Novel Design For Electrical Fan

by

NORAISHAH A RAZAK

FINAL YEAR PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Novel Design For Electrical Fan

by

NORAISHAH A RAZAK

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved by:

____

(Dr. Taib Ibrahim)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2010

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.

____

Noraishah A Razak

ABSTRACT

The ceiling fan uses an electrical motor but this motor is not fully used. The idea of this project is to utilize the ceiling fan's electrical motor so that it can operate as a normal ceiling fan and at the same time generate a power supply to other loads. Therefore, the aim of this project is to produce the novel design of electrical machine which can operate as motor and generator at the same time. Literature review has be conducted in order to produce and then propose the new design. The proposed design is established using Finite Element Analysis (FEA) software which is ANSYS. ANSYS is used in developing two dimensional (2-D) model for the electrical machine design. The method of creating a model in ANSYS is called modeling. The created model is then meshed. This method is called meshing. Meshing method prepares the model for simulation process. The meshed model then go through calculations executed by ANSYS. After the solution is obtained, the simulation of flux distribution can be observed.

ACKNOWLEDGEMENTS

First and foremost, I would like to praise God the Almighty for His help, guidance and love. With His blessings bestowed upon me, I managed to overcome all obstacles in doing this project. In this opportunity, I would like to express my heartfelt gratitude to everyone that has contributed in the project.

My deepest appreciation and gratitude goes to my Final Year Project Supervisor, Dr. Taib Ibrahim for his supervision, commitment, professionalism, advice, guidance and support throughout this final year project studies.

A special acknowledgement, appreciation and deepest gratitude goes to:

- Ir. Dr. Mohd. Shiraz Aris, from Mechanical Engineering Department of Universiti Teknologi PETRONAS.
- Technicians in Electrical and Electronics Engineering Department and Information Technology Department. They are Encik Musa, Encik Ruslan Idris and Puan Siti Hawa Tahir.
- Sarah Koo Shuk Yee, Nur Fatin Alias, Noor Azliza Abdull Kadir, Rubiah Ab. Ghani and Raja Hafizi for their help.
- My dearest mother, family and friends for the endless moral support and prayers.

Last but not least, I would like to express my gratitude to those who had helped me directly or in directly in undertaking this project throughout the entire two (2) semesters. Their contributions and guidance are highly appreciated.

TABLE OF CONTENTS

CERTIFICATION OF APPROVAL .... **i**

CERTIFICATION OF ORIGINALITY .... **ii**

ABSTRACT .... **iii**

ACKNOWLEDGEMENTS .... **iv**

LIST OF FIGURES .... **viii**

CHAPTER 1: INTRODUCTION 1

1.1 Background of Study 1

1.2 Problem Statement 2

1.3 Objectives 2

1.4 Scope of Study 2

CHAPTER 2: LITERATURE REVIEW 4

2.1 Electrical Ceiling Fan Motor 4

2.2 Permanent Magnet Motor 5

2.2.1 Exterior Permanent Magnet (EPM) 6

2.2.2 Interior Permanent Magnet (IPM) 7

2.2.3 Permanent-Magnets Axial Rotor 8

2.3 Finite Element Analysis Software, ANSYS 9

2.3.1 Finite Element Analysis 9

2.3.2 ANSYS 9

2.4 Electromagnetic Theory 10

2.4.1 Flux distribution 10

2.4.2 Laws of electromagnetic induction 11

2.4.3 Induced electromotive force (emf) in a rotating coil . 12

2.4.4 Magnetic susceptibility and permeability 13

CHAPTER 3: METHODOLOGY 15

3.1 Procedure Flow 15

3.2 Materials Identification 16

3.2.1 Permanent Magnet (Rotor) 16

3.2.2 Back iron (Rotor) 17

3.2.3 Stator 18

3.2.4 Windings (Winding coil) 19

3.2.5 Air 21

3.3 Details of the procedures 21

3.3.1 Data research and gathering 21

3.3.2 New design of electrical machine 22

3.3.3 Development of 2-D model 22

3.3.4 Simulation with ANSYS 22

3.4 Tools 22

3.4.1 ANSYS 22

CHAPTER 4: RESULTS 23

4.1 'Novel Design for Electrical Fan' using axial configuration 23

4.2 Simulation of the new design with ANSYS 24

4.2.1 Creating the geometry 24

4.2.2 Define materials 26

4.2.3 Generate Mesh 27

4.2.4 Apply Loads 29

4.2.5 Obtain Solution 29

4.2.6 Review Results 29

CHAPTER 5: CONCLUSION 31

5.1 Conclusion 31

5.2 Recommendations 31

REFERENCES 32

LIST OF FIGURES

Figure 1: Permanent Split Capacitor (PSC) Starting Mechanism 5

Figure 2: Exterior Permanent Magnet 6

Figure 3: Interior Permanent Magnet.. 7

Figure 4: Permanent-Magnets Axial Rotor 8

Figure 5: The Flowchart of Final Year Project 1 15

Figure 6: The Flowchart of Final Year Project 2 16

Figure 7: Magnet properties 17

Figure 8: Back iron properties 18

Figure 9: Stator properties 19

Figure 10: Winding coil properties 20

Figure 11: Air properties 21

Figure 12: 'Novel Design for Electrical Fan' using axial configuration 23

Figure 13: Keypoints and lines of the 2-D model 25

Figure 14: Areas of the 2-D model created 26

Figure 15: PLANE53 Geometry 27

Figure 16: Areas with assigned materials 28

Figure 17: Meshed areas 28

Figure 18: Simulation of flux distribution 30

CHAPTER 1
INTRODUCTION

1.1 Background of Study

The electrical ceiling fan system uses a motor to operate. The type of motor used is single-phase induction motor. Single-phase induction motor has only one stator winding and it operates with a single-phase power supply. The type of single-phase induction motor used is squirrel cage. The ceiling fan motor currently operates as a motor only. This means that the electrical ceiling fan motor is not fully utilized. However, the motor can generate electricity by connecting stators and rotor back to back. This is done with the objective to fully utilize the fan motor by constructing it to be a generator and a motor at the same time. The generator can therefore supply power to other loads, for example, the domestic lighting system.

The study involves designing the motor to function as a generator and a motor simultaneously. Nevertheless, this design may experience heaviness due to the construction. Therefore, there is a need to propose a design which can overcome this problem and at the same time meet the requirement of the project. The requirement of the project is to enable the electrical machine to function as motor and a generator at the same time.

