage
PV	-	Photovoltaic
NEM	-	Net energy metering
SEDA	-	Sustainable Energy Development Authority
AC	-	Alternating current
DC	-	Direct current
ESSs	-	Energy storage systems
SDG	-	Sustainable Development
BMI	-	Body mass index
ktoe	-	Kilotonnes of oil equivalent
emf	-	Electromotive force
UNDP	-	United Nations Development Programme
kWp	-	Kilowatt peak
MWp	-	Megawatt peak
TNB	-	Tenaga Nasional Berhad
RM	-	Ringgit Malaysia
kWh	-	Kilowatt hour
RE	-	Renewable energy
MW	-	Megawatt
GoMEn	-	Government Ministries and Entities
NOVA	-	Net Offset Virtual Aggregation
kW	-	KiloWatt
SMP	-	System Marginal Price
RPM	-	Revolution per minute
A	-	Ampere
NiMH	-	Nickel-metal hydride
W	-	Watt
Rp	-	Rupee
Wh	-	Watt hour
Nos	-	Number of items
W	-	Watt
LiPol	-	Lithium polymer
Ah	-	Ampere hour
MOSFET	-	Metal oxide semiconductor field effect transistor
CPU	-	Central processing unit
mA	-	Milliampere
LCD	-	Liquid crystal display
kg	-	Kilogramme
cm	-	centimetre
SPST	-	Single pole single throw
SPDT	-	Single pole double throw
DPST	-	Double pole single throw
DPDT	-	Double pole double throw
NO	-	Normally open

NC	-	Normally close
DoA	-	Days of autonomy
DoD	-	Depth of discharge
BBTM	-	Battery bank times multiplier

CHAPTER 1

INTRODUCTION

1.1 Background

What is clean energy? Clean energy is an energy that is produced from a source that does not release any gas pollutants such as carbon. This source is usually generated from renewable energy such as solar energy. It is important to make use of natural resources to gain energy to reduce the dependency on fossil fuels and coal to avoid pollution. One of the best examples of clean energy that is widely used is solar energy. In Malaysia, SEDA has introduced NEM to encourage users to use solar energy in their households whereby the excess energy generated by the solar panel will be exported to the grid to be credited to the electric bill thus, minimising the electric bill.

Solar energy is a sustainable and widely embraced renewable energy source that is derived from harnessing the sun's radiant energy. This is achieved through the use of photovoltaic cells, which convert sunlight into electrical power. However, the effectiveness and consistency of solar energy are influenced by its dependence on sunlight, making it vulnerable to variations caused by weather conditions and the time of day. In order to optimize the generation of solar energy, energy storage systems (ESSs) can be integrated to enhance capacity and reliability. These systems are designed to store surplus energy from the power grid and can be utilized during periods of limited sunlight, thereby ensuring a more consistent and reliable energy supply.

In addition, there is an alternative way to produce a clean energy such as using a generator. The generator generates energy by converting mechanical energy into electrical energy. This can be explained based on Faraday's law of electromagnetic induction whereby it is stated that the emf is induced when the magnetic flux changes. The electric generator consists of a rotor and stator. Examples of renewable energy that use the principle of the generator are wind energy and hydropower. Those renewable energies are able to generate energy due to the mechanical force exerted onto the turbine which causes the rotor to rotate and thus generate energy. For example, the strong wind exerts force on the turbine to generate energy and as for hydropower, it uses water to spin the turbine.

By integrating a generator into a bicycle, it can produce energy. The rotation of the pedal is able to generate energy as it exerts force onto the generator by connecting the rear wheel of the bicycle to the generator using a belt. Thus, it can easily generate energy with smaller costs compared to using renewable energy which has a high installation cost. It may not produce sufficient energy to supply the household, but it can be used for smaller appliances such as lamps, charging phones and others. It can also be used as an alternative energy source during the intermittence of renewable energy. Moreover, instead of wasting human energy, we can use it to generate electricity and increase physical activity by exercising. Hence, we will be able to maintain our health due to the increase in physical activity as it requires us to cycle to generate energy.

To raise awareness on the alternative energy resource, a crane game is integrated into the bicycle generator and consequently encourages people to exercise by incorporating fun into exercise. This is because the popularity of crane games has increased over the years. Crane machines which originated in the United States in the 1890s can now be found in other countries such as South Korea, Japan, Malaysia and others. Crane machines, also known as claw machines, have been popularised around the world resulting in the creation of an online claw machine whereby the claw machine is controlled via devices such as phone or computer by using an app or website such as Toreba. The prize obtained from the game will be shipped to the users. Therefore, by combining both bicycle generator and claw machine, users would be able to have fun and generate energy while exercising.

1.2 Addressing Global Warming Through Bicycle Generator Project

Based on Sustainable Development Goal 7 (SDG 7): Affordable and Clean Energy this project is able to make full use of human exercise and convert it into electricity. Thus, creating an alternative and cleaner power source. Therefore, reduce the reliance on the electrical grid, even if the electricity generated is on a smaller scale compared to renewable energy such as solar energy. However, this project demonstrates the potential for small-scale, renewable energy sources to contribute to overall energy needs, especially during periods of intermittency. Human-powered generation offers a more controllable source, especially when combined with battery storage, to make full use of the energy generated when there is unreliable grid access or during times of peak energy demand.

This project also correlates with Sustainable Development Goal 13 (SDG 13): Climate Action. This is because fossil fuels are used to generate electricity which becomes the contributor to greenhouse gas emissions. By using an alternative method like a bicycle generator, it reduces the impact of climate change as it does not release carbon gas. Besides that, it has a low initial investment compared to solar energy and wind energy as it needs a high cost of installation. Hence, it can be an alternative energy generator for developing countries or individuals who want to install an alternative energy resource that does not cost much. Even though it may not be suitable for large-scale generation, the project serves as a possibility of being an alternative resource.

1.3 Problem Statement

The renewable energy used such as solar energy and wind energy does not generate optimum energy due to intermittency. For example, solar energy cannot be generated during nighttime or when there is no sufficient sunlight due to weather conditions. As for wind energy, it depends on the speed of wind. If the weather conditions are sunny with inconsistent wind speed, it will affect the energy generated. Thus, those renewable energy is unable to generate maximum energy. Besides that, renewable energy has a high initial cost which makes it difficult to be used by everyone due to the tight budget. This makes them unable to decrease their dependency on fossil fuels. Thus, the usage of fossil fuel will increase due to increase in population and energy consumption over the year as shown in Figure 1.1.

An increased in obesity in Malaysia among the adolescent had been occurring for years. The percentage of overweight and obese in Malaysia is 50.1%. However, 14.8% from that percentage consists of children who are under 18 years old which [1]. In Malacca, there's about 32.3% of adolescents that are overweight and 24.8% are physically active in 2022 [2]. The data is shown in Figure 1.2 and Figure 1.3. This shows that the majority of adolescents are not physically active which leads to adolescents being obese. This will lead to various diseases such as high blood pressure, high blood cholesterol and stroke. Physical activities are important as it helps to get rid of toxic from our body. It also helps us to avoid from being obese by maintaining our body mass index BMI in a normal range which is within 18.4 to 25.

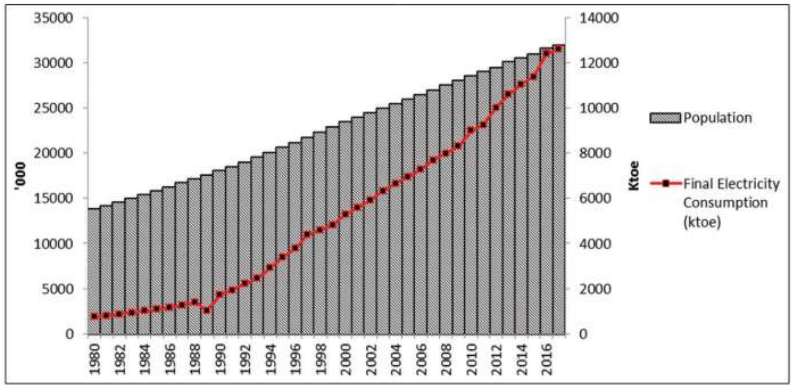

Figure 1.1The electricity consumption and population over the years [3]

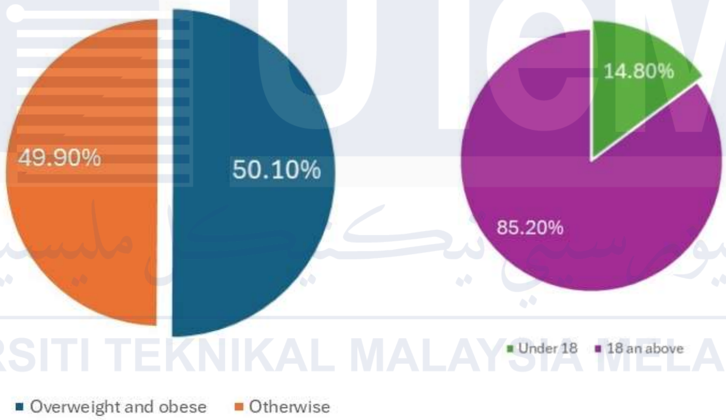

Figure 1.2The percentage of overweight and obese for under 18 years old in Malaysia

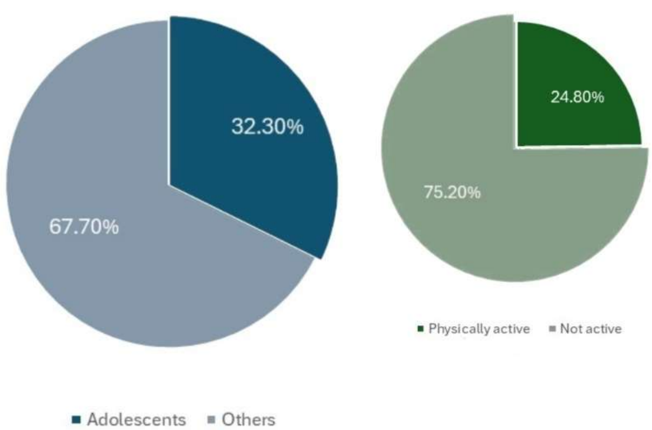

Figure 1.3The percentage of adolescents and physically not active in Malacca

1.4 Project Objective

The main aim of this project is to propose a way to encourage adolescents to exercise and to overcome the intermittence of renewable energy which reduces the reliability and efficiency of renewable energy by having alternative energy resources. Specifically, the objectives are as follows:

a) To design a bicycle generator that supplies energy to power a low powered load such as the crane machine to incorporate fun into exercising. Due to having such low percentage of adolescents that are physically active, a fun exercise activity is designed to attract more adolescents to be more active.

b) To generate an energy using bicycle by using the principle of electromagnetic induction whereby, when the magnetic flux is changed, an emf is induced. The bicycle generator can be used as a substitution of energy source when renewable energy generates low energy during intermittency.

c) To analyse the performance of the bicycle generator based on charging rate and factors affecting the energy generated to produce an optimum energy based on the voltage, current and power generated.

1.5 Scope of Project

The scope of this project are as follows:

a) The project can be placed at a recreational area such as playground, park, picnic area or any sheltered place.

b) Being able to supply energy to appliances that uses low power.

c) A simple crane machine game that uses one axis movement.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Renewable energy plays major role in in providing clean energy to minimise the negative impact on the environment such as global warming, greenhouse effect and climate change. Moreover, the increased of energy demand causes the depletion of fossil fuels which is the main resources for a lot of places. It was found that the production rate of the source is sufficient for another 41.8 years [4]. In Malaysia, the dependency of fossil fuels which causes the need to explore an alternative energy resource such as wind energy, solar energy and other renewable energy resources. In addition, the usage of fossil fuels as the main resource leads to climate change as the burning of fossil fuels causes greenhouse gas emissions [4].

Due to the urgency of finding a sustainable energy resources solution, an innovative approach is being explored such that the use of generators is used to generate energy by converting mechanical energy into electrical energy. One of the examples of this principle is wind energy. Therefore, by applying the principle of work of wind energy into bicycle generators, energy can be generated by converting the mechanical energy from the pedaling into electrical energy and thus producing clean energy that is carbon free. Furthermore, not only it can generate energy but also promote physical exercise. Subsequently, it encourages a healthier lifestyle and increases physical activity.

Incorporating fun elements into the energy solution can be highly effective as it can encourage individuals to be more active and generate energy for personal use. Therefore, crane game mechanism is used for this project. To operate the crane game, it requires generation of energy from the bicycle by pedaling. That way individuals will be rewarded with playtime for their effort to generate energy. The individual will also have a pleasant exercising experience as it incorporates fun into generating energy and physical activity which causes them to be more inclined to exercise frequently. Additionally, it educates people on energy generation and sustainability.

2.2 Understanding [Global/Current Issue] in the Literature

Sustainable Development Goal 7 (SDG 7): Affordable and Clean Energy aims to provide a carbon-free and high efficiency in generating energy. Based on UNDP, to achieve the goal, it is important to invest in renewable resources to raise energy production by 2030 [5]. This is because the usage of fossil fuels releases carbon gases which can be observed in Malaysia as it is ranked as the world's highest emitter of greenhouse gases. Furthermore, the carbon dioxide emission in Malaysia has risen from the 1980s and hence, the emission of greenhouse gases has an average compounded growth rate of 7.9 percent from 1990 to 2006 [4]. Thus, it is encouraging to use an alternative energy to reduce the release of carbon gases.

