A Novel Design of Ceiling Fan System

By

Nur Ain Bt Misnan

12411

A project dissertation submitted to the

Electrical & Electronics Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfillment of the requirement for the

Bachelor of Engineering (Hons)

(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved by:

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(DR TAIB IBRAHIM)

Project Supervisor

CERTIFICATION OF ORIGINALITY

I hereby verify that this report was written by me, Nur Ain Bte Misnan, (12411). I am responsible for the work I have been submitted in this project, the work have done is my own except as specified in the references and acknowledgements.

(NUR AIN BT MISNAN)

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ABSTRACT

There are many electrical appliances used in every house. One of them is the ceiling fan where it consumes between 70 to 90 Watts of electrical energy. This makes it the second highest appliance to consume electricity. The conventional ceiling fan is designed based on induction machine. However, the induction machine is not very efficient. Another weakness of the conventional ceiling fan is that it does not fully utilize the rotating part in it. This paper aims to use the rotating part in the ceiling fan to regenerate electricity to be used in other household appliances. This concept uses the basic design of the internal and external rotor which is to be used to build the system. Thus, this design could help to reduce energy consumption and making the ceiling fan more efficient compared to the conventional ceiling fan. The literature review in this paper is done to study the various types of machines which could be selected to be used in designing the new type of ceiling fan. Such machines are the induction machine, synchronous machine, the DC machine and the permanent magnet. The proposed design for the motor and generator are determined after the comparison had been done between all the designs. The proposed design is simulated and analyzed using the finite element software, ANSYS software, ANSOFT MAXWELL. The results obtained from the simulation are in term of the flux distribution and the air gap distribution. After analyzing the result, it is found that the design chosen proved to be working successfully.

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CHAPTER 1: INTRODUCTION

1.1 Background of Project.

In Malaysia, generation of electricity keeps increasing every year as shown in the Figure 1. Electricity consumption by people also increasing each year and only start reducing starting year 2009 as shown in the Figure 2 [1]. This might due to the electrical appliances that have been improved to be more efficient and energy saving.

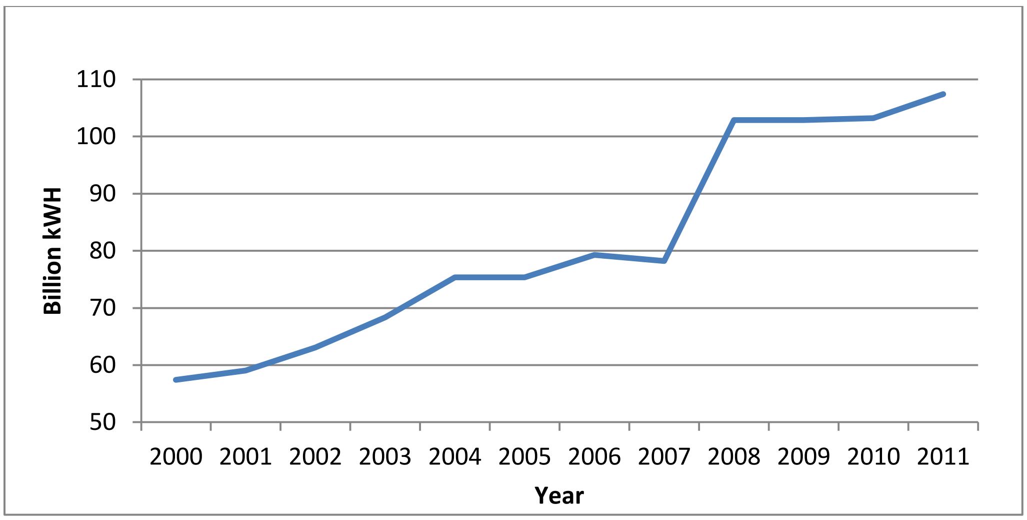


Figure 1 : Electricity-production (billion kWh) [1]

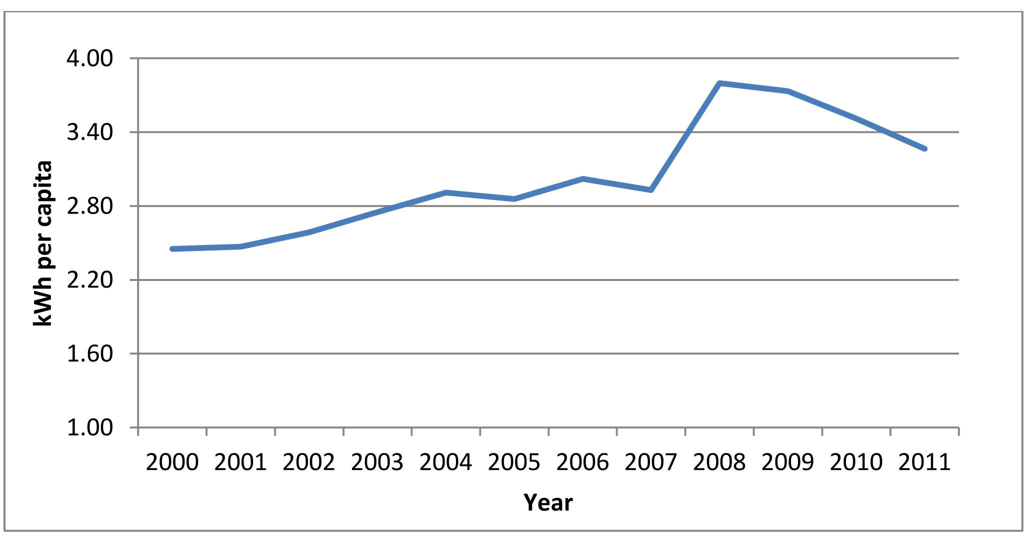


Figure 2 : Electricity consumption per capita (kWh) [1]

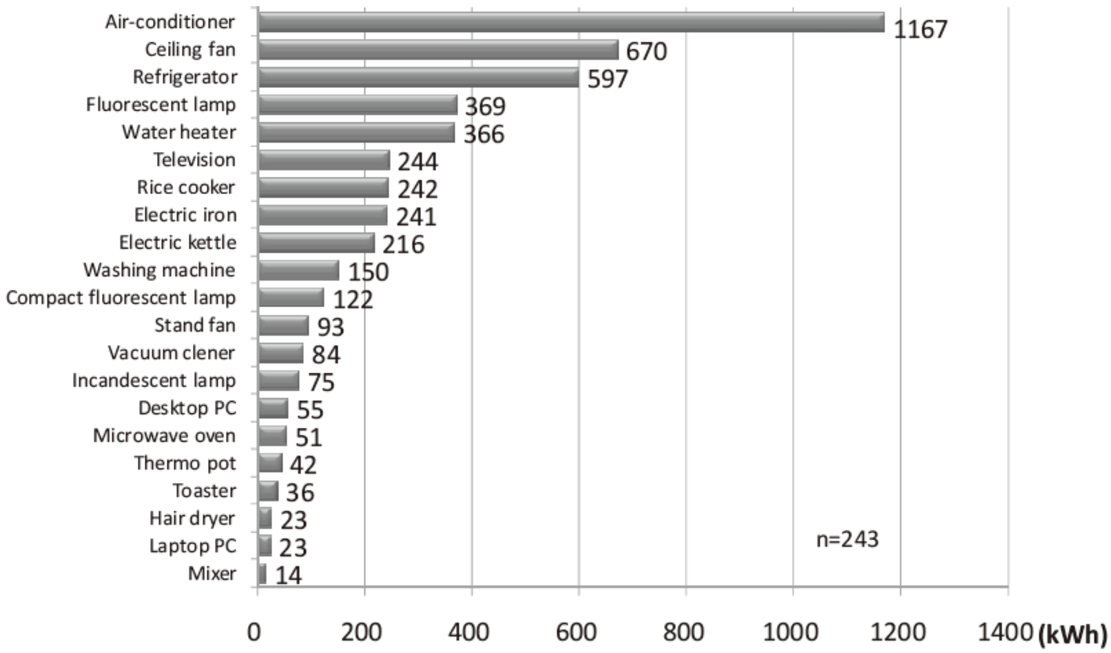


Figure 3 : Energy consumption in residential unit in Malaysia [24]

Using electrical appliances which save power consumption can be reduced the energy consumption. Besides that, energy consumption in house and buildings can be controlled by improving the design of electrical appliances. Considering Malaysia climate that warm and humid throughout the year, ceiling fan is one of the most important appliances in each house. Usually ceiling fan has power rating of 70-90 kW, it consume about 5% of the total energy usage of each house per month [2]. As per shown in Figure 3, ceiling fan is the second highest in consuming electrical energy in each house. This ranking make the project become more relevant to modified the conventional ceiling fan.

Conventional ceiling fan use single-phase induction motor with design of external rotor. Induction machine used in the ceiling fan usually a low cost machine that operates at high slip, therefore the performance is poor. Normally the conventional fan is supplied by 110V or 220V. Conventional fan at least have three speeds that can be change accordingly. Power consumption and details for each speed is as shown in Table 1. High speed consumes more power and current. Several modification has been done to improve the performance of ceiling fan, but it still have problem on efficiency and pulsating torque [3].

Table 1: Result of the conventional ceiling fan [3]

Speed	Speed (rpm)	Power (Watt)	PF (cos θ)	Volt (V)	Current (A)
Low	100	19	0.52	220	0.16
Mid.	160	42	0.78	220	0.24
Hi.	200	65	0.996	220	0.29

The rotation part of ceiling fan will be utilized in order to generate electricity that can be used to other electrical appliances. The author had design a system which combines generator and motor in one system.

The idea of redesigning the ceiling fan system is basically to produce the more efficient and effective system. This motor will reduce the power consumption and reduce the power consumption cost. The idea is also want to utilize the rotating part of the fan; the rotating part can be used to generate electricity. The electricity produced might not large, but it can support to supply other appliances with small power consumption.

1.2 Problem Statement

Ceiling fan is widely used especially in the tropical country such as Malaysia. The system is not fully utilized while actually it can be upgraded and modified in order to generate electricity. The new design is about combining motor and generator that can produce electricity in one system. Hence, the new system is to utilize and improve the conventional ceiling fan system using simulation in ANSYS software, ANSOFT MAXWELL.

1.3 Objective

The main objective of this project is to design and model a novel ceiling fan system that can generate electricity to other suitable appliances. The other sub objectives are:

1. To conduct a literature review on various type of motor, various parameter of motor that leads to find the perfect combination to design the novel ceiling fan system.
2. To propose and finalize the most suitable design of motor and generator that can be combined into one system.
3. To simulate the proposed design by using the finite element analysis and analyzed the results obtain.

1.4 Scope of study

The scope of study covers the types of electrical machines. In the literature review there are research on induction machine, synchronous machine, DC machine and permanent magnet. This is to determine the most suitable types of machines that will be used in the novel design. Besides that, the construction of conventional ceiling fan has been studied to determine the size of the machine and to help modify the system.

From the previous design and literature review, the author also will determine the material which will be suitable for the design. Besides that, the design needs to consider the type of magnet, tooth type and number of slots and poles which will be analyzed to find the perfect design.

The design of the novel ceiling fan will undergo simulation and analyzing process in the ANSYS software, ANSOFT MAXWELL. The simulation of motor and generator will be done separately. After both machines produce the desired result, it then will be combined to produce the complete system. The data gathered will then be analyzed.

1.5 Design Concept of Novel Ceiling Fan System.

The novel design of ceiling fan consists of two parts, the motor to rotate the fan and the generator which produce supply to other appliances. The basic idea can be illustrated in Figure 4 where it can be seen that there will be two main parts which are the motor and generator.

In the motor, the stator's winding will be injected by current. When currents move in a coil, it will produce magnetic flux. The magnetic flux from the stator will interact with the magnetic flux produced by the permanent magnet. Therefore, fan will be turn on and works like the conventional fan.

In the generator, the rotor from both the generator and stator are connected to each other. So they will move simultaneously. A moving permanent magnet will result in a moving magnetic flux. The magnetic flux will penetrate to the coil at the stator. Therefore, electricity will be generated.