1.2 Problem Statement

The electrical ceiling fan motor is not fully utilized. By designing the machine to function as a generator and a motor simultaneously, the fan motor will be fully utilized. The new topology of this electrical machine will consist of two stators and a rotor. By inventing a new topology of electrical machine for a household fan, the energy can be produced in order to be utilized to other load such as the domestic lighting system.

1.3 Objectives

The objectives of ‘Novel Design for Electrical Fan’ Project are:

i. To propose a new design of electrical machine that modifies the electrical ceiling fan motor. The electrical machine will function as a generator and a motor simultaneously; hence supplying power to other loads rather than just operate as a conventional ceiling fan.
ii. To analyze the design using Finite Element Analysis (FEA) software, ANSYS.

1.4 Scope of Study

This project is aimed to develop two dimensional (2-D) electromagnetic simulation using Finite Element Analysis (FEA) software which is ANSYS. ANSYS is used for the simulation of flux distribution and back electromotive force (back emf) of a new design of the modified ceiling fan motor. The simulation is then observed.

The study on the 2-D simulation of flux distribution and back electromotive force (back emf) will be done during Final Year Project 2 (FYP 2). This project is to be completed approximately within one year time frame (two semesters). For the first semester, the scope of study is to do various researches involving the basic concept of ceiling fan motor, permanent magnet motors, Finite Element Analysis and Finite Element Analysis Software, ANSYS. At the end of FYP 1, two new machine designs are identified.

For the second semester, one of the two designs is chosen to be modified so that theoretically, the machine will be suitable for a single-phase power supply. The single-phase power supply is 240 V in a typical Malaysian's household. At the end of FYP 2, it is targeted that the simulation of flux distribution and back electromotive force (back emf) from the new design is completed so that this simulation can be observed. This means that there is no need to build the real prototype of the design. This method saves cost, time and energy.

CHAPTER 2
LITERATURE REVIEW

2.1 Electrical Ceiling Fan Motor

The electrical ceiling fan system uses a motor to operate. The type of motor used is single-phase induction motor. Single-phase induction motor has only one stator winding and it operates with a single-phase power supply. The type of single-phase induction motor used is squirrel cage. Since the fan motor is single-phase, the motor is not self-started when connected to a power supply. The necessary torque is not generated therefore causing the motor to only vibrate and not rotate [1].

Most single-phase motors have a main winding and an auxiliary winding to provide the starting torque, both in quadrature to help generate the phase-shifted magnetic field [1].

The auxiliary winding current from the main winding is phase-shifted. A capacitor connected in series with the auxiliary winding causes the motor to start rotating. In most fan motors, the capacitor and the auxiliary winding remain connected. This configuration is called permanent split capacitor (PSC) AC induction motor. This motor is considered to be the most reliable single-phase motor. At rated load, it can be designed for optimum efficiency and high power factor (PF) [1].

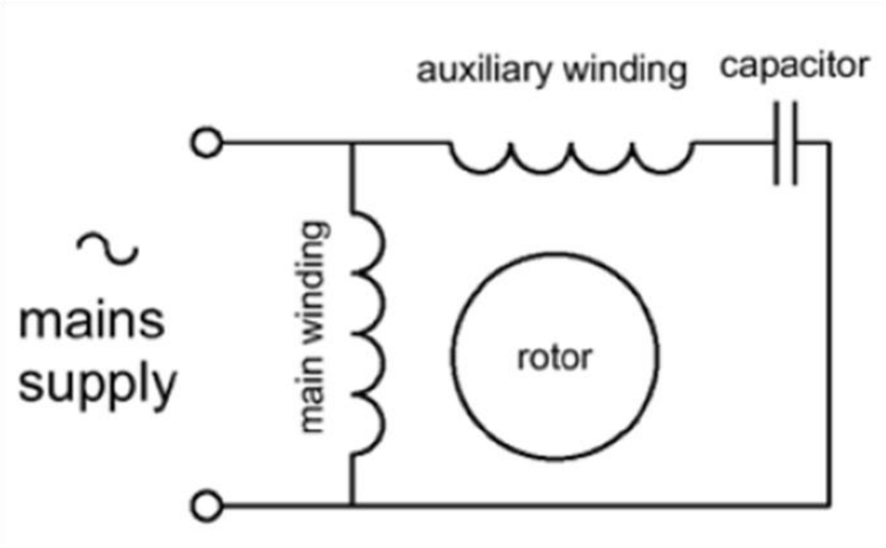


Figure 1: Permanent Split Capacitor (PSC) Starting Mechanism [1]

2.2 Permanent Magnet Motor

The use of permanent magnets (PMs) in the construction of electrical machines brings the following benefits [2]:

1. No electrical energy is absorbed by the field excitation system and thus there are no excitation losses which mean substantial increase in the efficiency.
2. Higher torque and/or output power per volume than when using electromagnetic excitation.
3. Better dynamic performance than motors with electromagnetic excitation (higher magnetic flux density in the air gap).
4. Simplification of construction and maintenance.
5. Reduction of prices for some types of machines.

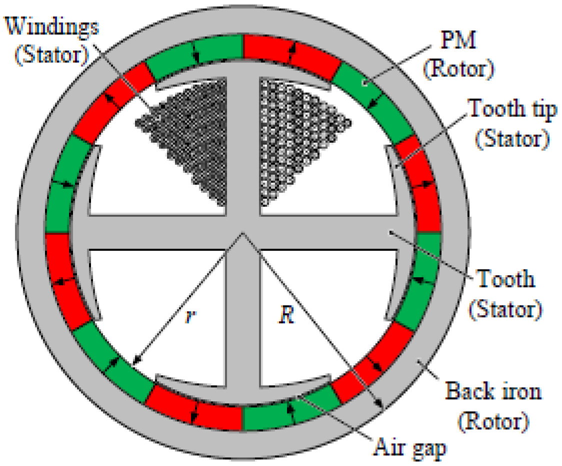
Types of rotary electrical machines:

1. D.C machines
2. A.C synchronous machines

3. Induction machines
4. Permanent magnet machines

In this project, the focus is on permanent magnet machines. For permanent magnets, there are two types of rotor architectures used. The types of rotor architectures are exterior permanent magnet (EPM) and interior permanent magnet (IPM). For EPM and IPM, there are various configurations in arranging the permanent magnets. The configurations are axial configuration and Halbach configuration or also known as Halbach Array. In this project, the axial configuration will be discussed.

2.2.1 Exterior Permanent Magnet (EPM)



. Exterior rotor machine with air gap radius *r* and outer radius *R*.