Sustainable Development Goal 13 (SDG 13): Climate Action is important as the world is facing climate change and global warming. It was stated previously that Malaysia is one of the main contributors to the emission of carbon gases which leads to climate change and global warming. Climate change has the potential to affect human health such as heatstroke due to the increase in temperature. For example, the average temperature increase in Peninsular Malaysia and East Malaysia has risen from 0.5°C to 1.5°C and from 0.5°C to 1.0°C respectively [6]. The rise in temperature will cause an increase in wildfires and consequently cause respiratory illnesses due to the air quality declines.

2.3 Net Energy Metering (NEM)

NEM is a renewable energy policy that prioritise the energy produced from the solar PV system to be consumed first. That way consumers are able to produce their own electricity for personal consumption. This scheme is suitable for domestic, commercial and industrial uses and each of the premises has its own permissible capacity which is 12kWp for single phase and 72 kWp for three-phase system for domestic customers. As for commercial customers and industrial customers the capacity is 1 MWp [7]. When the solar PV system produces more energy than needed, the excess energy is exported to the TNB. The exported energy will be paid depending on the cost per kWh unit.

The solar photovoltaic (PV) system harnesses sunlight and converts it into electrical energy in the form of direct current (DC). This DC electricity is then converted into alternating current (AC) using an inverter, making it suitable for consumption by household or commercial appliances. The inverter plays a crucial role in this process as it not only facilitates the conversion of DC to AC but also monitors and logs important energy data which is then transmitted to cloud storage. In scenarios where the energy generated by the solar PV system is insufficient to meet consumption needs, consumers rely on energy imported from the grid to supplement their requirements. Based on the exported energy which is the energy generated by the solar PV and the imported energy, it will affect the monthly electric bill as it flows through the meter to be calculated according to the tariff.

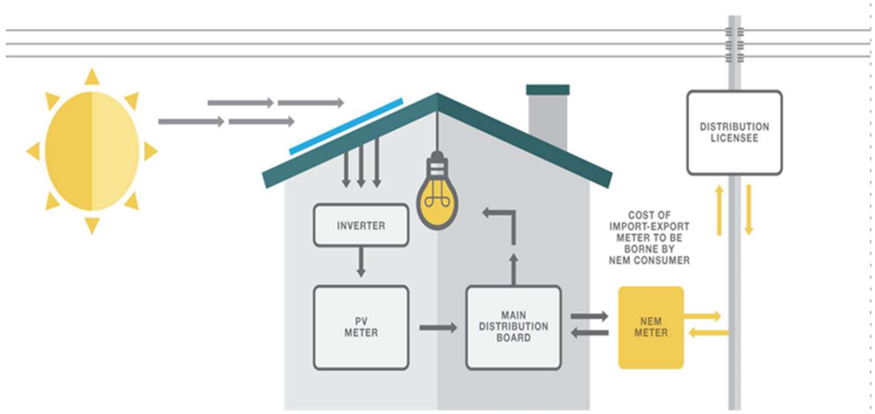

Figure 2.1The concept of NEM [7]

2.3.1 NEM 1.0

In NEM 1.0, the energy exported by the solar PV system will be credited in the next billing at a displaced cost of 0.31 RM/kWh unit [8]. In this scheme, the rate depends on the consumption of energy. This is because it is based on the current displaced that is much lower than regulated power retail tariff [9]. As the rate increases when the consumption of energy increases. There is no service tax applied to her first 600 kWh but 1.6% RE fund applied to the total of electricity used. Therefore, NEM 1.0 is suitable for low energy consumption such as lower than 200 units due to the lower rate cost compared to the higher rate for high energy consumption.

The monthly billing depends on the total energy consumption, $E_{consumption}$, total energy produced by the solar PV system, E_{PV}, the displaced cost, DC and the electricity tariff, *Tariff*. For example, to calculate the monthly bill for domestic users, Tariff A is used and the tariff used for different premises will be different. The price of consumption ($P_{consumption}$) is first calculated is the product of $E_{consumption}$ and Tariff as shown in Equation 1. The price of energy produced (P_{PV}) is then calculated by multiplying E_{PV} with DC based on

Equation 2. Once $P_{consumption}$ and P_{PV} is obtained, the difference between those values will be calculated using Equation 3 to calculate monthly bill, E_{Bill} [10].

Equation 1

$$P_{consumption} = E_{consumption} \times Tariff \quad ...(1)$$

Equation 2

$$P_{PV} = E_{PV} \times DC \quad ...(2)$$

Equation 3

$$E_{Bill} = P_{consumption} - P_{PV} \quad ...(3)$$

Table 2.1 Domestic Tariff

Tariff A – Domestic Tariff	Unit price (cent/kWh)
For the first 200 kWh (1 – 200 kWh) per month	21.80
For the next 100 kWh (201 – 300 kWh) per month	33.40
For the next 300 kWh (301 – 600 kWh) per month	51.60
For the next 300 kWh (601 – 900 kWh) per month	54.60
For the next kWh (901 kWh onwards) per month	57.10

2.3.2 NEM 2.0

NEM 2.0 was implemented as an improvement for NEM 1.0 as it consists of advantages. However, this scheme is specifically for consumers in Peninsular Malaysia that registered with TNB [10]. In this scheme, 500 MW distribution is reserved and is split into domestic and non-domestic [9]. The exported bill calculated uses the same tariff as the tariff used in NEM 1.0. However, it does not use the tariff the same way as it did previously because in NEM 2.0 it is used in a reverse order. This makes the exported energy bill have a higher rate than the previous scheme when a higher energy consumption is used.

The calculation used for NEM 2.0 is much simpler compared to the calculation used in NEM 1.0. The monthly electricity bill is dependent on the net energy imported, E_{Import} and exported, $E_{Exported}$ at one-to-one basis. It still uses the same tariff as there has been no changes in the tariff for the past years. The net total, E_{net_total} is calculated by finding the difference between $E_{Imported}$ and $E_{Exported}$ to and from the grid based on Equation 4. Once the E_{net_total} is obtained, the electricity bill, E_{Bill} can be calculated by multiplying E_{Total} with the *Tariff* as shown in Equation 5. Thus, it is proven that the electricity bill with NEM 2.0 scheme is much lower compared to the previous [10].

Equation 4

$$E_{net\_total} = E_{Exported} - E_{Imported} \qquad \ldots(4)$$

Equation 5

$$E_{Bill} = E_{net\_total} \times Tariff \qquad \ldots(5)$$

2.3.3 NEM 3.0

NEM 3.0 is introduced due to the high demand for solar power from the industry and also aiming to increase its use. The Energy and Natural Resources Minister introduced NEM 3.0 through KeTSA on 29th December 2020. This programme offers more chances for consumers to install solar panels and thus saving their money on their electricity bill. NEM 3.0 is divided into 3 programme which are NEM Rakyat Programme, NEM GoMEn Programme (Government Ministries and Entities) and NOVA Programme (Net Offset Virtual Aggregation). An additional of quota has been allocated to NEM Rakyat and

NOVAW which were 100 MW and 300 MW respectively. From 2021 to 2024, NEM 3.0 will be in effect with a total quota allocation of 1550 MW [11].

2.3.3.1 NEM Rakyat Programme

This programme is specifically for Domestic Consumers whereby the energy generated by the solar PV will be consumed first, which is similar to the previous schemes and the excess energy that is not in use will be exported to the grid. The credit of the exported energy will offset the electricity bill on a one-on-one offset basis in 10 years of operation. Although the programmer prioritises using self-consumption, many consumers may be away during weekdays or holidays, leading to excess energy being sent back to the grid. Therefore, any credit earned from the exported energy will be carried over for up to a year. Those consumers who have applied on any previous solar programme are not eligible for this scheme. The premise of the consumer that apply this programme must not be use as a business [11]

2.3.3.2 NEM GoMEn

NEM GoMEn is somewhat similar to NEM Rakyat but purely for commercial purposes. Therefore, license is required to apply for this programme and therefore once the application of NEM is approved, consumer has to apply for a license. The capacity limit for solar PV installations is different NEM Rakyat. For commercial purposes, the maximum capacity is 1000 kW or less depending on the electricity service. The maximum capacity is capped at 75% of the highest recorded electricity demand during the past year if it is businesses with medium voltage service. However, when the service has yet reached a year, it will be based on the estimated demand. As for homes and businesses with low voltage service, the maximum capacity is capped at 60% of the fuse rating used for direct meter connections or 60% of the rating of the current transformers used in the meter [11].

2.3.3.3 NOVA

The NOVA programme also requires license similar to NEM GoMEn. NOVA is designed for solar energy to be used on-site wherever possible. This means that energy produced by the solar PV will be consumed by the premise first. However, there are situations where the energy generated by the solar PV is not fully used. This is due to the limitations of the building needs or seasonal changes in the electricity usage. Thus, the excess energy that cannot be used on-site will be exported to the grid based on the situation. However, the way the excess energy credited is slightly different as it is based on the Average SMP. The excess energy credited per month will be used to offset electricity bill for the next month [11].

2.4 Energy storage

As technology progresses, the demand for energy increases and thus causes an increase in the release of carbon due to the dependence of fossil fuels as the main resource. Energy storage systems (ESSs) plays a crucial role in improving the power grid efficiency and reliability. This is because ESSs is able to store energy and use it when needed such as during intermittency when using solar energy or win energy as the energy resource [12]. For example, the solar energy cannot be fully dependent due to the inconsistent efficiency and performance. Solar energy depends on the sunlight, time and the condition of the weather. When those conditions are not favourable, there will be no continuous energy from the solar PV. Therefore, to avoid the problem from occurring, energy storage is implemented [13].

In the energy storage system, it is important to maintain the functionality of the battery so that it reaches its normal life expectancy by monitoring the power flow regulation through the battery used [14]. Therefore, a charge controller is crucial and it is used in charging and discharging the battery for solar energy, wind energy and other resources [15]. To prevent the battery from overcharging, the reverse current is blocked to maintain the deep cycle of the battery properly fed. Controllers monitor the battery by preventing over-discharging and display the battery status. An example of a charge controller is a solar charge controller that regulates the flow of voltage and current generated by the PV panel to the battery [16].

2.5 Generator

Generator consists of two types which are AC generator (alternator) and DC generator that uses the principle of Faraday's law of electromagnetic induction whereby it predicts the interaction between magnetic field and electric circuits and produce electromotive force (emf). Both generators generate electricity using the conversion of mechanical energy to electrical energy. This can be explained using the Lenz's law of electromagnetic induction, electromagnetic force induced will generate current that induces a counter magnetic field which is against the magnetic field of the current. However, both AC generator and DC generator will produce a different type of current which are AC and DC respectively. The AC generator can be either in a single – phase generators or three - phase generators [17].

In the working principle of a DC generator, in accordance with Faraday's law of electromagnetic induction, a conductor placed within a variable magnetic field experiences an induced electromotive force (emf). Furthermore, Fleming's right-hand rule dictates that the direction of this induced current alters whenever the conductor's motion changes direction. Consider a clockwise-rotating armature with a conductor on the left side moving upwards. Once a half of rotation by the armature is completed, the conductor's motion direction reverses, becoming downward. Consequently, the current direction within each armature conductor also reverses. However, the use of a split-ring commutator ensures that the connections of the armature conductors are reversed synchronously with the current reversal. This mechanism facilitates the production of a unidirectional current at the terminals.

As for the AC generator or alternator, the rotation of the armature within the magnetic field's influence occurs along an axis perpendicular to the field lines. This motion induces continuous variation in the armature's magnetic flux linkage. Thus, an electric current is induced within the circuit encompassing the galvanometer, slip rings, and brushes. The deflection of the galvanometer in both positive and negative directions signify the presence of an alternating current. The application of Fleming's Right-Hand Rule allows for the determination of the induced current's direction. Hence, the changes of direction of the current in AC generator occur periodically producing AC electrical power while the current in DC generator only flows in one direction and produces DC electrical power.

2.5.1 Factors affecting the electromagnetic field (emf)

The emf induced, E_g by the generator depends on the total number of conductors, Z, number of poles, P, the flux per pole, ϕ, the number of parallel paths in the armature, A and the armature speed in RPM, N which is based on Equation 6 [18]. Thus, the emf depends on the speed of the armature because emf is directly proportional with armature speed. When armature speed increases, the generated emf increases. Reference [19] had carried out an experiment of using a stepper motor as DC generator. To prove the stepper motor is working as a generator, the relationship between the voltage generated and rotation of generator is studied. It was found that the stepper motor acts like a DC generator because the voltage generated increases when the rotation of generator increases [19].

