DESIGN OF ROTARY MACHINES FOR CEILING FAN

By

Noor Nadhirah Binti Khalid

15664

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

SUPERVISOR: ASSOCIATE PROFESSOR DR TAIB IBRAHIM

CERTIFICATION OF APPROVAL

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Electrical and electronics Engineering Programme
Universiti Teknologi PETRONAS
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BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL AND ELECTRONICS)

Approved by,

____

(Associate Professor Dr Taib Ibrahim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(NOOR NADHIRAH BINTI KHALID)

ABSTRACT

As Malaysia climate are hot and humid, ceiling fan become one of the most important electrical machine that should be installed in every house. Unfortunately, there is some energy that does not have being fully utilized from conventional ceiling fan. By using simple conversion of energy, from mechanical energy to electrical energy or vice versa are being applied in this project.

Therefore, in order to utilize the energy that being produced by the conventional ceiling fan, a design has being introduced which is combined the motor-generator system using axial configuration. There are some previous technologies of ceiling fan that using other configuration which need some improvement that can be develop using the design that being introduced. Motor-generator system using axial configuration is using one rotor and two stator arrangement which stator part is for motor and generator and rotor part is the combination part for generator and motor.

As the proposed design is being introduced according to the specification that being referred to the motor-generator system using radial configuration, the simulation design is being illustrated using Ansoft Maxwell software and the electrical analysis has being conducted which are consist of the induced voltage from the motor and generator part, air gap flux density between stator and rotor of motor and generator and the flux linkage of the motor-generator system.

The optimization of the simulation of design structure has been implemented and improved as time goes by in order to have a good design and improve the output of the electrical analysis that had being conducted. The result of the electrical analysis is being compared using the reference design of motor-generator system that using radial configuration. Based on the comparison between both configurations which are axial and radial, the good design of motor-generator system can be determine using the open circuit test that being conducted on electrical analysis of the design.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

In the introduction chapter, it consists of several sub topics includes the background of study, problem statement, objectives and scope of study which are being elaborated based on the project.

1.1 BACKGROUND OF STUDY

In Malaysia with humid and warm climate, ceiling fan becomes one of the important electrical machines that being installed inside every house for cooling purposes. Kubota et.al [1] had conducted several surveys that gave an outcome regarding the usage of electrical appliance in certain area. Therefore, Figure 1 shows that top five electrical machines that being frequently used in a house are television, refrigerator, washing machine, rice cooker and ceiling fan. Besides, the consumption of these electrical machines up to 24 hours per day and the energy consumption per year are around 1200 KWh as shown in the Figure 2. Therefore, it can be conclude that ceiling fan is one of the main contributors that contribute on the frequently electrical machine application usage in conducted area.

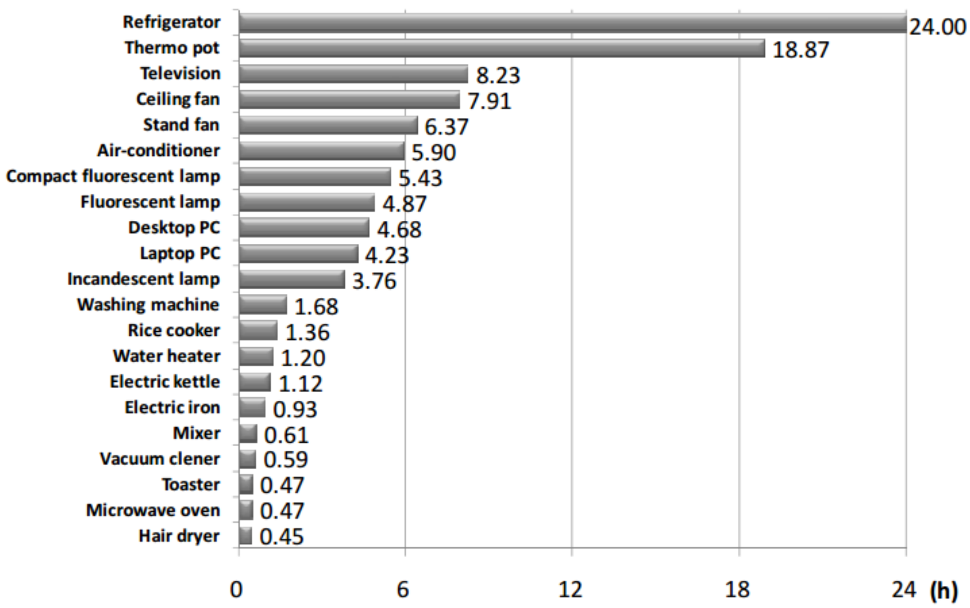


Figure 1: Daily Usage of Appliances in Hours [1]

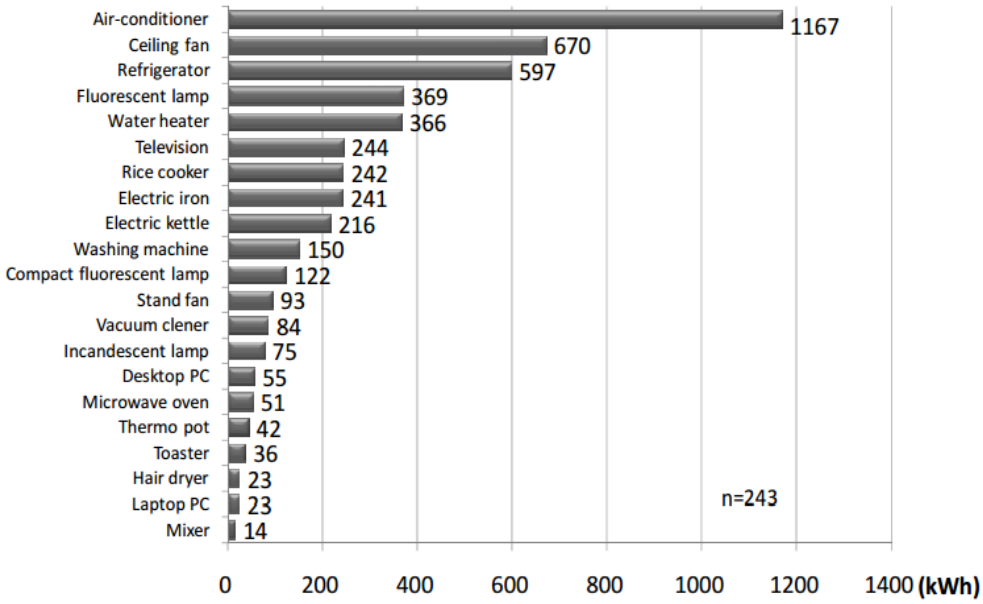


Figure 2: Yearly Electricity Consumption [1]

Hence, the ceiling fan should be fully utilize on it functions where there are renewable energy inside the motor of the ceiling fan. The renewable energy that comes from ceiling fan is known as kinetic energy which is being produced by the element inside the motor called rotor.

Renewable energy is one of the energy resources that most of the researchers or scientists want to discover the full potential of each resource. One of the renewable energy is that always being overlooks their existence by most of the researchers or scientists is kinetic energy. A lot of movements are being considered as kinetic energy such as the movement of ceiling fan, rotating of wheel and many more. Therefore, some research on this topic need to be studied as it may discover new potential that can be used for next generation.

Hence, the purpose of this project is to come out with a novel design of the electrical machine for the ceiling fan that can utilize this overlook kinetic energy into beneficial sources like electrical energy. This concept of conversion energy as shown in Figure 3 is from mechanical energy to electrical energy using a device called generator meanwhile conversion from electrical energy to mechanical energy is using a device called motor. This novel design of ceiling fan capable of generating electricity as the system of the electrical machine of the ceiling fan is a combination of motor and generator.

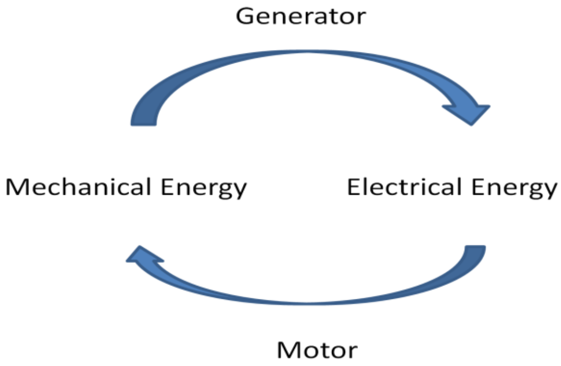


Figure 3: Energy Conversion

1.2 PROBLEM STATEMENT

The conversion of the energy in the ceiling fan is not being fully utilized as the kinetic energy from the ceiling fan rotation is being disperse into the air. The mechanical rotation from the existing ceiling fan is being considered as the wasted kinetic energy where it needs to be captured and converted into the electrical energy. The novel design of the ceiling fan system where the combination of the motor and generator is being used to do the conversion of energy. The mechanical energy from the motor is being considered as a turbine to the generator. Thus, with this concept as shown in Figure 4, there is one proposed design of the motor-generator system inside the ceiling fan is being introduced which using the axial configuration.

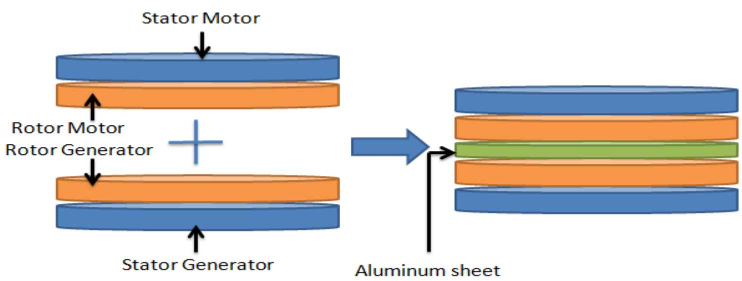


Figure 4: Conceptual Design

1.3 OBJECTIVES

1) To conduct extensive literature review on electrical machine technologies for electrical ceiling fan
2) To propose a new design of ceiling fan system which consist of motor and generator combined into one system
3) To simulate the optimize proposed design by using finite element software, Ansoft Maxwell Software

1.4 SCOPE OF STUDY

1) Research on literature review on the existing technologies on the ceiling fan structure, radial and axial structure of ceiling fan motor or generator
2) Research on design specification of the stator and rotor of the motor and generator which includes the types of the materials of stator, rotor and permanent magnet, number of slots and poles, and the dimension of the design.
3) Propose a design which combined motor and generator into a system of ceiling fan
4) Simulate and analyze the proposed design based on the electrical analysis of open test circuit which are flux distribution, induced voltage and air gap flux density
5) Finding on comparison of radial and axial structure based on the electrical analysis
6) Thesis writing on the finding of the proposed design and the electrical analysis of the design.

This introduction chapter concludes the summarization of the project where the objectives and the background of the project is being explained clearly. Besides, the problem statement and the scope of study is telly between each other.

CHAPTER 2

LITERATURE REVIEW

In this literature review chapter, it explains the existing technologies regarding the ceiling fan, the energy harvester and the specification of the rotor and stator for the motor and generator for the modification of the ceiling fan.

In order to have a better understanding on the designing of the electrical machine of the ceiling fan with combination system of motor and generator, the author had goes through, analyzes and reviews the existing research paper that related to this project. First of all, the current technologies of ceiling fan is the basic knowledge that should know in order to proceed with the designing a new ceiling fan structure.

Figure 5: Bladeless Ceiling Fan [2]

Dave [2] said that the bladeless ceiling fan is called Exhale fan as shown in Figure 5 is being invented by Nik Hiner and Richard Halsall. This innovation is being inspired by the cyclonic air movement. With this inspiration, they created a bladeless ceiling fan that only uses 360-degree movement of air to remove the unspotted hot spot within a room. In contrast to conventional ceiling fan that has some weakness in term of air movement in a room. Thus, bladeless fan is one of the current technologies that give a lot of benefit to humankind.

Figure 6: Haiku Smart Ceiling Fan [3]

Nick [3] mentioned in his article where the innovator company which called the Haiku shown in Figure 6, they come out with a new invention that use their own technology called SenseME technology where a device that can detect a presence of someone to turn on any device that use SenseME technology. This SenseME technology is being applied into ceiling fan where it used a range of sensor in order to regulate the temperature in a room and also to detect someone that entering the room. Besides, this ceiling fan is being integrated with high-efficiency of Light Emitting Diode (LED) that can automatically adjust the brightness of the room. This technology can be categories as green technology where saving energy is being applied in this situation. It is a great technology to be use for present and future time.