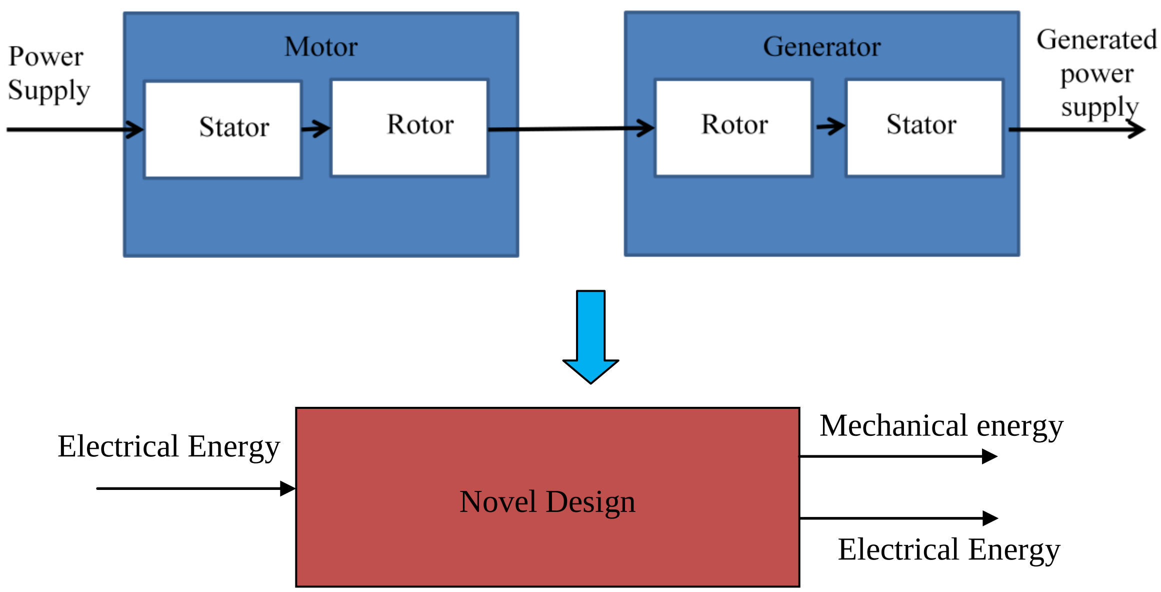


Figure 4 : Block diagram for ceiling fan system

CHAPTER 2: LITERATURE REVIEW AND PROPOSED DESIGN

2.1 Introduction

In this chapter, several types of electrical machines are studied and considered in the design for the project. There are four types of machines that can be selected to produce the novel design of ceiling fan system, which are the induction machine, synchronous machine, DC machine and permanent magnet. Each machine has their advantages and disadvantages. Besides that, the design consideration for the new design is also determined. The novel design has been proposed for further analysis.

2.2 Rotary Machine Technologies

2.2.1 Induction Machines

The induction motor is commercially used in certain application. It is simpler than synchronous motor. There are two classes of polyphase motors which is squirrel cage and wound motor. Basically induction motor works when the magnetic field in the rotor is induced by current flowing in the stator. There is a connection between the rotor and any of line supply [4].

The squirrel cage motors like Figure 5 are consists of stator, which known as armature of synchronous motor, and have ‘squirrel-cage’ rotor with bearing to support it. Rotor acts as the secondary and stator as primary because stator receives the power. Field in this type of synchronous machine has squirrel cage winding. It contains of several number of metal bars that connected at each end. Current in the armature will produce the rotating field. When the squirrel-cage is cutting the rotating field, it will produce voltages and currents just like other motor when their field is being cut by their conductor [4].

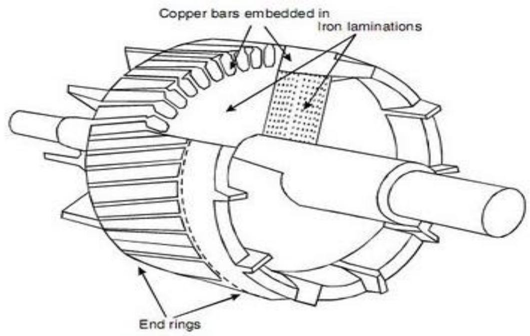


Figure 5 : Squirrel cage induction motor [5]

Instead of having a series of conducting bars in the rotor, a wound-rotor motor has wire-coil windings as in Figure 6. It has external resistance that help the motor produce high torque by using the low starting current. The resistance may decrease when the motor is accelerating up it speed. At the full speed, the rotor is short circuited [6]. Usually this type of motor is used for heavy load [4]. The squirrel cage need high current to start up, there are 4 ways to startup the motor, using directly across the line, by autotransformers, then by resistance in series with the stator winding and by step down transformers [4].

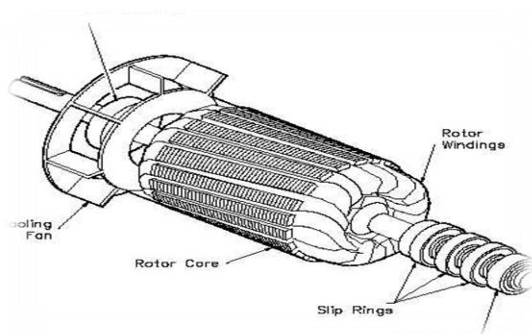


Figure 6 : Typical wound-rotor for induction motor [7]

Poor performance during the low speed is the disadvantages for this motor. This is due to the relative complexity of the physical assembly of the stator [8]. Wound-rotor motor is mostly used in heavy load machines. The other disadvantage for this induction machine is it needs a high current to start up [4]. So it is not suitable to apply the concept in the ceiling fan design

2.2.2 Synchronous Machine

Figure 7 shows the principle of synchronous machine. Figure shows a two pole synchronous motor. 3-phase voltages will be supply to the motor. As a result it will produce a 3 phase current that at the end will produce a uniform rotating magnetic field. Two magnetic fields will present each time, so the rotor will be in straight line with the particular magnetic field. The magnetic field is rotating due to the 3 phase supply, so the rotor will also rotate because it attracted to the magnetic field. In the simple word, the rotor will always chasing the rotating magnetic field produce by the stator [9].

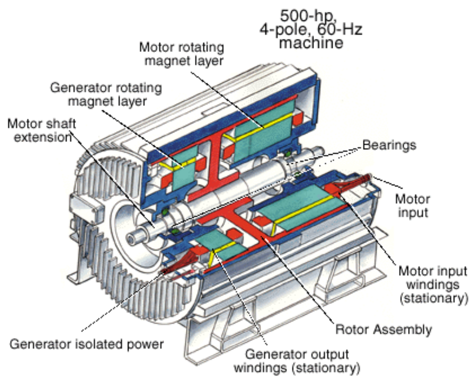


Figure 7 : A two-pole synchronous motor [24]

Cannot self-exciting and cannot start alone even load is not connected, it require an external source for supplying dc excitation to the rotor. The first who try to overcome this problem is Zipernowsky, he putting an additional commutator which help them start up using alternating current [10]. Synchronous motor's application also limited because of their power supply requirement and complex design of the stator. It is decided that the difficulty to build the stator winding and the multi-phase power supply make this synchronous motor un-suitable to replace induction motor for the ceiling fan [8]. The cost can be higher due to the complexity of the design. Synchronous motor also need 3 phase supply to operate and the supply need to be inject at stator and rotor. Due to the many disadvantages of the motor, the author decides not to use this design.

2.2.3 DC Machine

As shown in Figure 8 is DC machine construction. It has brushes and needs a DC supply to function. The functions of DC generator and DC motor are interchangeable. Both of them have same structure. It consists of electromagnet, armature and commutator with brushes [4]. DC machines are usually kind of expensive to manufacture, suffer from brush wear and high maintenance. It is also relatively noisy during operation [8]. The design need to have an AC-DC converter because it need direct supply. Due to the stated reason, DC machine is not suitable to be selected to design the ceiling fan motor and generator.

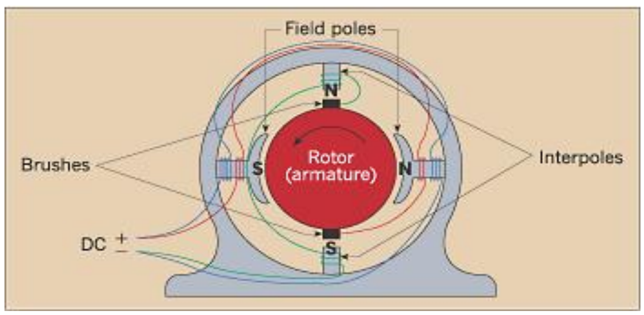


Figure 8 : DC machine

2.2.4 Permanent Magnet Machines

A simple configuration of permanent motor is, it have permanent magnet as the pole, stator, and stator winding. Permanent magnet generates its own magnetic field automatically. Electricity is not required to produce the magnetic field. Permanent magnet motors have many advantages such as high power density, high efficiency and low manufacturing cost [11]. Permanent motor technology has been improved day by day; they are widely used in the high performance control-system. It also has better dynamic performance than motor with electromagnetic excitation. Permanent magnet motors also have simple construction and maintenance. Due to the simple construction it has low manufacturing cost and in term of weight it slightly light [8].

Permanent magnet machine operation is quite simple compared than other type of machine. Current will be injected to the stator; this current will produce a magnetic flux. Then this magnetic flux will interact with permanent magnet at rotor, and then the rotor will rotate. Permanent magnet machine usually can be found in fan, blowers, refrigerator and etc [17].

The problem for permanent magnet motors mainly about their cogging torque produce because of the interaction of stator's teeth and rotor's permanent magnet. The cogging torque may result a vibration and noise effect. J. Henry and H. Pixii are two example of person who using permanent magnet excitation in electrical machines as early as 19th. The technology improved by Alnico back in 1932.

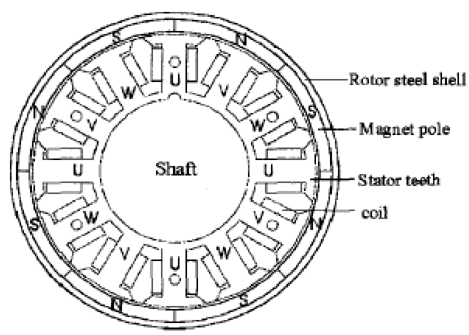


Figure 9: Analysis model of the exterior-rotor BLDC motor with 8 poles and 12 slots [11]

Park et al [11] do analysis on the effect of eddy current generated in the rotor steel shell of exterior-rotor type magnet. As shown in Figure 9 the design is used for hard disk and DVD drives. The design has a rotor steel shell that not laminated. The steel shell that rotates at high speed will result eddy current induced in the motor. It may affect the motor performance. Eddy current induced in permanent magnet that bonded between each other may be neglected because it has high resistivity. Eddy current of the rotor steel shell makes the winding current and torque ripple higher because of the flux level change. The magnetic flux distribution is as Figure 10.

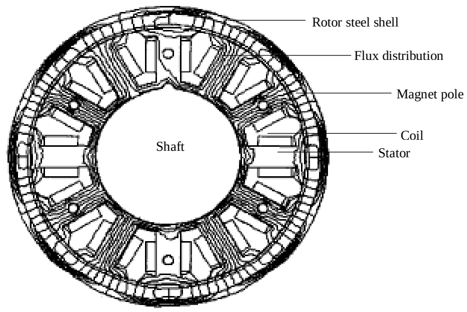


Figure 10 : Magnetic flux for the analyzed model [11]

Figure 11 shows the basic design for internal rotor permanent magnet motor. This design has rotor part inside the stator. The design has 4 pole and 4 tooth at the stator. Figure 12 shows design by Faiz, the design has 16 slots and 4 poles. This large number of pole and slot help to make the motor to be more efficient and have low cogging torque [13].

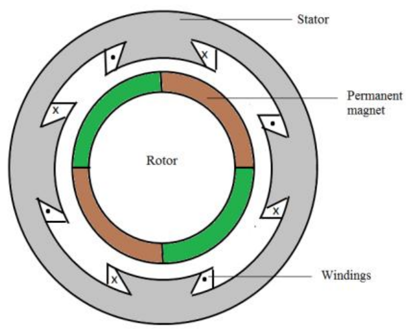


Figure 11 : Basic internal rotor design [4]

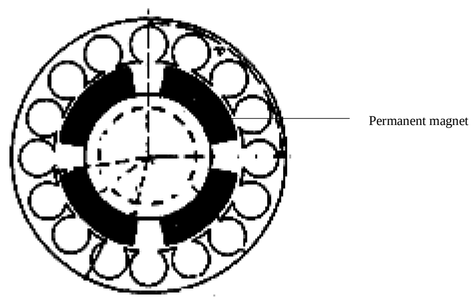


Figure 12 : Interior permanent magnet motor [14]

Number of slot and pole are one of the crucial factors in designing a motor. Reichert [10] has constructs an exterior-rotor with a slot/pole ratio of 6/16 as shown in Figure 13 for his stirred bioreactors. Several topologies for exterior-rotor has been analyze before deciding to pick 6/16 slot/pole. Motor with five stator slot result needs five-phase drive. High current is permanently needed to levitate the rotor in its center. Motor which have stator slot number higher than six is not considered because more slot will result a small space for winding. This may cause insufficient magnetomotive force.

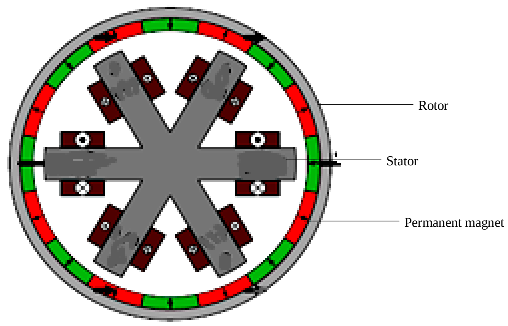


Figure 13 : 6/12 slot/pole ratio [10]

Upadhyay [20] had design an interior rotor like in Figure 14. He embedded permanent magnet in the rotor and used his design in the high speed application. He found that magnet shifting can be utilized to improve the torque for motor. He also found that shaping the rotor pole can reduce the cogging torque.

