ANALYSIS OF OPTIMUM COIL PARAMETER OF PERMANENT MAGNET GENERATOR FOR ENERGY HARVESTING APPLICATION

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A report submitted in partial fulfillment of the requirements for the degree

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ABSTRACT

With the increasing demand of electricity all around the globe, the importance of portable electrical energy supply cannot be taken lightly. As we know, electricity is very important to us nowadays. Our daily life depends on electric-powered devices. Thus, a portable energy source seems like the great solution to the problem. This is where this project becomes handy. In this project, a permanent magnet generator (PMG) is designed for motion energy harvesting application. The harvesting mechanism was driven by human motion as it can be wear on and the energy that was produced will be stored into battery. The design process of the PMG for motion energy harvesting includes several steps. The design focused only on the optimizing coil parameter of the PMG. Firstly, the PMG are modeled by using GMSH software and analyzed using Finite Element Method. All data gained from the Finite Element Method are then analyzed to ensure that the PMG are able to produce the desired output. After the analysis, it was found out that the PMG is able to produce 50W of output power with certain setting of the coil parameter. Previously, a lot of energy harvester has been introduced such as solar panel, tidal harvester and wind harvester. This project is the new variation of energy harvester which uses the motion energy to generate electricity and it is hoped to help other researcher or provide useful guide to produce a much better portable energy harvesting device in the future.

ABSTRAK

Dengan pertambahan permintaan terhadap tenaga elektrik di seluruh dunia, keperluan terhadap punca tenaga elektrik mudah alih amat dititikberatkan. Seperti yang kita tahu, tenaga elektrik amat penting dalam kehidupan seharian kita. Kita bergantung kepada perkakasan yang menggunakan tenaga elektrik. Oleh itu, punca tenaga elektrik mudah alih adalah penyelesaian terbaik bagi permasalahan ini. Projek ini boleh membantu untuk menyelesaikan permasalahan ini. Dalam projek ini, penjana magnet kekal (PMK) telah direka untuk kegunaan penuaian tenaga gerakan. Mekanisma tuaian digerakkan oleh pergerakan manusia kerana peranti tersebut boleh dipakai dan tenaga yang terhasil akan disimpan didalam bateri. Proses mereka PMK untuk kegunaan penuaian tenaga gerakan dijalankn melalui beberapa langkah. Pertama sekali, PMK direka menggunakan perisian GMSH dan dianalisis menggunakan kaedah unsur terbatas. Kesemua data yang diperoleh dari kaedah unsur terbatas kemudiannya dianalisis untuk memastikan PMK berupaya menjana hasil yang dikehendaki. Setelah melakukan analisis, didapati bahawa PMK berupaya menjana 50W kuasa melalui penyesuaian tertentu terhadap parameter gegelung. Sebelum ini,banyak penuai tenaga telah diperkenalkan seperti panel solar, penuai air pasang, dan penuai angin. Projek ini adalah variasi penuai tenaga dimana ia menggunakan tenaga gerakan untuk menjana elektrik and diharapkan supaya projek ini mampu membantu penyelidik dan memberi bimbingan untuk menghasilkan penuai tenaga yang lebih baik di masa hadapan.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Electrical energy is a form of energy that can be generated by using generator. The generator converts mechanical energy to electrical energy. The generator was first discovered by the famous Michael Faraday in 1831 based on the principle of electromagnetic induction. While the conventional generator uses petroleum and gas to generate electricity, it has become a major concern to know that the supply for the essential ingredients in conventional electrical generators are depleting. Petroleum reserve that exists on earth was expected to run out in the next 50 years.

In a modern fast moving world, researchers have put a lot of energy and effort to overcome the problem of increasing electrical tariff and knowing the fact that the electrical energy supply will run out in line with the last consume of petroleum supply. A lot of ways to overcome this problem has emerged. Among them are the generation of electricity from solar, wind, thermal and etc. The latest technology to be implemented to generate electricity is by using kinetic energy from any moving body. The generation technique was called motion energy harvesting.