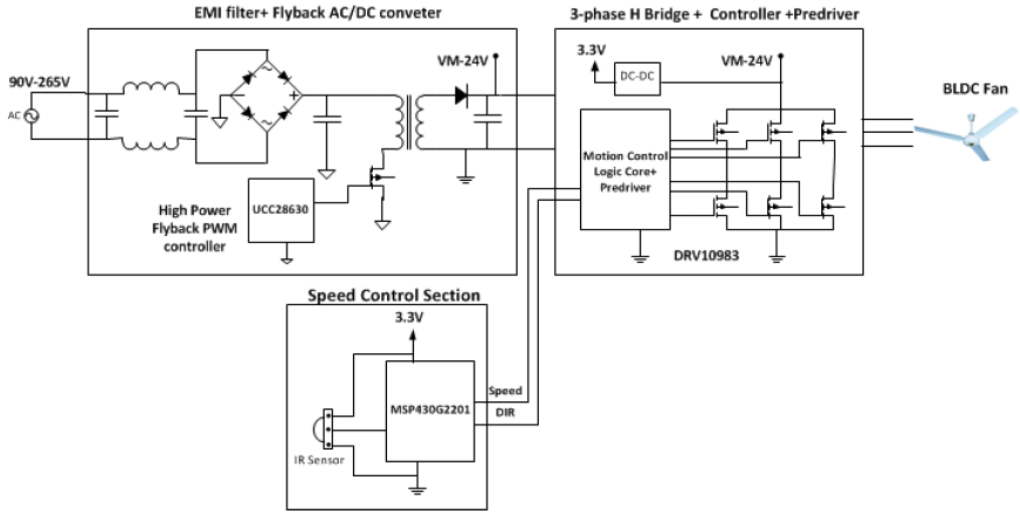


Figure 7: Functional Block Diagram of BLDC Ceiling Fan Controller [4]

Based on Texas Instrument Company [4], Figure 7 shows a reference design for Brushless DC ceiling fan controller with sensor-less sinusoidal current control for their customer to solve any problem regarding that product that they produced. It is involve with the controller for the ceiling fan. The technologies that they used are the Alternating Current – Direct Current (AC-DC) section where it control the main AC input range to generate smaller voltage as input to the ceiling fan itself. Other than that, for motor control section, it is based on an integrated chip that integrates a 3-phase BLDC motor control, H-bridge inverter and also regulates the output voltage to support the external load. Last but not least, it has Infrared remote control based speed section which it decode the remote input and generate Pulse Modulation Width duty cycle command for fan speed control. Thus, with these features, it can provide the great technology for ceiling fan.

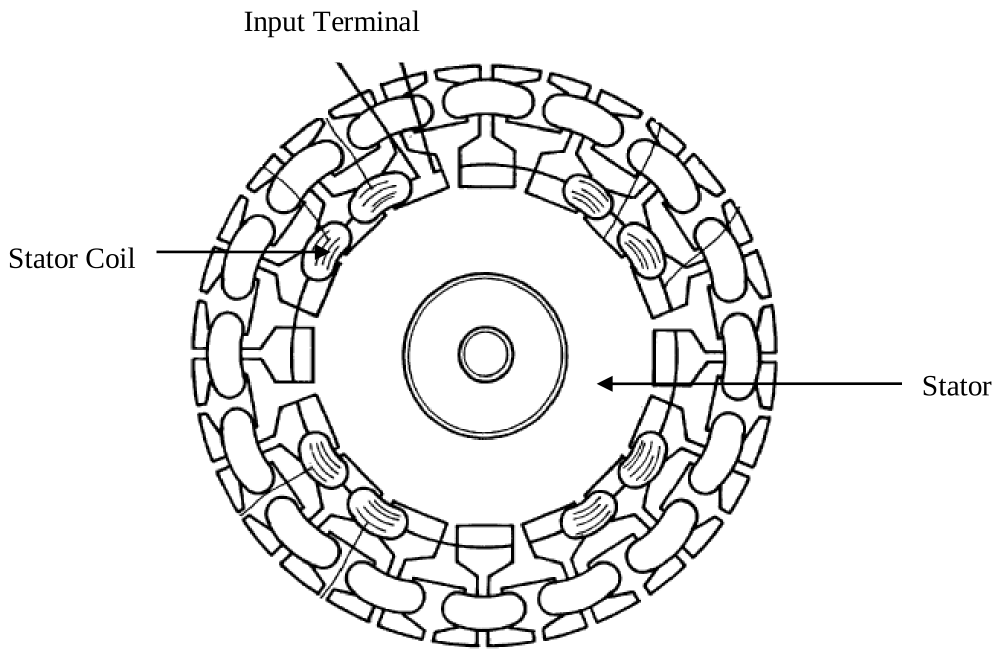


Figure 8: Stator Coil (Skip or pass through winding process) [5]

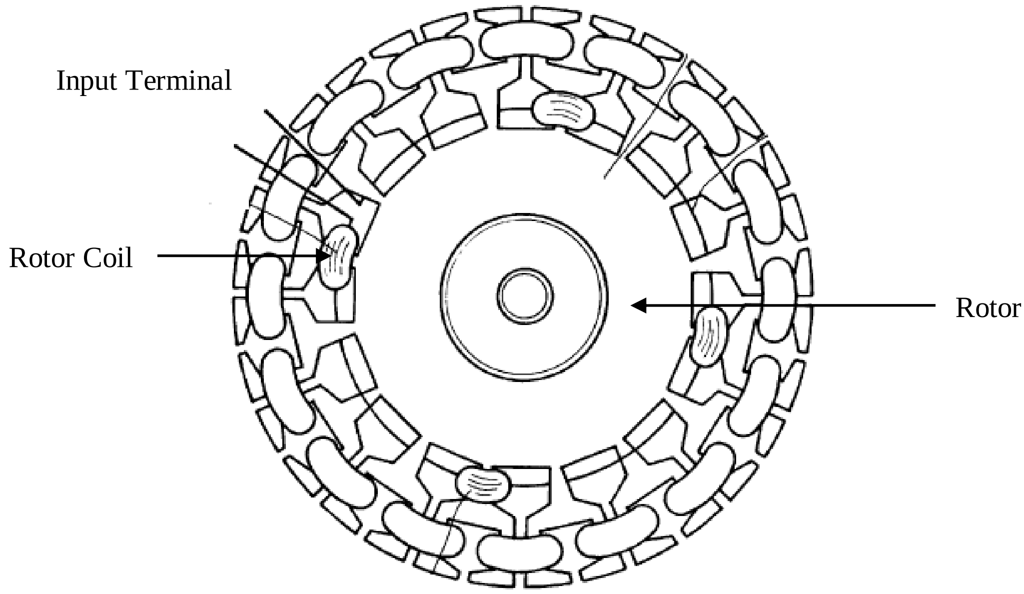


Figure 9: Rotor Coil (Skip or pass through winding process) [5]

Tsay [5] innovate a design patent which is instead of using current to change the speed of the ceiling fan, they come out with a design that manipulates the coil structure at the stator to adjust the speed. This design uses skip or pass through winding process as shown in Figure 8 and Figure 9. This method of winding can distribute an even magnetic field for the fan rotor to eliminate the interval noises from the current. Thus, using this method, three adjustable speed of ceiling fan can be obtained.

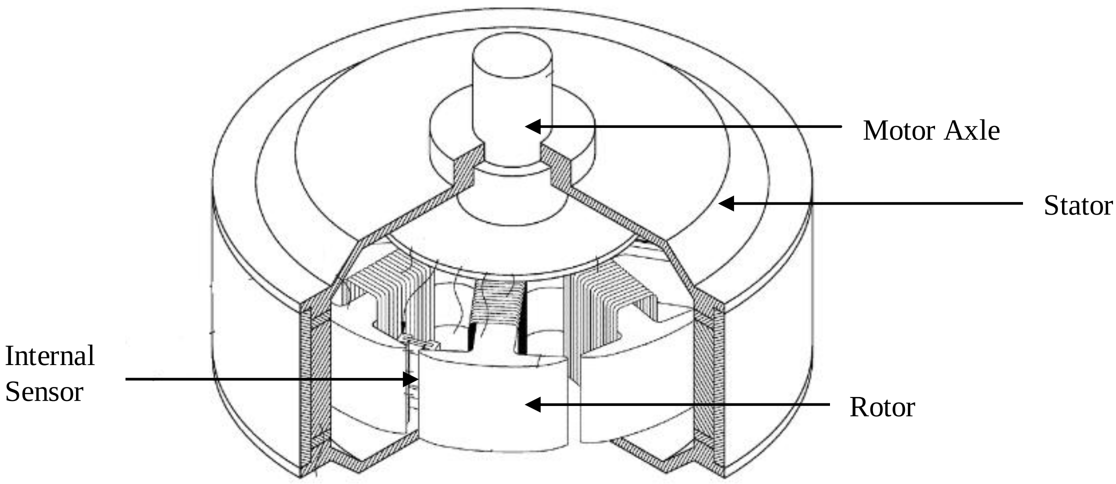


Figure 10: 3D of invention design by Yao et.al [6]

Yao et. al [6] also innovate a design patent shown in Figure 10, the main objective for this design to make the structure of the ceiling fan motor become easy to assemble in order to improved the efficiency for assembly job. Besides, this design also provides a ceiling fan motor that has effectively reduced the sensing error between the sending magnet and sensor. This is to ensure the stability of the rotor during the operation. Yao et.al [6] provides with three ideas where each of the ideas bring different improvement parallel to the objectives that they want to achieve.

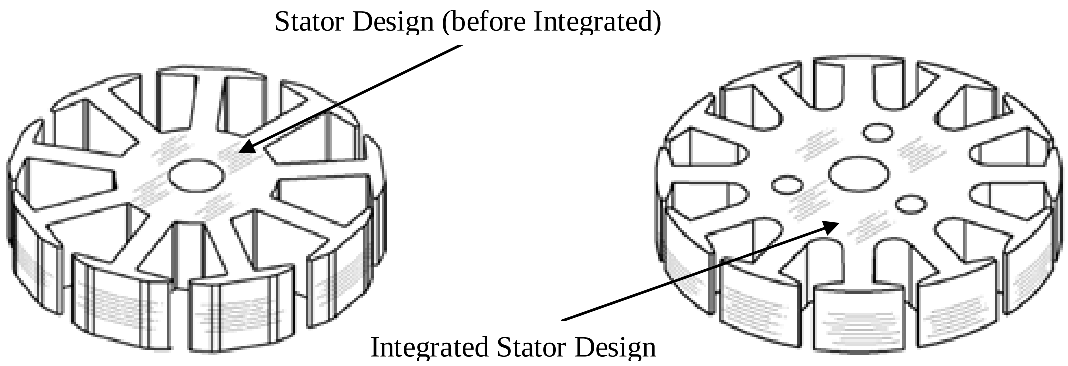


Figure 11: Design of integrated stator [7]

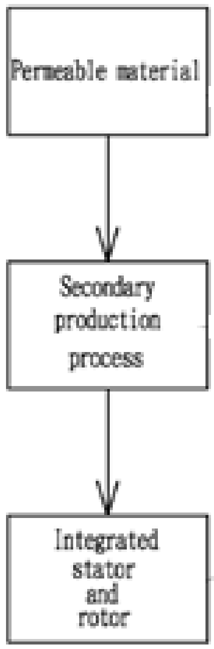


Figure 12: Flow chart of integrated stator and rotor [7]

Chang [7] is the inventor which creates an integrated stator and rotor for Direct Current brushless (DCBL) ceiling fan motor as shown in Figure 11. The means of integrated design of stator and rotor is where they are made from permeable material through secondary production process as shown in Figure 12. This can improve the electrical efficiency and reduced the low working temperature. Besides, the inventor also introduced the electrical controlling circuit which includes the computer microprocessor, power supply, frequency converter, phase detector and remote control device. This controlling circuit is being introduced in the design of DCBL ceiling fan motor in order to control the speed and the orientation of the motor.