Figure 2: Exterior Permanent Magnet [3]

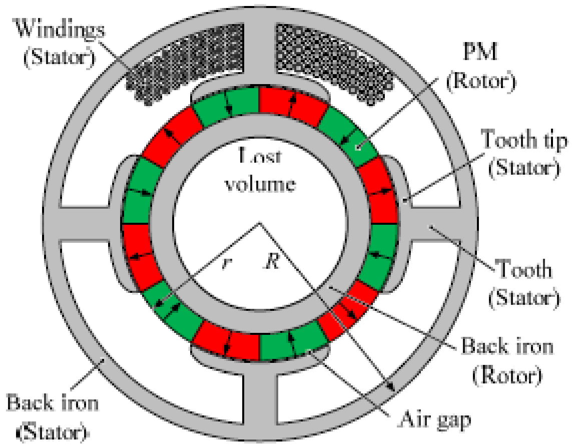
The advantages of Exterior Permanent Magnet (EPM):

1. EPM design produces higher electromotive force and torque [4].
2. Highest torque can theoretically be achieved with exterior rotor type for the largest possible air gap radius r = R (Xr = 1) [3].

The disadvantage of Exterior Permanent Magnet (EPM):

1. For the exterior rotor configuration, all the windings have to be placed in the inner part of the motor, so the space for the stator with the coils is limited. This means that the air gap radius has to be larger than a certain minimum value so that the exterior rotor configuration makes sense in terms of torque compared to the interior rotor type [3].

2.2.2 *Interior Permanent Magnet (IPM)*



Interior rotor machine with air gap radius r and outer radius R.

Figure 3: Interior Permanent Magnet [3]

The advantages of Interior Permanent Magnet (IPM):

1. IPM design can be driven at a speed more than the highest speed of the EPM design with the same load condition because the electromotive force constant of IPM design is smaller than that of EPM design [4].
2. IPM designs are much less sensitive to demagnetization since the magnets are not directly face to the armature winding. This fact proves that IPM designs are more suitable for high-speed applications [4].

The disadvantage of Interior Permanent Magnet (IPM):

1. IPM design has higher field weakening capability because of the fact that much of the armature reaction flux is passing through the iron part above the magnets and this distorts the magnet flux seriously [4].
2. The interior rotor configuration allows a very compact setup, since the rotor can be built very small. However, this results in a small torque due to the short lever arm being the air gap radius [3].

2.2.3 Permanent-Magnets Axial Rotor

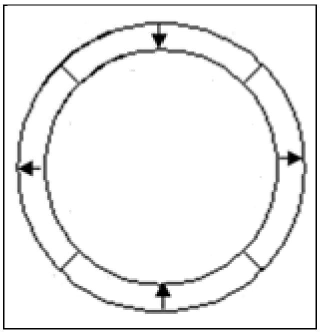


Figure 4: Permanent-Magnets Axial Rotor

The above picture shows the permanent magnets with axial configuration. Increasing the amount of axial misalignment of the permanent magnet rotor and stator proportionally increases the speed and reduces the torque. The permanent magnet rotor is offset axially to provide axial misalignment between the rotor magnet poles and the stator, reducing the effective magnet pole strength or flux to the stator [5].

2.3 Finite Element Analysis Software, ANSYS

2.3.1 Finite Element Analysis

Finite Element Analysis (FEA) is a computer-based numerical technique for obtaining near-accurate solutions to a wide variety of complex engineering problems where the variables are related by sets of algebraic, differential, and integral equations [6].

Its applications include estimation or prediction of structural strength and behavior, modeling, simulation, and design optimization in engineering branches such as solid mechanics, fluid mechanics, thermodynamics, electromagnetic, acoustics, and the like. State-of-the-art FEA can now be applied to highly non-linear problems involving convoluted geometries, inelastic material dynamics, and fluctuating process conditions [6].

2.3.2 ANSYS

ANSYS, Inc. develops general-purpose finite element analysis and computational fluid dynamics software. ANSYS is best known for its ANSYS Mechanical and ANSYS Multiphysics products [7].

ANSYS Mechanical and ANSYS Multiphysics software are non exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems [7].

ANSYS Mechanical technology incorporates both structural and material non-linearities. ANSYS Multiphysics software includes solvers for thermal, structural, CFD, electromagnetic, and acoustics and can sometimes couple these separate physics together in order to address multidisciplinary applications. ANSYS software can also be used in civil engineering, electrical engineering, physics and chemistry [7].

2.4 Electromagnetic Theory

This new design of electrical fan motor is a type of electrical machine which consists of a rotor (moving part), two stators (stationary parts) and also permanent magnets. The permanent magnets are mounted on the rotor. The flux is generated by the permanent magnets which flows through the teeth of the stators via the small air gap to generate the induced voltage. In modeling the new design of electrical fan, the study about magnetic field must be done in order to determine the type of magnet that will be used and the output voltage that will be generated at the outer part of the stator. After having considered the type of magnet, only then 2-D model can go through the simulation process. In the simulation process, the flux distribution can be observed.

2.4.1 Flux distribution

The space around a magnet or any current-carrying conductor is called a magnetic field. The basic magnetic field vector is called *magnetic induction* and denoted by B, also known as the magnetic flux density [9].

The magnetic flux through a coil of area A in a uniform magnetic field of flux density B is defined as [9]:

$$\Phi = B.A = BA \cos \theta$$

Φ = Magnetic flux

B = magnetic induction

A = Area in a uniform magnetic field of flux density, B

θ = Angle between the normal to the area A of the coil and the direction of B

The SI unit of magnetic flux is called Weber (Wb). The unit of B is therefore Wb/m^2 or tesla (T). In CGS units, magnetic induction is expressed in gauss [9].

$$1 \text{ tesla} = 1 \text{ Wb m}^{-2} = 10^4 \text{ gauss}$$

The magnetic intensity H at a point in a magnetic field is related to the magnetic induction B at that point by [9]

$$B = \mu_0 H$$

Where μ_0 is a constant called the permeability of free space. In SI unit, μ_0 has the value [9]

$$\mu_0 = 4\pi \times 10^{-7} \text{ Weber/amp. meter (or Henry/meter)}$$

In an isotropic medium, B and H have the same direction [9].