Human being is subjected to moving since we were born until the end of our lifetime. Human move to work, get to another place and to communicate. By implementing the

dynamic of human movement into the motion generator we can generate electrical energy simply by manipulating the motion energy created when we are moving. This type of generation is suitable for small power application.

To generate energy that produces high output, the generator needs an external force or a 'prime mover' acting as a shaft to move the rotor. This prime mover is connected to a pendulum to act as a motion harvester since a pendulum is a very conventional and easier method for this task.

1.2 Problem Statement

With the depletion of petroleum and gas which is the main source of electrical power generation, researcher has come out with new way to generate electrical power. This includes harvesting of free and renewable source of energy that can last for a long period of time. One of the famous renewable energy is the solar energy but implementation of photovoltaic cell is very expensive. So, researcher have move on to a new energy source which are free and much cheaper to realization. Motion energy can be implemented on any moving body and this means anything that moving. As we know, energy cannot be generated by its own. It can only be converted from one energy to another. Thus, it is a literally a waste of energy when people move around without knowing that they can actually generate power from just walking down the street or doing house chores.

In the future, all devices were expected to be powered by electrical power. As we can see in this millennium, the electricity and human cannot be separated. Electricity is essential to human as the entire world runs on it. This goes to the small and portable gadget. The main source of power for these small and portable gadgets is battery. Even though battery seems to be the ideal source of energy to empower the gadget or other electrical device, it has its own drawback. The battery cannot last forever. As the electrical charge inside it runs out, the battery must be replaced with a new one. This is applied to a non-rechargeable battery. As for the rechargeable battery, a huge time must be spent to charge the battery to the full until it can be used again.

This energy harvester device proposes a portable mechanism so that it can be carried anywhere. This energy harvester gives an output of 50W which is very suitable for low power application such as lighting, radio, charger and small power fan. This motion energy harvester has an output of 24V and 2A current which is stored inside two 24 volt batteries connected to the generator.

1.3 Objectives

The main aim of this project is to design a portable generator for energy. The performance of the generator design is analyzed. The following objectives are considered for this project:

a) To simulate and propose the design of generator for 50W motion energy harvester
b) Analysis the output power of the generator for motion energy harvester

1.4 Scope of Work

This project covers the scope of designing the permanent magnet generator as the device to harvest the motion energy and convert it to electrical energy. The generator then, are be examine and analysis. The result of the analysis is be computed.

This project can be divided into several parts or stages. The first is to study the basic principle of the Permanent Magnet Generator (PMG). The next step is to develop, design and analyze the PMG based on the best design computed. All the results of the analysis are computed to propose the best design for the generator for motion harvesting.

The limitation for this Final Year Project is only the design, analysis and proposal for the generator of the motion harvesting are done which is using advanced software tools such as GMSH software for finite element analysis, Origin8 for data computation and Solidworks for modeling the design. Others limitation is the study for mechanical elements such as stress and tension are not included. The fabrication process are also postponed because of the fabrication process requires high resources.

1.5 Report Outline

This thesis consists of 5 chapters. The first chapter covers the introduction, problem statement and the objective of this project. The scope of study and report outline also included in this chapter.

The second chapter stressed out on the overview of electrical energy generation from renewable source and evolution of energy harvesting in Malaysia. It also emphasize on the new motion harvesting principles. Besides, chapter two will also state the overview of energy harvesting device that been proposed and the overview of related published result of energy harvesting device.

The next chapter is the methodology which explains in detail the procedures and steps for this research and project. Design and simulation software which are used to complete this project also explained in this chapter.

The fourth chapter will be discussing about the result which is the model of the energy harvesting device. The generator structure will also be discussed. Lastly, the fifth chapter will be a conclusion for the project. A suggestion and recommendation was presented as guidelines for other researcher in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Electrical Energy Harvester from Renewable Source

This chapter will be discussing about the overview of electrical energy harvester from renewable source such as solar, wind, geothermal, and ocean. Besides that, basic operation of permanent magnet generator, overview of the energy harvesting device and the related result by other research will also be discussed.