Equation 6

$$E_g = \frac{PZ\phi N}{60A}$$

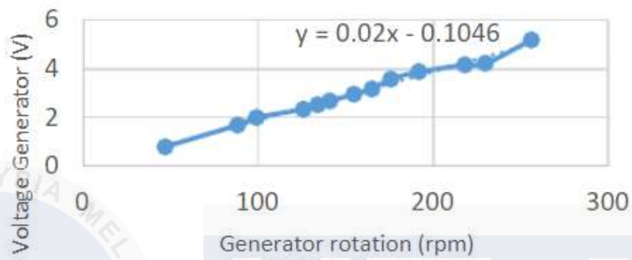

Figure 2.2The relationship between generator rotation and voltage generated [19]

Furthermore, since the emf increases, it will also affect the armature current flowing. Based on the ohm's law, when the emf increases, the armature current increases. Thus, armature current is directly proportional with the emf generated. Reference [20]. had carried out to investigate the effect of rotational speed on the generator. The experiment was carried out by increasing the speed of rotation from 6000 RPM to 10 000 RPM resulting in the armature current increasing from 14.4 A to 22.1 A. In the same experiment, it also shows an increase in terminal voltage when the speed of rotation of the generator increases from 39.6 V to 65.1 V [20].

Table 2.2 The relationship between terminal voltage and armature current [20]

Speed (RPM)	Terminal Voltage	Armature current
	Test data	Test data
6000	39.6 V	14.4 A
8000	53.7 V	18.5 A
10000	65.1 V	22.1 A

2.6 Bicycle generator

The use of pedal power to generate electricity has been studied. This is to provide a reliable alternative energy source for people in remote areas without access to the national power grid. Even though it is not a new concept, it hasn't yet been widely adopted commercially. This technology allows for human-powered electricity generation in a faster and more efficient way. Pedal-powered generators or bicycle generators can be used to operate various tools and machinery, including water pumps, agricultural hand tools, and even furniture-making equipment. Additionally, it can provide power or recharge electronic devices like laptops, phones, and even power grinders and water well pumps. For example, some countries, like India, have successfully implemented pedal-powered tools as part of their sustainable development initiatives [21]. This can be achieved by using either alternator, generator or dynamo.

2.6.1 Alternator

By using an alternator, the kinetic energy from pedaling is converted into rotational energy through a gear system that spins a flywheel. Reference [22] shows that the alternator is connected to the flywheel with a coupling belt as shown in Figure 2.3. This AC generator converts the rotational energy into electrical energy. In the principle of alternator, when a coil is rotated within a constant magnetic field, a voltage is induced at the coil's terminals which allows for the powering of a connected load. A voltage is induced with an alternating current when the coil rotates at a uniform speed within a consistent magnetic field. This is due to the changing position of the coil relative to the magnetic poles [23]. Thus, the induced voltage is directly influenced by the strength of the magnetic field and the rotational speed of the coil.

The generated power is stored in a charging circuit in a battery, eliminating the need for constant pedaling speed. Depending on the electrical load, the system can convert the stored DC voltage back into AC using an inverter. A step-up transformer is used to increase the voltage for powering appliances. Thus, it is easier to reach the desired rotational speed for efficient power generation. While the alternator's output varies with pedaling speed due to the alternator producing less power and lower frequency at low RPM and vice versa, this variation has minimal impact because the electricity is ultimately converted to DC and stored in the battery for later use [22].

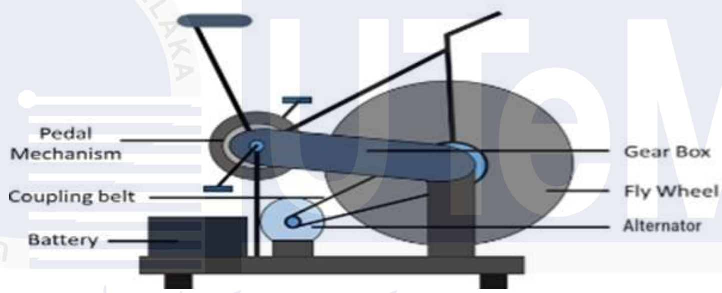

Figure 2.3The bicycle generator set up using gymnasium bicycle

2.6.2 Bicycle generator with dynamo

Bicycle dynamos are a type of alternator specifically designed for bicycles that utilize permanent magnets to generate alternating current (AC) electricity. This AC current can directly power devices designed for AC operation or converted into direct current (DC) using a rectifier, to power DC devices. If the dynamo consists of commutator, it will produce a DC current because the commutator acts as rotary switch which causes the direction of the current produced to be reversed and thus produces DC [24]. Two primary types of bicycle dynamos exist which are hub dynamos that is integrated into the hub of a bicycle wheel and bottle dynamos which is similar in function to hub dynamos and are usually mounted near the rear wheel of the bicycle and function as miniature alternators.

The power output of a bicycle dynamo, determined by the rider's pedaling effort. Reference [25] shows the dynamo that was driven by the hub motor had generated an average of 12V and 2A when a 12V dynamo is used. The power generated is sufficient for powering low-power devices. Many commonly used electronic gadgets, such as mobile phones and portable music players, fall within this category. These devices can be conveniently charged either while actively riding the bicycle or by pedaling while the bicycle remains stationary. Besides that, the compact size and lightweight nature of bicycle dynamos make them a practical. Referring [26], it uses a dynamo to generate power by attaching it to the bicycle's tire and uses NiMH as the battery as shown in Figure 2.4. That way when the tire rotates, it will make a contact with the dynamo resulting in the roller in the dynamo to rotate and generate energy [26].

Figure 2.4The circuit of bicycle generator using dynamo

2.6.3 Generator

Reference [27], a generator of 3-12 V, type DC and variable generator is used by connecting it to the battery and inverter as shown in Figure 2.5. When the load is attached, the force from the pedal causes the largest sprocket which is connected to the small sprocket to rotate along with the small sprocket. The back wheel rotates due to the small sprocket that is located in the center of the shaft. The back wheel is coupled with the DC generator through a flat belt [27]. Thus, the current produced is in DC converted into AC using an inverter to be supplied to the load and the DC current will also be stored in the battery directly.

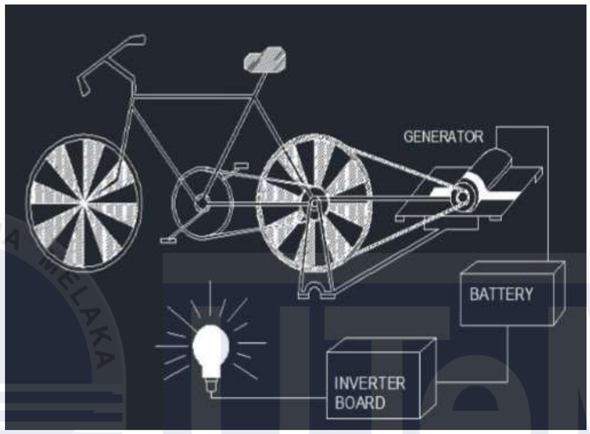

Figure 2.5The schematic diagram of the bicycle generator

2.6.4 Difference in using alternator and dynamo

Dynamo and alternator have a similar working principle generally whereby it converts mechanical energy into electrical energy [24]. However, to use an alternator, a power supplied for initial excitation using a battery to produce magnetic field. Dynamo does not need any external current or excitation as it consists of permanent magnet instead of electromagnet. Reference [26] shows the difference between using alternator and dynamo in the output power, current generated and application. It was found that dynamo produces less output power which is 3W while alternator produces 100W – 300W. The current generated by the dynamo is lower than alternator which is 22A at max RPM while alternator generates 60A and above. The dynamo can only charge 3 1.2V NiMH batteries as it can only supply low power appliances such as LED lamps and fans [26] . However, an alternator can provide power to appliances such as TV and DVD players.

Table 2.3 The differences between alternator and dynamo

	Alternator	Dynamo
Excitation current	Needed	Does not needed
Power generated	100W – 300W	3W
Current generated	60A or more	22A
Applications	High power and low power Eg, TV, DVD players iPod etc	Low power devices Eg. Mobile phones, LED lamps etc

2.6.5 Power generated from the bicycle generator

The power generated is dependent on the speed of rotation. To obtain an optimum speed, the rotational speed must not exceed or less than the maximum and minimum of the generator speed. An average person is able to generate about 75W while a more active person is able to generate twice as much as the power generated by an average person and 50W is generated by a person who is much smaller and weaker. Therefore, an average person can sustain 150W for about 2 hours and 225W for about 30 minutes [24]. Thus, an average person is able to generate about 200W in an hour which is equivalent to a 25W fluorescent light bulb being lit up for 8 hours [15]. To calculate the power generated, the current and voltage generated are measured first and the product of those two data shows the power generated as shown in the Equation 7. The power generated, *P* depends on the current, *I* and voltage, *V* generated. Since the voltage and current generated depend on the rotational speed of the generator, when the rotational speed increases, the power generated increases due to the increase in the current and voltage induced. This can be proved based on the result obtained by researchers as shown in the tables and graphs below.

Equation 7

$$P = VI \qquad \dots (7)$$

Table 2.4 The generation of voltage at different speed obtained [28]

Speed(RPM)	Voltage (V)
950	50
1680	100
2668	150
3386	200
4182	220
4436	240

Table 2.5 The effect of current generated with different RPM [29]

Speed(RPM)	Current (A)
1000	0.58
1500	0.8
2500	1.2
3200	1.8
5000	2.2

Table 2.6 The effect on power generated with different RPM [24]

Speed(RPM)	Power (W)
0	0
144	20
190	29
206	32.5
213	35
243	40
250	45
260	55
284	60
314	68
340	80
370	90
400	125
415	130
420	135
440	142

2.6.6 Impact of bicycle generator to the electric bill

Bicycle generator is able to reduce the electric bill as it can act as an alternative power supply. Reference [30] shows the effect of bicycle generator to the electric bill. It was found that the bill with usage of bicycle generator is lower than without bicycle generator as shown in the Figure 2.6. In the research, it uses 3 LED bulbs and 1 table fan as illustrated in Table 2.7. The total expense for a day is Rs 3.25 (RM 0.18) and thus, it is about Rs 98 – 100 (RM 5.54 – 5.65) for a month. The power generated by in the research is 91.25Wh for a person and 456Wh for a family of 5 - 6 people.

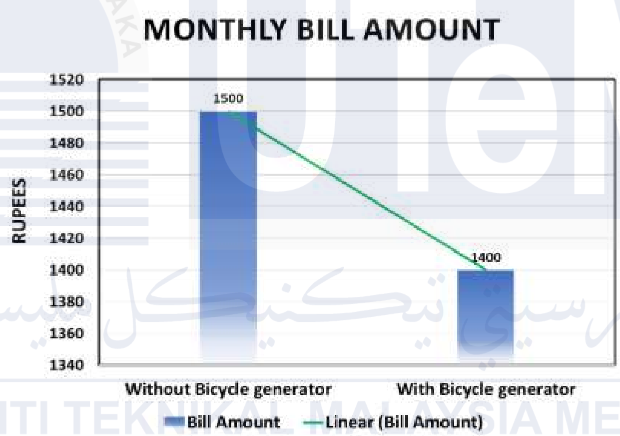

Figure 2.6The electric bill with and without bicycle generator

Table 2.7 Power consumption rate

Electrical components	Power consumption	Electricity Rate (Rupees/unit)	Amount (Rs.)
LED bulbs (3 Nos.)	0.216	6.25 (RM0.30)	1.35 (RM0.08)
Table Fan (1 Nos.)	0.304		1.90 (RM0.11)

2.7 Claw machine

Around 1890, a penny candy vendor built the first coin-operated crane game. The Erie Digger, the first crane game to be patented, was created in 1926. The early devices had a metal arm that resembled a steam shovel or crane and could be raised and lowered by turning a crank. They were powered by steam alone. The majority of the time, choosing or winning the desired reward was merely a matter of luck. Coins and paper money were frequently used as prizes. The game has altered once more in the past few years. These days, a lot of claw machines feature a chip that modifies the claw's grip strength based on how many games have been played [31].

Reference [32] the claw machine is created through a joystick or button interface to execute basic grasping tasks and retrieve objects. The motors used in the control of the claw consist of DC motors, servo motors, and potentially stepper motors, depending on the specific model. This depends on factors such as cost-efficiency, operational speed for retrieving prizes, gripping force to secure objects, and precise control over claw movement. An Arduino microcontroller serves as the central processing unit, facilitating communication and control of the employed motors. DC motors are typically chosen for X-axis and Y-axis movements due to its rapid response time for user input to have a better experience as it enables smooth claw positioning. Moreover, a servo motor is used for grasping claws, for high precision and stability during the gameplay.