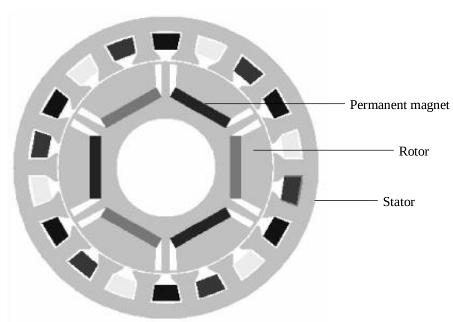


Figure 14 : Internal permanent magnet motor with embedded permanent magnet [20]

Permanent magnet motor has higher efficiency [21]. This is stated by Faiz when he designs a ceiling fan as shown in Figure 15. He uses an external rotor permanent magnet BLDC motor and he said that it has 30% - 50 % efficiency.

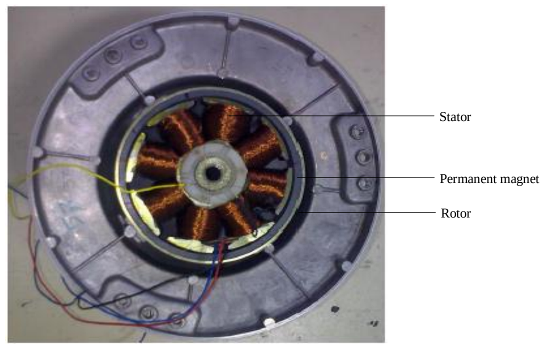


Figure 15 : Ceiling fan using PM BLDC

2.3 Design Consideration

In designing the novel design for the ceiling fan there are four considerations that is considered, which are:

I. Number of pole and slots
II. Teeth shape
III. Type of permanent magnet
IV. Configuration of magnet

Numbers of slot and pole pair can be determine using Table 2. This table shows the feasible slot/pole number combination [15].

Table 2 : Number of pole and slot number [15]

	Feasible slot number	
Number of pole pair, p	$2p \pm 1$	$2p \pm 2$
1	3	-
2	3	6
4	9	6
5	9	12
7	15	12
….	…	…

Number of slots and poles will affect the cogging torque, efficiency of motor, size of slot and pole and the magnetization effect. From Figure 16 and Figure 17, it show how number of pole and slot can affect the performance of permanent magnet generator [22]. Combination of number of slots and poles that result a small slots/poles ratio will produce a higher output power.

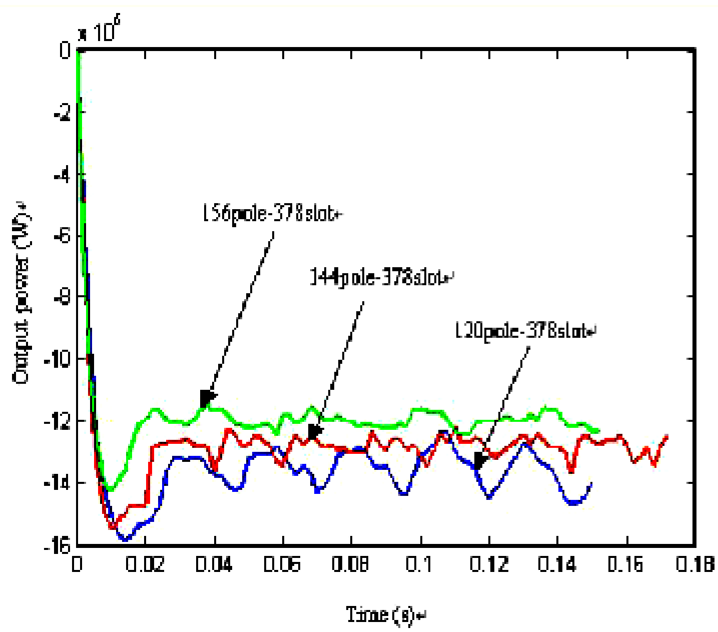


Figure 16 : Constant number of slots, vary the number of poles [22]

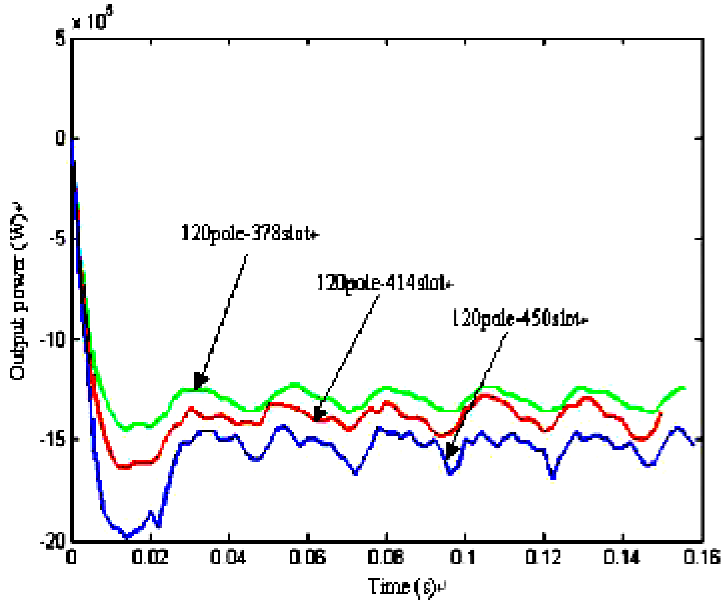
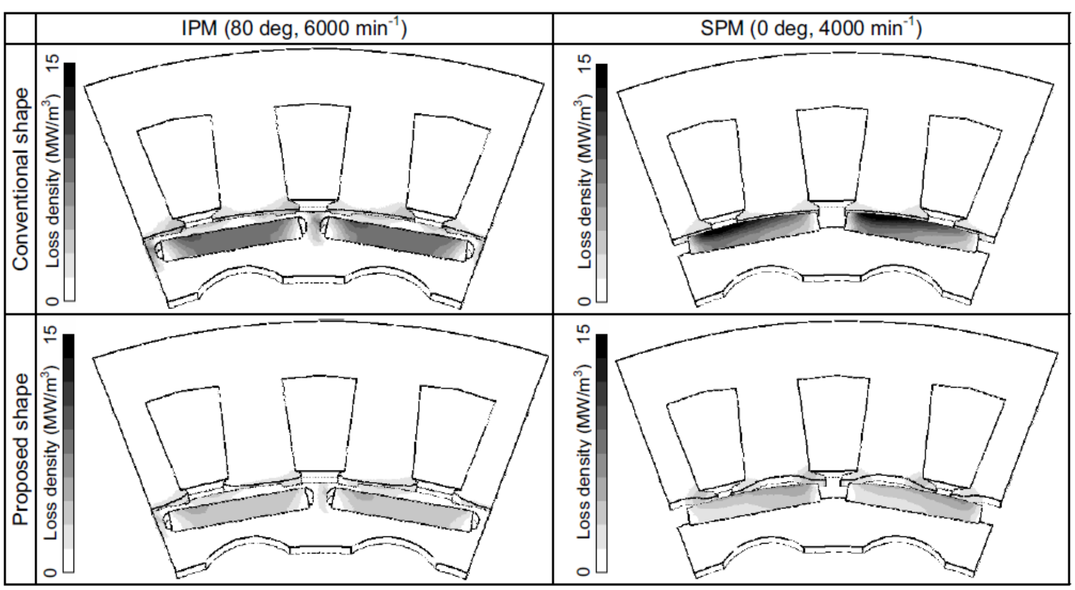


Figure 17 : Constant number of pole, different number of slots [22]

Yamazaki et al [23] had done research on how the teeth shape can affect the loss density of the magnets. They made two types of new design for tooth, one with anchor shape and one tooth with cup shape. By comparing the two proposed design with the conventional design, it shows that the proposed design manage to reduce the loss density as pictured in Table 3.

Table 3 : Various configuration of tooth design [23]



There are several types of permanent magnet with their own characteristic. The best type of magnet is rare-magnet. Rare-magnet made by several minerals compound. NdFeb is one example of rare-magnet that has good magnetic properties. It has higher remanent magnetic flux but rare-magnet is limited and expensive. Alnico is other type of magnet that has high magnetic remanent flux density and low temperature coefficients. It can allow a high air gap at high temperature. Alnico easy to magnetized and demagnetize once we use it in any application. Lastly, ferrites; ferrites is the cheapest magnet in term of cost. It has high coercive force but lower remanent magnetic flux. Ferrites have a very high electric resistance, this result to small eddy current losses [17].

Configuration of magnet of the rotor gives effect to the magnetic flux that will be reacting with the winding at the stator. There are several topologies for permanent magnet configuration such rotor. Figure 18 shows interior-magnet rotor. This configuration is difficult to build and expensive. Figure 19 show design by Honda which show a double layer magnet in the rotor. The configuration helps to reduce flux linkage [16]. Figure 18 shows design for the modified surface magnet. The usual design, its magnet did not fully cover the rotor [17]. The surface magnets have a simpler design and cost effective.

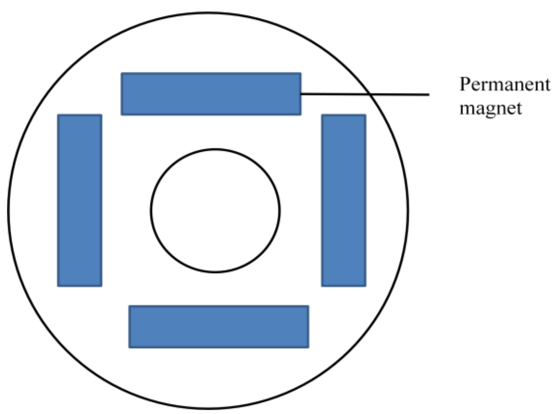


Figure 18 : Interior-magnet rotor

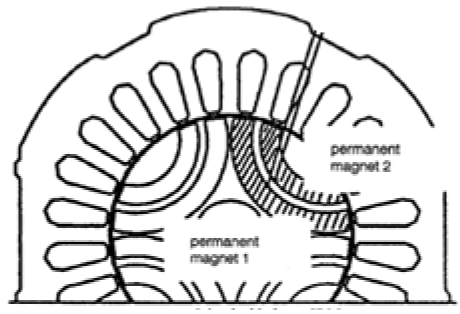


Figure 19 : Rotor configuration of double-layer IPM [16]

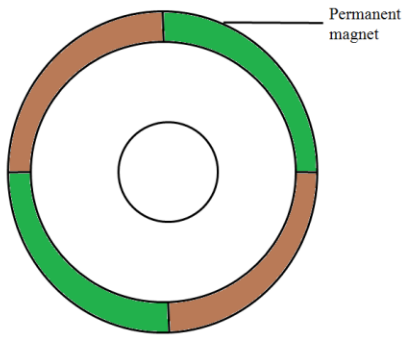


Figure 20 : Modified surface magnet rotor.

2.4 Proposed Design

In deciding the design for novel ceiling fan system there are important criteria that the system must be simple, cost effective and workable. By comparing and understand the basic of external and internal rotor concept for rotary permanent magnet motor, a basic design for external rotor and internal rotor are the most suitable for the ceiling fan.

The external rotor as shown in Figure 21 will be act as the motor, which it will have current and rotate the motor for the ceiling fan to be function. The stator consists of two poles that have a larger tooth tip. A larger tooth tip helps the flux density to have more space to flow through it. This will reduce the core loss of the motor. The external rotor have two pole of magnet that been attached to each other.

The internal rotor will act as the generator. It has four poles at the rotor and four slots at the stator. The generator as refer to Figure 22 has a bigger number of pole and slot because that characteristic can produce an efficient system of generator. The magnet is also attached to each other.

Figure 23 shows the proposed design for the system. The external rotor design will be inside the internal rotor design. The rotor will be attached to each other and being separate by Aluminium.

For this novel design, rare earth magnet are not chosen because of its hard to find and expensive. Therefore, we are using Alnico in the system. The design need to be optimized to get the optimum result.

By using the novel ceiling fan design, the rotating part of the fan is utilized to generate electricity. It also very efficient compared to the conventional design because it used permanent magnet machine concept.

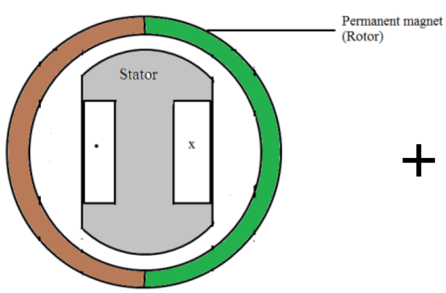


Figure 21 : External rotor (Motor)

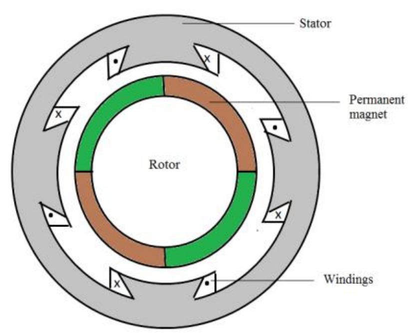


Figure 22 : Internal rotor (Motor)

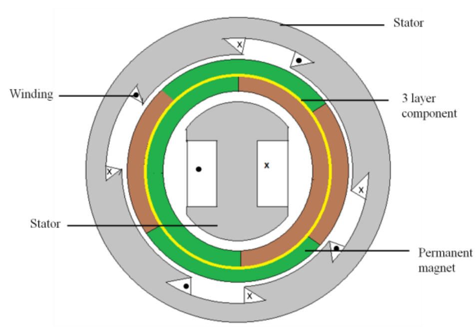


Figure 23: Combination of internal and external rotor

Throughout the time, the proposed design has been improved. For the motor part, the new design consist of 4/4 pole/slots as shown in Figure 24 is simulate. While for the generating part which use the internal rotor concept, it has 4/14 pole/slots as shown in Figure 25. Combination of both internal and external rotor machine as shown in Figure 26 is also being simulated in Ansys software, ANSOFT MAXWELL.