2.4.2 Laws of electromagnetic induction

Faraday's experiments showed that the change of magnetic flux linked with an electric circuit gives rise to an electromotive force (emf) in the circuit, known as the induced electromotive force (emf). The induced electromotive force (emf) gives to an induced current when the circuit is closed. This phenomenon is called the electromagnetic induction. There are two laws of electromagnetic induction [9].

a. Faraday's Law

"The magnitude of the electromotive force (emf) induced in a circuit in electromagnetic induction is proportional to the rate of change of the magnetic flux linking the circuit."

b. Lenz's Law

"The direction of the induced electromotive force (emf) or the current in electromagnetic induction is always such as to oppose the very cause (i.e., the change of magnetic flux) which produces it."

Combining the above two laws, the induced electromotive force (emf) is given by [9],

$$e = -\frac{d\Phi}{dt}$$

Where Φ is the flux linked with a circuit at time t. The negative sign signifies that the induced electromotive force (emf) opposes the change in flux and hence called the back electromotive force (back emf). In SI units, e is expressed in volts, Φ in Webers and t in seconds so that the constant of proportionality in ($e = -\frac{d\Phi}{dt}$) is unity. The direction of the induced electromotive force (emf) and hence of the induced current is given by Fleming's Right Hand Rule [9].

2.4.3 Induced electromotive force (emf) in a rotating coil

If a coil has an area A and the normal to its plane makes an angle θ with the uniform magnetic field B, the flux linked with the coil is [9],

$$\Phi = NAB \cos \theta$$

Where N is the number of turns in the coil. If the coil is rotated with a uniform angular velocity ω about an axis in the plane of the coil and at right angles to the field, the induced electromotive force (emf) is given by [9],

$$e = -\frac{d\Phi}{dt} = -\frac{d}{dt}(NAB\cos\omega t)$$

Or, $$e = NAB\ \omega\ \sin \omega t = e_0 \sin \omega t$$

Where e_0 = NABω is the maximum induced electromotive force (emf). We see that the induced electromotive force (emf) varies sinusoidally with time [9].

2.4.4 Magnetic susceptibility and permeability

For an isotropic medium in which B, H and M are all in the same direction, the relation is [9],

$$B = \mu_0 (H + M)$$

For isotropic linear magnetic materials, M is linearly related to H [9],

$$M = x_m H$$

The dimensionless scalar quantity x_m is called the magnetic susceptibility of the medium. Combined equation of B and M [9],

$$B = \mu_0 (1 + x_m) H = \mu H$$

Where μ is called the magnetic permeability of the medium. μ is a constant and like μ_0 carries the units of H/m [9],

$$\mu = \mu_0 (1 + x_m)$$

The dimensionless quantity $\mu_r = \mu/\mu_0$ is called the relative permeability of the medium [9]. This,