Figure 2.7The claw machine created [32]

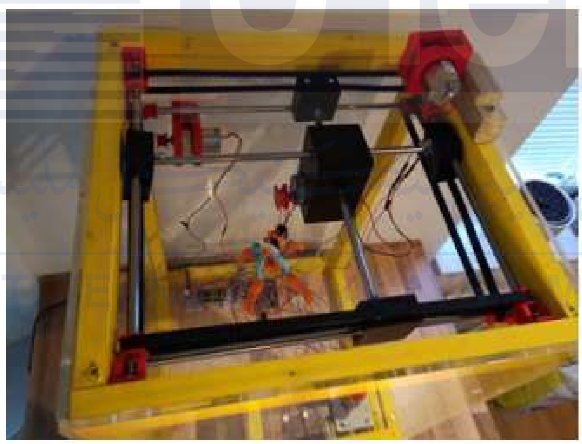

Figure 2.8The construction of the X-axis and Y-axis movement [32]

2.8 Summary

In conclusion, in Malaysia SEDA implemented a programme called NEM to encourage the usage or installation of solar PV systems to achieve the goals in SDG which were goal 7 and goal 13. NEM allows the user to generate power to be consumed by the premise. To ensure a continuous supply of power to the load, battery is integrated into the system. However, the battery used must be regulated using a charge controller to prevent overcharging. Besides solar PV systems, wind energy is another type of renewable energy that uses a generator in the wind turbine to generate energy when the wind rotates the turbine. Consequently, shows that any external motion act on the generator will produce energy. Therefore, the rotation of the wheel from the bicycle can be used as the external force. There are various ways of implementing the generator concept without using the generator on a bicycle which is by using dynamo or alternator. The working principle of dynamo and alternator may be different, but it uses the conversion of mechanical energy to electrical energy. The power generated by the dynamo and alternator will differ when compared. The power generated by the dynamo will be low and therefore the claw machine that acts as the load needs to be low-powered.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this project the voltage and current generated by the bicycle generator will be analyse. It will manipulate the power factor by adjusting the number of revolutions per minute to determine if sufficient power can be generated to operate a claw machine. Matlab, Proteus, and Arduino are used to simulate and estimate the results. The design of the claw machine will be low power to ensure it can be operated by the bicycle generator. Therefore, a power management system will be necessary to regulate and optimize the power generated by the bicycle for smooth operation of the claw machine. The power generated will serve as the token for the claw machine and will need to be sufficient to operate the machine. The generated energy will be used as a token to play the game.

3.2 Selecting and Evaluating Tools for a Sustainable Development

A suitable generator will be used for the bicycle to generate optimum power to power the claw machine. Therefore, the current generated by the bicycle generator must be compatible with the claw machine that is using Arduino. A dynamo will be used to generate energy due to the principle of Faraday's Law of electromagnetic induction as it is more affordable than an alternator. The implementation of rectifier is needed to convert the AC current produced by the bicycle generator to DC to power the Arduino that requires DC power. A capacitor will be used to smoothen the current making it stable for the Arduino. 10 resistors of 120Ω, 2W is used where each dynamo will be connected to 5 resistors in parallel resulting the resistance to be 24Ω to measure the current generated. Additionally, a buck converter will be used to ensure that the input voltage for the Arduino UNO (7-12V) remains within the input voltage range. This is because the bicycle generator usually generates 12V. Energy storage is implemented to ensure a continuous operation of the claw machine. Therefore, a solar charge controller will be used to regulate current flow to the load and battery. The claw machine's energy efficiency and low power requirement is important to use as the guide to decide on lightweight materials and suitable components used. Furthermore, the utilization of voltage sensor is used to ensure that the battery is charging for a certain periods that will serve as a token.

3.3 Methodology

This project presents an alternative way with low-cost to generate electricity using the pedaling of a bicycle and a dynamo. The project focuses on the design and implementation of energy storage by using the battery as the backup power when not pedaling. The project is based on the concept of energy storage, the principle of electromagnetic induction and NEM. The approach is based on quantitative type to develop a sufficient generator to power a low-powered claw machine to raise awareness on alternative low-cost energy. Figure 3.1 shows the flowchart of the research design.

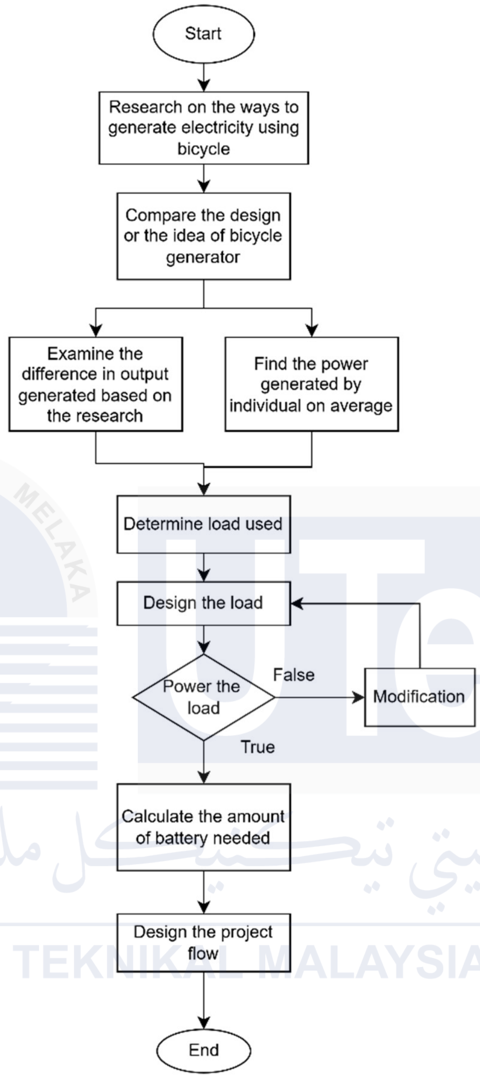

Figure 3.1Flowchart of the development of the project

3.3.1 Experimental setup

This thesis presents the possibility of generating energy powered by pedaling that acts as the supply to the claw machine to raise awareness among the society. The energy is generated from the bicycle using a dynamo. Furthermore, the battery will supply to the load when energy is not generated. With the help of the solar charge controller, it will prevent the battery from over-charging. The voltage and current generated will be measured by the voltage sensors and current sensors to calculate the power generated. The user will be able to play the claw machine when it is cycled for 30 minutes with sufficient voltage and current generated. The claw machine consists of one axis which is the left and right movement of the claw using servo motor with the principle of rack and pinion. The user will be rewarded with the prize if the claw that consists of another servo manages to push the prize down.

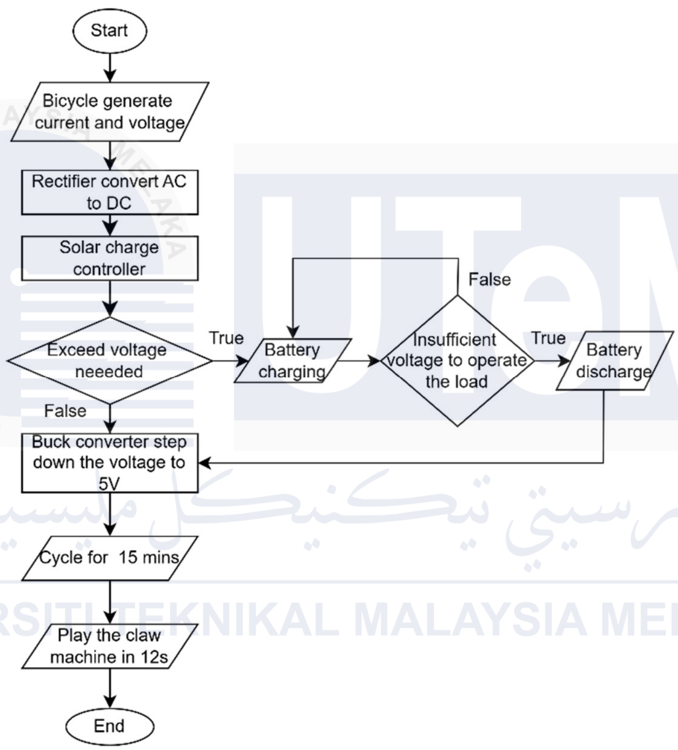

Figure 3.2Flowchart of the operation of the project

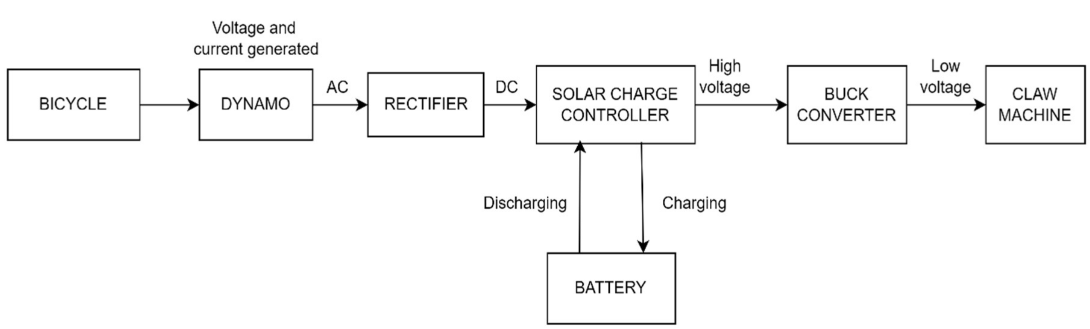

Figure 3.3Integration system of bicycle generator

3.3.1.1 Equipment

a) Bicycle Dynamo

Figure 3.4Bicycle dynamo

A bicycle bottle dynamo, which is known as rim dynamo is used as an electrical generator to generate electricity for the light. This generation occurs through the conversion of mechanical energy to electrical energy. The dynamo will be attached to the rim of the bicycle to allow it to be rotated by the rotation of the wheel. There is a permanent magnet rotating in the dynamo within the coils of the wire. Therefore, the magnet in the dynamo is rotated against the rim of the tire as producing energy to power the light. A 6W 12V rim dynamo will be used.

b) Rectifier

Figure 3.5Rectifier

A bridge rectifier will be use to convert AC current to DC current. The bridge rectifier is a full wave rectifier that converts both positive and negative cycles of an AC current into a DC current. It consists of four diodes that are arranged in a bridge circuit configuration. To smoothen the converted DC current, a capacitor is used to smoothen the current by reducing any remaining ripple in the current to produce a stable output.

c) Solar charge controller

Figure 3.6Solar charge controller

A solar charge controller which is also known as a solar charge regulator is used in off-grid and hybrid off-grid solar PV systems to control the voltage and current generated by the PV ensuring the battery used is charged safely. This helps to prevent the battery from overcharging and thus making sure the battery reaches its expected life cycle. Therefore the solar charge controller will be used to ensure that the battery did not overcharged.

d) Lead Acid Battery

Figure 3.7Lead acid battery

Lead-acid battery is a secondary battery as it is able to recharge. Therefore, the chemical reaction in the battery is reversible for charging and discharging of the battery. Moreover, the lead-acid battery is cheap and safe to use compared to other batteries like

LiPol battery. Despite being heavy and big, it is also durable and has a wide range of temperature resistance. Therefore, the battery that will be used for this project is a lead-acid battery of 6V 4.5Ah.

e) Buck converter

Figure 3.8Buck converter

To step down or reduce the voltage that maintains the power generated, a buck converter is used. The reduction is controlled by the input of the buck converter through a capacitor, inductor and switches. MOSFET is usually used as the switching device for high-side switches while diode is used for low-side switching. The output of the voltage is varied by controlling the duty cycle. Buck converter will be used to ensure that the input to the Arduino will not be out of the voltage range.

f) Arduino UNO

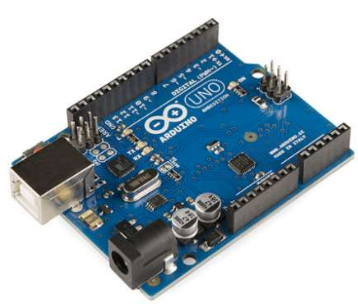

Figure 3.9Arduino UNO

Arduino is a microcontroller that controls specific tasks within electronic systems by combining the functions of a central processing unit (CPU), memory, and input/output interfaces. Arduino consists of 14 input and output in total which is the combination of analog and digital pins. The voltage range of Arduino is within 7-12V. It uses coding to control the function of the components using a software called Arduino IDE. It uses DC current to power the Arduino and each input current is about 20mA. The Arduino will be used as the microcontroller for the claw machine.

g) Voltage sensor

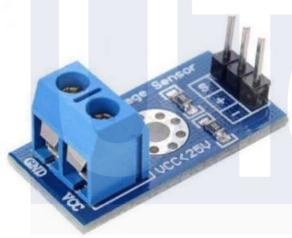

Figure 3.10 Voltage sensor

Voltage sensor will be used to measure voltage across a circuit or components by connecting it parallel to the component that needs to be measured.

h) Resistor

Figure 3.11 Resistors

Wire wound resistors is a type of resistors that limit the flow of current and has the ability to handle high power with good accuracy and stability. It has a high power dissipation with low resistance.

i) Liquid crystal display (LCD) with I2C

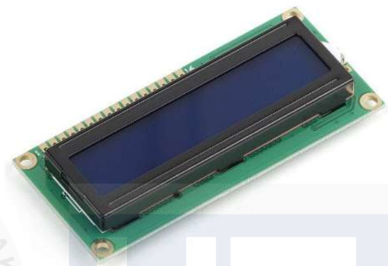

Figure 3.12 LCD

LCD uses liquid crystal in the display panel. The brightness of the LCD is controlled using a potentiometer. The LCD consists of numbers of columns and rows to display any number or symbols simultaneously. It uses Hitachi 44780 - based character LCD to display the symbols and consists of 14 pins. The LCD will be able to display the voltage and current values.