2.1.1 Solar

The sun, as we know it is our nearest star. Without it, life would not exist on this planet. The sun's energy was harvested every day in many ways. For example, when we hang our laundry outside to dry in the sun, we are using the sun's heat to do work that is drying our clothes. All plants use the sun's light to make food using photosynthesis. Animals, in the other hand eat plants for food. And as we have learned, production the coal, oil and natural gas that we use today comes from decaying plants hundreds of millions of years ago. So, fossil fuels are actually sunlight stored millions of years ago.

Indirectly, the sun or other stars are our energy source. Even nuclear energy comes from a star because the uranium atoms used in nuclear energy were created in the fury of a nova – a star exploding. Among the most usage of solar energy is for the solar water heater. The solar water heaters were being used all over the United States in 1980s. It was proved to be a big improvement from coal-burning stoves and wood. We can use artificial gas made from coal to heat water, but it cost much more the price we pay for natural gas today.

Many houses used solar water heaters. As much as 30 percent of the homes east of Los Angeles, were equipped with solar water heaters, in 1897. Solar systems were used in Arizona, Florida and many other sunny parts of the United States as improvement to mechanical were made. Tens of thousands of solar water heaters had been sold on 1920s. However, large deposits of oil and natural gas were discovered in the western United States which makes these low cost fuels to replaced heaters from solar source.

But today, solar water heaters are making a huge comeback. There are more than half a million of them in California alone and they were used to heat water for use inside homes and businesses. Panels on the roof of a building, contain water pipes which when the sun hits the panels and the pipes, the sunlight warms them. That warmed water can then be used as home usage or even for swimming pool.

Figure 2.1 shows the solar water heater. The flat plat collector will collect the heat from the sun. Antifreeze liquid is used as the heat storage element. It then will be flow to the heat exchanger chamber. This chamber is used to contain the water to be supplied. The cold water will be supplied into the chamber. Heat exchange process wills occurs which cause the cold water to heat up according to the collected temperature from the flat plat collector. The heated water will be supplied to the house.

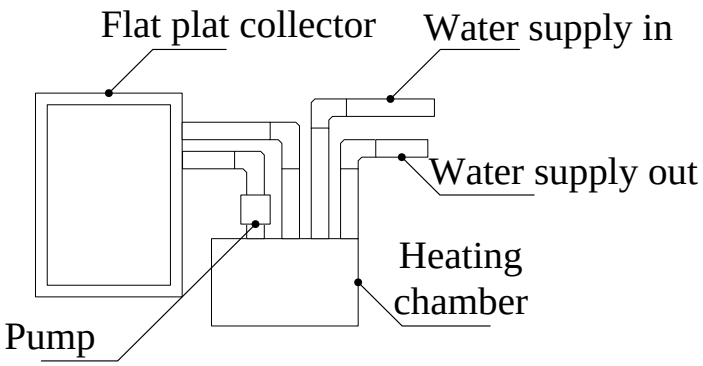


Figure 2.1: Solar Water Heater

Solar energy can also be used to generate electricity. Some solar power plants use a highly curved mirror called a parabolic trough to focus the sunlight on a pipe running down a central point above the curve of the mirror such as one in the California's Mojave Desert. The mirror focuses the sunlight onto strike the pipe, forcing the water to be steam. That steam can then be used to turn a turbine to generate electricity.

There are huge rows of solar mirrors in Mojave Desert arranged in what's called "solar thermal power plants" that use this idea to generate electricity for more than 350,000 homes. However, the problem with solar energy is that it works only when the sun is shining. Therefore, on cloudy days and at night, the power plants can't generate electricity. A "hybrid" technology has been developed so that during the daytime they use the sun. At night and on cloudy days they burn oil and natural gas to boil the water so they can generate electricity.