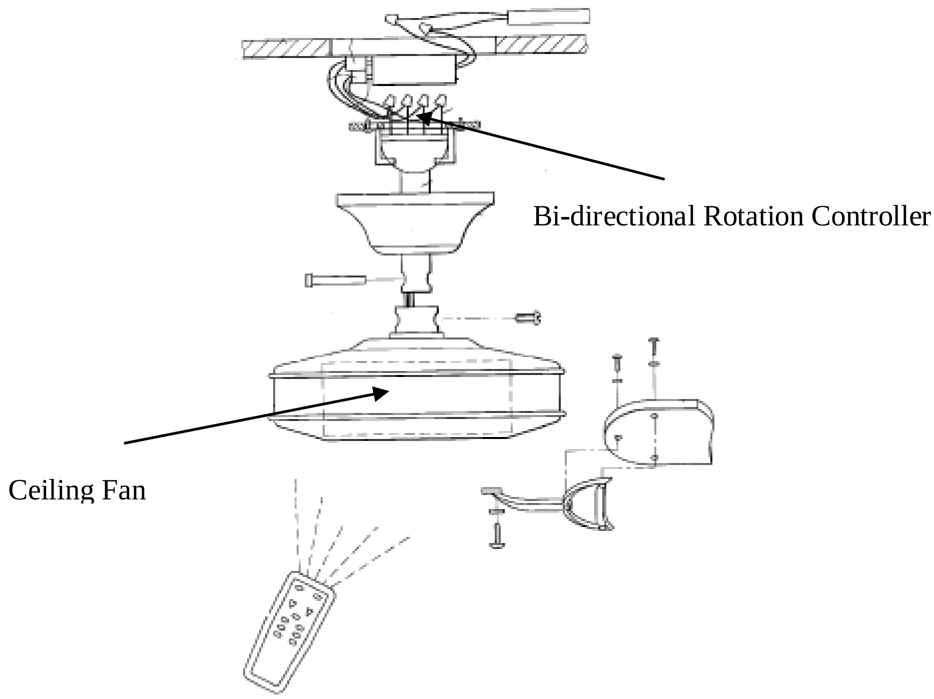


Figure 13: Ceiling fan design with bi-directional rotation control [8]

Liu [8] the inventor introduces the ceiling fan design with bi-directional rotation control as shown in Figure 13. This invention is simple to be used and low cost production. It is related to the infrared transmitter from the remote fan controller transmit the signal to the receiver at the ceiling fan. The signal is being processed by microprocessor which connected to the relay switch circuit where it can control the direction of current inside the coil. Then, the current will trigger the state of motor either Normally Closed for positive direction or Normally Opened for negative direction. This represents the bi-directional of the motor. Microprocessor can control the SYNC signal to make sure that the motor is completely stopped moving before it change the direction. This to ensure the life span of motor is increased.

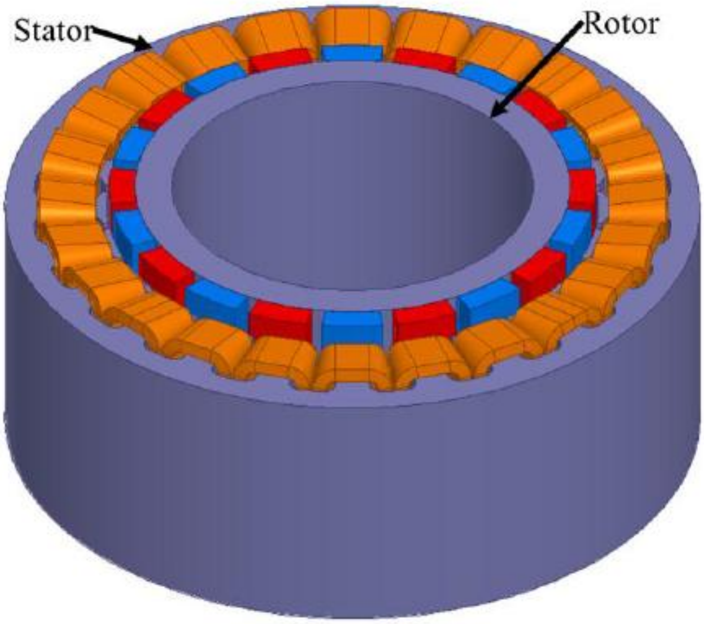


Figure 14a: Radial-flux machine. [9]

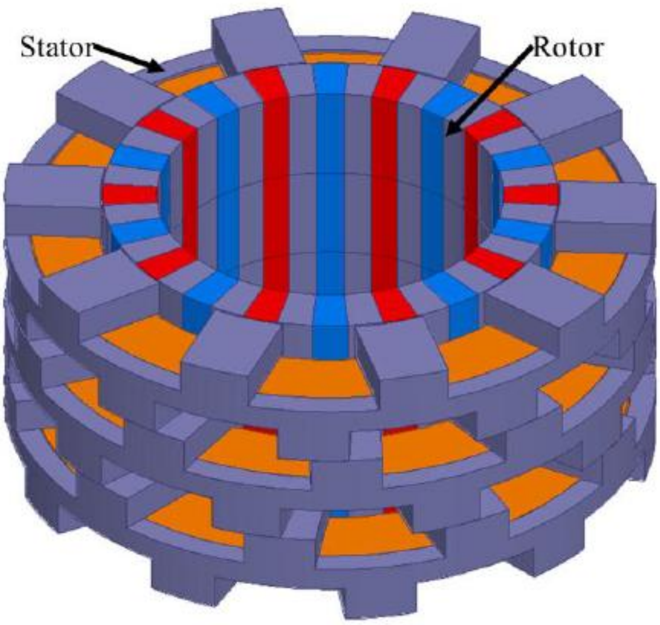


Figure 14b: Transverse-flux machine.[9]

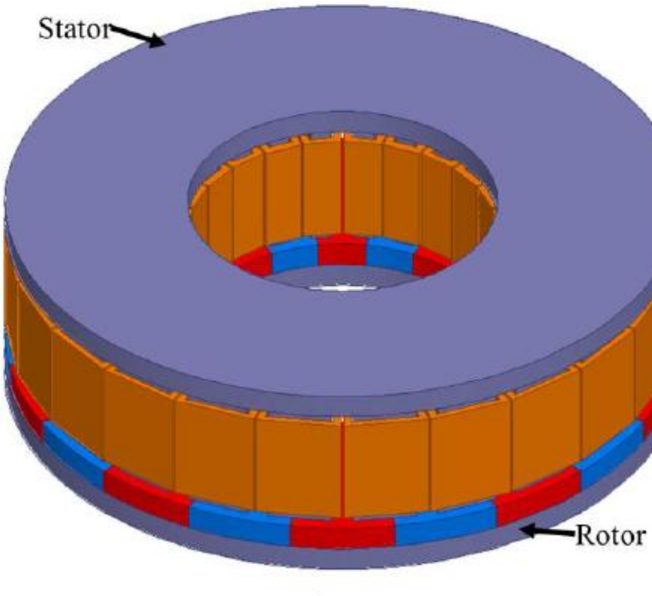


Figure 14c: Axial-flux machine. [9]

Joo et.al [9] provides the comparison performance between radial, axial and transverse flux machine as shown in Figure 14a, Figure 14b and Figure 14c. They do the analysis on three different machines with three different configurations. The output powers from these three machines are almost the same which is 15kW at 300rpm. They said that radial flux (RF) machine and transverse flux (TF) machine has higher efficiency compare to axial flux (AF) machine. AF machine has high current density and low efficiency due to high rated current. TF machine has better torque density compare to RF and AF machines but due to high cogging torque as TF machine has high torque ripple, thus it can be conclude that AF machine as high and better torque density compare to RF machine. Below is shows the different configurations of three machines and the result of all analysis done on those three machines.

For energy harvester device, Toh et.al [10] provide some analysis based on energy harvester from rotating structure. They do the analysis on power generated using flyback power conversion circuit where the highest power obtain when the load resistance is matches with armature resistance. Besides, they also do on flip over speed analysis where it determines the limit speed of the motor that it can stand before the motor become unstable. They also do analysis on off-axis performance where when there is misalignment on the system, the power generated performance is reduced.

Gadkari et.al [11] produce an energy harvesting system from ceiling fan where the motor from the fan rotates the dynamo that attached to it and the AC current will transfer to the charging circuit and the output voltage being store in the battery or directly being use. The output voltage that being produced by the generator based on number of turns in a coil, strength of magnet and rate of magnet turns. Besides, the advantages of this system where it has low initial cost, no emission of hazardous element where it can protect the environment, minimum maintenance cost and reduced the cost to transmit the electricity along power lines. The disadvantages of this system are the incorporation of dynamo's mechanism may reduced the speed of the fan where it can reduced the power generated by this system, electricity generated is lesser compare electricity consumed and the energy loss is too high.

Other than that, for topic specification of the stator and rotor of the motor and generator, Sathaye [12] produced several analyses on the potential global benefits if there is an improvement on the ceiling fan efficiency. Based on the research that they found in the India, it is found that the usage of brushless direct current (BLDC) motor has lower consumption lever compare to induction motor when both fans are operating at the same speed. They also highlight the improvement that can be made on induction motor to increase the efficiency. There are; by increasing the amount of active material (lamination winding) either lamination steel or lamination copper, by reducing the air gap between the rotor and stator and by using standard-grade aluminum for die-cast rotor. The improvement on active materials can improve the magnetic quality of the rotor and winding. Besides, the reduction of the air gap can increase the magnetic torque induced by the winding on the rotor. Lastly, the usage of standard-grade aluminum to reduced the weight of the rotor.

Last but not least, topic on electrical analysis on the design structure of motor and generator, Liu et.al [13] are focusing on the improvement that can be made on the ceiling fan to save the energy. For conventional ceiling fan use up to 65W at high speed operation but with their design that use permanent magnet synchronous motor (PMSM) inside the ceiling fan can reduce the energy up to 50%. This is mainly focus on energy conservation. Beside, this design can reduced the energy usage, it also have low cogging torque as they are using sin back EMF voltage and sin wave form current to modified the cogging torque. Method that being used in their research is PMSM and flux analysis where they are using 8 poles with 12 slots of rotor with each slot being winded by single layer coil. This design can be applied for energy conservation.

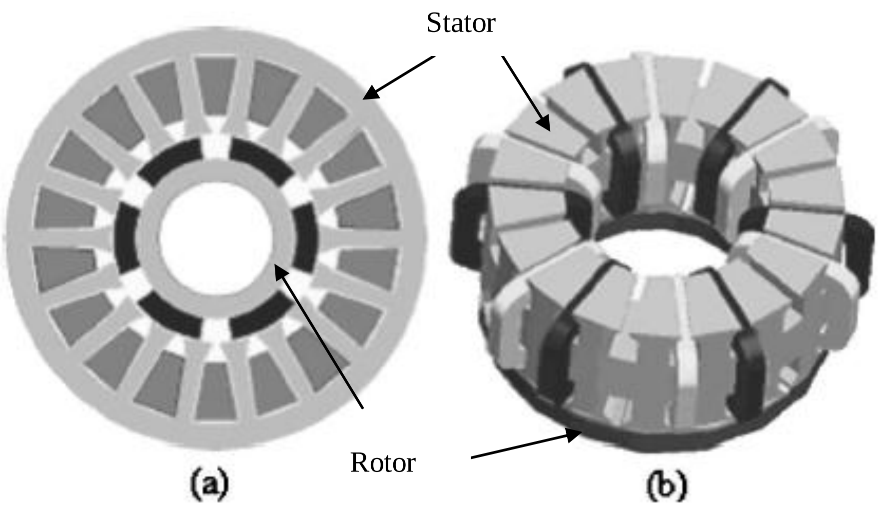


Figure 15: Radial and Axial flux PM BLDC motor [14]

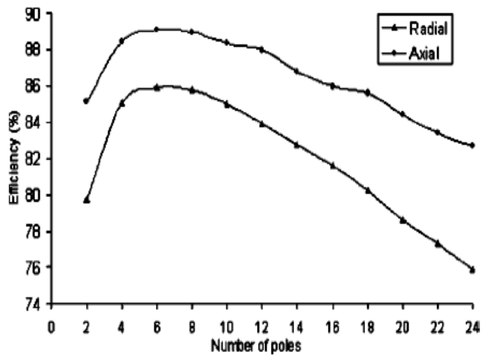


Figure 16: Motor weight Vs Slot electric loading [14]