$$\mu_r = \frac{\mu}{\mu_0} = 1 + x_m$$

CHAPTER 3

METHODOLOGY

3.1 Procedure Flow

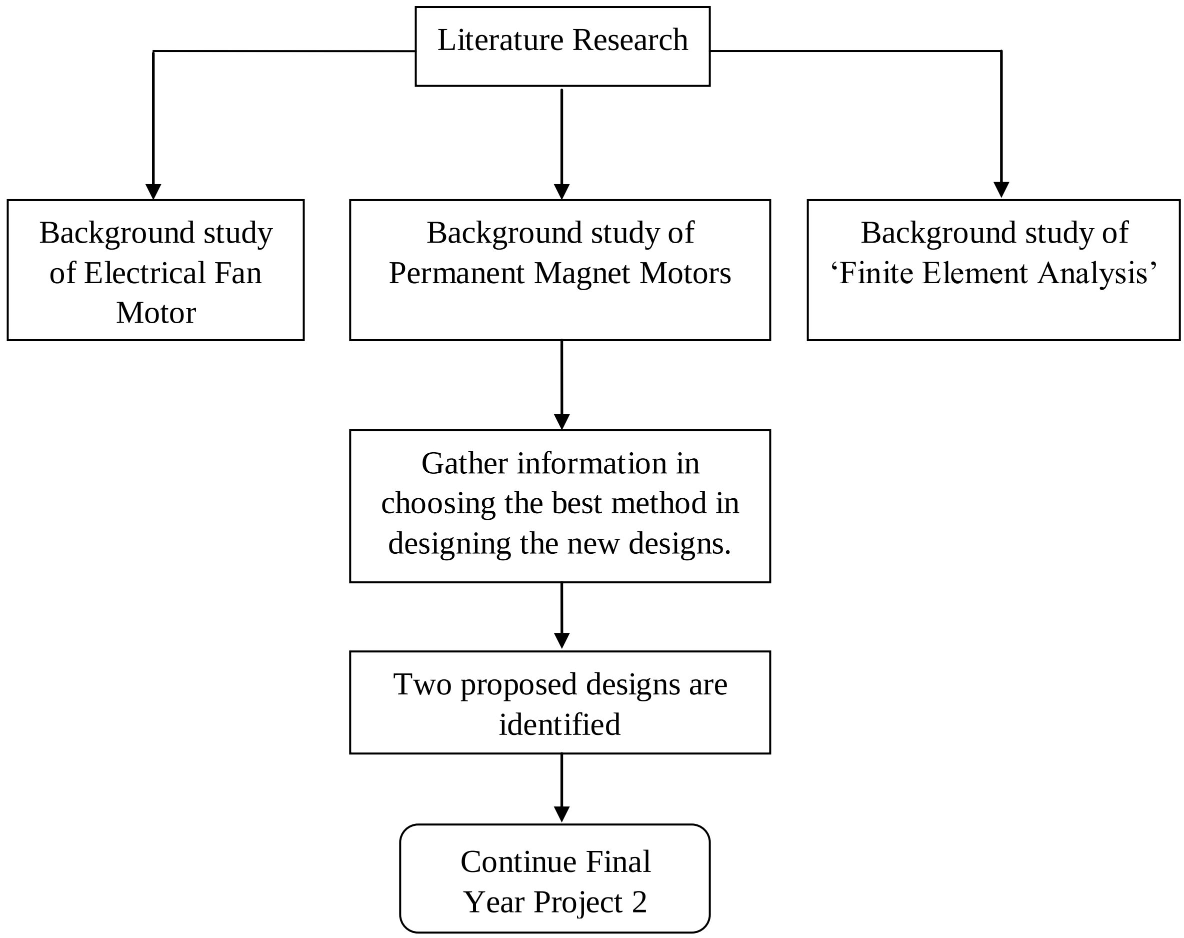


Figure 5: The Flowchart of Final Year Project 1

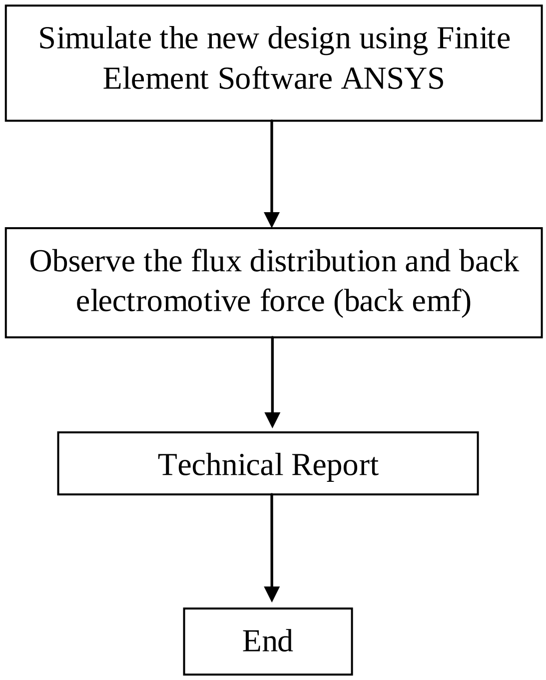


Figure 6: The Flowchart of Final Year Project 2

3.2 Materials Identification

3.2.1 Permanent Magnet (Rotor)

The rotor of this new design of electrical machine consists of permanent magnets which can generate flux. The magnet properties which have been decided are:

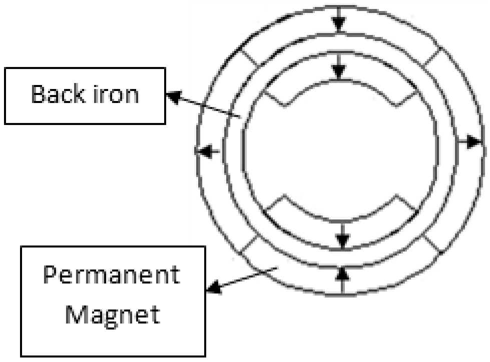
Diagram		
Material	NdFeB – N30EH	
Properties	Coercive Force	871 kA/m
	Intrinsic Force	2411 kA/m
	Max working temperature	200°C
	Density	7.4 g/cm³
	Remenance flux density	1.114 T
	Maximum energy product, BH_{max}	241 kJ/m³
Dimension	Diameter	33.5 mm

Figure 7: Magnet properties

3.2.2 Back iron (Rotor)

The rotor is the moving part of the electrical machine. The construction of this rotor is circular in shape. This means that this new design of electrical machine is a rotary machine. The back iron is at the rotor. The back iron plays an important role to enhance flux linkage and reduce flux leakage so that the designed machine is with the characteristics of high flux and power density [8]. The design parameters of this back iron is:

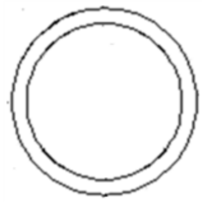
Diagram		
Material	Mild Steel	
Properties	Electrical resistivity	$10 \times 10^{-8}\ \Omega m$
	Relative permeability	800
	Density	$7.85\ g/cm^3$
Dimension	Diameter	3.5 mm

Figure 8: Back iron properties

3.2.3 Stator

Stator is the static or stationary part of the electrical machine. At each tooth of the stators is the winding coil.

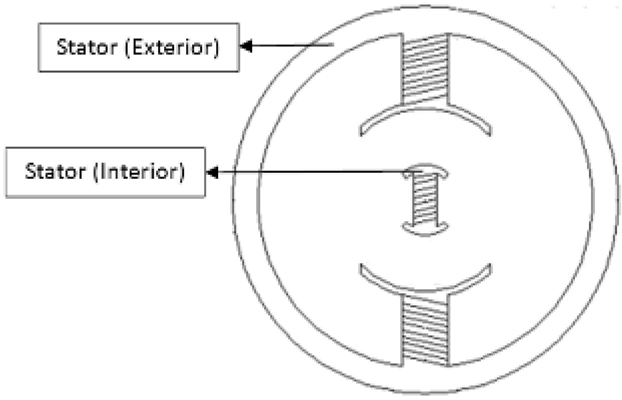
Diagram		
Material	Somaloy 700	
Properties	Composition	Iron powder particles (Ferum)
	Electrical resistivity	400µ Ωm
	Relative Permeability	700
	Density	7.5 g/cm³
Dimension	Diameter	Interior: 20 mm Exterior: 130 mm

Figure 9: Stator properties

3.2.4 Windings (Winding coil)

Winding coil is the conductor where the current flows. The current that flows can produce magnetic field around the conductor.

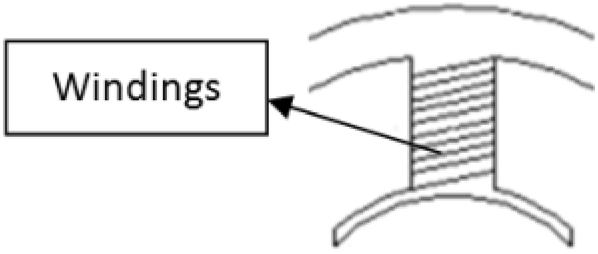
Diagram		
Material	Copper (cuprum)	
Properties	Electrical resistivity	16.8n Ωm
	Relative permeability	0.999 994
	Density	8.94 g/cm^3

Figure 10: Winding coil properties

3.2.5 Air

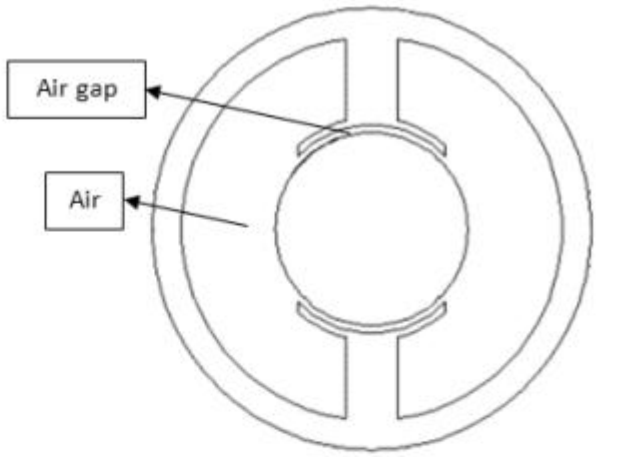
Diagram		
Material	Air	
Properties	Electrical resistivity	4×10^{13} Ωm (at sea level)
	Relative permeability	1.000 000 37
	Density	1.127 kg/m³ (40°C)

Figure 11: Air properties

3.3 Details of the procedures

Throughout this project, there are some procedures to be followed. This is to ensure that the project can be accomplished within the given time frame.