j) Servo motor

Figure 3.13 Servo motor

A servo motor is a motor that moves in an angular or linear position with precision compared to other motors like DC motor and stepper motor. A servo motor is used for applications such as toy cars, robotics, etc. It consists of gear arrangements to produce torque despite using a small and lightweight material. Different servomotors have different torque which can be determined by the rating in kg/cm. It will be used for the axis movement of the claw machine.

k) Toggle

Figure 3.14 Toggle

A toggle is a type of switch that consists of a lever that closes or opens the circuit to complete the circuit. There are a few types of toggle switches which are single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST) and double pole double throw (DPDT). Toggle switches are usually used to control the light switch, electronic devices and others. In this project, it will be used to turn on the circuit.

l) Push button

Figure 3.15 Push button

A push button switch is similar to a toggle switch whereby it helps to complete the circuit by allowing or preventing the current from flowing. However, a push button works momentarily. A push button consists of a normally open (NO) and normally close (NC). A NO switch allows current to flow when the button is hold while in NC, current will flow continuously until the push button is hold to break the circuit. Therefore, a NO push button will be used to control the movement of the claw.

m) Buzzer

Figure 3.16 Buzzer

Buzzer is type of output that produces a buzzing or beeping sound. There are few types of audio signaling devices which are piezoelectric, mechanical or electromechanical. Buzzer is usually used for an indication or alarm. Buzzer will be used in the project.

n) Infrared sensor (IR sensor)

Figure 3.17 Infrared sensor

An infrared sensor (IR sensor) is a device used to detect infrared light and radiation from an object by emitting a infrared radiation and the reflected or absorbed infrared radiation is measured.

o) Rack and pinion

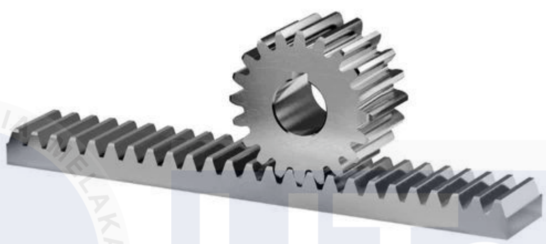

Figure 3.18 Rack and pinion

An infrared sensor (IR sensor) is a device used to detect infrared light and radiation from an object by emitting a infrared radiation and the reflected or absorbed infrared radiation is measured.

3.3.1.2 Software

a) Matlab

Figure 3.19 Matlab logo

Matlab is a software that helps to analysis and design circuits or systems with the help of programming language. Matlab is used for designing circuits for simulation and obtaining results that can be expected when it is applied to real-life situations. It can also help to compare the result obtained by visualising it in the form of a graph. Matlab also can be used for modeling and prototyping a design.

b) Proteus

Figure 3.20 Proteus logo

Protues is used for PCB design based on the schematic design used. However, it can also be used for the simulation of components or microcontrollers such as Arduino UNO. It can import coding used for the Arduino UNO into the software to simulate the project. The software is widely used by engineers and designers to stimulate the microcontroller and the electronic components virtually before implementing it into a physical prototype.

c) Arduino IDE

Figure 3.21 Arduino IDE logo

Arduino IDE is a software that is used for designing the coding that will be implemented into the Arduino microcontroller. The software is used to control the function of the electronic components. The software is easy to use as it uses C++ language for the coding. Moreover, it has an extensive library that can be downloaded to make the coding much simpler and even consists of pre-written code and examples.

d) Tinkercad

Figure 3.22 Tinkercad logo

Tinkercad is a free online platform that is used to offer 3D design, electronics, and coding. The platform is user-friendly due to the simplicity of designing 3D models. Therefore, the software is particularly well-suited for beginners to create a 3D design or 3D model that is suitable with 3D printing. Moreover, the software can also design circuits virtually and simulate it before applying it to physical prototypes. The coding used in the software is not complicated since the coding used is a block-based interface, allowing users even without strong fundamentals to create coding.

3.3.2 Calculation of battery

The battery configuration is calculated to ensure a continuous flow of current when the bicycle is not generating any power. The calculation is based on the solar and battery configuration method of calculation with modification based on generation of bicycle generator.

- Step 1(Calculation of power of the load and supplied):

Assuming the load needs 6V with maximum current of 0.5A and the voltage generated by the bicycle is 16V and 0.6A.

$$P_{load} = 6 \times 0.5 = 3W$$

$$P_{supplied} = 16.\times 0.6 = 9.6W$$

- Step 2 (Number of dynamo):

  Energy needed for the load to operate: $3 \times 10 = 30Wh$

  Number of dynamo: Energy ÷ (Peak hour power generated × Efficiency)

  Assume the efficiency of the dynamo is 70% and for 3 hours it produces optimum power.

$$\frac{30}{3 \times 0.7} = 20W$$

$$\frac{14.3}{9.6} = 1.49 \approx 2\ dynamos$$

- Step 3 (Daily average):

  Assume the efficiency of rectifier is 80%

  AC average + (DC average ÷ rectifier efficiency)

$$0 + \frac{30}{0.8} = 37.5Wh$$

- Step 4 (Battery bank capacity):

  Assume DoA is 0.25 (6 hours)

  (Daily average × DoA × BBTM) / DoD

$$\frac{37.5 \times 0.25 \times 1.05}{0.5} = 19.688Wh$$

- Step 5 (Battery bank):

  (Battery bank capacity) / (Battery voltage)

$$\frac{19.688}{12} = 1.641Ah$$

Number of batteries:

$$\frac{1.641}{4.5} = 0.3.65 \approx 1\ battery$$

3.4 Project design and installation

The focus on the bicycle generator is to maximise the generation of voltage and current by the dynamo that is sufficient to charge the 12V 4.5ah battery. The generated energy will be used as a token to play the crane machine. Therefore, the crane machine design should be sufficient to be powered by the bicycle generator.

Figure 3.23 Dynamos installed on the tyre

Instead of using 1 dynamo, 2 dynamos of 12V 6W were used instead to increase the voltage and current generated. 2 dynamos were installed onto the bicycle on the same side of the wheel to reduce the friction between the tyre. This is because, if the other dynamo is installed on the other side of the tyre, it will be difficult to rotate the tyre due to the clamping of dynamo from each side of the tyre which causes more friction. Moreover, the installation of dynamo on each side of the tyre will cause the tyre to wobble, which will affect the power generated by the dynamo due to the wobbling of tyre being inconsistently rotating the dynamos.

Figure 3.24 Ir sensor as tachometer

An IR sensor is used as a tachometer to measure the speed of the wheel's rotation in RPM. A mark on the tyre is used for the IR sensor to detect, functioning similarly to detecting the blade of a motor. Each time the IR sensor detects the mark, it registers one pulse per rotation. The IR sensor counts the number of pulses in one second to calculate the rotational speed in RPM.

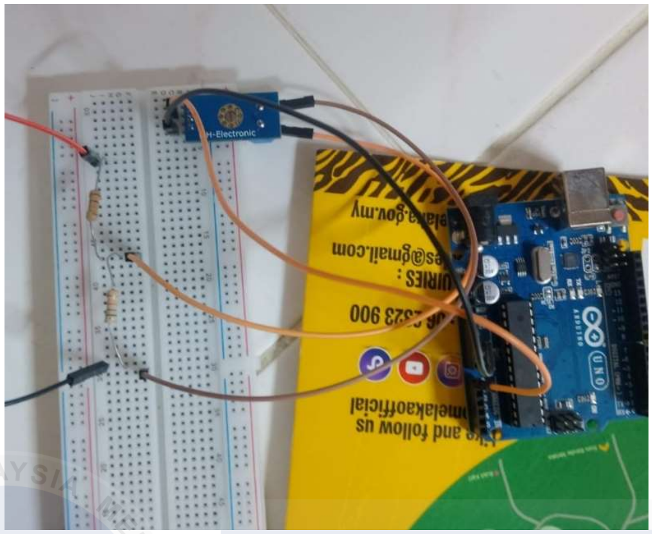

Figure 3.25 Voltage divider is used

The voltage sensor used has a limitation of 25V and, therefore, is unable to read voltage higher than 25V. To overcome this limitation, a voltage divider is used with a 56kΩ resistor and a 10kΩ resistor in series, limiting the voltage reaching the sensor. By integrating the same voltage divider into the voltage sensor circuit, an external voltage divider is added. To determine the required resistors used, a calculation is performed, assuming the dynamo can generate up to 30V wiith no load and a 10kΩ resistor is used. The voltage across R_2 is reduced to 25V to be measured by the voltage sensor and thus, R_2 is determine. Despite the calculated 50kΩ is obtained, 56kΩ resistor was the only one available for purchase.

$$25 = 30(\frac{R_2}{10 + R_2})$$

$$25(10 + R_2) = 30R_2$$

$$R_2 = 50k\Omega$$

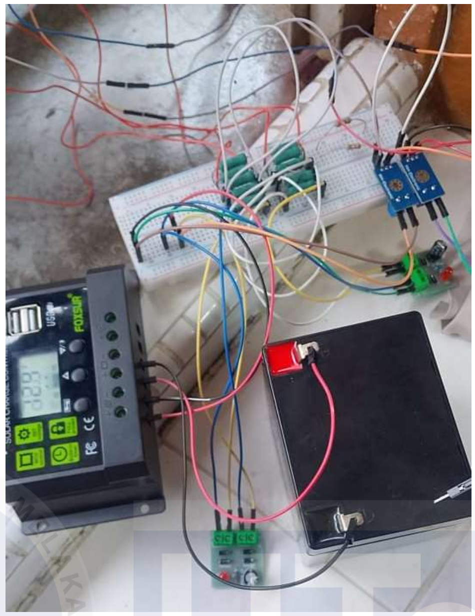

Figure 3.26 Charging of battery in series arrangement

The charging of the battery in a series connection is done by connecting the converted current from AC to DC in series, as DC is much easier to work with compared to AC due to the phase difference between the two dynamos when voltage is generated. Therefore, in parallel connection, the converted currents was connected in parallel as well instead of using the AC current.

A load of five 120Ω resistors is used in a parallel connection for each dynamo due to the limitation of the rectifier, which has an 18V input. To maximize the voltage generated, the selected resistor value was calculated based on 12V 6W dynamo.

Using the formula of :

$$P = (\frac{V^2}{R})$$

$$6 = (\frac{12^2}{R})$$

$$R = 24\Omega$$

It was found that 24Ω is needed. Therefore, 5 resistor with the value of 120Ω in parallel connection is used due to the equivalent resistance of 24Ω.

The charging rate of the battery by the dynamo is tested over 30 minutes in both series and parallel connections. Based on the analysis obtained, the series connection provides a higher charging rate. Consequently, further experiments are conducted by charging in a series connection for 1 hour multiple times, using the same and different individuals, to investigate the effect of the cyclist on the charging rate.

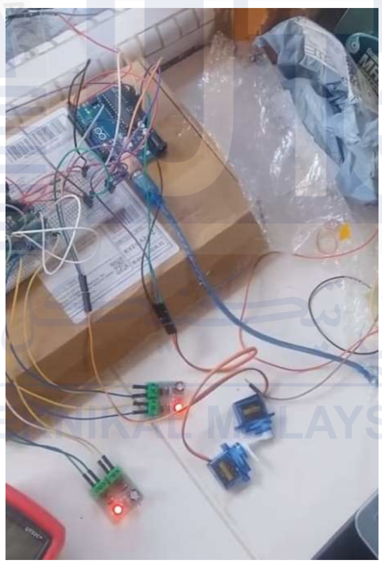

Figure 3.27 Testing of claw machine component powered by bicycle dynamo

The bicycle generator is then used to power the claw machine, which is connected to a buck converter that acts as a voltage regulator by maintaining the supplied voltage at 7V, within the range of the Arduino Uno. This ensures that fluctuating voltage is avoided. A test is conducted to ensure that the bicycle generates sufficient voltage and current to power the claw machine components.

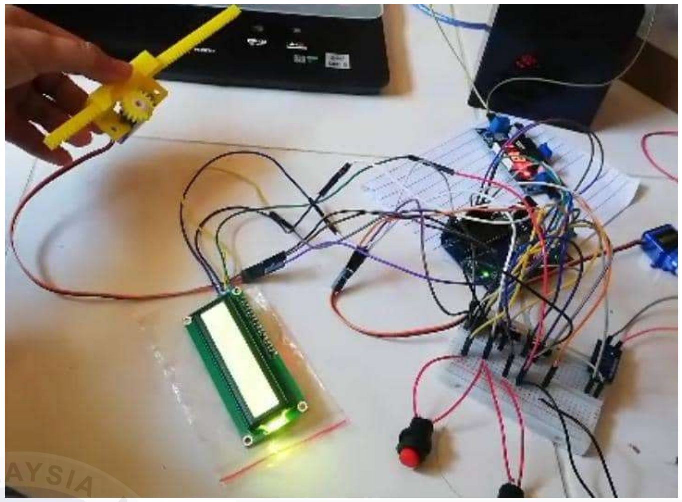

Figure 3.28 The components of the claw machine

The components used for the crane machine include a voltage sensor to measure the charging voltage supplied by the bicycle over 15 minutes and an LCD to display the charging state and the time limit for playing the crane machine. A rack-and-pinion mechanism is used for the x-axis movement of the crane, which is controlled by push buttons. The movement along the x-axis is limited by switches at both ends, ensuring that the servo does not rotate continuously.