The large number of slots for generator part is by following the conventional design of ceiling fan. The concept applied and material assign was still the same with the previous design.

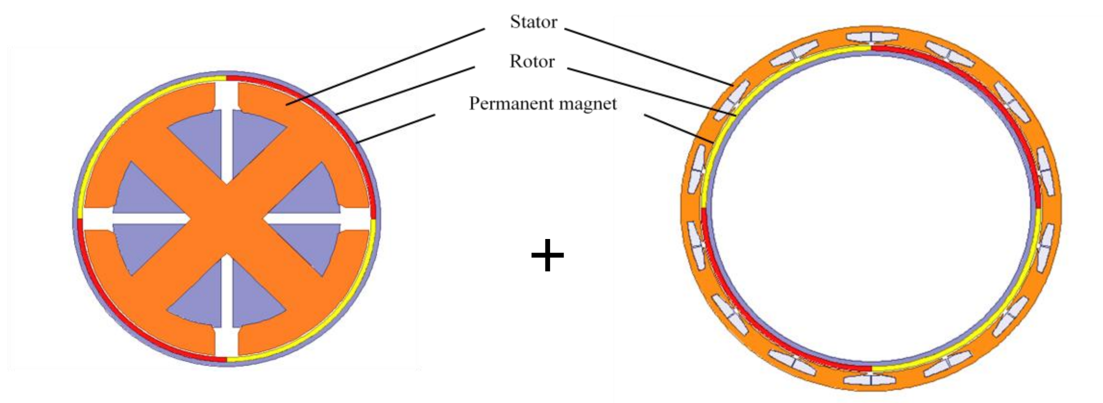


Figure 24: External rotor (Motor)

Figure 25 : Internal rotor (Generator)

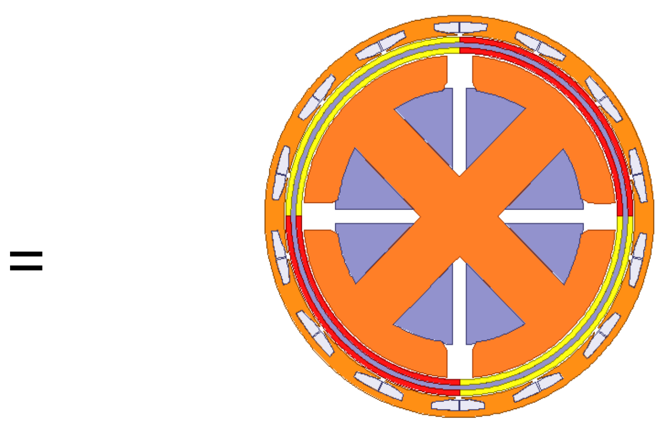


Figure 26 : Combination of internal and external rotor

2.5 Conclusion

The literature review has been conducted and provides many information regarding electrical machines. It helps the author to determine the most suitable types of machines and design consideration in designing the novel design. In the literature review, advantages and disadvantages for each type of machine has been determined. Thus, permanent magnet machine has been chosen in the designing process based on the advantage of having simple design and high efficiency compare than other type of machine. It is important to determine the suitable number of slots/poles, type of permanent magnet and tooth design for the novel design. After all the consideration has been made and analyzed, the author proceeds with the design process.

The novel design of ceiling fan machines contains internal rotor and external rotor of permanent magnet machines. The external rotor acts as the motor and function like the conventional ceiling fan, while the internal rotor acts the generator that will generate electricity. Both designs are combined and complete design of machines is produced.

CHAPTER 3: METHODOLOGY

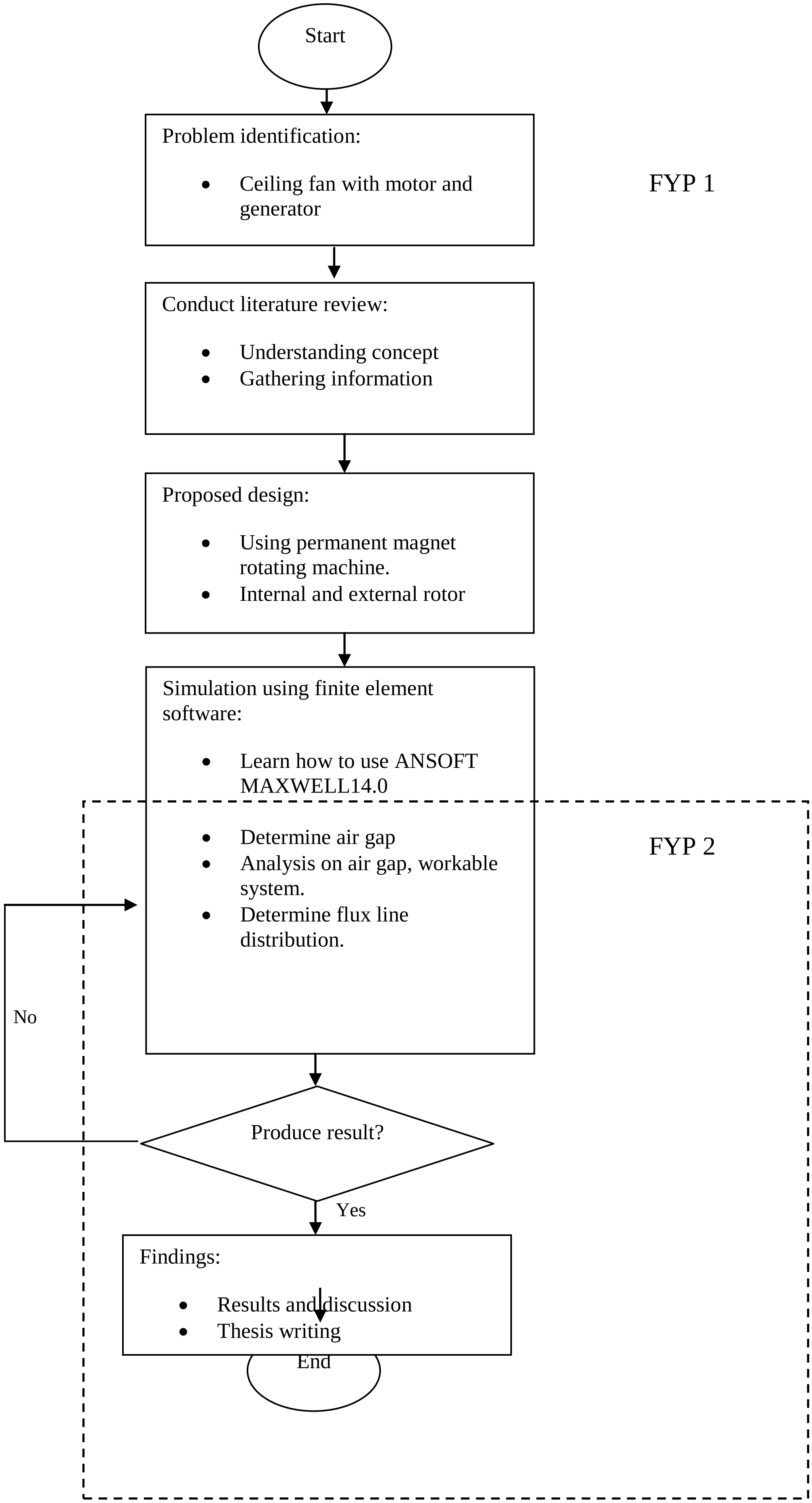
3.1 Introduction

In this chapter, methodology used in the project will be discussed. The novel design of ceiling fan system will be simulated and analyzed using ANSYS software, ANSOFT MAXWEL. The details of procedure regarding simulation will be discussed.

3.2 Finite Element Methods.

Finite elements methods have been introduced in 1940s and for the first time, finite element analysis is applied in aeronautical design and structural analysis. Finite element analysis can obtain the most accurate design for electrical machines. The numerical solutions that develop in this method mostly based on the distribution of the electric and magnetic fields. The solution regarding fields still can be calculated even though the system use different materials and have time-various fields. The optimum machines design can be used using it [18].

3.3 Procedure



3.4 Details of the Procedure

3.4.1 Problem identification.

The conventional ceiling fan system is not fully utilized. The new design will combine motor and generator so that the system can produce electricity and supply to other suitable appliances.

3.4.2 Conduct literature review.

Literature review in this project is about understanding the concept of motor and generator. Research has been conducted for various type of machine. Besides that, information regarding design consideration also has been collected. Information are gathered from journals, textbooks and internet.

3.4.3 Proposed design.

The novel design of ceiling fan machine is combining motor and generator. Basically it has two stators and one rotor. The concept of internal rotor and external rotor has been applied in designing the novel design. External rotor concept is for motor while internal rotor concept is for generator. Further explanation regarding the design will be discussed in proposed design section.

3.4.4 Simulation using finite element software.

ANSYS software, ANSOFT MAXWELL is user friendly software to use to simulate the particular design. ANSYS software, ANSOFT MAXWELL is widely used among engineers to design machines component or system. The simulation allows us to create a particular condition for the machines and see what the effect. Analysis on the design also can be done by ANSYS software, ANSOFT MAXWELL [19]

Procedure in using ANSYS software, ANSOFT MAXWELL.

1. The solution type was selected. In this project, transient magnetic solution type of solution is selected. It consists of time-stepping solver. Time of simulation can be set by the user.
2. The unit used during the simulation was set to default.
3. The design was drawn in the simulation software. In this project, 2D type of drawing is used. Design can be edit using Boolean operation and other application. Design also can be import from dwg. type of drawing.
4. Materials for each component have been assigned. For this project material used are copper, alnico, steel, and aluminium. Aluminium permeability is set for value 0.001 tu avoid flux from internal rotor and external rotor being clash with each other. Each Alnico has value of 0.8 Tesla.
5. The boundaries for the operation have been created. Boundaries are the solution area for the design.
6. Mesh operation for each component was applied. In this project, mesh operation is set to have 1000 of maximum numbers of elements.
7. Analysis setup for the simulation was created. Project is divided into three, the internal part and external part are simulated separately, when both design produce the desired flux distribution, it then simulated the combine design. All three simulation process use step time of 0.02 second with end of 1.2 second.
8. Motion also can be setup for the electrical machine. The angular speed for the design is set to 220 rpm by referring to the speed of conventional ceiling fan.
9. After the designing part was completed, the design needs to be validated and analyzed.
10. If no error detected, there will be result based on magnet flux distribution, magnetic flux density, torque and force for the design also can be observed.
11. Result can be compile in animation format and graph.

3.5 Conclusion

The novel design of ceiling fan machines contains internal rotor and external rotor of permanent magnet machines. Both designs are combined and complete design of machines is produced. The design will be undergo all procedure that has been discussed in this chapter. In the next chapter the results obtained from the simulation will be discussed.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the design from previous chapter has been simulated in ANSYS software ANSOFT MAXWELL. The simulation is done to obtain the desired result regarding fluxes distribution, flux distribution in the air gap and torque for the system. The performance of the machine also tested in this chapter. Results and discussions for the novel design are discussed in this chapter.

4.2 Result and Discussion

Table 4 shows the dimension and configuration for the novel ceiling fan system. It has been modified to have the same size as per conventional ceiling fan to ensure size did not affect the power consume. Dimension of the design as shown in the Figure 27.