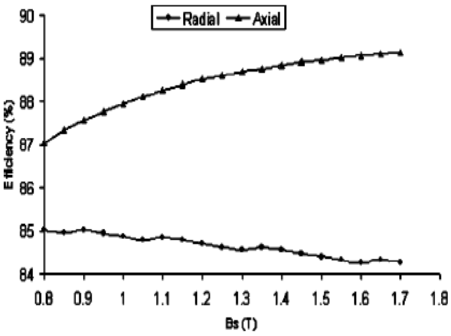
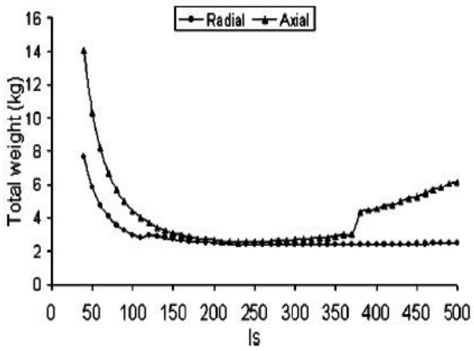


Figure 17: Flux density plot [14]



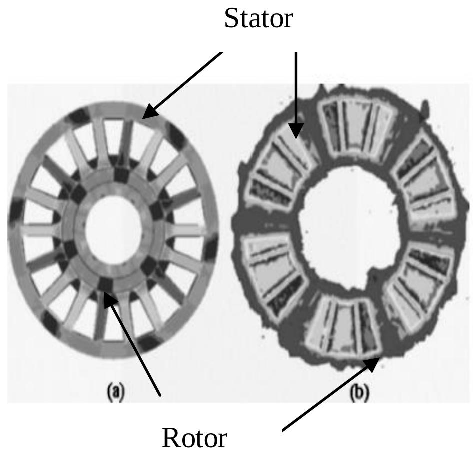


Figure 18: Efficiency VS no of poles [14]

Figure 19: Efficiency Vs stator flux density [14]

Table 1: CAD and FE on RF and AF PM BLDC motor [14]

Parameter		Radial		Axial	
		CAD	FE	CAD	FE
Average torque (N m)		1.913	2.02	1.91	1.98
Average airgap flux density (T)		0.796	0.793	0.799	0.866
Stator flux density (T)	Stator core	1.6	1.55	1.557	1.537
	Stator teeth	1.6	1.778	1.55	1.537
	Rotor core	1.8	1.786	1.641	1.635
Phase-inductance (mH)		5.55	5.83	4.89	5.29

Uphadhyay et.al [14] are doing the comparison between axial field (AF) and radial field (RF) permanent magnet performance by changing various parameters at one time using computer aided design (CAD) and finite element method (FEM) as shown in Figure 15. The parameters that they change at one time during the simulations are number of magnet pole, number of slot, permanent magnet properties, airgap length, stator flux density, airgap flux density, current density and slot electrical loading. Based on these parameters as shown in Figure 16, Figure 17, Figure 18, Figure 19 and Table 1, they conclude that the efficiency at rated load for AF is better compare to RF due to better utilization of conductor length. The performances of maximum efficiency for both fields are at 6 poles before the performance decrease due to higher iron losses due to high frequency. When soft magnet material is being used in this simulation, the performances of both fields also increase within 3% but AF has higher performance compare to RF. Overall conclusion that they come out is the AF motor efficiency is 4% higher compare to RF motor.

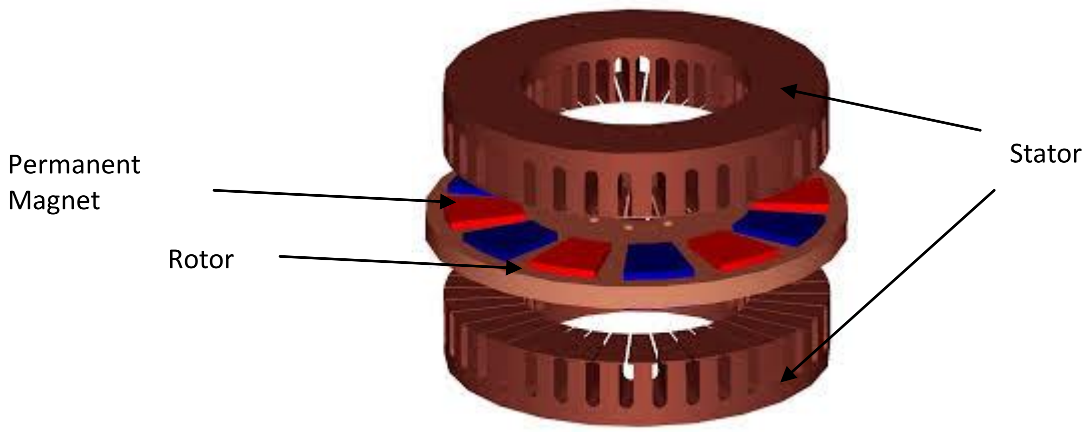


Figure 20: One Rotor Two Stator Configuration [15]

Parviainen [15] innovate and analyze the design of the axial-flux permanent-magnet low-speed machine and also on comparison of performance of radial-flux and axial-flux machine, he do research on design of axial flux machine that using configuration of one rotor and two stators as shown in Figure 20. Referring to the configuration of one rotor and two stators, the output power obtains by using this configuration is 5kW rated at 300 revolutions per minutes speed. This configuration gives a low speed and high torque for the industrial application. It is comply with the research that being done by Parviainen. Besides, he also do some comparison between axial flux and radial flux configuration based on one machine specification which is 55kW machine using different speed of 150, 300, and 600 revolutions per minutes speed. The analysis that is being done to do the comparison is based on the efficiency and power factor of machine.

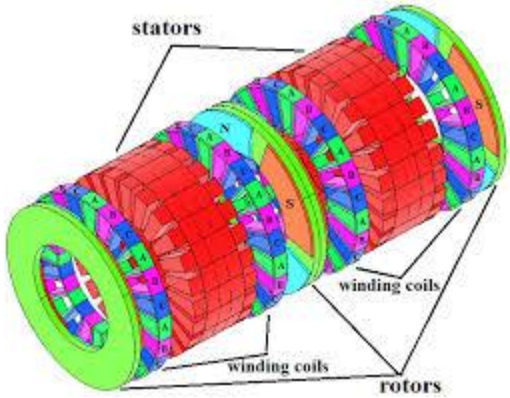


Figure 21: Configuration of Multistage of Axial Flux Permanent Magnet Machine [16]

Mahmoudi et.al [16] stated that axial flux permanent magnet machine has the capability of flux weakening, the elimination of field excitation and rotor loses can be reduced. This is due to the construction of the design where less core material is being used. It is related to have a high torque-to-weight ratio that influences the performance of the machine. Besides, this configuration can reduce the noise and vibration that being produce when there machine is turn on. Figure 21 shows multistage of axial flux configuration of permanent magnet machine that being design by Mahmoudi et.al

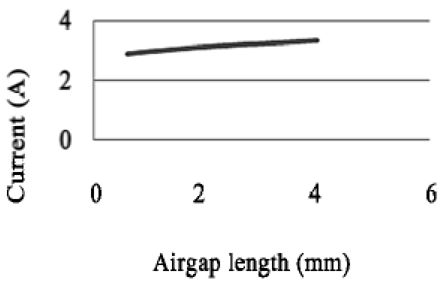


Figure 22: Terminal Current Vs. Airgap Length [17]

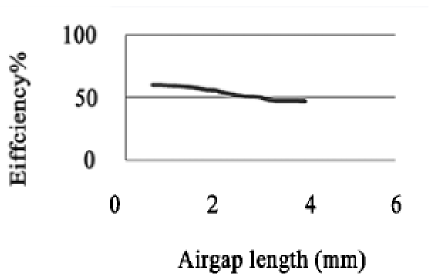


Figure 23: Efficiency Vs. Airgap length [17]

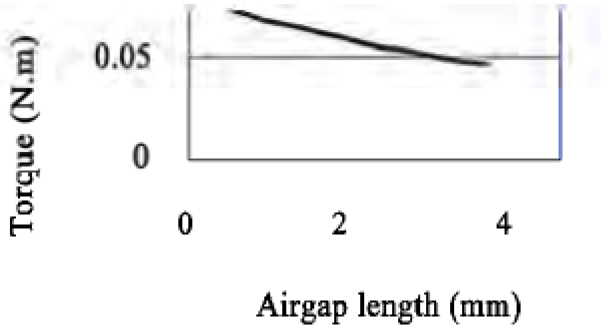


Figure 24: Output Torque Vs. Airgap Length [17]

Modarres et.al [17] conducted a research on axial flux hysteresis motor based on air gap variation. It is a self- starting synchronous motor that use hysteresis characteristic of magnetic field. By varying the air gap length, the flux distribution in the hysteresis rig also change accordingly and the output of the motor is measured based on terminal current in Figure 22, the efficiency of the motor in Figure 23 and torque as shown in Figure 24.

As a conclusion for literature review chapter, the existing technologies for the ceiling fan consist of several types which include the types of innovated ceiling fan such as bladeless ceiling fan and smart ceiling fan. Besides, the energy harvester device is consist of dynamo and controller system and the specification of the stator and rotor is relates to the innovation design by the previous researchers.

CHAPTER 3

METHODOLOGY

In this methodology chapter will be discuss on the research methodology, project activities, key milestone for the project, gantt chart of the project, tools that will be used during this project, proposed design and last but not least is design methodology.

3.1 RESEARCH METHODOLOGY

This research methodology part will be discussing on how to analyze the data and obtain the output result. Figure 25 shows the overview of the research methodology of FYP 2. It explains the process flow of the research that being carried out.

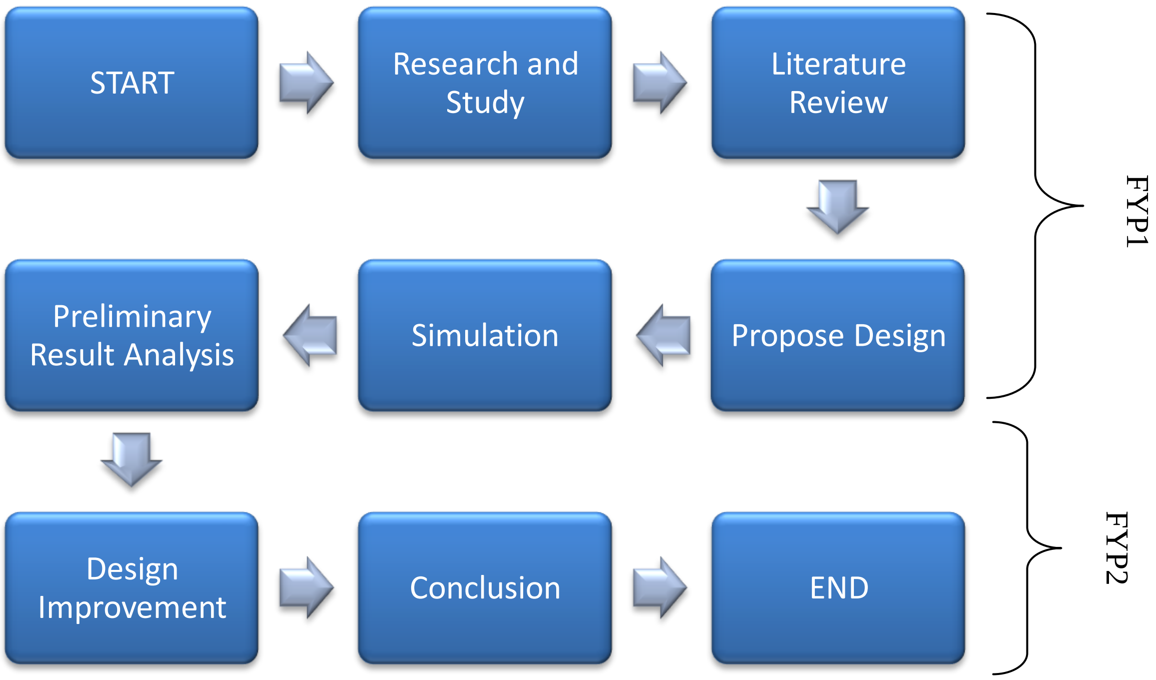


Figure 25: Research Methodology

3.2 PROJECT ACTIVITY

Project Activities shows the details description on each part of the research methodology as shown in Figure 26. It shows the project activities description based on the research methodology where it explain each of the activity done for each part.