3.3.1 Data research and gathering

This is the literature review of the project. The study involves understanding the basic operation of electrical ceiling fan motor, identifying the types of permanent magnet motors and understanding the ‘Finite Element Analysis’ (FEA) software, ANSYS.

3.3.2 New design of electrical machine

The new topology of this electrical machine will consist of two stators and a rotor. By inventing a new topology of electrical machine for a household fan, the energy can be produced in order to be utilized to other load such as the domestic lighting system.

3.3.3 Development of 2-D model

After literature review is done, a 2-D model of the new design is then developed using ANSYS software. This method is called modeling.

3.3.4 Simulation with ANSYS

The 2-D model which has been developed using ANSYS then goes through the simulation process. The simulation of the 2-D model is used to observe the flux distribution.

3.4 Tools

3.4.1 ANSYS

ANSYS is the software used for constructing 2-D model of the new design. The 2-D model of the new design is used for simulation. From the simulation results, the flux distribution can be observed.

CHAPTER 4
RESULTS

From the studies conducted, a new design has been proposed as illustrated in Figure 12. This design has two stators and a rotor.

4.1 'Novel Design for Electrical Fan' using axial configuration

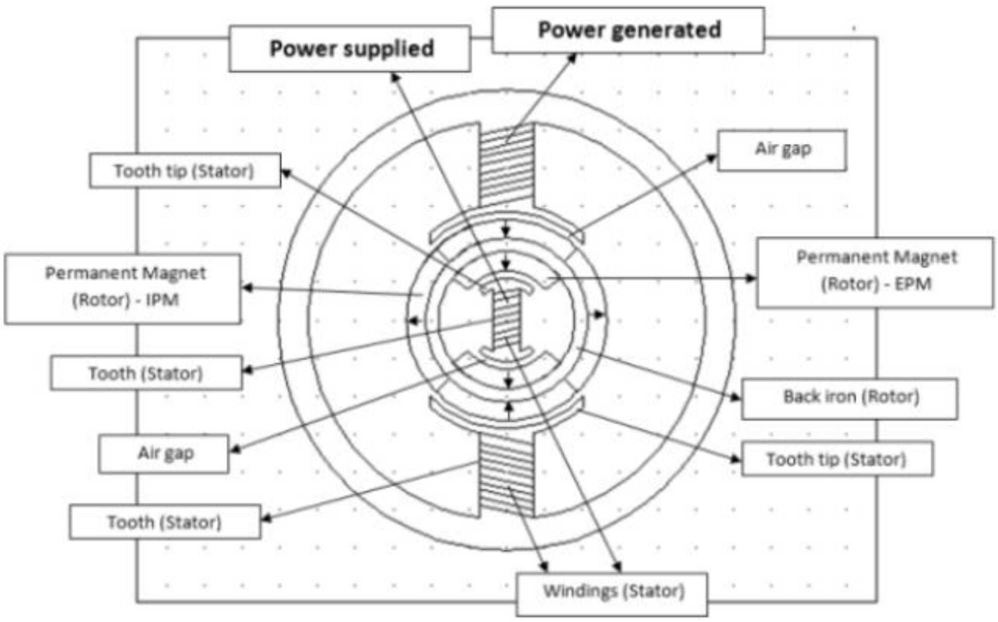


Figure 12: 'Novel Design for Electrical Fan' using axial configuration

The benefits of the proposed designs are:

1. This design uses permanent magnets (PMs) configuration. PMs in construction of electrical machines have many advantages as compared to

field excitation system. The advantages are higher efficiency, higher torque and/or output power per volume, better dynamic performance (higher magnetic flux density in the air gap) as well as simplification of construction and maintenance.

2. The proposed design has construction which consists of two stators and a rotor. This configuration theoretically enables the electrical machine to function as a motor as well as a generator.
3. The construction which consists of two stators and a rotor has a compact size.

4.2 Simulation of the new design with ANSYS

The 2-D model which has been developed using ANSYS then goes through the simulation process. The simulation of the 2-D model is used to observe the flux distribution.

4.2.1 Creating the geometry

The first step in the process of simulation with ANSYS is the creation of geometry model. The model is created directly with the ANSYS pre-processor. The model is design using keypoints. The keypoints are obtained through calculations. The model can also be created using CATIA or GAMBIT. The model that has been created can then be imported into ANSYS. However, it is better to use ANSYS pre-processor directly in creating the model so that the geometrical features would not be lost. Creating the model is the most tedious part in this project and it takes a long duration of time to be completed.

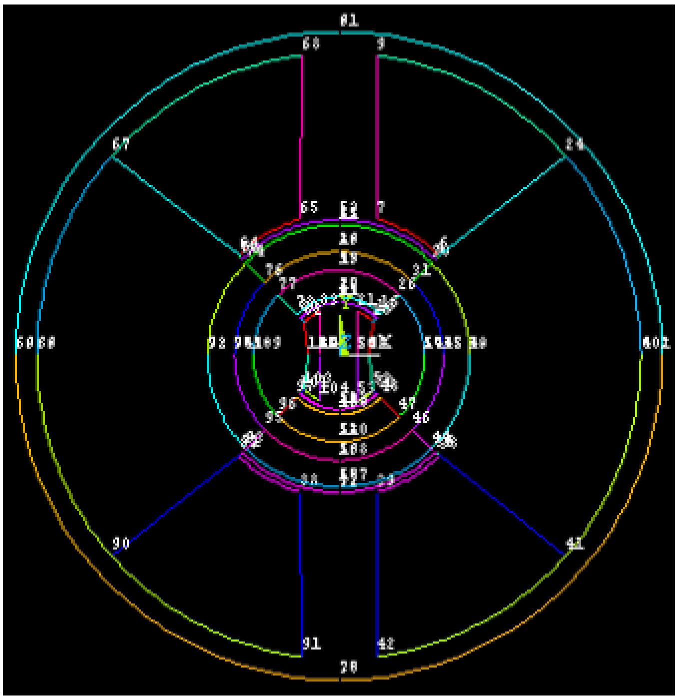


Figure 13: Keypoints and lines of the 2-D model

After creating the model using the keypoints, the next step is to create the area for each material. It is important that all the keypoints are linked together and that there is no stray keypoint in the model. Any stray keypoint will result error and the area will not be created.