Figure 3.29 The crane machine attached to the bicycle

The crane game is attached to the back of the bicycle along with the battery. The lower compartment consists of the charging devices which were battery, solar charge controller, resistors, buck converter and rectifier. The dynamo is attached or installed onto the rear wheel of the bicycle which is then connected to the lower compartment. The solar charge controller regulates the state of battery by ensuring that the battery does not overcharge.

3.5 Summary

This chapter proposed a methodology for designing a bicycle generator that powers up the claw machine and uses the power generated as a token to raise awareness. The main focus of this methodology is to generate power for the claw machine and observed the power generated. The claw machine design focuses on using a low-powered component and making it simple to avoid needing a high power. To achieve that, the complexity and the feasibility have to be balanced out. By making it simple, the claw machine will need a lower power to operate. Therefore, the simulation is needed to estimate the effect of rotation on the voltage and current to figure out the importance of the rotation of the dynamo in power generation. To ensure the claw machine operates for 10 hours straight, a battery of lead-acid with 6V 4.5Ah needs to be used.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter focuses on the results and analysis of the relationship between the speed of rotation, the voltage generated, the current generated and the power generated by the bicycle dynamo. A study on the difference between the series and parallel arrangement of dynamo was carried out to find which arrangement is best suited for charging the battery. The discharging of the battery to run the crane machine game is investigated to estimate the time needed to cycle to replenish the charges that had been used. The dynamos are connected without load to find the specification of the two dynamos based on the graph of voltage against the speed of rotation in RPM plotted. The comparison of performance between two different dynamos is carried out by connecting it to a load where the voltage load is the voltage generated and the current generated will be calculated to find the power generated. The performance of using different arrangements is then carried out by charging the battery for 30 minutes to find the charging rate for each arrangement. The discharging rate of the battery is measured by discharging the battery to run the crane machine for 1 minute to determine the time taken needed to cycle to generate sufficient energy. The voltages obtained were measured using a voltage sensor and multimeter.

Figure 4.1The final product

4.2 Results and Analysis

Table 4.1 Voltage generated with different speed during no load for dynamo 1

Speed (RPM)	Voltage generated (V)			
	V1	V2	V3	Vave
0	0	0	0	0
60	9.1	10.0	8.8	9.30
120	12.1	12.4	13.1	12.53
180	20.3	20.3	21.0	20.53
240	26.3	26.0	27.2	26.50

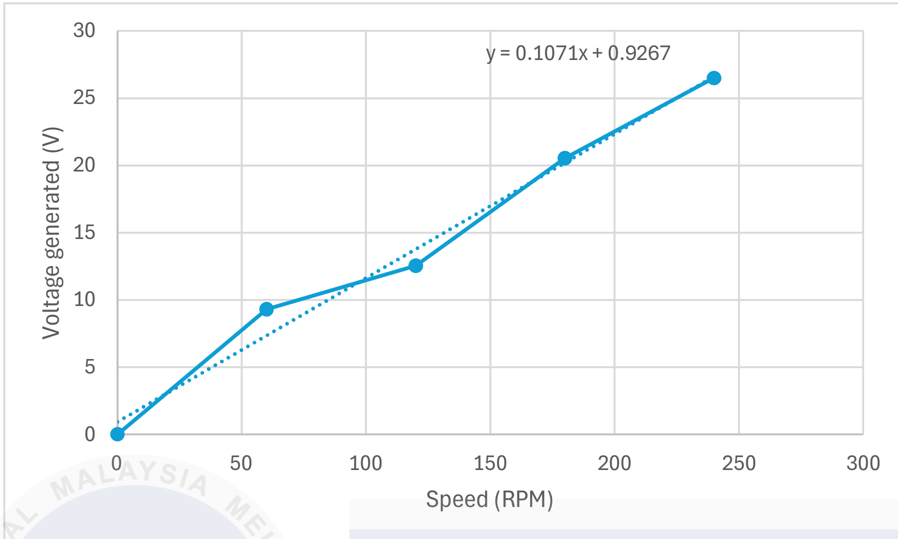

Figure 4.2The relationship between speed of rotation and voltage generated during no load for dynamo 1

Table 4.2 Voltage generated with different speed during no load for dynamo 2

Speed (RPM)	Voltage generated (V)			
	V1	V2	V3	Vave
0	0	0	0	0
60	7.6	8.5	7.9	8.00
120	10.4	11	11.2	10.87
180	14.8	15.3	16.1	15.40
240	20.2	22.1	22.8	21.70

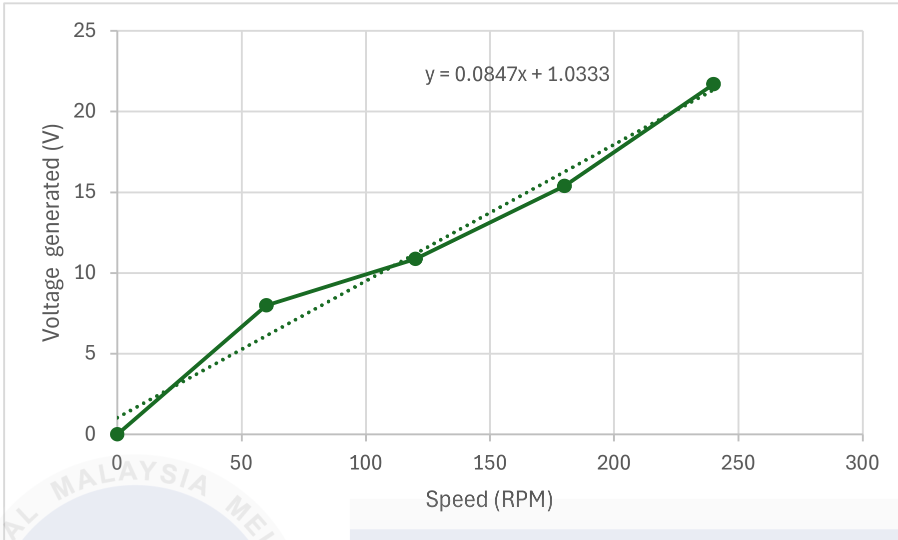

Figure 4.3The relationship between speed of rotation and voltage generated during no load for dynamo 2

Based on the graphs, both dynamos show the same relationship between the speed of rotation in RPM and voltage generated. The speed of rotation is unable to achieve higher than 240rpm due to human limitation, however, the findings prove that as the speed of rotation increases, the voltage generated increases as well. Thus, the voltage generated depends on the speed of rotation of the dynamo. The graph shows that both dynamos have different specifications in factors like number of poles, flux per pole and number of parallel paths in the armature.

Table 4.3 Voltage and current generated with different speed with load of 24 ohm for dynamo 1

Speed (RPM)	Voltage generated (V)				Current generated (I)	Power generated (W)
	V1	V2	V3	Vave		
0	0	0	0	0	0	0
60	6.33	8.4	8.32	7.68	0.32	2.46
120	9.16	9.82	10.74	9.91	0.41	4.09
180	13.44	13.67	14.06	13.72	0.57	7.85
240	16.12	16.38	16.42	16.31	0.68	11.08

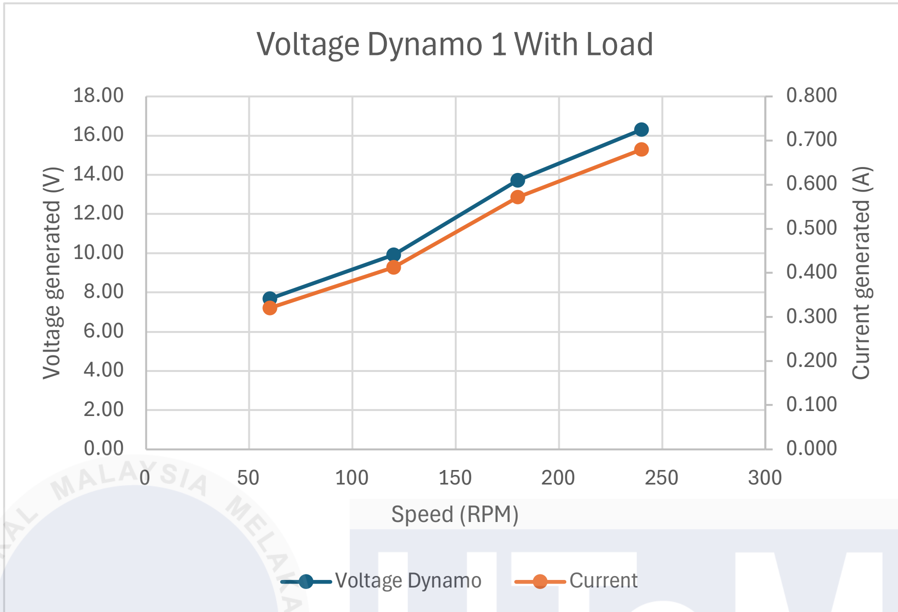

Figure 4.4The relationship between speed of rotation and voltage generated along with current generated during load for dynamo

Table 4.4 Voltage and current generated with different speed with load of 24 ohm for dynamo 2

Speed (RPM)	Voltage generated (V)				Current generated (I)	Power generated (W)
	V1	V2	V3	Vave		
0	0	0	0	0	0	0
60	7.66	8.31	9.25	8.41	0.35	2.94
120	10.27	11.57	12.17	11.34	0.47	5.36
180	12.37	12.92	13.17	12.82	0.53	6.85
240	17.17	17.88	18.12	17.72	0.74	13.09

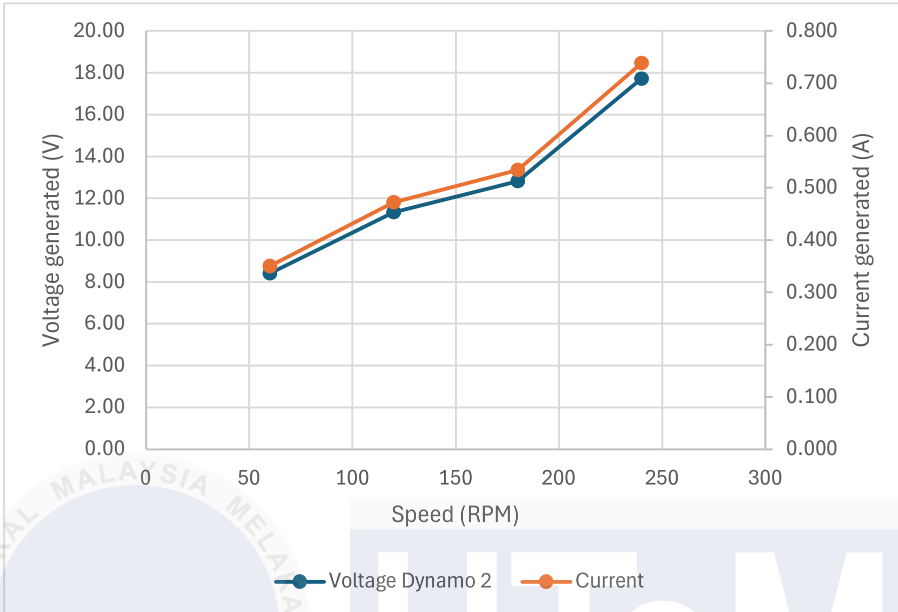

Figure 4.5 The relationship between speed of rotation and voltage generated along with current generated during load for dynamo 2

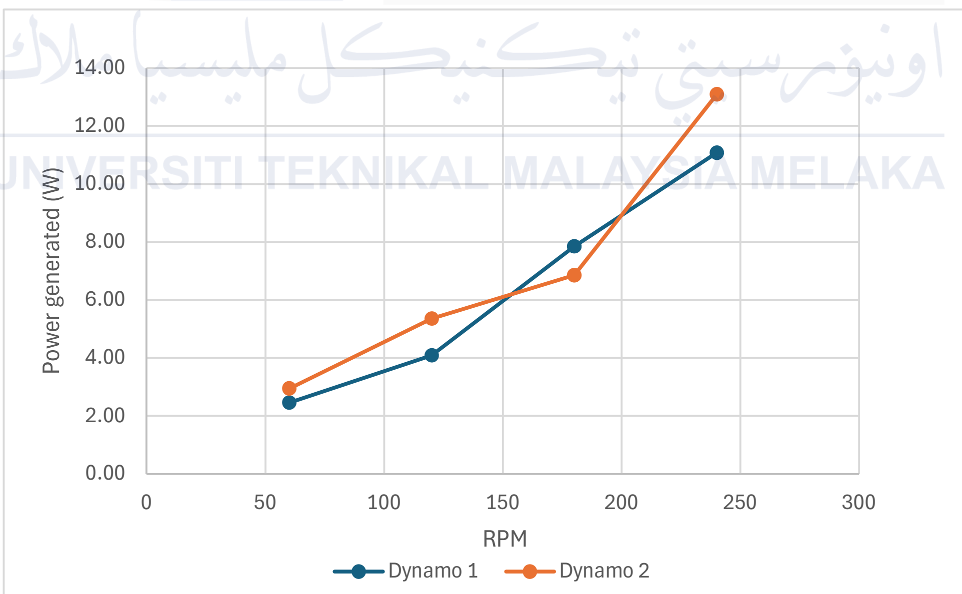

Figure 4.6 The difference in power generated by dynamo 1 and dynamo 2

Graph in figure 4.3 and figure 4.4 shows the relationship between the speed of rotation and the voltage generated and current generated for both dynamos while graph in figure 4.5 illustrates the relationship between the speed of rotation and the power generated by those dynamos. It was found that as the speed of rotation increases, the power generated increases due to the increase in voltage generated and current generated. The current generated is obtained by using the formula of $V=IR$, where the resistance used is 24ohm. The power generated is obtained using the formula $P=VI$. Based on the reading obtained, dynamo 2 has a better performance compared to dynamo 1 as it generates more power than dynamo 1. This is due to the different specifications of the dynamo which affects the voltage generated and current generated.