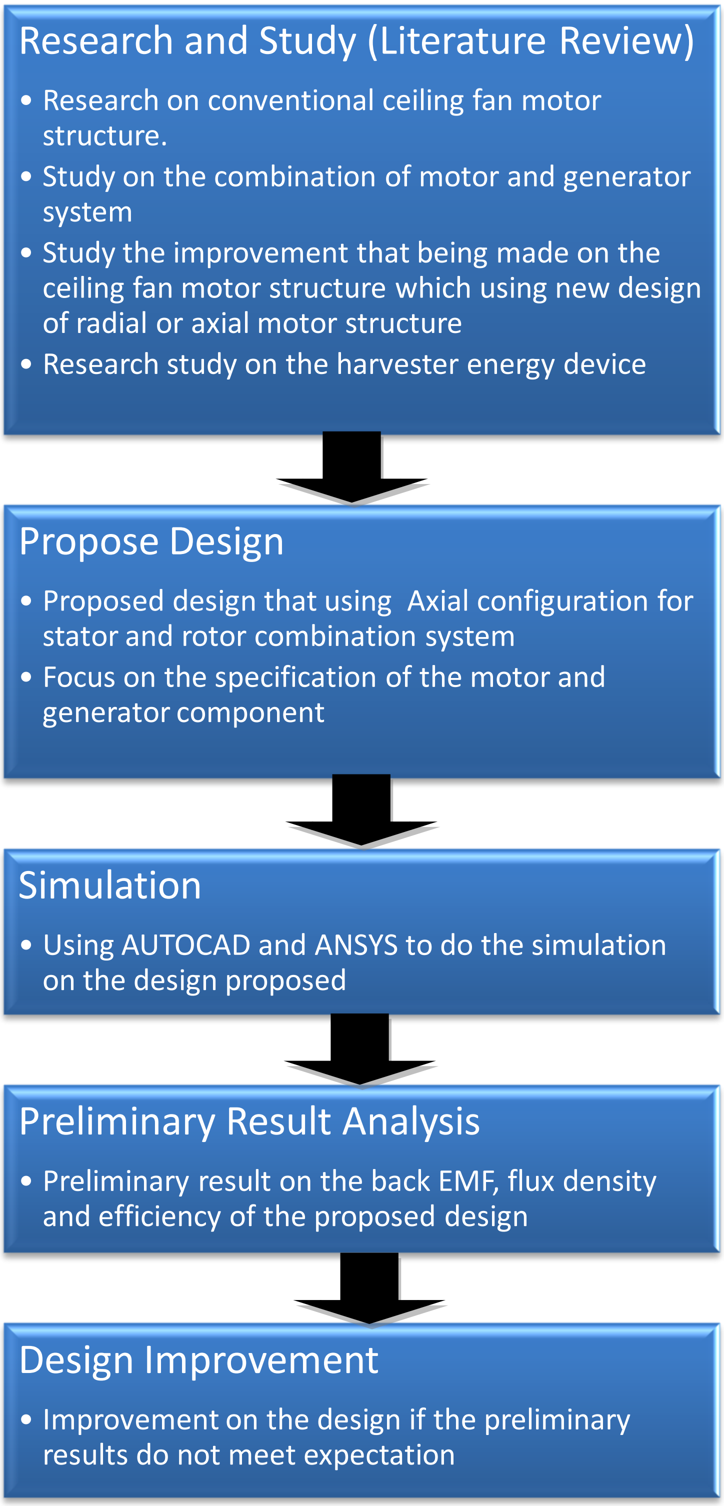


Figure 26: Project Activities

3.3 KEY MILESTONE

Figure 27 (Refer Appendix 1) shows the key milestone that author need to take note on the specific task in order to make sure that all the task and documentation can be done in the specific time.

3.4 GANTT CHART

Table 2 (Refer Appendix 2) shows the Gantt chart of the FYP 2. It shows the timeline that need to follow in order to make sure the task is being done on the respective timeline,

3.5 TOOLS

SOFTWARE

- AUTOCAD
- ANSYS
- Microsoft office

3.6 PROPOSED DESIGN

Based on the literature review part on chapter 2, there are various ideas on designing of motor-generator system that being implemented for the ceiling fan system. Therefore, the author proposed a novel design of the ceiling fan system that being modified from the existing design that used axial configuration where the magnetic field move in axially along the side way of the machine.

Figure 28 shows the conceptual design of the stator and rotor configuration where it consists of two part, which are motor and generator. This design using a concept design single rotor double stator where the rotor for motor and generator part will be attached together and rotates simultaneously. This ceiling fan design will use permanent magnet as the rotor for both motor and generator.

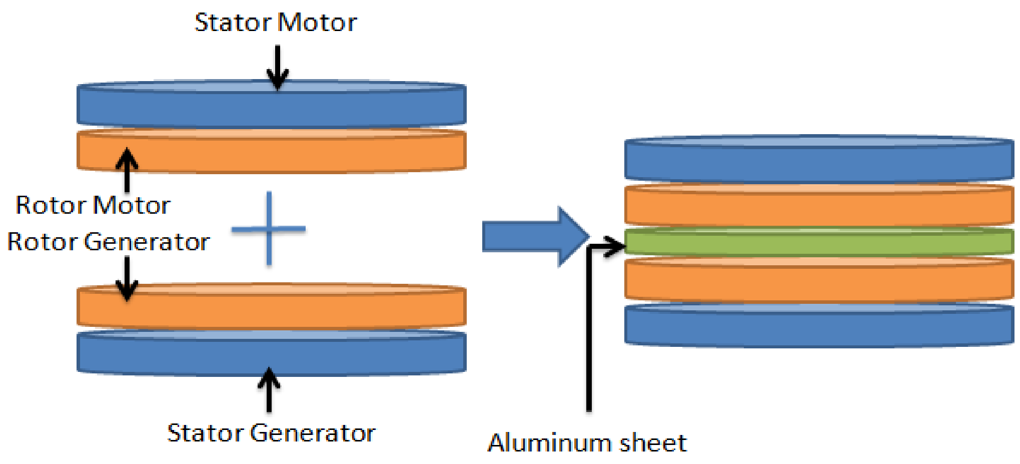
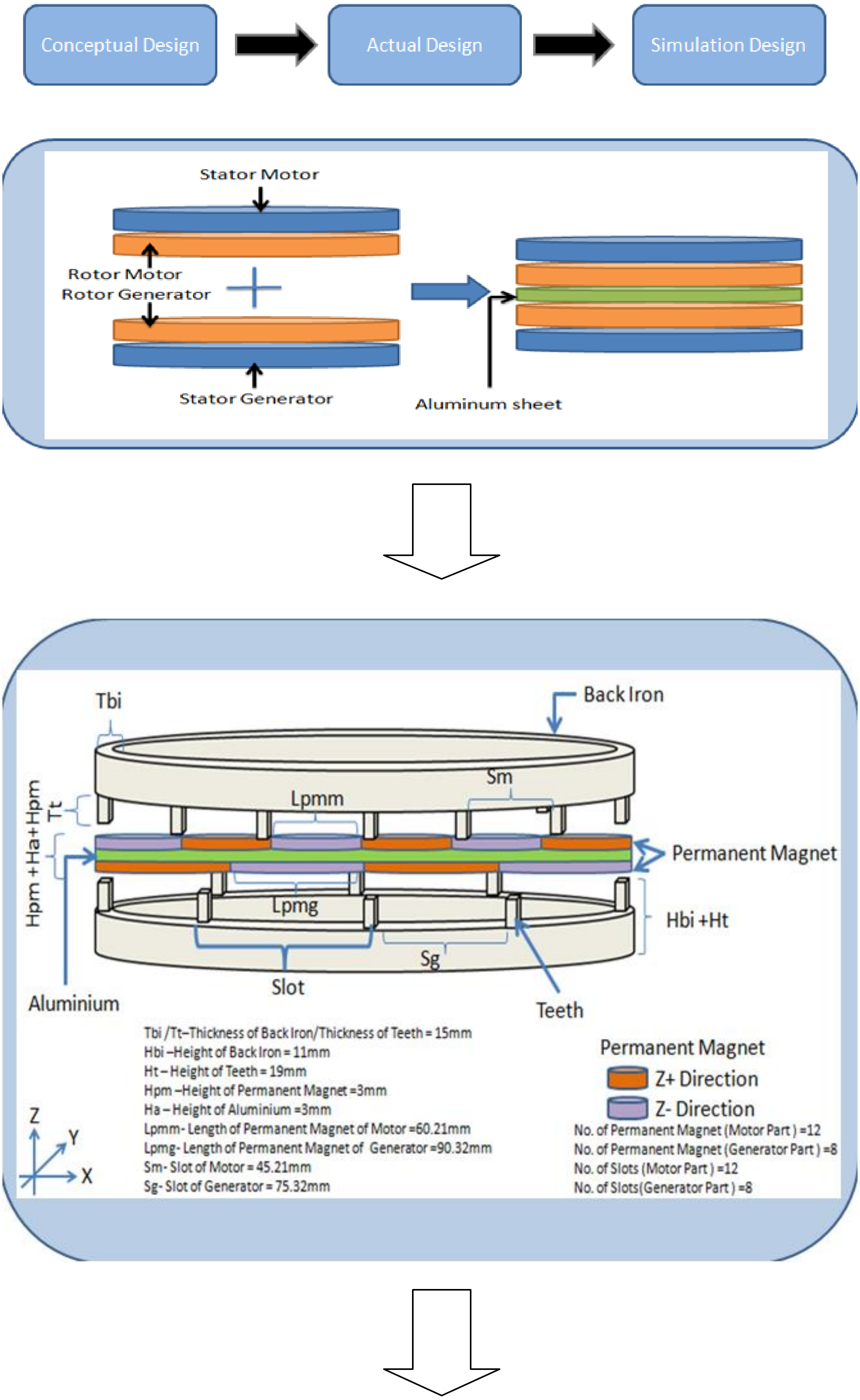


Figure 28: Conceptual Design (Axial Configuration)

The motor part for ceiling fan will carries the same function as conventional ceiling fan where the motor will be feed the electricity from the power source and directly supply to the winding at the stator motor. The coil carrying conductor that have the current flow will generate the magnetic flux at the winding stator. The interaction between the magnetic flux from the stator and magnetic flux from the permanent magnet at the rotor will causes the rotor to rotate. In this case, the electrical energy is converted into kinetic energy.

The rotor for both motor and generator are attached together separated by aluminum sheet as the flux insulator to avoid any magnetic interference from both rotor parts. As the rotor of the motor rotates, the generator rotor that consists of permanent magnet will also rotate simultaneously. The constant magnetic flux from the rotor will be captured by the winding stator of the generator, thus the voltage will be induced and generate the electricity.

3.4 DESIGN METHODOLOGY



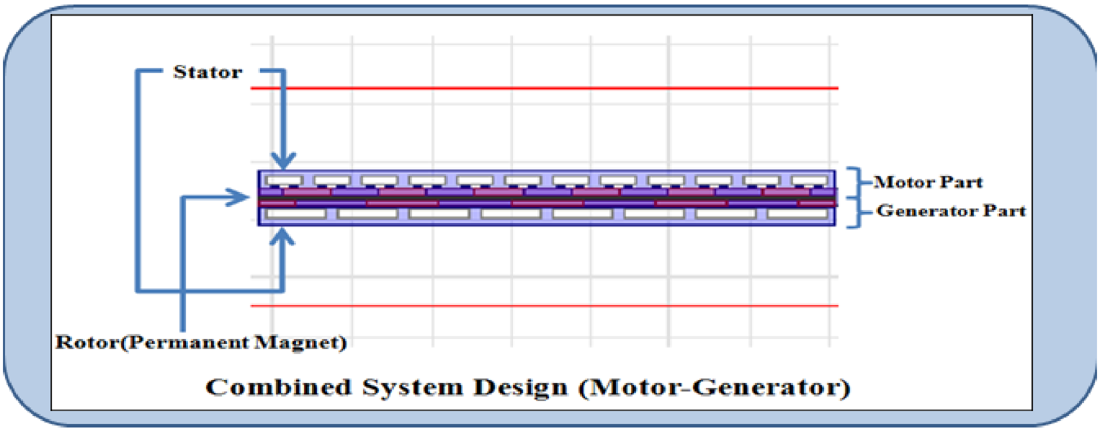


Figure 29: Design Methodology

Figure 29 shows the design methodology where it starts from conceptual design where the proposed design is being introduced. Then, the actual design is where the specification of the proposed design is being set up accordingly. This specification is being referred to the specification of radial configuration of motor and generator system of previous technology. Meanwhile, for simulation design is the design that being simulate using Ansoft Maxwell in order to observed the electrical analysis of the system.