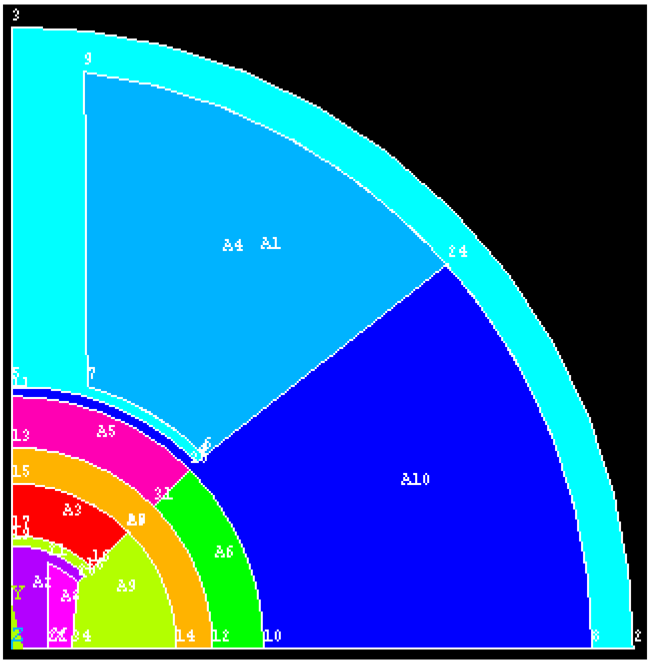


Figure 14: Areas of the 2-D model created

4.2.2 Define materials

After all areas are successfully created, the next step is to define materials. To define materials, there are two (2) steps identified. The steps are:

1. Set preferences

2. Specify material properties

After creating the areas, it is important to set preferences. In this design, ‘Magnetic Nodal’ is chosen at ‘Preferences’. After choosing ‘Magnetic Nodal’ at ‘Preferences’, the next step is to specify the material properties. It is important to specify the material properties for the magnetic permeability of air, back-iron, permanent magnet, winding coil and stator. For simplicity, all material properties are assumed to be linear.

4.2.3 Generate Mesh

After all the steps in 'Define Materials' are done, this means that the design is ready to be meshed. There are three (3) steps in order to generate mesh. The steps are:

1. Define element types and options
2. Assign material properties
3. Mesh the model using MeshTool
4. Scale model to meters for solution

After creating the material properties, it is important to define element types and specify options associated with these element types. For this model, the element type PLANE53 (2-D 8-Node Magnetic Solid Elements) is chosen. PLANE53 is an element for 2-D (planar and axis-symmetric) magnetic analysis. This element is defined by eight nodes with up to four (4) degrees of freedom per node and has nonlinear magnetic capability for modeling B-H curves or permanent magnet demagnetization curves. Figure 15 shows the diagram of PLANE53 element.

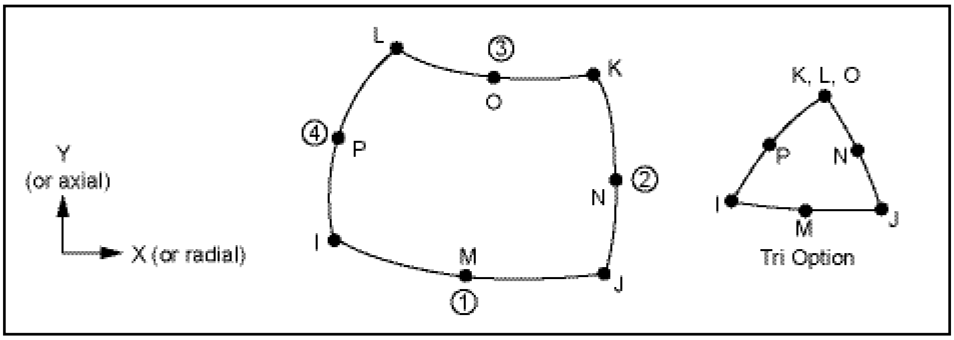


Figure 15: PLANE53 Geometry

After choosing PLANE53 in defining element types and specifying options associated with these element types, the next step is to assign material properties.

The material properties should be assigned to air, permanent magnets, winding coils, stators and back-iron areas.

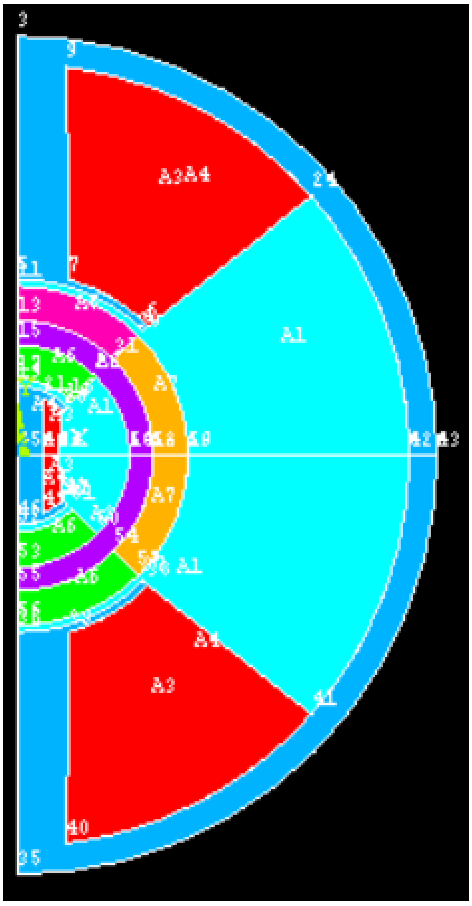


Figure 16: Areas with assigned materials

After assigning the material properties, the model is then meshed.

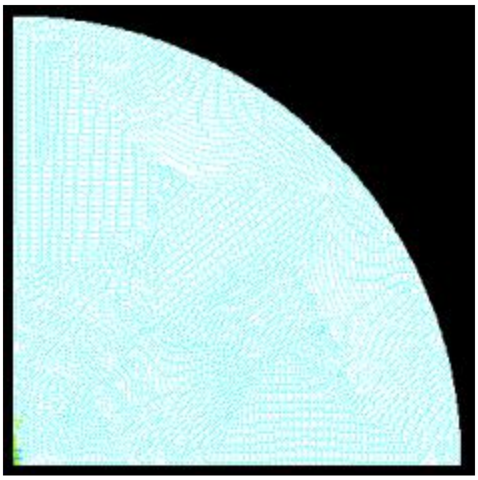


Figure 17: Meshed areas

For a magnetic analysis, a consistent set of units must be used. In this model, MKS units are used. Therefore, the model is scaled from millimeters to meters.