Another form of solar power plants to make electricity is called a Central Tower Power Plant, where sunlight is reflected off 1,800 mirrors circling the tall tower. The mirrors are called heliostats and it can move and turn to face the sun all day long. The reflected light is focused onto the top of the tower at the centre of the circle where a fluid is turned from liquid to steam. This steam can be used to turn the turbine and eventually generates electricity.

This solar harvesting technology was first built in the year 1980s and it was rebuilt in California as the experimental power plant given the name Solar II. This experimental power plant uses the sunlight to change heat into mechanical energy. This power plant was said to

make enough electricity to power about 8,000 homes. Scientists say larger central tower power plants however can generate electricity for 50,000 up to 200,000 homes.

Figure 2.2 shows the solar thermal electricity circuitry. The parabolic trough like in the **Figure 2.3** will be used to collect the sun heat [9]. By using a curve-shaped glass or aluminum, the parabolic trough will focus the heat energy from the sun, towards the liquid container. The heated liquid then will be pumped to the heat exchanger chamber and turbine. The turbine will rotate the generator, thus producing electricity. Cooled water will be rotated back to the parabolic through or other chamber where other heating process using different source of heating, occur. The heated liquid will be channeled back to the turbine.

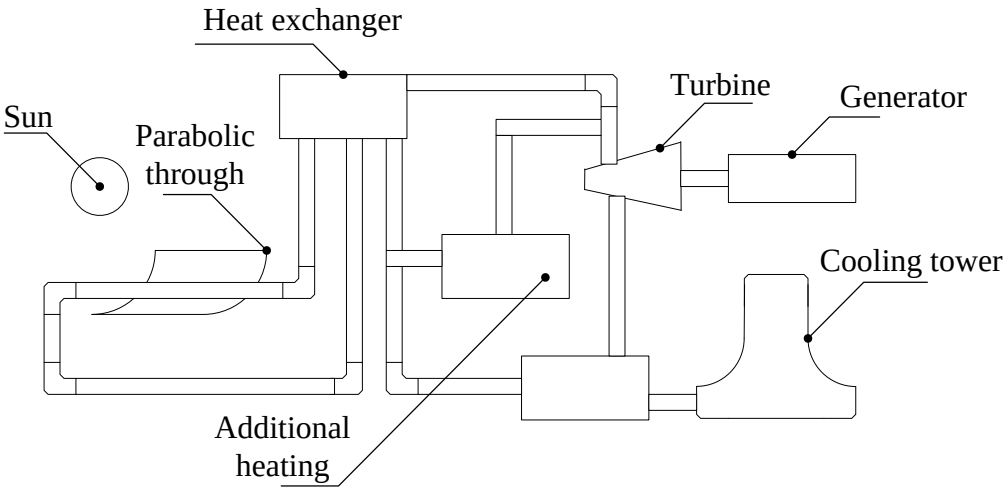


Figure 2.2: Solar Thermal Energy Harvesting

Figure 2.3: Parabolic trough

We can also convert the solar energy directly to generate electricity using solar cells. Solar cells or called photovoltaic cells or PV cells in short as shown in **Figure 2.4**. It can be found on many appliances as small as calculators, even on spacecraft. They were first developed in the 1950s for use on U.S. space satellites. They are made up of silicon, a special type of melted sand. Individual solar cells are arranged together in a module and then, these modules are grouped together in an array. Some of these arrays are set on special tracking devices to follow sunlight during the day to optimize the process of solar energy harvesting.