As conclusion, in this chapter, the research methodology was conducted in order to study the best design configuration for combined system machine for ceiling fan. Basically, there are three stage of case studied that will be performed ; To conduct literature review on permanent magnet machine in order to obtain the best design configuration, to stimulate the proposed design using the finite element analysis, Ansoft Maxwell software and to do an electrical analysis based on open test circuit on proposed design using the software.

CHAPTER 4

RESULT AND DISCUSSION

In this result and discussion chapter, the simulation result will be explain in term of the simulation design and electrical analysis which includes the flux distribution, induced voltage, flux linkage and air gap flux density. Beside, the optimization and comparison of the design will be discuss and explain clearly in this chapter.

As stated in chapter 3 part 3.3 proposed design, the design concept has being illustrate in 2 Dimension (2D) design with concept of linear motion to do the electrical analysis on the design. It has two major parts which consist of motor and generator as shown in figure 30 and Figure 31.

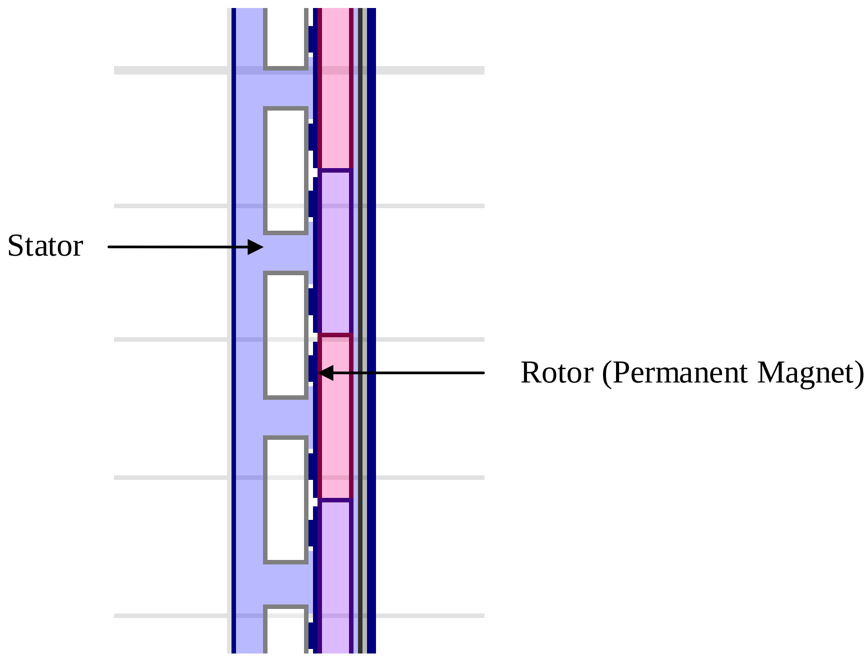


Figure 30: Motor Part – Stator and Rotor

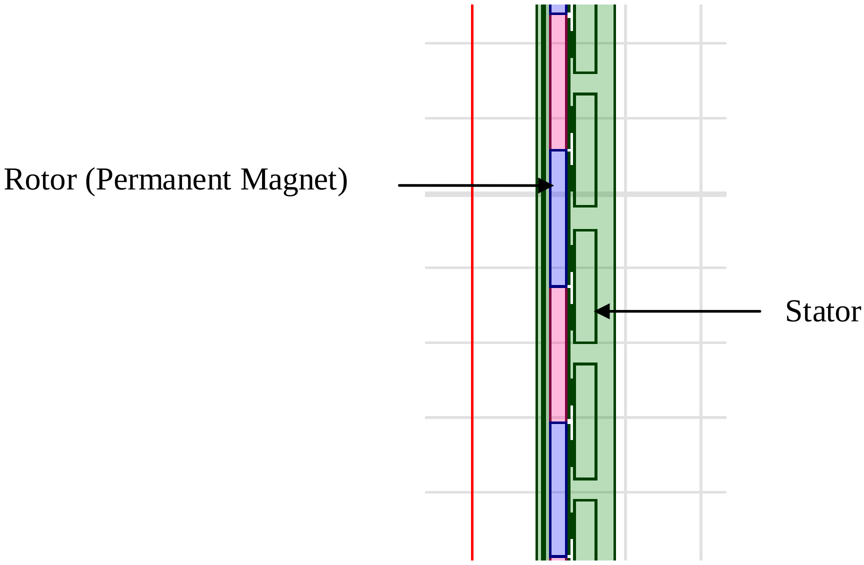


Figure 31: Generator Part – Stator and Rotor

Figure 30 and 31 show the separate part of motor and generator with their own stators and rotor. As shown in the figures, for stator of motor part, it has 12 slots with 6 poles meanwhile for stator of generator part is 8 slots with 4 poles. For the rotor of motor and generator has same quantity of permanent magnet with the value of slots as shown in Figure 32.

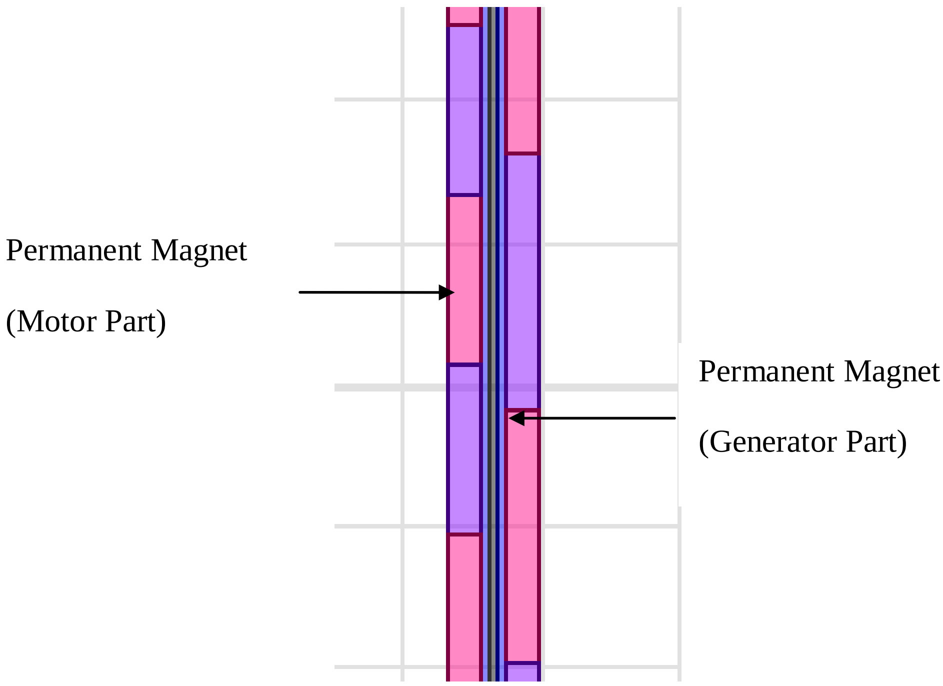


Figure 32: Permanent Magnet Design

Figure 33 shows the combination part of motor and generator which use the configuration of one rotor two stators of axial design.

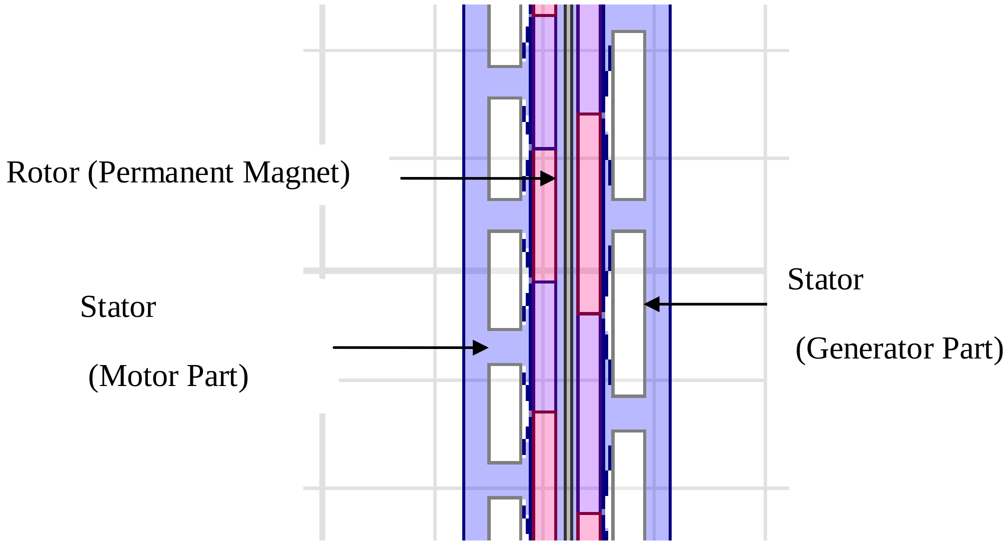


Figure 33: Motor-Generator System – Two Stators and One Rotor

After the simulation design is being conducted using finite element software which is Ansoft Maxwell, the simulation analysis is being retrieved which consists of flux distribution, induced voltage, flux linkage and air gap flux density. These electrical analyses are being compared between axial configuration and radial configuration. For radial configuration electrical analyses is obtain from previous study.

For flux distribution is where the magnetic flux flow through the stator is correct order which follow the axial configuration. Figure 34 and Figure 35 show the flux distribution for motor and generator part which combination of stator and rotor for each part. Figure 36 shows the flux distribution of the combined system using axial configuration.