Table 4.5 Voltage generated, battery voltage and speed of rotation during charging for 30 mins in parallel connection

Time (min)	Voltage dynamo 1 (V)	Voltage dynamo 2 (V)	Voltage parallel (V)	Speed (RPM)	Voltage battery (V)
0	0	0	0	160	12.530
5	10.17	10.13	11.60	160	12.535
10	10.23	9.90	11.46	160	12.523
15	9.50	9.33	10.66	120	12.520
20	8.87	8.60	11.08	160	12.520
25	9.47	9.40	10.34	160	12.520
30	10.13	9.40	11.42	180	12.516
Initial voltage battery state		12.53V	Initial voltage battery state		12.50V

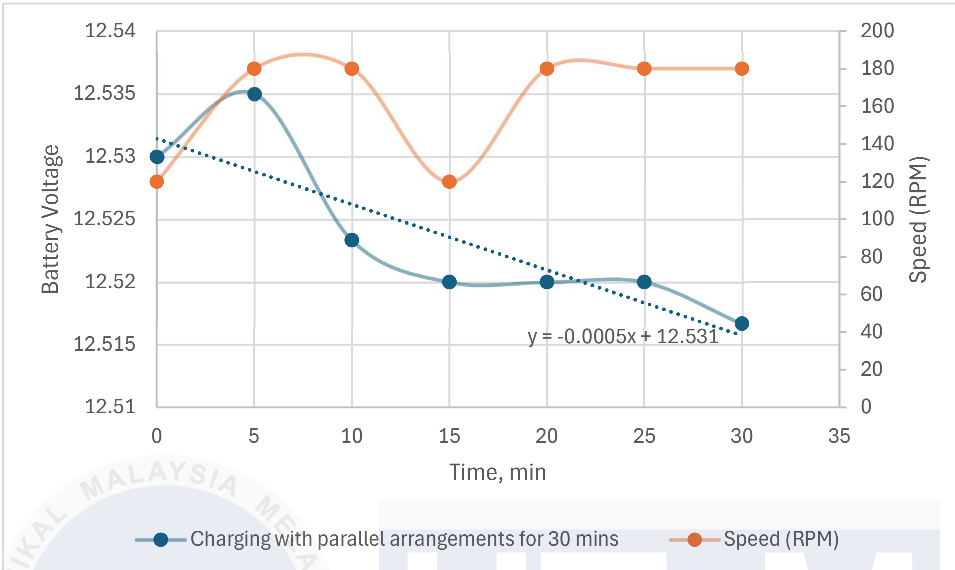

Figure 4.7Battery voltage and speed of rotation during charging for 30 mins in parallel connection

The charging rate for series and parallel arrangements is carried out for 30 minutes. According to graph in figure 4.6, the battery was unable to be charged resulting in the battery constantly discharged as shown in the decrease in battery voltage. The battery voltage is measured after it does not show any changes and it shows that the battery voltage decreases from 12.56V to 12.53V. This is because the voltage generated by the dynamos in parallel to charge the battery is insufficient as it can only be generated up to 11.46V. To charge a 12V sealed lead acid battery, a voltage of more than 12V is needed. The parallel arrangement is not reliable is also due to the different specifications of both dynamos which causes the voltage generated to be varied and thus, harder to achieve 12V. The voltage generated for each dynamo is compared to the voltage in parallel because voltage parallel will be based on the higher voltage generated by the dynamos.

Table 4.6 Voltage generated, battery voltage and speed of rotation during charging for 30 mins in series connection

Time (min)	Voltage dynamo 1 (V)	Voltage dynamo 2 (V)	Voltage Series (V)	Speed (RPM)	Voltage battery (V)
0	0	0	0	0	12.50
5	7.51	7.43	14.76	160	12.78
10	7.37	6.89	14.64	160	12.83
15	6.78	6.64	14.73	180	12.88
20	6.97	6.36	13.43	140	12.87
25	7.04	6.46	13.41	160	12.86
30	7.25	6.59	13.83	140	12.83
Initial voltage battery state 12.50V		12.50V	Initial voltage battery state		12.53V

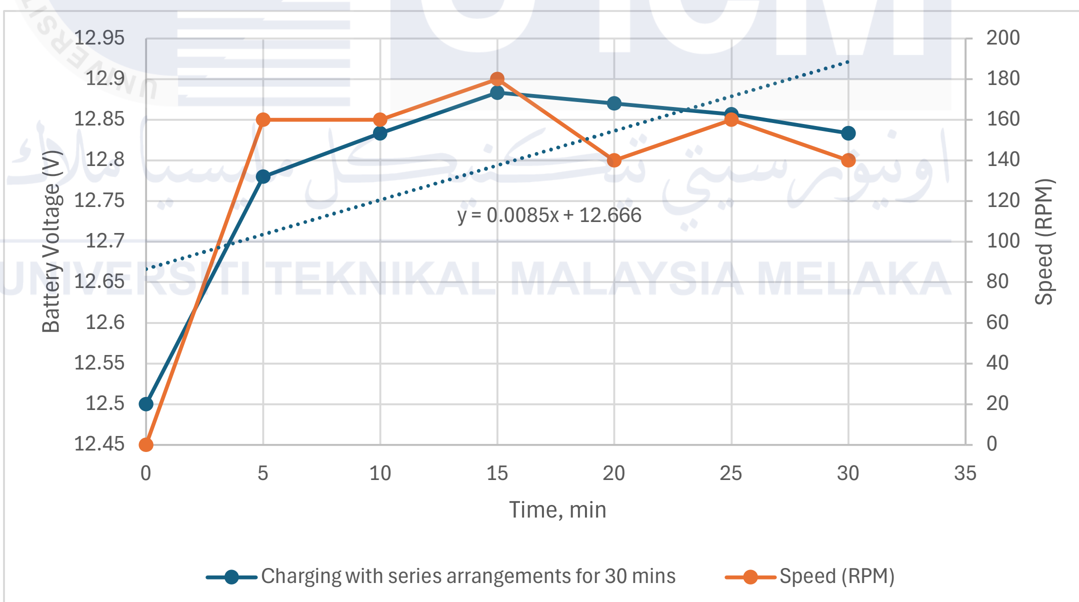

Figure 4.8Battery voltage and speed of rotation during charging for 30 mins in series connection

As for series arrangements, it was found that the battery voltage increased from 12.53V to 12.56V. This is because in a series arrangement, the dynamos were able to generate up to 15.26V which is sufficient to charge the battery in 30 minutes as the voltage generated is more than 12V throughout the charging state despite having varied speeds of rotations. Based on the DC voltage obtained by each dynamo, it was found that the voltage generated initially was high but gradually decreased due to fatigue, causing the speed of rotation to decrease. For series, the DC voltage for each dynamo was measured instead of the AC voltage because unlike parallel arrangement, the DC voltage does not depend on higher voltage. Instead, the voltage used to charge the battery is the total DC voltage generated by both dynamos. Therefore, despite fatigue, it is still able to generate more than 12V making it a viable option to charge the battery instead of parallel arrangement.

Table 4.7 Voltage generated, battery voltage and speed of rotation during charging for 1 hr in series connection (First attempt)

Time (min)	Voltage dynamo 1 (V)	Voltage dynamo 2 (V)	Voltage Series (V)	Speed (RPM)	Voltage battery (V)
0	0	0	0	0	12.53
5	8.19	8.09	16.72	180	12.80
10	6.70	6.83	13.37	180	12.77
15	6.83	6.47	13.37	180	12.83
20	7.02	6.59	13.43	180	12.92
25	7.07	6.67	13.47	180	12.91
30	6.83	6.84	13.58	180	12.98
35	7.11	6.48	13.56	180	12.98
40	7.09	6.50	13.45	180	12.97
45	7.05	6.48	13.43	180	12.97
50	7.12	6.22	13.38	180	12.95
55	7.25	6.30	13.42	180	12.97
60	7.09	6.15	13.32	180	12.93
Initial voltage battery state		12.53V	Voltage battery once stabilise		12.61V

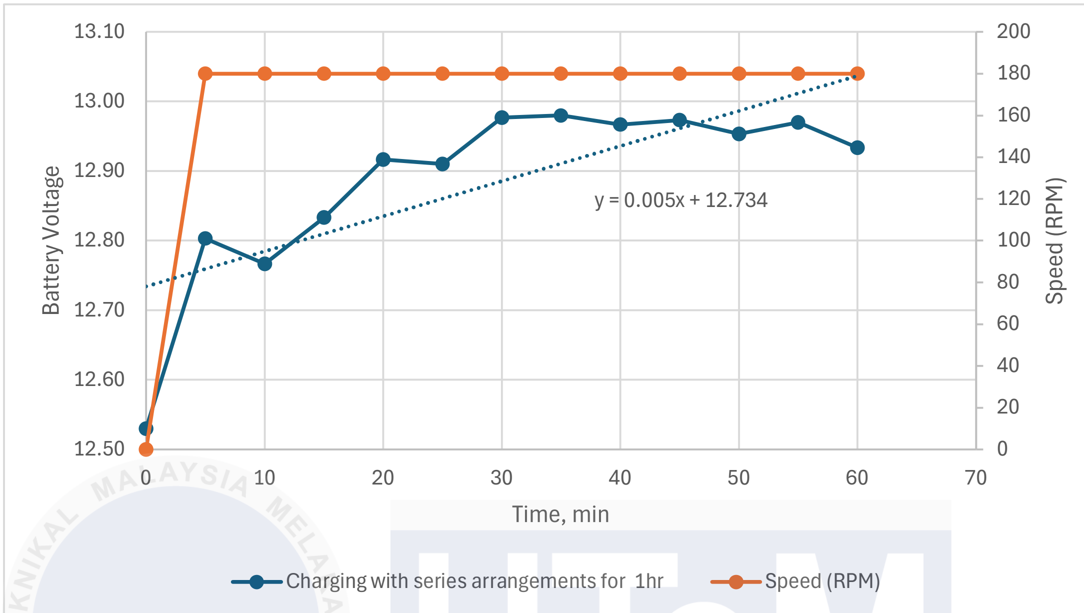

Figure 4.9Battery voltage and speed of rotation during charging for 1 hr in series connection (First attempt)

Table 4.8 Voltage generated, battery voltage and speed of rotation during charging for 1 hr in series connection (Second attempt)

Time (min)	Voltage dynamo 1 (V)	Voltage dynamo 2 (V)	Voltage Series (V)	Speed (RPM)	Voltage battery (V)
0	0	0	0	0	12.20
5	7.47	7.59	15.13	180	12.74
10	6.48	6.84	13.28	180	12.80
15	6.61	6.71	13.32	180	12.82
20	6.57	6.80	13.35	180	12.84
25	6.58	6.78	13.31	180	12.87
30	6.73	6.79	13.55	180	12.86
35	6.66	6.82	13.34	180	12.87
40	6.74	6.72	13.37	180	12.86
45	6.68	6.79	13.35	180	12.86
50	6.63	6.57	13.35	180	12.88
55	6.83	6.71	13.39	180	12.89
60	6.72	6.60	13.71	180	12.89
Initial voltage battery state		12.20V	Voltage battery once stabilise		12.36V