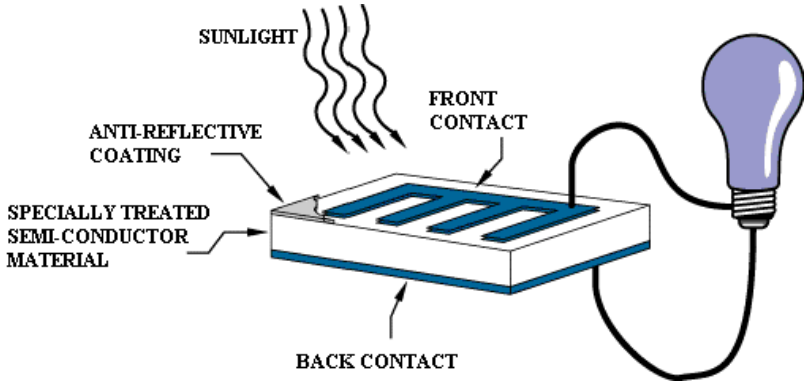


Figure 2.4: Build up of PV cells

The electrical energy generated from solar cells can be used directly in a home for lights and other appliances. Besides that, we can store solar energy in batteries to light a roadside billboard at night or for an emergency roadside cellular telephone when no telephone wires are around. PV cells have been installed in experimental cars which convert sunlight directly into energy to power electric motors on the car.

Figure 2.5 shows the process of solar energy harvested by using solar panel or photovoltaic (PV) cells. When sunlight strikes the solar cell, electrons are knocked loose. They move toward the treated front surface. An electron imbalance is created between the front and back. When the two surfaces are joined by a connector, a current of electricity occurs between the negative and positive sides. The current are fed to the controller to be stored using battery or inverted to AC power using inverter.

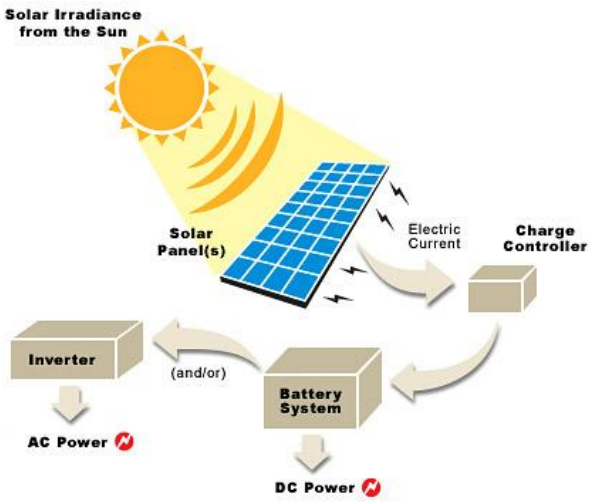


Figure 2.5: Solar energy harvesting

2.1.2 Thermal

From the first creation of the Earth, the geothermal has been existed. "Geo" in the geothermal means earth, and "thermal" means heat. Thus, geothermal means earth-heat. Below the top layer of the mantle or the Earth crust is a hot liquid rock called magma. The crust of the earth situated on this liquid magma mantle. This magma, when it breaks through the surface of the earth in a volcano called lava. 100 meters journey below the earth crust, the temperature of increases about 3 degrees Celsius. For, 10,000 feet below ground, the temperature of the rock will be hot enough to boil water.

Deep under the surface, underground water sometimes makes its way close to the hot rock and turns into boiling hot water or into steam. The hot water can reach the temperatures of more than 148 degrees Celsius which is hotter than boiling water (100 degrees Celsius). This water does not turns into steam because it has no contact with the air in the surrounding. When this hot water comes up through a crack in the earth, it is called hot spring. Sometimes it explodes into the air as a geyser. The Paleo-Indians used hot springs in for cooking thousands of years ago. In other places around the world, people used hot springs for a place to joy and