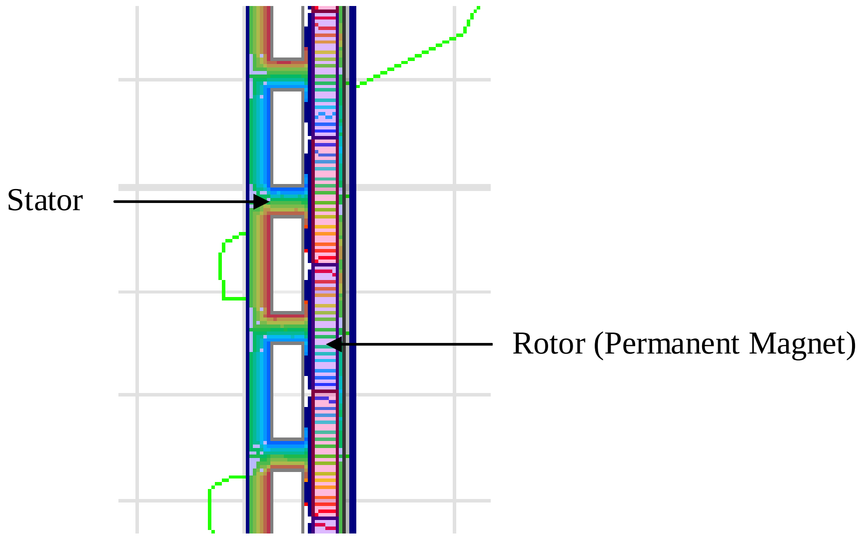


Figure 34: Open Flux distribution for Motor Part

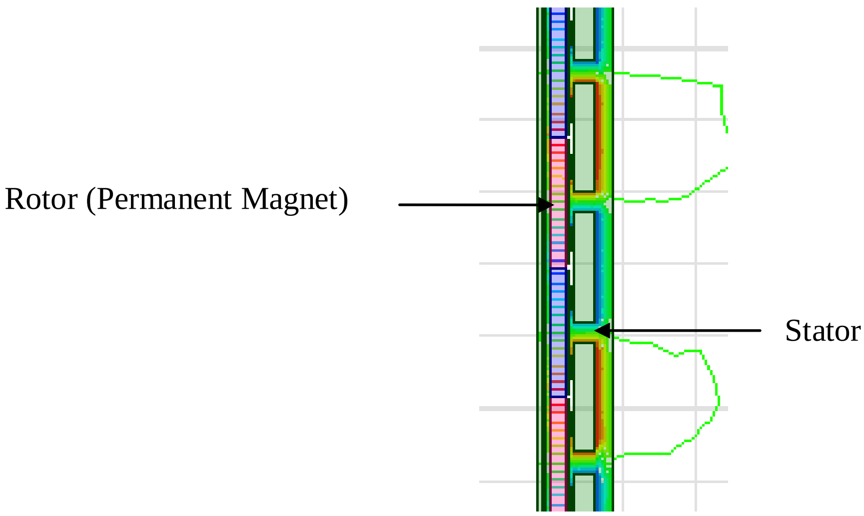


Figure 35: Open Flux distribution for Generator Part

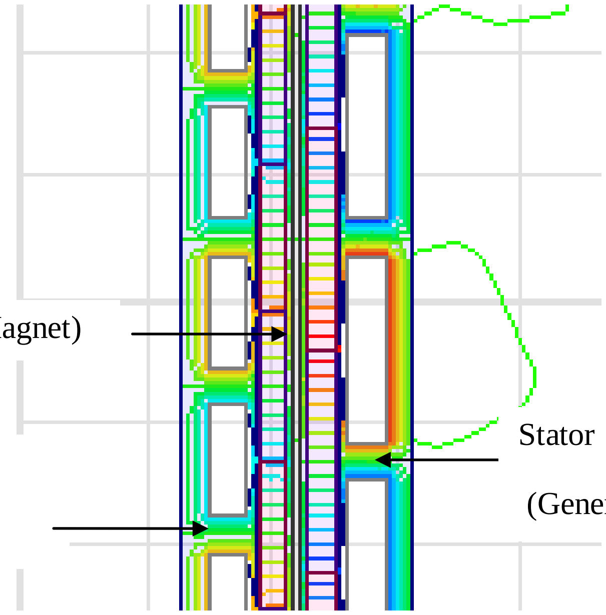


Figure 36: Open Flux distribution for combined system

Based on Figure 36, it shows that the flux is going out from the north-pole orientation of permanent magnet and going in to the south-pole through the stator. These interaction between north-pole and south-pole cause the magnetic flux being evenly distributed throughout the stator due to presence of lamination iron for both motor and generator part. Flux distribution for motor and generator part is being separated by iron and aluminium so that permanent magnet for both motor and generator does not give effect to each other.

Induced voltage is one of the electrical analysis that being observed from this simulation design. In order to obtain induced voltage in the simulation, coil must be assign and the specification of the coil is being referred to the radial configuration parameter which is 250 turns for the winding coil. To analyze the study of effect of flux linkage and induced voltage, the current for the winding coil is being set to 0A for both motor and generator part.

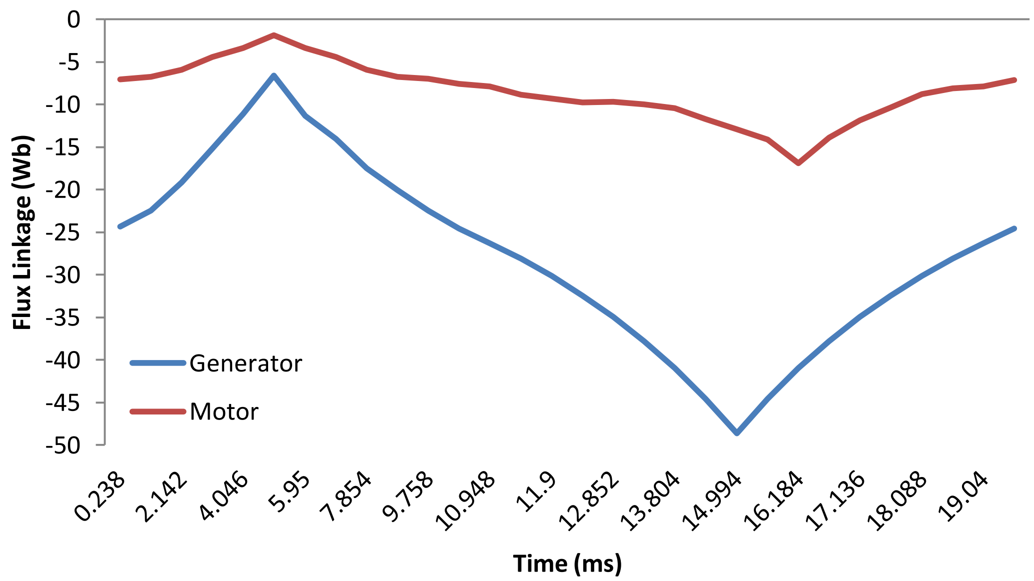


Figure 37: Flux Linkage- Axial Configuration

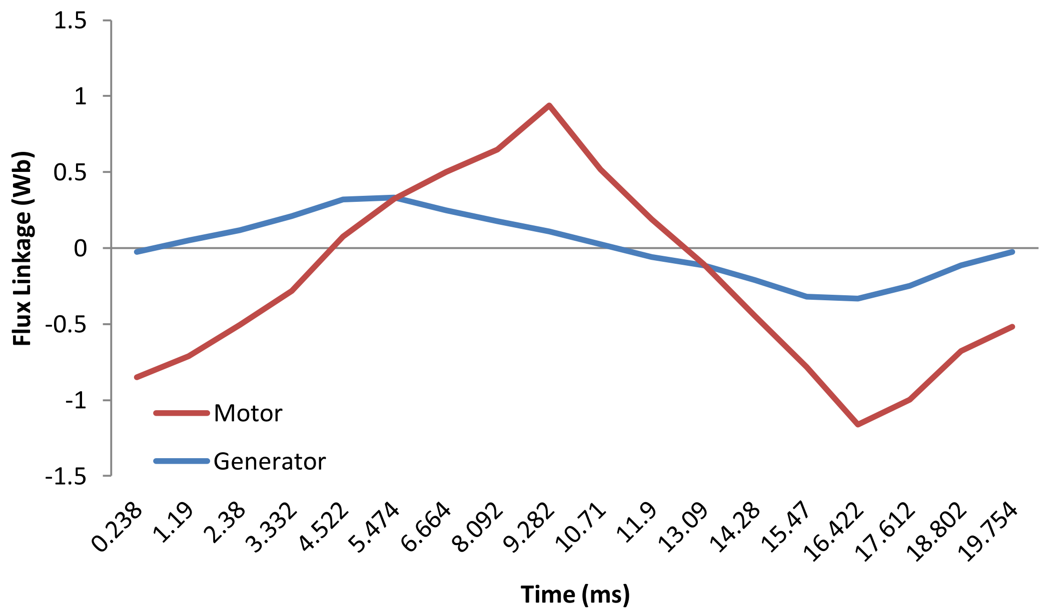


Figure 38: Flux Linkage – Radial Configuration

Figure 37 and 38 show the flux linkage for motor and generator for axial and radial configuration. Flux linkage is flux density flowing through the winding coil multiplied by the surface area which referred as number of coil turns. Flux linkage is affected by number of turns and the magnetic field.

For axial configuration, the flux linkage for motor part is approximately between -3Wb to -17Wb and for generator part is between -7Wb to -48Wb. Meanwhile, for radial configuration, the flux linkage for motor part is 0.9Wb to -1.4Wb and for generator part is between 0.3Wb to -0.3Wb

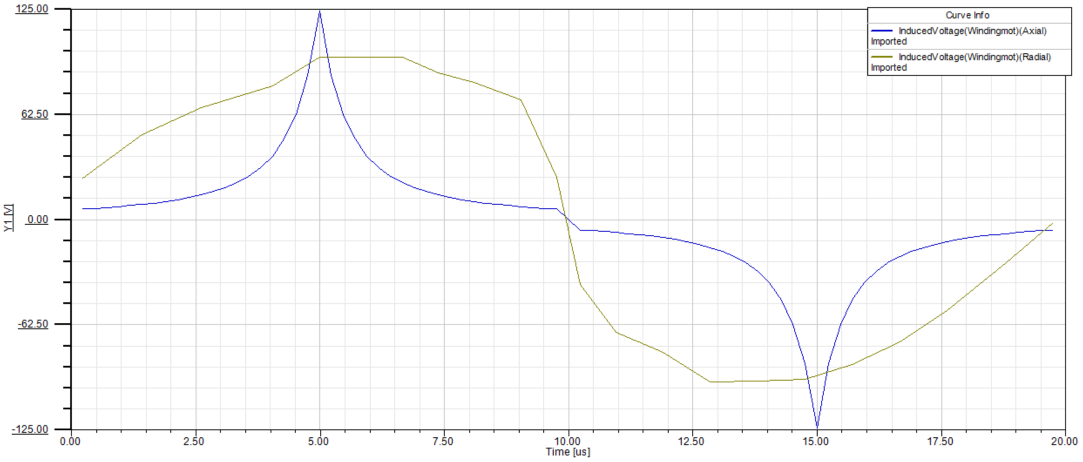


Figure 39: Induced Voltage – Motor Part

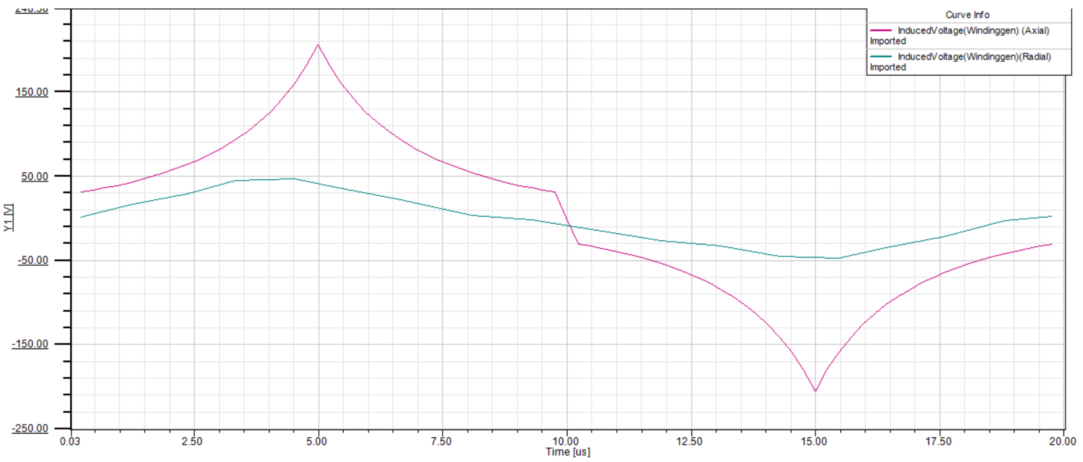


Figure 40: Induced Voltage – Generator Part

Figure 39 shows the induced voltage for motor part of axial and radial configuration. Meanwhile, Figure 40 shows the induced voltage for generator part for axial and radial configuration. Referring to both figures, axial configuration had produced higher induced voltage compare to radial configuration.

As the induced voltage will be observed, Figure 39 show the maximum value of root mean square (rms) voltage that being produced by the motor part of axial and radial configuration respectively is approximately 124V and 90V. Meanwhile, Figure 40 shows the maximum value of rms voltage that being produced by the generator part of axial and radial configuration respectively is approximately 190V and 50V.