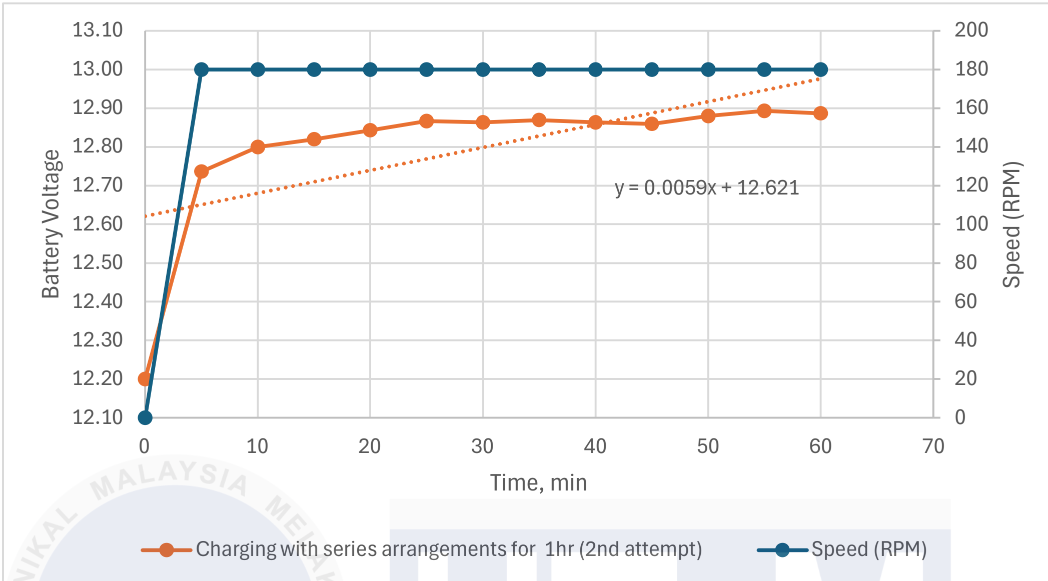

Figure 4.10 Battery voltage and speed of rotation during charging for 1 hr in series connection (Second attempt)

Table 4.9 Voltage generated, battery voltage and speed of rotation during charging for 1 hr in series connection (Third attempt)

Time (min)	Voltage dynamo 1 (V)	Voltage dynamo 2 (V)	Voltage Series (V)	Speed (RPM)	Voltage battery (V)
0	0	0	0	0	12.36
5	6.90	6.53	13.37	160	12.88
10	6.99	6.42	13.41	180	12.90
15	7.27	6.11	13.43	160	12.92
20	7.26	6.25	13.43	180	12.94
25	7.22	6.03	13.29	180	12.89
30	7.10	6.31	13.33	180	12.89
35	7.17	6.16	13.40	180	12.88
40	7.04	6.25	13.28	160	12.91
45	6.93	6.36	13.24	140	12.89
50	6.90	6.28	13.33	140	12.89
55	6.91	6.24	13.12	120	12.85
60	6.90	6.20	13.12	120	12.85
Initial voltage battery state		12.36V	Voltage battery once stabilise		12.57V

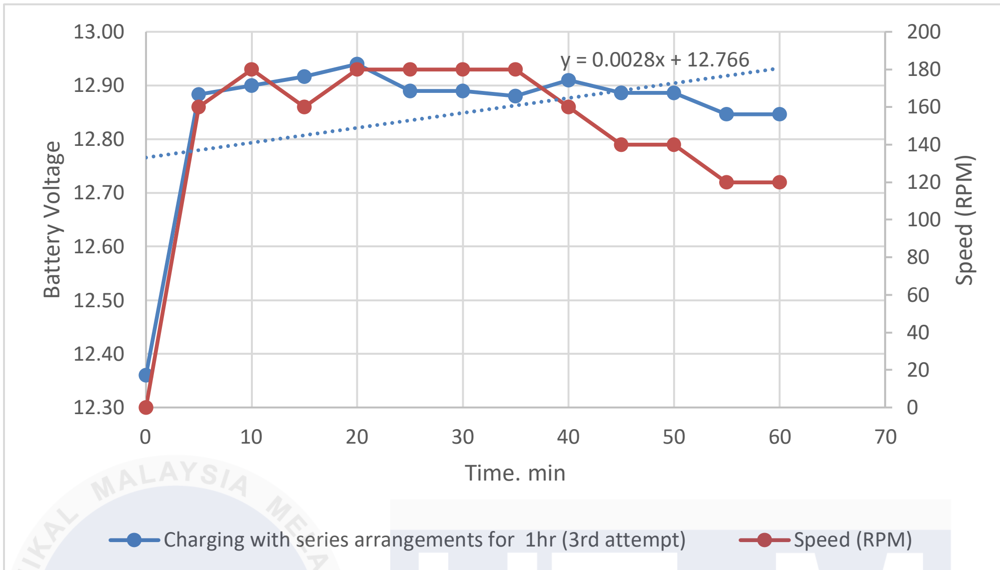

Figure 4.11 Battery voltage and speed of rotation during charging for 1 hr in series connection (Third attempt)

A number of charging efforts were made, each lasting an hour rather than the 30 minutes that were initially carried out. The charging rate was found to change with each try. Since the uniformity and speed of rotation rely on an individual's stamina, this difference is mostly caused by human constraints. The battery voltage increases from 12.53V to 12.61V in the first try. The voltage went from 12.20V to 12.36V on the second try and from 12.36V to 12.57V on the third. These show that the battery was effectively charged in every instance, despite the inconsistency in charging rate which were 0.005V/min, 0.0059V/min and 0.0028V/min respectively. The cyclist's weariness causes the variations in battery voltage and the voltage generated by the dynamo initially were more than the second half of the charging state due to the losses such as heat loss at the dynamo and other component. Moreover, during the riding, there were brief breaks in between, which reduced the pedaling pace and, as a result, the voltage produced decreases by slightly. This shows that the human endurance affects the system's ability to generate electricity consistently.

Table 4.10 Voltage battery used to play the crane machine for 1 min

Time (min)	Voltage battery (V)		
	First attempt	Second attempt	Third attempt
5	12.45	12.43	12.42
15	12.44	12.43	12.42
30	12.43	12.43	12.40
60	12.43	12.42	12.40
Initial voltage battery (V)	12.53	12.51	12.50
Final voltage battery (V)	12.51	12.50	12.49
Voltage drop (V)	0.02	0.01	0.01
Average voltage drop (V)			0.013

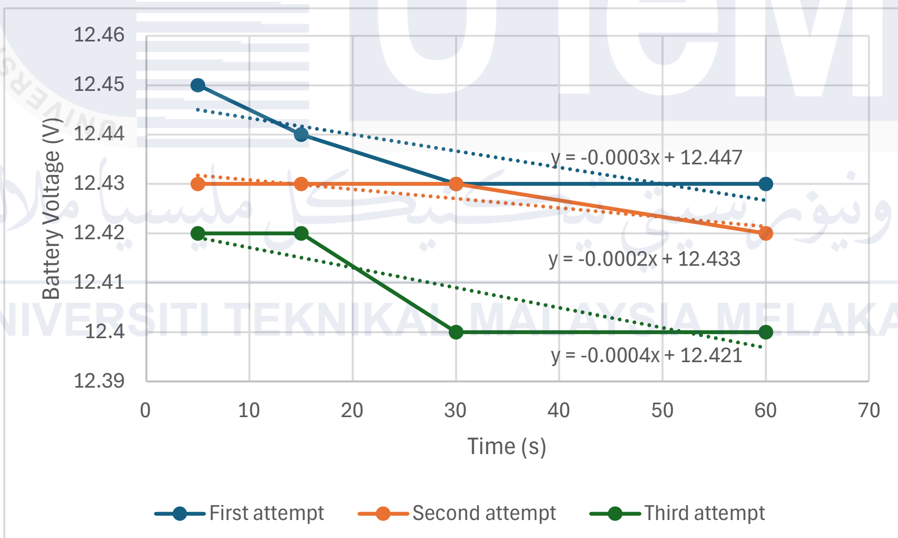

Figure 4.12 Voltage battery used to play the crane machine for 1 min

The discharging rate of the crane machine was tested 3 times by running the machine purely on battery power for 1 minute giving the estimation of the crane machine used to play. It was observed that the battery voltage decreased slightly from 12.53V to 12.51V, 12.51V to 12.50 and 12.50V to 12.49 respectively. Thus, a decrease of 0.013V for a single minute of operation while playing one round of the crane machine is obtained. The small decrease is due to the crane machine build was low powered since the components used does not require high voltage and current along with shorter time to play the game. Thus, lesser power is needed to play the claw machine. Based on this discharging rates which were within the range of 0.0002V/sec to 0.0004V/sec, the time required for the cyclist to generate enough energy to power one round of the crane machine was calculated. Hence, 15 minutes of cycling is sufficient to for a 1 round of the claw machine.

Using the highest discharging rate obtained which was 0.0004V/sec:

$$0.0004\ X\ 60mins = \ 0.024V/min$$

For 1 minute, the discharging rate to play the claw machine is 0.024V/min. Thus, the duration of cycling needed to charge the battery is calculated with the lowest charging rate which was 0.0028V/min.

$$\frac{0.024}{0.0028} = 8\ minutes$$

In 8 minutes, the battery is able to be charged back to its original state of charge. Thus, 15 minutes is sufficient to charge the battery with the consideration of limited stamina and speed of rotation.

4.3 Summary

The results obtained shows the importance of speed rotation to generate high voltage and current, resulting in high power generation. This is due to the voltage generated by a dynamo depends directly on its speed of rotation, while the power generated increases with both voltage and current generated. The differences in performance between Dynamo 1 and Dynamo 2 highlight how specifications such as the number of poles, flux per pole, and armature design affect output. The parallel and series arrangements of dynamos were compared for charging a 12V sealed lead-acid battery. The parallel arrangement was ineffective due to insufficient voltage generated by the dynamos that is caused by the difference in dynamo specifications. However, the series arrangement successfully charged the battery, as the combined voltage in series consistently exceeded the required 12V threshold. The result of charging rate shows that human endurance was one of the factor influencing the system's performance, with speed and uniformity of rotation decreasing over time due to fatigue. Thus, lead to an inconsistent charging rates during extended cycling sessions, though the battery was still charged effectively in each attempt. The discharging rate of the claw machine was small due to its low power requirements to function, allowing for efficient energy use. It was calculated that 15 minutes of cycling is sufficient to recharge the battery to its original state which can be used as the token to play the claw machine. In conclusion, the series arrangement is suitable for charging the battery efficiently and charging rate of the dynamo to charge the battery is affected by human stamina and dynamo specifications since the voltage and current generated is heavily depend on the speed of rotation of the dynamos.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The bicycle generator system is sufficient to generate energy to power the crane machine. The voltage and current generated depend on the rotation speed of the bicycle, which is limited by human stamina. As a result, there is a limit to the voltage and current that can be achieved. The dynamo's specifications play a crucial role in determining the most suitable arrangement for the system whether in series or parallel. Additionally, the charging rate varies based on the cyclist's stamina due to different individuals have varying cycling abilities. Some able to maintain a consistent cycling speed for an extended period, while others may experience fluctuating speeds which causes an inconsistent voltage and current generation.

Despite this, the system is capable of charging the battery at varying rates depending on the cycling speed. As a result, the time required to fully charge the battery is influenced by the individual's cycling effort. However, the system is designed such that 15 minutes of cycling is generally sufficient to recharge the battery enough to power the crane machine, ensuring The crane machine can be powered by the energy produced by the bicycle generator system. The bicycles rotation speed which is the limit of human endurance determines the voltage and current produced. Consequently the maximum voltage and current that can be attained has been established. When choosing the best configuration for the system the dynamos specifications are very important. Additionally the cyclists stamina affects the charging rate. Cycling skills vary from person to person some can cycle at a steady pace for a long time while others may have erratic speeds. Unreliable voltage and current generation are the results of this variation. In spite of this the system can charge the battery at different rates based on the speed of cycling. Therefore a persons cycling effort affects how long it takes to fully charge the battery. Nonetheless the system is made so that cycling for 15 minutes is usually enough to recharge the battery and power the crane machine guaranteeing its continued use. its usability for extended play.

5.2 Potential for Commercialization

The bicycle generator that powers a crane machine game has a lot of potential for commercialization particularly when it comes to entertainment and sustainable energy solutions. This project can be used in a variety of industries including gaming entertainment education and renewable energy as the need for environmentally friendly technologies grows. In the gaming and entertainment industry the bicycle-powered crane machine game can be promoted as an interactive environmentally friendly attraction for theme parks arcades and entertainment venues. By providing a renewable energy-powered substitute for conventional arcade games it offers a unique selling proposition that appeals to customers who are concerned about the environment. Furthermore off-grid energy solutions in places with poor access to electricity can be achieved through the commercialization of bicycle-powered generators plus it is a cheaper option for an alternative energy compared to solar energy that require a high installation cost. The systems portability and adaptability make it appropriate for powering lights small appliances or low-energy devices in emergency situations remote areas or outdoor events making it as an alternative option to generate energy instead of depending fully on solar energy.

5.3 Future Works

For future improvements, the performance of bicycle generator can be improved as follows :

i) Same type of dynamos is used with the same specification to ensure that the voltage generated by both dynamos is similar so that parallel arrangement can be used to gain more current.

ii) Instead of using dynamo, an alternator or motor can be used to increase the generation of both current and voltage, to increase the charging rate of the battery.

iii) Implementing gear ratio to rotate the dynamo with lesser rotation of the bicycle. Thus, higher speed of rotation of the dynamo can be obtained easily with few speeds of rotation of the bicycle resulting in higher voltage and current generated.

iv) Replace the traditional bearings and moving parts in the bicycle with low-friction bearings and components to reduce mechanical losses and increase the efficiency of energy during pedaling, ensuring more energy is being converted.

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