Table 4 : Dimension for novel ceiling fan system

Parameters	Size (mm)
Generator (internal rotor)	
Stator outer diameter	150
Stator inner diameter	140
Number of slots/pole	14/4
Air gap	1
Size of permanent magnet (rotor)	5
Size of aluminum	5
Motor (external rotor)	
Size of permanent magnet (rotor)	5
Air gap	1
Stator outer diameter	123
Stator inner diameter	108
Number of slots/poles	4/4

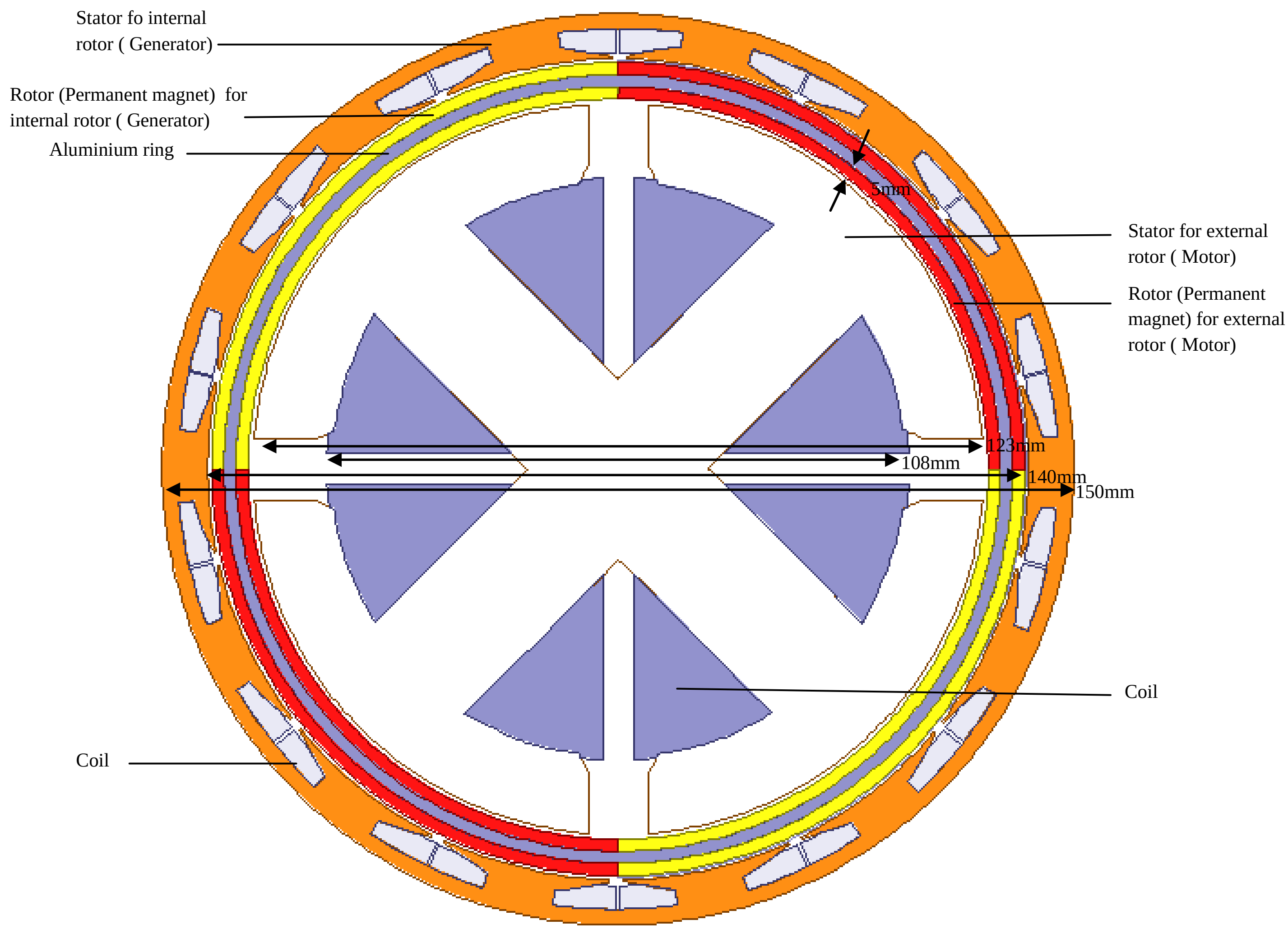


Figure 27 : Dimension

4.2.1 Mesh

Figure 28 shows the mesh plot of the project. Same mesh plot is assign to all three simulation which is simulation for internal rotor, external rotor and the combination of internal and external rotor. Mesh plot will be used by the solver to solve many equation regarding the design. Large number of mesh will lead to more accurate result but time consuming. As for this project, the simulation assign mesh inside selection part with maximum value is 1000.

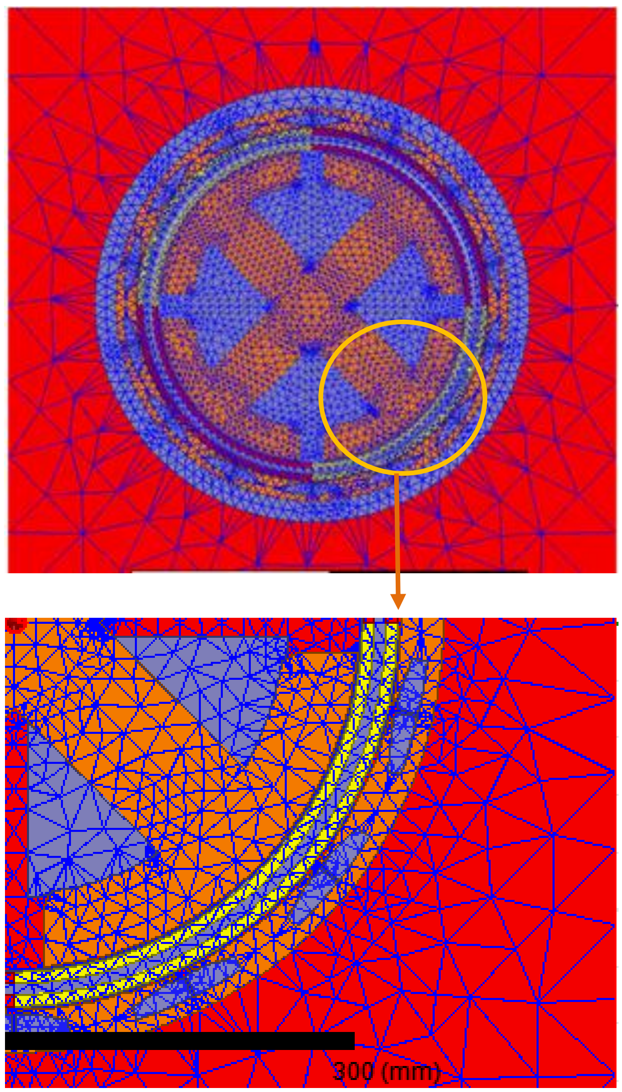


Figure 28: Mesh plot

4.2.2 Internal Rotor (Motor)

<u>Open flux distribution.</u>

Figure 29 shows the direction of magnetic field movement for the external rotor part. The design have four magnet that hold by the aluminium ring. The direction of magnet is going inward and outward alternately. The different direction of magnet result the magnetic flux to move inside the stator.Figure 30 shows the magnetic flux line. As can we can see the figure, the flux did not peneterate the aluminum ring. This is because the author use aluminum ring with permeablity value approaching 0. Figure 31 shows how the flux will be move when the simulation of 1.2 second s time limit is running. The different shape of flux line is due to the movement of rotary part which is magnet and aluminium ring. The rotor speed is 220 rpm, same with the conventional ceiling fan speed.

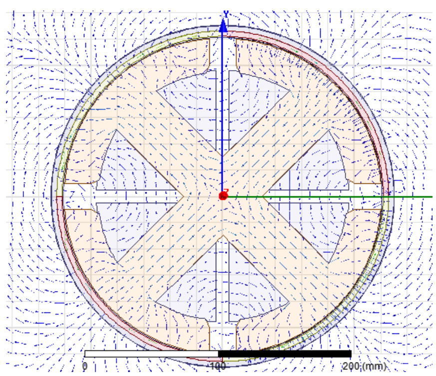


Figure 29 : Direction of magnetic flux

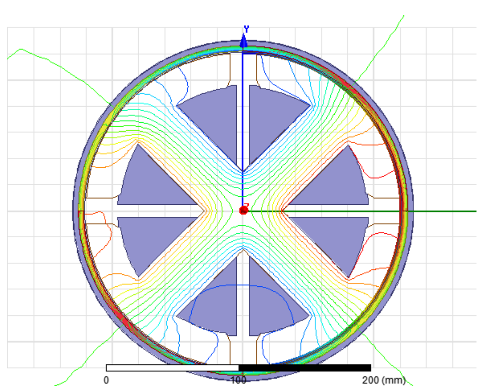
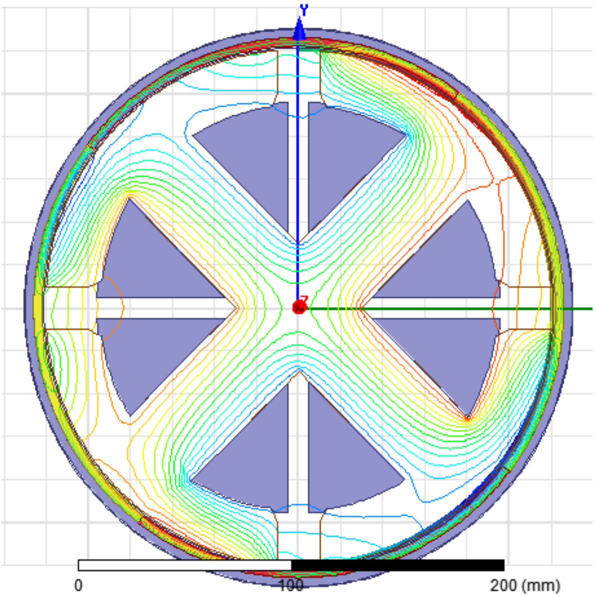
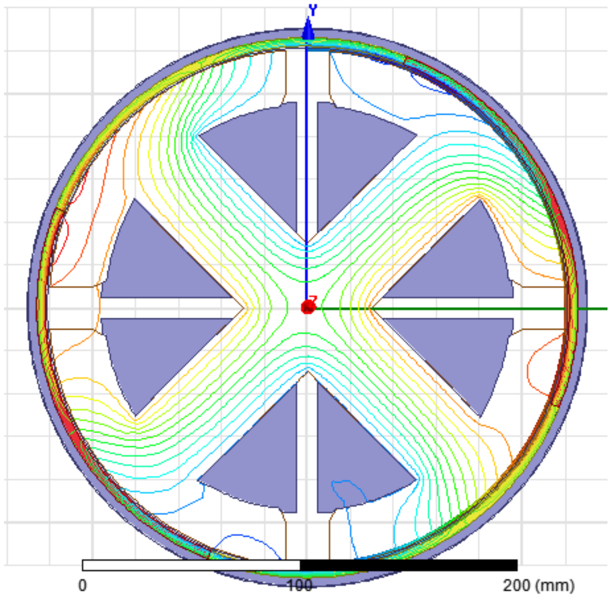


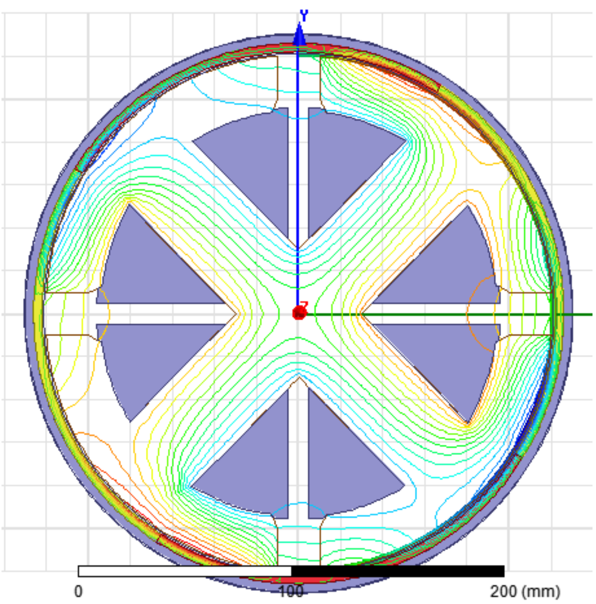
Figure 30 : Flux line at step time = 0 second

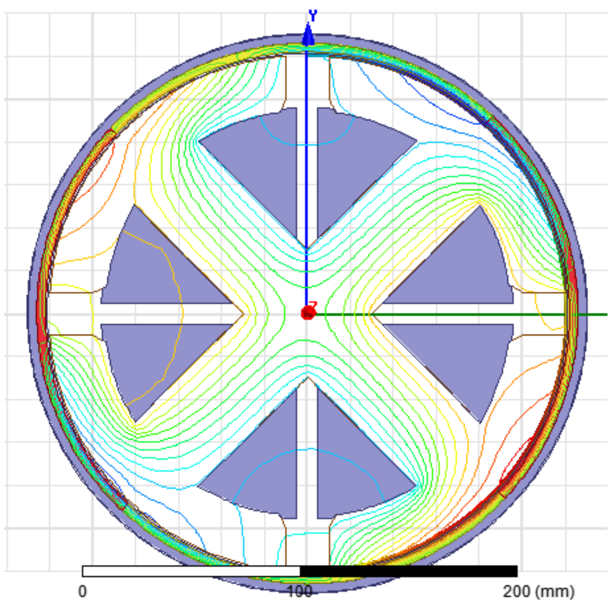




a) Step time = 0.04second

b) Step time = 0.12 second





c) Step time = 0.18second

d) Step time = 0.24 second

Figure 31 : Rotary movement for external rotor (Motor)

Air gap flux distribution and torque.

Figure 32 shows the position of rotating part, in 1.2 seconds it can complete four cycles with angular speed of 220 rpm. Figure 33 shows the magnetic flux density at the air gap of external rotor part. Every peak indicates the density located at the tooth of the stator. The effect of flux's flow in the stator result a curve in every peak.