4.2.4 Apply Loads

After all areas are meshed, the steps in ‘Apply Loads’ can be proceed. The steps in applying loads are:

1. Apply the current density
2. Obtain a flux parallel field solution

The current density is defined as the number of coil windings times the current, divided by the coil area. The areas picked for this method are the winding coils at the stators. After this step, a perimeter boundary condition is applied in order to obtain a ‘flux parallel’ field solution. This boundary condition assumes that the flux does not leak out to the outside of the model’s perimeter.

4.2.5 Obtain Solution

After applying the current density and applying a perimeter boundary condition, the next step is to solve the meshed model. At the ‘Main Menu’, choose ‘Solution> Solve> Electromagnet> Static Analysis> Opt & Solve.

4.2.6 Review Results

After ANSYS finished with the calculations, an information window informing that the solution is done will popped up. This means that the results can be viewed. Close the window. To review the results, go to Main Menu> General Postproc> Plot Results> Contour Plot> 2D Flux Lines. From this step, the flux distribution can be observed.

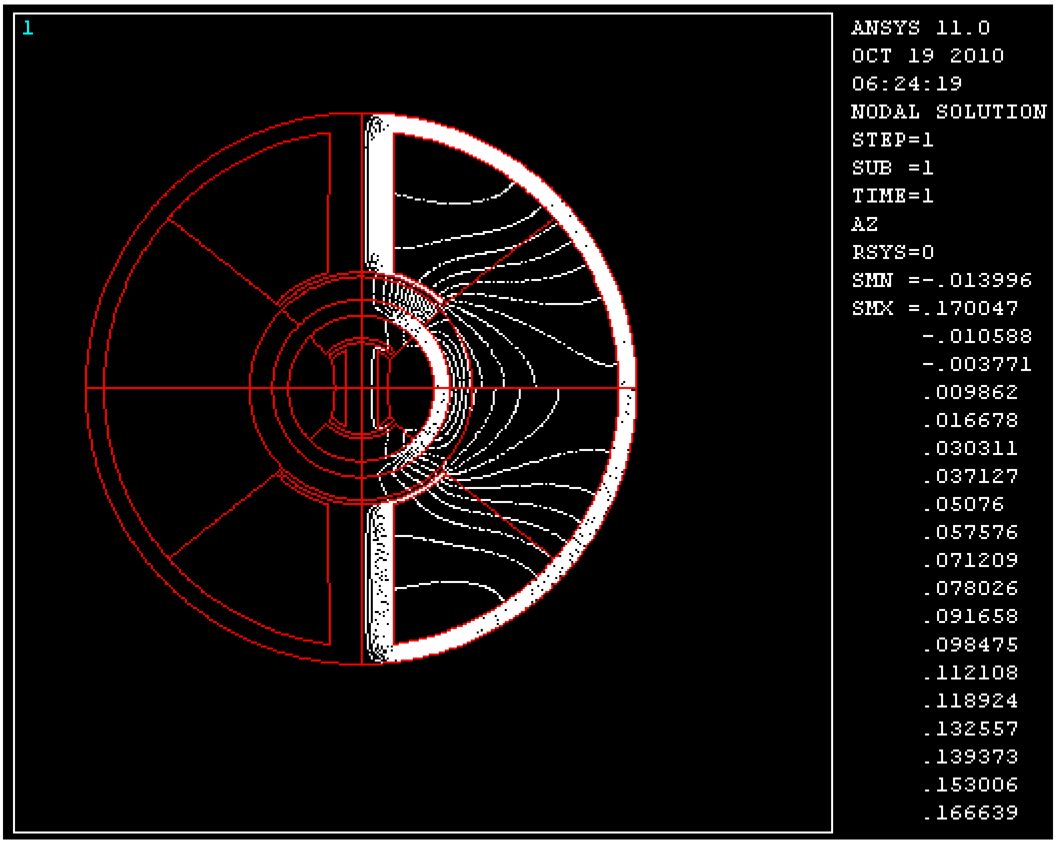


Figure 18: Simulation of flux distribution

CHAPTER 5
CONCLUSION

5.1 Conclusion

Literature review on various types of permanent magnets motor has been conducted such as the constructions of interior permanent magnets motor (IPM) and exterior permanent magnets motor (EPM). The permanent magnets configuration, axial configuration is also studied. After the literature review is done, a proposed design is identified. This design uses permanent magnets. After the design has been identified, the design goes through a low-frequency electromagnetic analysis. The electromagnetic analysis is carried out using ANSYS. This analysis has determined the flux distribution around the electrical machine design.

5.2 Recommendations

Some recommendations are suggested for future work:

- Deep understanding in modeling and analysis in order to create a better design of the new electrical machine.

- After obtaining correct results of flux distribution and back electromotive force (emf), optimization method can be done.

REFERENCES

[1] Cuauhtemoc Medina (07/2008), “Ceiling Fan Speed Control: Single-Phase Motor Speed Control Using MC9RS08KA2”, Freescale Semiconductor, Inc., 2008.

[2] Jacek F.Gieras, Mitchell Wing (2002), “Permanent Magnet Motor Technology: Design and Applications”, 2nd ed., Marcel Dekker, New York.

[3] Thomas Reichert, Thomas Nussbaumer, Johann W.Kolar, “Torque Scaling Laws for Interior and Exterior Rotor Permanent Magnet Machines”, technical report, Zurich.

[4] M.A Jabbar, A.M Khambadkone and Liu Qinghua, “Design and analysis of exterior and interior type high-speed permanent magnet motors”, technical report, National University of Singapore.

[5] Brushless permanent magnet motor with variable axial rotor/stator alignment to increase speed capability, May 3, 2010, http://www.freepatentsonline.com/6492753.html.

[6] Finite Element Analysis (FEA), May 3, 2010, http://www.siliconfareast.com/fea.htm.

[7] ANSYS, May 3, 2010, http://en.wikipedia.org/wiki/Ansys

[8] Cheng-Tsung Liu, Jyn-Wei Chen, Kun-Shian Su, “Characteristics of a Disc Permanent Magnet Linear Synchronous Machine with Back Iron”, technical report, IEEE Transactions on Magnetics.

[9] Prantosh Chakraborty (2005), “Electricity and Magnetism”, 2nd Ed., New Age International (P) Limited.