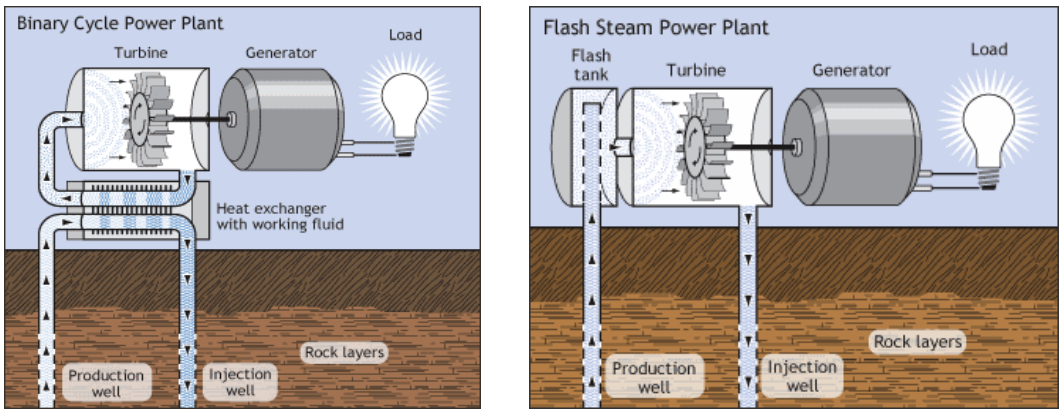
resting. The Romans built elevated buildings to enjoy hot baths while the Japanese have enjoyed natural hot springs for hundreds of years.

Nowadays, people use this geothermally heated hot water for swimming pools and in spa. The hot water from below the ground can also be used to warm buildings up to grow plants and vegetables indoor. In San Bernardino, in Southern California, hot water from below ground is used to provide heat to the buildings during the winter. Miles of insulated pipes were used to carry the hot water to dozens of public buildings. Animal shelters, retirement homes, state agencies, a hotel and convention center are some of the buildings which are heated using this method. Steam or hot water from underground can also be used to generate electricity using a geothermal power plant. Holes are drilled into the ground and pipes lowered into the hot water so that the hot steam or water comes up through these pipes from underground.

A geothermal power plant is like a regular power plant except that it has no fuel that was burned to heat water into steam. The hot water or steam in a geothermal power plant is heated by the earth. Then, it goes into a special turbine where the turbine blades spin and the shaft from the turbine is connected to a generator to generate electricity. The steam then gets cooled off in a cooling tower. When the steam or hot water was cooled off from the cooling process, a white smoke alike substance will appear. The cooled water can then be pumped back below ground to be reheated by the earth. This will ensure that the harvesting of geothermal energy can be continued.

Inside the power plant, hot water flows into turbine and out of the turbine. The cycle turns the generator, and the generated power goes out to the transformer and then to the transmission line that connect the power plants to our homes, school and businesses. The upper 10 feet below ground level stays the same temperature, almost everywhere in the Earth that is between 10 and 16 degrees C. In a basement of a building or in a cavern underground the temperature of the area is almost always cool. Heat pump system can be used to supply the heat to these underground building from hot steam source. The pipes of the pump system are buried near the building. Inside these pipes a fluid, like the antifreeze in a car radiator is circulated.

Thermal energy can be harvested using binary cycle and flash stem power plan. Both use the same source of energy which is the geyser which was among the free, renewable energy found on earth as shown in **Figure 2.6**. Production well will collect the hot water steam from the geyser. With binary cycle, the heat exchanger will be used to transfer the heat energy from the steam to the turbine while in flash steam, the hot steam will be used solely without other heat exchanger element. The turbine will be connected to the generator which when the turbine rotates, the generator will be able to produce electricity.



(a) (b)

Figure 2.6: Binary cycle power plant (a) and Flash steam power plant (b)

2.1.3 Wind

Wind can be used to do work. The kinetic energy of the wind can be changed into other forms of energy, either mechanical energy or electrical energy. When a boat lifts a sail, it is using wind energy to push it through the water. This is one form of work. Farmers have been using wind energy for many years to pump water from wells using windmills. In Holland, windmills have been used for centuries to pump water from low-lying areas. Wind is also used to turn large grinding stones to grind wheat or corn, just like a water wheel is turned by water power.