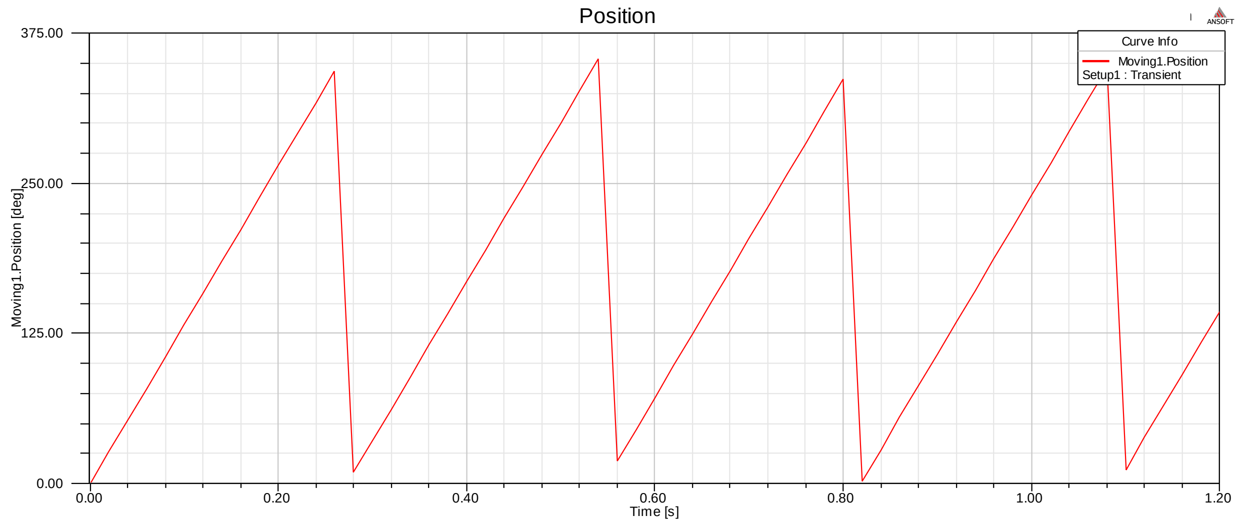


Figure 32 : Position vs. Time

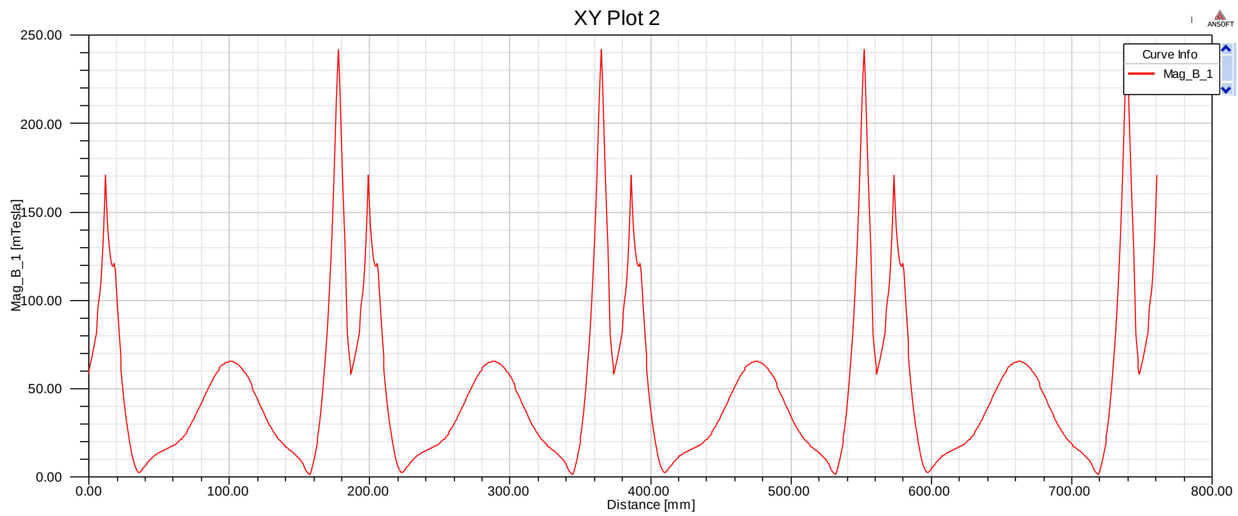


Figure 33 : Magnetic flux density at the air gap

Figure 34 shows the torque of the motor. The torque value in the starting time is slightly different, but throughout the time, the torque value is more similar. The torque occurs due to the machines that will rotate when it is functioning.

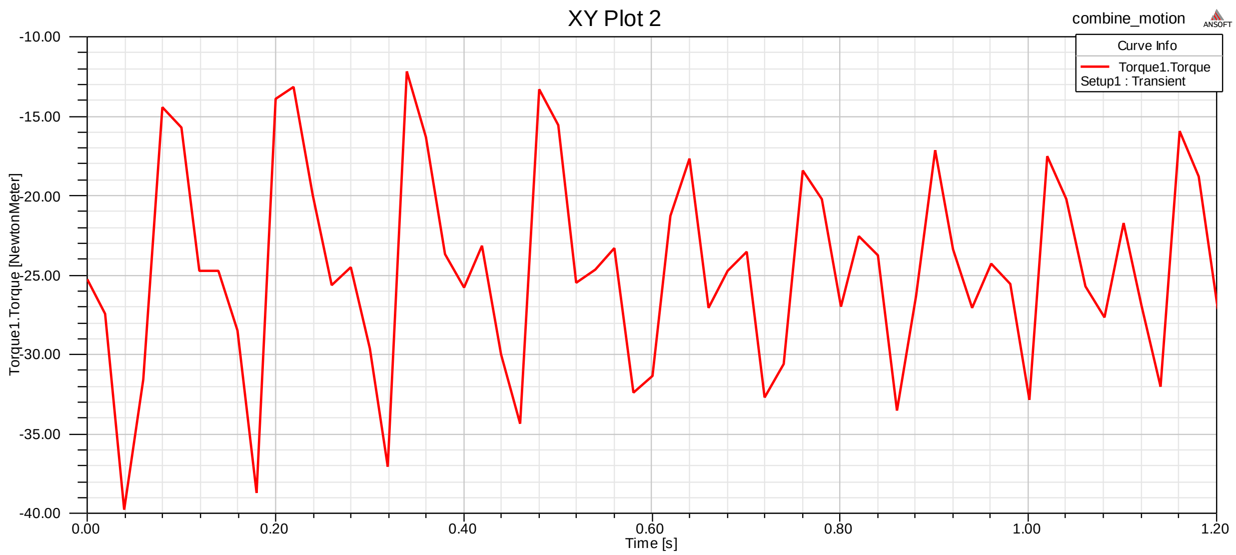


Figure 34 : Torque vs. Time

4.2.3 Internal Rotor (Generator)

Open flux distribution.

Figure 35 shows the direction of magnetic field movement for the internal rotor part. The design have four magnet that hold by the aluminium ring. The direction of magnet is going inward and outward alternately. The different direction of magnet result the magnetic flux to move inside the stator and circulate in it.Figure 36 shows the magnetic flux line. As can we can see the figure, the flux did not peneterate the aluminum ring. This is because the author use aluminum ring with permeability value approaching 0. While Figure 37 shows how the flux will be move when the simulation of 1.2 second s time limit is running. The different shape of flux line is due to the movement of rotary part which is magnet and aluminium ring. The rotor speed is 220 rpm, same with the conventional ceiling fan speed.

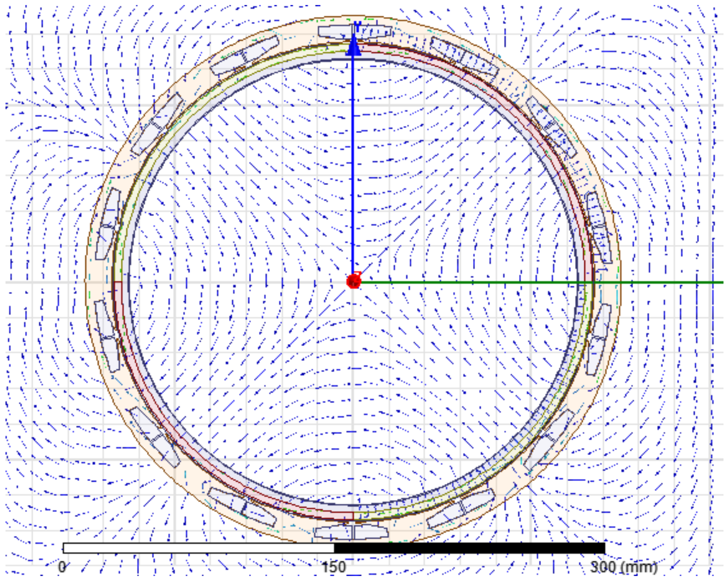


Figure 35 : Direction on magnetic flux

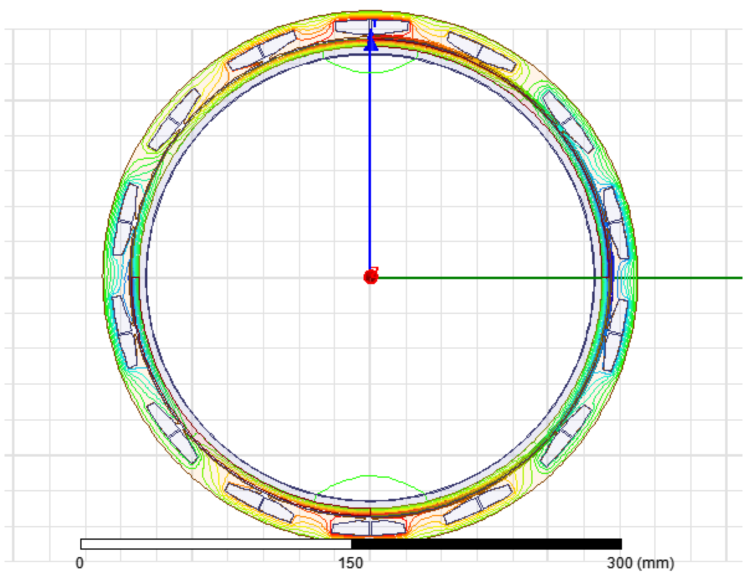
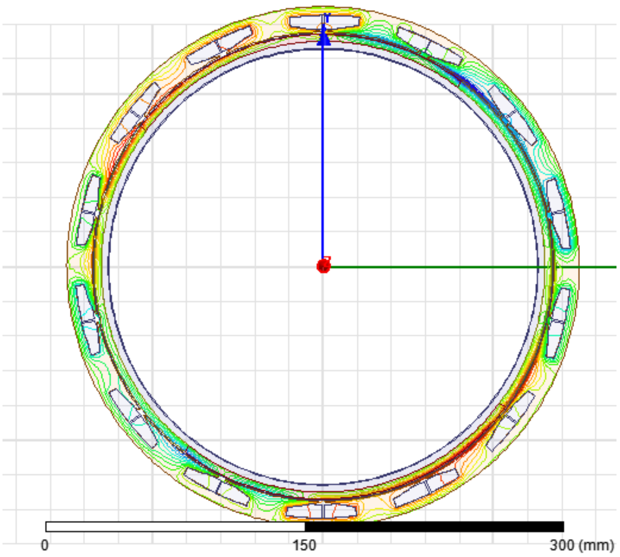
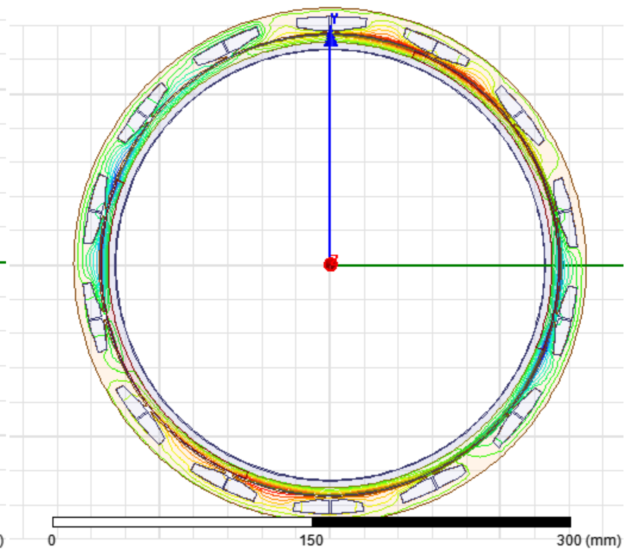


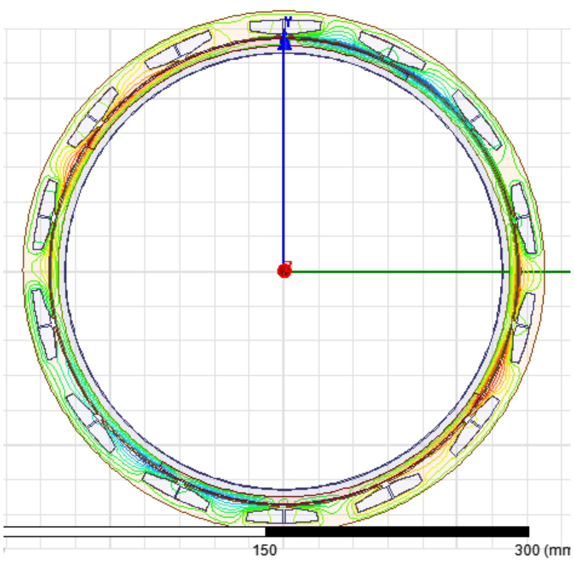
Figure 36 : Flux line at step time = 0 second



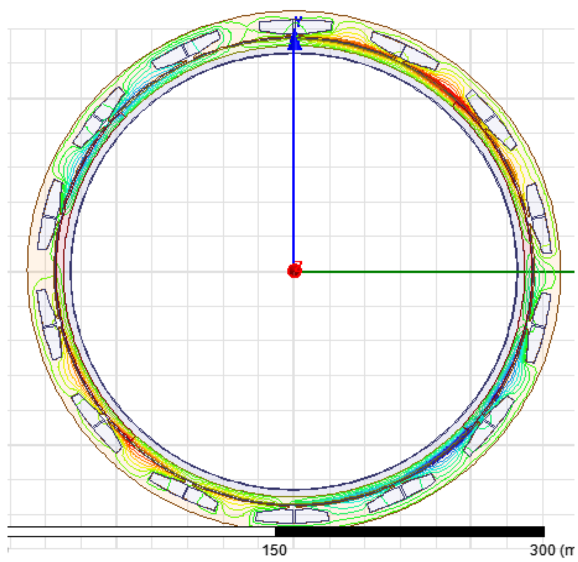
a) Step time = 0.04 second



b) Step time = 0.12 second



c) Step time = 0.18 second



d) Step time = 0.24 second

Figure 37 : Rotary movement for internal rotor (Generator)

Air gap flux distribution and torque.