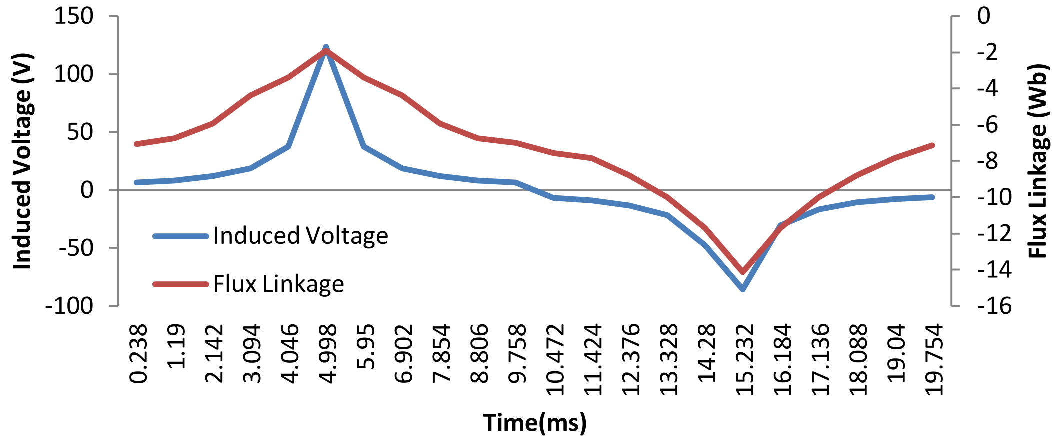


Figure 41: Induced Voltage and Flux Linkage- Motor Part Axial Configuration

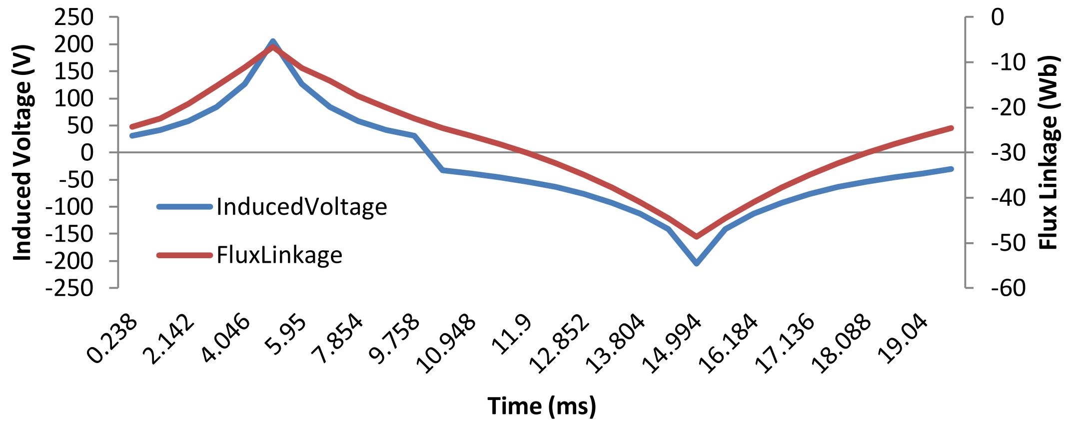


Figure 42: Induced Voltage and Flux Linkage- Generator Part Axial Configuration

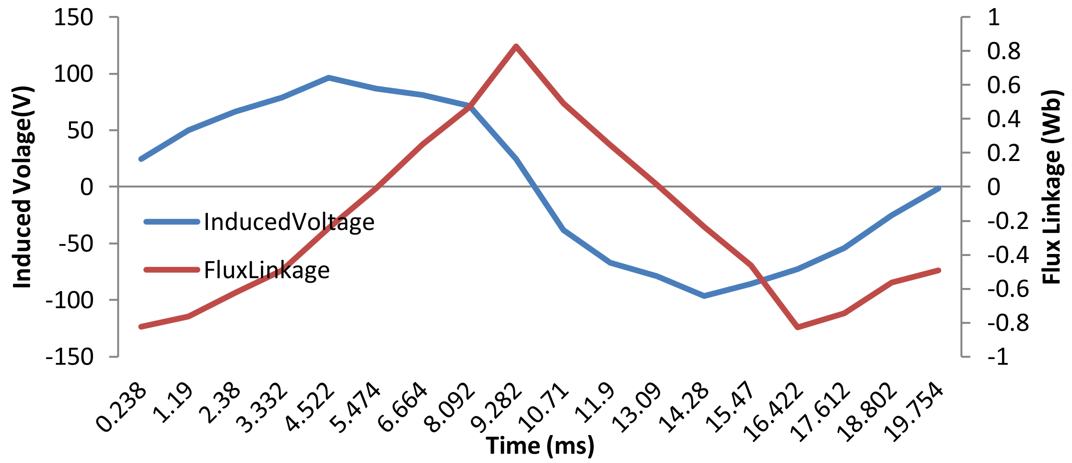


Figure 43: Induced Voltage and Flux Linkage- Motor Part Radial Configuration

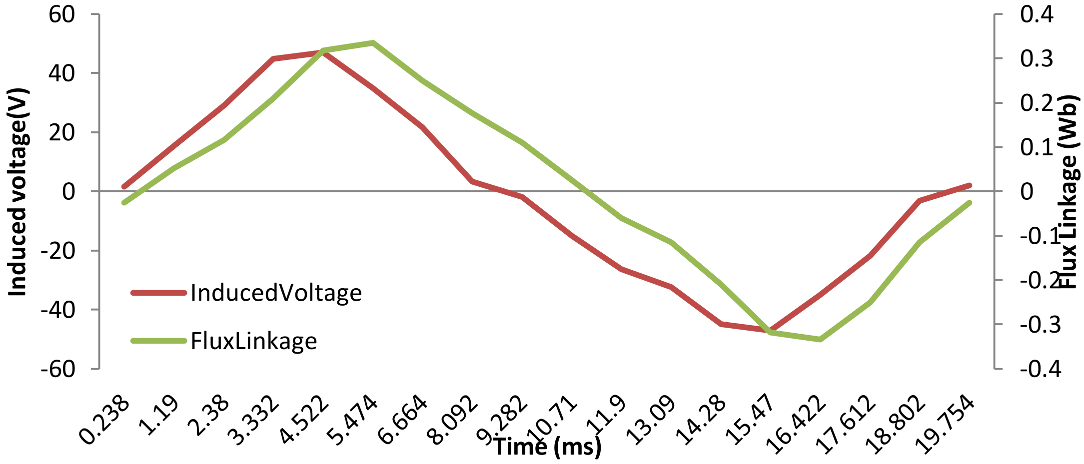


Figure 44: Induced Voltage and Flux Linkage- Generator Part Radial Configuration

Figure 41, Figure 42, Figure 43 and Figure 44 proved that the induce voltage is proportional to the flux linkages produce by the motor and generator.

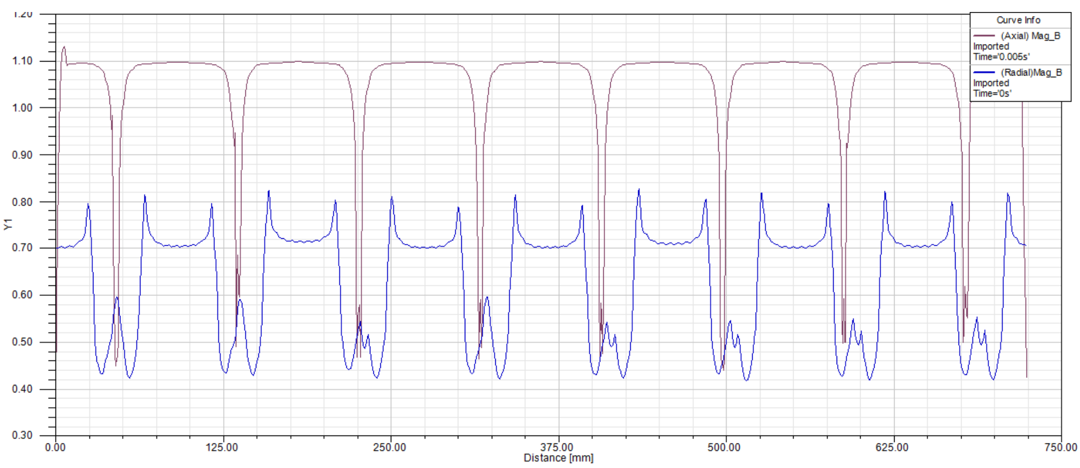


Figure 45: Air gap flux density- Motor Part

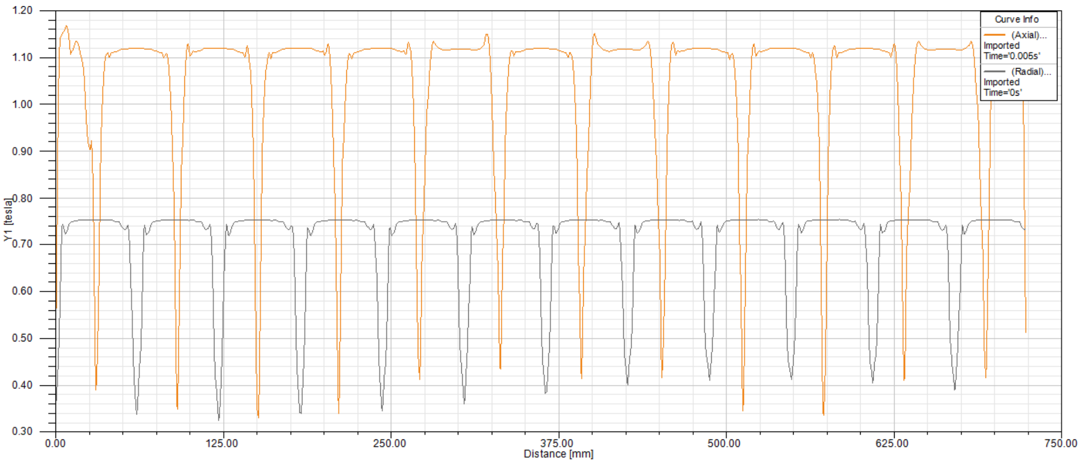


Figure 46: Air gap flux density- Generator Part

Figure 45 and Figure 46 show the air gap flux density between stator and rotor of motor and generator for axial and radial configuration. Air gap between stator and rotor is needed to ensure that the rotor can be rotate and it needs to have a suit length of air gap to control the magnetizing power. This air gap can encounter the noise and vibration of the motor or generator if it is in uniform gap

Based on Figure 45, the highest value of flux density produce at the motor side is approximately 0.770 Tesla for radial configuration and 1.12 Tesla for axial configuration. Meanwhile, Figure 46, at the generator side the maximum value of flux density produce is 0.958 Tesla for radial configuration and 1.10 Tesla for axial configuration. Based on both result of air gap flux density, it prove that there is a flow of magnetic flux into the stator for both motor and generator, and it is confirm that there is possibility in generating electricity at the inner stator which represents the generator.

As conclusion for this chapter, the simulation result, optimization of the design and the comparison between the designs are being explained and justified accordingly. It can be conclude that the axial configuration has better performance compare to radial configuration.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

As stated in the literature reviews from several papers that have been conducted for the designing of the motor-generator using different configuration of the design such as radial, transverse and axial configuration which has been presented. Besides, the researchers and focusing on the existing ceiling fan technologies which includes the bladeless ceiling fan and smart ceiling fan which has some controller according to the situation inside the room itself.

The proposed design of the modified ceiling fan with axial configuration, the wasted kinetic energy can be fully utilize where it will converted into an electrical energy that can be used for other purposes. This proposed design that using axial configuration has better performance in term of the open circuit test that being simulated on the proposed design compare to the radial configuration.

The simulation of the proposed design on electrical analysis is focusing on flux distribution, induced voltage, flux linkage and air gap flux density. An open circuit test are done for these where no current are allowed to flow through the system in order to observe the behavior of the electrical analysis components.

Two different configurations which are axial and radial are used to observe the electrical analysis. Axial configuration show better performance compared to radial configuration. As the comparison has been made, the result shows all the electrical analysis of the axial configuration has higher performance compare to radial configuration.

In this study, the improvement on the simulation design is necessary for a better electrical analysis of rotary motion for axial configuration system. It can be improved in term of design where 3 Dimension (3D) designs can be introduced for axial configuration by using Ansoft Maxwell. 3D design can be clearly explain the rotary motion of the axial configuration system. Beside, the electrical analysis for rotary motion for axial configuration can be obtained correctly according to the rotary motion of the system.

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APPENDIX 1

1
- Continue on the design improvement
- Restructuring the design from previous design during FYP1
- chnage the design analysis from rotary motion to linear motion

2
- Improve the electrical analysis especially induced voltage
- other analysis is being conducted which is air gap flux density and effeciency of the system

3
- submittion of progress report on the current task and result obtain from the latest design

4
- improve and refining the design in term of electrical analysis

5
- ELECTREX and Pre-SEDEX preparation
- submittion of draft of final report

6
- viva for FYP2
- submittion of desertation (soft bound)

7
- submittion of desertation (hard bound)
- submition of technical paper

Figure 27: Key milestone

APPENDIX 2

Table 2: Gantt chart

No	Description	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
1	Project work Continuation																
	simulation (optimization)																
	simulation (refining the design)																
2	submission of progress report																
3	Project work Continuation																
	improvement on simulation																
4	Pre-SEDEX																
5	submission of draft final report																
6	submission of Dissertation (soft Bound)																
7	submission of technical paper																
8	Viva																
9	submission of Dissertation (hard Bound)																