The speed and position for external rotor part is same as illustrated in Figure 32. Figure 38 shows the position of rotating part, in 1.2 seconds it can complete four cycles with angular speed of 220 rpm. Figure 38 shows the magnetic flux density at the air gap of internal rotor part. Every peak indicates the density located at the tooth of the stator. The effect of flux's flow in the stator result a curve in every peak.

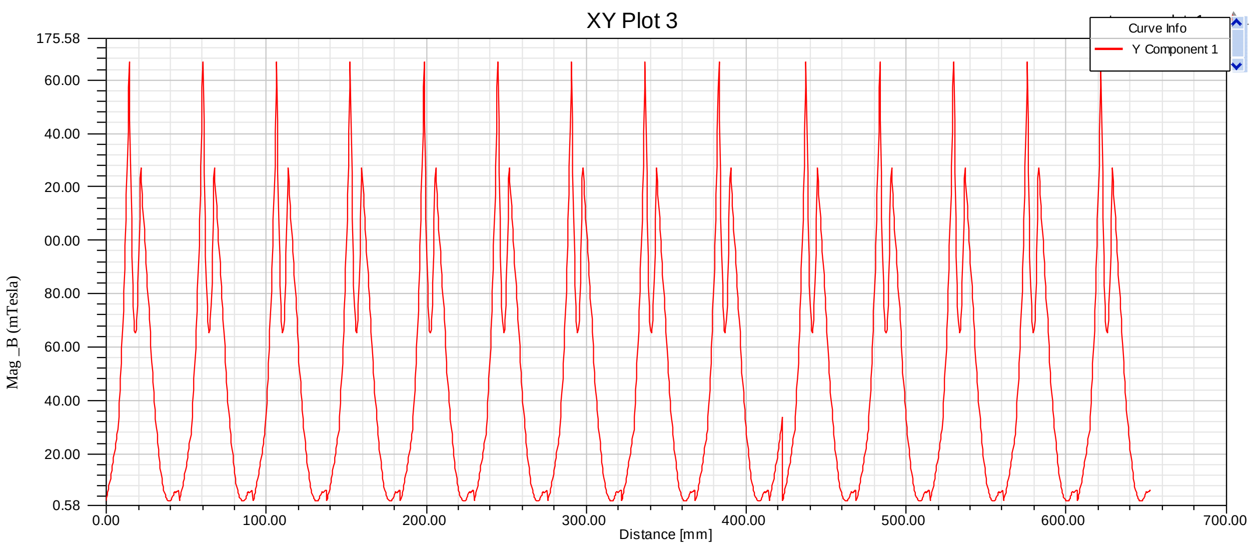


Figure 38 : Magnetic flux at the air gap for internal rotor

Figure 39 shows the torque of the motor for internal rotor part. The torque value in the starting time is slightly different, but throughout the time, the torque value is more similar. The torque occurs due to the machines that will rotate when it is functioning.

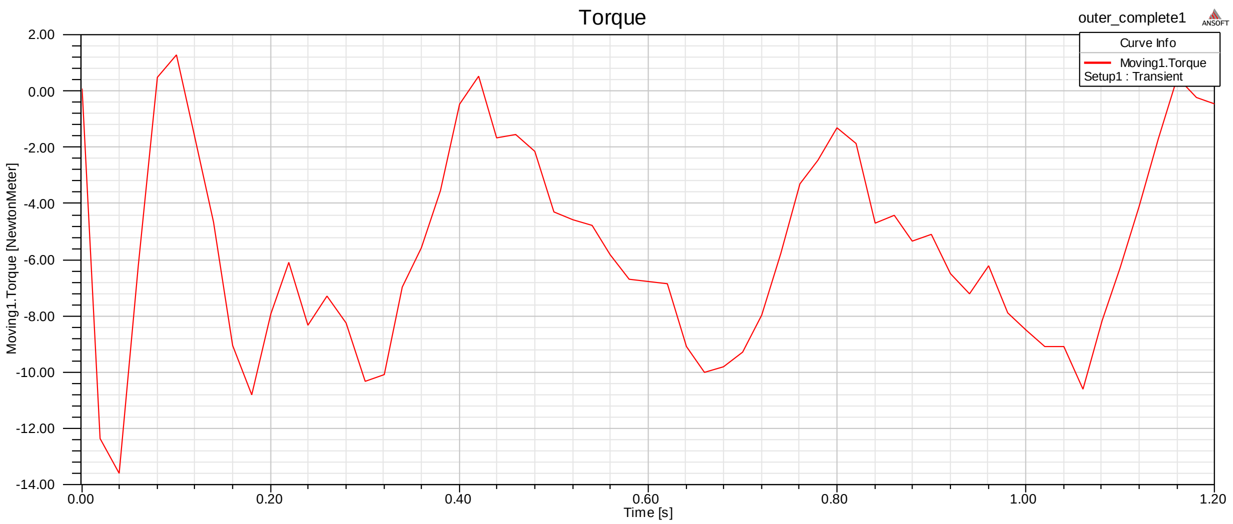


Figure 39 : Torque vs. Time

4.2.4 Combination of Internal Rotor and External Rotor (Full System).

Figure 40 and Figure 41 show direction of magnet flux and the flux line obtain when both internal rotor part and external part being combine together. The rotating part consist of two layers of magnet that have aluminuim ring in between them to hold them. Figure 42 shows the flux distribution when the rotating part rotate. The pattern of the flux is exactly the same if both machine function separately. Flux from internal and external rotor did not have conflict with each other because the author use alumunium ring with permeability of the material approaching 0 running. The different shape of flux line is due to the movement of rotary part which is magnet and aluminium ring. The rotor speed is 220 rpm, same with the conventional ceiling fan speed.

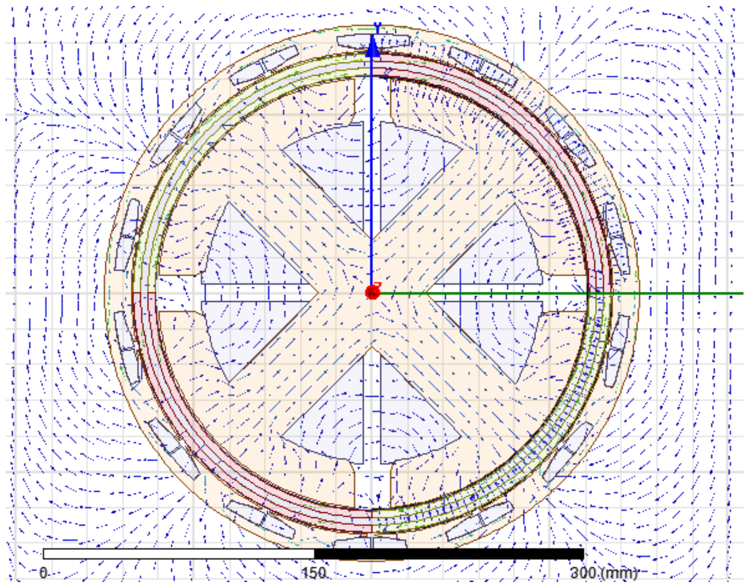


Figure 40 : Direction of magnetic flux

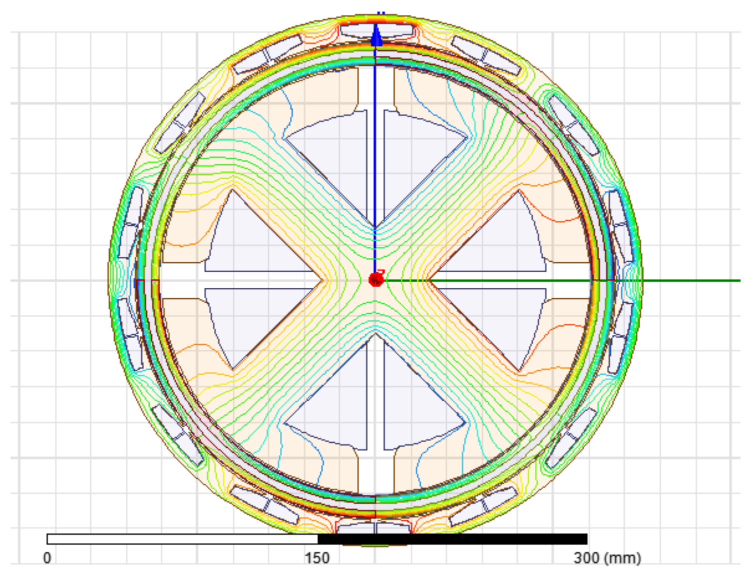
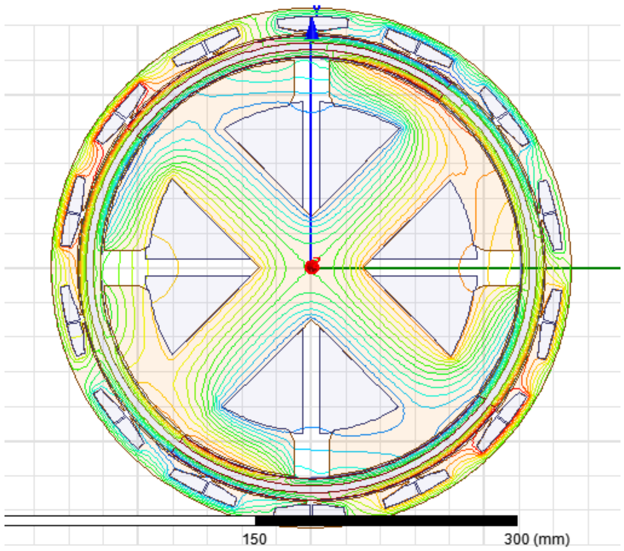
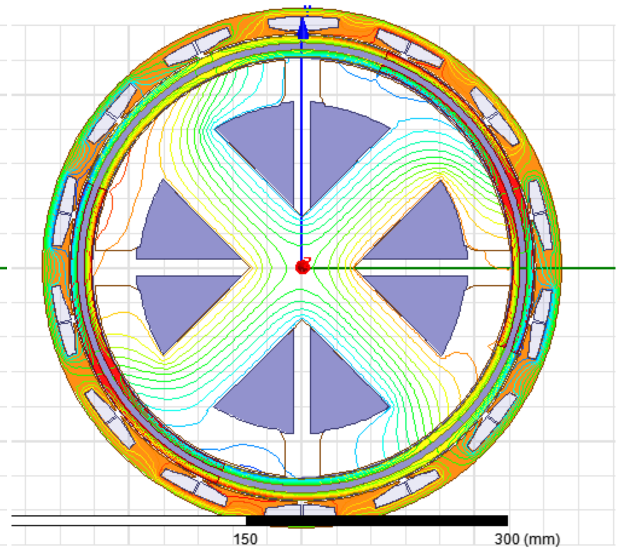


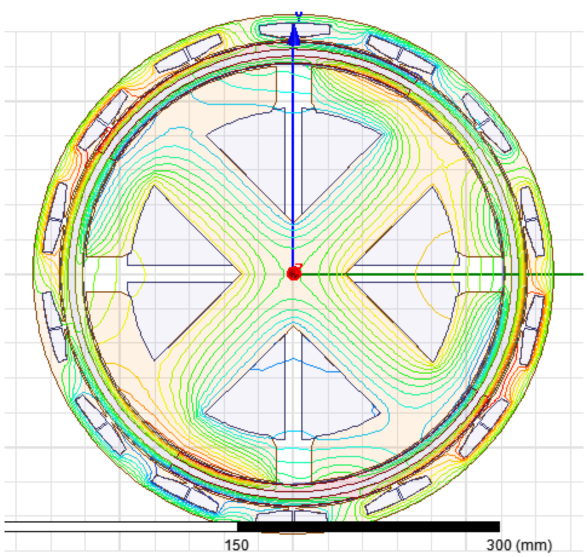
Figure 41 : Flux distribution, step time = 0 second



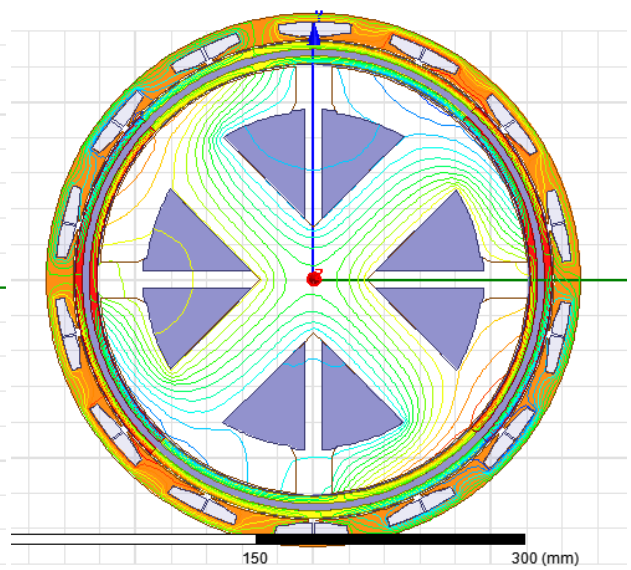
a) Step time = 0.04second



b) Step time = 0.12 second



c) Step time = 0.18 second



d) Step time = 0.24 second

Figure 42: Rotary movement for the combining system

Air gap magnetic flux distribution.

As show in Figure 43 and Figure 44, is the air gap magnetic flux distribution motor (internal rotor) and motor (external rotor) for the combining simulation, the results obtain are still same if the system work separately. There is no unwanted effects in the air gap magnetic flux distribution due the aluminium ring that has been use as the separator of motor and generator. The aluminium ring avoid the magnetic flux from penetrate to other unwanted part.

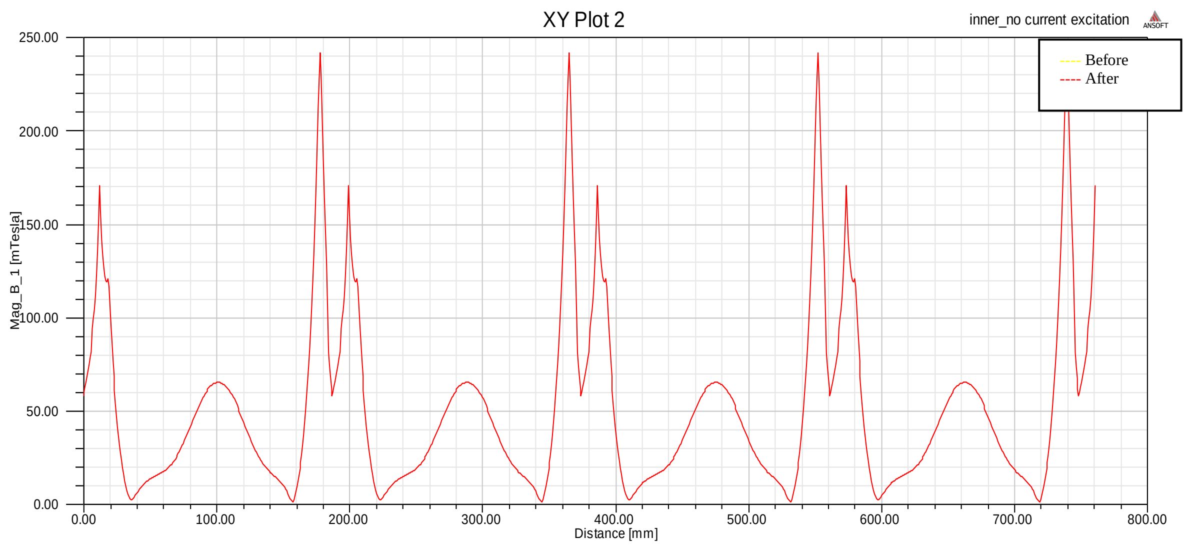


Figure 43 : Air gap magnetic flux distribution for external rotor

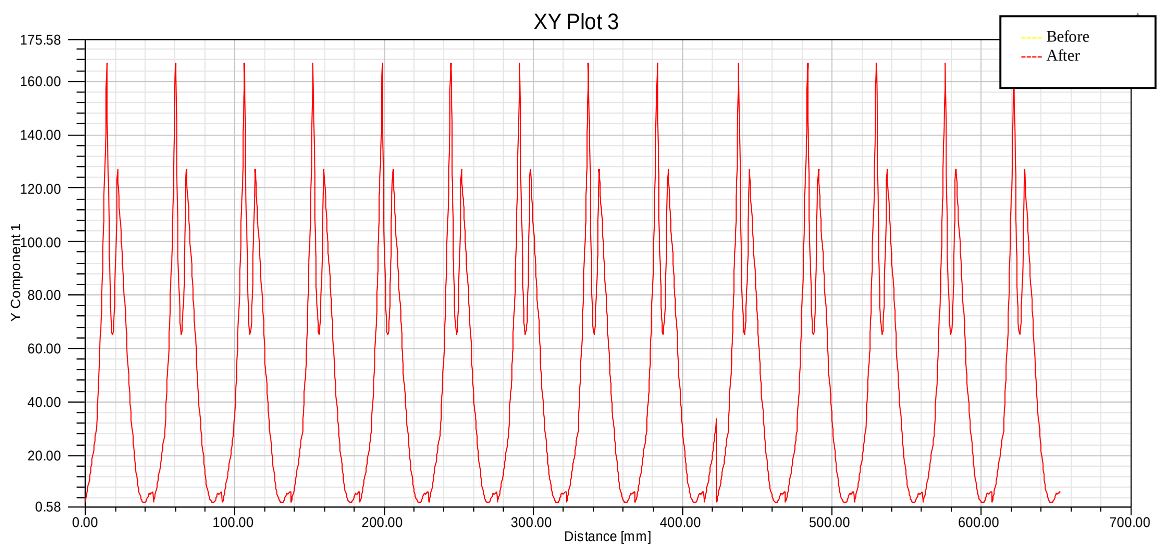


Figure 44 : Air gap magnetic flux distribution for internal rotor

4.3 Conclusion

The results obtained shows that the system can work both with the motor and generator simulated separately or combined. The results for air gap magnetic flux distribution, position and torque show the system can be work properly. For the combining simulation, the results obtain are still same if the system work separately. There is no unwanted effects in the air gap magnetic flux distribution due the aluminium ring that has been use as the separator of motor and generator. The aluminium ring avoid the magnetic flux from penetrate to other unwanted part.

CHAPTER 5: CONCLUSION

5.1 Conclusion

The literature review has been conducted with various types of electrical machines which are the induction machine, synchronous machine, DC machine and permanent magnet. After comparing the advantages and disadvantages for each type of electrical machines, the combination of external and internal rotor of permanent magnet motor has been introduced for the ceiling fan system. Permanent magnet motor is selected due to its advantages because electricity is not required to produce the magnetic field. It also has high power density, high efficiency and low manufacturing cost. Moreover, it has better dynamic performance than motor with electromagnetic excitation. The design of the permanent magnet motor is simple and therefore the maintenance is low.

Therefore, the basic design of permanent magnet external rotor and the internal rotor which consist of the suitable number of pole/slot and type of tooth has been used in the simulation. The literature review has been conducted to come out with the new design of ceiling fan system.

The simulation in the ANSYS software, ANSYS MAXWELL software is based on the specifications that have been decided. Separate simulation of generator and motor is to ensure both part can function correctly. The simulation had also been done with both parts combined together. The results for both parts are still the same whether it is being simulated separately or combined together.

The project is relevant because of its improvement and modification of electrical machine technology. Combining two concepts of machines can produce a product that gives benefits to the users. The author believe that outcome from the project can lead to a new generation of ceiling fan. In conclusion, the objective of the project has been achieved.

5.2 Recommendation

In the future, the optimization of the system could be done by changing some parameters such as number of pole and slots, number of magnet used and type of magnet used which can vary the results obtain. It is also recommended to simulate the system using other software.

REFERENCES

[1] "Historical Data Graphs per Year" http://www.indexmundi.com

[2] "Auditing Energy Usage for Households", Report by A DDC Project Publication. Version 2.

[3] C. S. Liu, J. C. Hwang; , "Development of Brushless DC Motor with Low Cogging Torque for Ceiling Fan," Power Electronics and Drive Systems, 2009. PEDS 2009. International Conference, , 2-5 Nov. 2009, pp.778-782.

[4] R. Miller, M. R. Miller, "Electrical Motors", 6th edition, pp. 32,275.

[5] "Squirrel-Cage Induction Motor", http://emadrlc.blogspot.com

[6] T. Ibrahim, "Short-stroke Single-phase, Tubular Permanent Magnet Motors for Refrigerant Application" University of Sheffield, PhD Thesis, May 2009.

[7] "Electrical Pictures " http://www.electrical-picture.com/wound-rotor-slip-ring-induction-motor/

[8] S. Huang, J. Liu, J. Gao, L. Xiao, " Optimal Design of the Rotor Structure for Interior Permanent Magnet Synchronous Motor" International Conference on Power Engineering, Energy and Electrical Drives, Spain, May 2011.

[9] S. J. Chapman, "Electrical Machines Fundamental" 5th Edition, pp.272.

[10] T. Reichert, T. Nussbaumer, J. W. Kolar, "Novel Bearingless Brushless Motor in Exterior Rotor Construction for Stirred Bioreactors" Power Electronics, Machines and Drives (PEMD 2010), 5th IET International Conference, , April 2010, pp.1-6, 19-21.

[11] S. C. Park, " Analysis of Exterior-Rotor BLDC Motor Considering the Eddy Current Effect in the Rotor Steel Shell", IEEE Transactions On Magnetic, May 1999, Vol. 35, No. 3.

[12] "Synchronous Motors General Principles" synchronousmotor.specaproduct.com

[13] Z.Q Zhu, D Howe, "Influence of Design Parameters on Cogging Torque in Permanent Magnet Machines.", IEEE Transaction on Energy Conversion, December 2000, Vol. 15, No. 4, pp. 407- 412.

[14] J. Faiz, "Two-Dimensional Magnetic Field Analysis of Internal-Rotor Permanent-Magnet Motors" IEEE Transaction on Magnetics, Sept 1999, Vol. 35, No. 5, pp. 4232 -4237.

[15] J. Wang, “Tubular Modular Permanent Magnet Machines Equipped with Quasi-Halbach Magnetized Magnet-Part 1: Magnetic Field Distribution, EMF, and Thrust Force,” IEEE Transaction on Magnetics, September 2005, Vol. 41, No. 9, pp.2470 – 2478.

[16] Y. Honda, T. Higaki, S. Morimoto, Y. Takeda, “ Rotor Design Optimization of Multi-Layer Interior Permanent-Magnet Synchronous Motor” Electrical Power Application, IEEE Proceeding, March 1998, Vol. 145, No. 2, pp.119-224.

[17] J. F. Gieras, M. Wing, “Permanent Magnet Motor Technology, Design and Applications”, 2nd Edition, pp. 1,194

[18] N. Bianchi, “Electrical Machines Analysis Using Finite Elements.”

[19] “ANSYS Software.” http://www.jlrcom.com/ansys-software.htm

[20] P. Upadhyay, K. R. Rajagopal, “Torque Ripple Minimization of Interior Permanent Magnet Brushless DC Motor Using Rotor Pole Shaping” Power Electronics, Drives and Energy Systems, 2006. PEDES ’06. International Conference, 12-15 December 2006, pp. 1-3.

[21] M.Fazil and ,K. R. Rajagopal “Development of External Rotor Single-Phase PM BLDC Motor Based Drive for Ceiling Fan”. Power Electronics, Drives and Energy Systems (PEDES) & 2010 Power India, 2010 Joint International Conference, 20-23 December 2010, pp. 1-4.

[22] Y. Zhang , F. Wang , "Choice of Pole-Slot Number Combination for PM Generator Direct-Driven by Wind Turbine". Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008. Joint International Conference, 12-15 October 2008, pp. 1-4.

[23] K.Yamazaki, K. Kitayuguchi “Teeth Shape Optimization of Surface and Interior Permanent-Magnet Motors with Concentrated Windings to Reduce Magnet Eddy Current Losses.” IEEE Transaction on Magnetics, Vol. 39, No.3. pp. 990-995.

[24] T. Kubota, S.Jeong, D.H.C Toe, D.R Ossen “Energy Consumption and Air-Conditioning Usage in Residential Buildings of Malaysia”, Journal of International Development and Cooperation, Vol.17, No.3. 2011, pp 61-69.

[25] “ Syncrhronous Motor Theory and Principle”, http://threephaseelectricmotor.com/synchronous-motor-theory-and-principle/

APPENDICES

FINAL YEAR PROJECT 1

No	Detail/Week	1	2	3	4	5	6	Mid Semester Break (7/02-11/02/2012)	7	8	9	10	11	12	13	14
1	Selection of Project Topic: A novel design of ceiling fan system.															
2	Preliminary Research Work: Research on literatures related to the topic															
3	Submission of Extended Proposal															
5	Proposal Defend															
6	**Project work :** • Familiarization using finite element software															
7	Submission of draft for interim report															
8	Submission of Interim Report Final Draft															

FINAL YEAR PROJECT 2

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Project work continue from FYP I**														
2	Submission of progress report.														
3	Submission of draft report.														
5	Submission of final report. Submission of technical report.														