REGENERATIVE BRAKING CONCEPT IN CEILING FAN

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

____

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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.

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Muhammad Waffiudin Bin Ab Aziz

ABSTRACT

This project investigates the characteristics of regenerative braking concept as well as study on the ceiling fan motor. With the objectives of carrying a research on regenerative braking for ceiling fan, it is important to understand the theory of regenerative braking first. The process of regeneration is entirely automatic and occurs when the motor over-runs or the demand speed is reduced, so that the motor's back EMF is greater than the output voltage from the controller. Based on this concept, it can be applied to ceiling fan since the ceiling fan is not fully utilized. Thus by designing, fabricating and testing a control circuit of regenerative braking, it can used to fully utilize ceiling fan. The methodology used to achieve its objectives is by research, proposal of new concept and several testing on the ceiling fan. First is testing on existing configuration of motor. Then it is followed by additional switch to determine the excessive current while turning off the motor and last one is testing on new control circuit in order to achieve the objectives of this project

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Ceiling fan is different from other types of fan in term of its functions. Others fan such as wall fan aims to produce a local wind meanwhile ceiling fan aims only to circulate air in room. Based on its name, it is installed on the ceiling in order to ventilate air in particular room. It employs hub-mounted rotating paddles to circulate air in order to produce a cooling or desertification effect [1]. Ceiling fan has three main components namely motor, blades and lighting [2]. Most important component in ceiling fan is motor and this project will focus solely on the motor configuration which is DC motor. DC motor is chosen since it experienced regenerative braking concept during operation.

Meanwhile, regenerative braking is a concept that will be applied to this project in order to store the wasted electrical energy in batteries. This will be done by control circuit that compromises speed limit switch and battery charger circuit. Regenerative braking concept is not a new concept but the application is limited only on vehicle especially hybrid vehicles [4]. Actually regenerative braking concept is the idea of stopping or slowing a running machine by means of converting the kinetic energy to electricity and utilized the energy with higher efficiency [5]. Normally this concept is widely applied to electric car. The concept is when the electric motor of a hybrid car begins to reverse direction, it becomes an electric generator or dynamo and this generated electricity is fed into a chemical storage battery and used later to power the car at city speeds [6].

1.2 Problem Statement

Nowadays ceiling fan is considered a must-have appliance in houses all around the world. In Malaysia we can see that the usage of ceiling fan is very wide since Malaysia's climate are wet and dry alternately throughout the whole year. Unluckily the usage of ceiling fan in houses is not fully utilized. This means that the motor used to operate the fan is not been used to its full limit. In motor operations, there are accelerating and braking processes. When the motor is powered up by electrical energy, the fan will accelerate which means that the electrical energy is converted to mechanical energy. Meanwhile when we turn off or slowing the speed of the fan or braking, the mechanical energy when the fan is turning is converted into electrical energy. Unfortunately this electrical energy is left wasted without proper handling. One of the ways to tackle this situation is to have regenerative braking concept applied to the ceiling fan. Using this concept, the electrical energy will be stored in batteries therefore it can be used for other appliances usage. Thus the need of this study is to conduct a research, to do simulation and circuit fabrication of the regenerative braking concept to be applied to ceiling fan. Therefore it will fully utilize the usage of ceiling fan in house.

1.3 Objective

The objectives of this project are:

- To carry out research on regenerative braking for ceiling fan
- To utilize the regenerative braking concept on ceiling fan
- To design, fabricate and test a control circuit of regenerative braking in order to fully utilize ceiling fan

1.4 Scope of Study

The scope of study comprises the study on regenerative concept in general. The study is on basic understanding of regenerative braking concept including its theory and applications. Next scope is running a simulation test for DC motor in order to check whether the motor of the ceiling fan can be work out to obtain the energy as stated in regenerative braking concept. For this test, the ceiling fan will be modeled using MATLAB Simulink and graph of DC motor parameters will be obtained.

The scope of study for this project also comprises design part where a control circuit will be design and fabricate. This is important in order to achieve the objectives of this project. Next is to conduct experiments on the control circuit and the ceiling fan based on the concept applied. The experiment will involve hardware part where the results will be compared with the simulation results. Finally improvement will be carried out for optimization purpose.

CHAPTER 2

LITERATURE REVIEW

2.1 Regenerative Braking Concept

Regenerative braking concept is fully applied to this project. According to study by Richard Torrens (1997) where his research was put in the internet, the process of regeneration is entirely automatic and occurs when the motor over-runs or the demand speed is reduced, so that the motor's back EMF is greater than the output voltage from the controller. When it happens, the motor will produce waste kinetic energy which is not used anymore but by means of charging circuit, this waste energy will be storing in batteries. In simple words, normally, the controller is supplying a voltage to the motor to drive it, but for regenerative concept the motor is generating a back EMF and stored in batteries. This back EMF is proportional to its speed, which mostly cancels out the drive voltage. Based on study by Richard Torrens (1997) also, when the motor goes faster, it’s back EMF rises and the current caused by the difference between the controller's output voltage and the motor's back EMF will falls. As the motor rotates fast enough, the motor current will falls to zero. Then back EMF is equals the controller's output. Later when the motor rotates even faster, the current goes negative and feeding back into the controller. With this, back EMF is now greater than the controller's output voltage. When the controllers accept this current and being fed back into it, regenerative braking will starts to occur.

Regenerative braking takes energy normally wasted during braking and turns it into usable energy. It is not, however, a perpetual motion machine. Energy is still lost through friction with the road surface and other drains on the system. The energy collected during braking does not restore all the energy lost during driving. It does improve energy efficiency and assist the main alternator. Adjusting the acceleration; power to the motor by advancing the speed control, we can adjust the braking; power from the motor by reducing the speed.

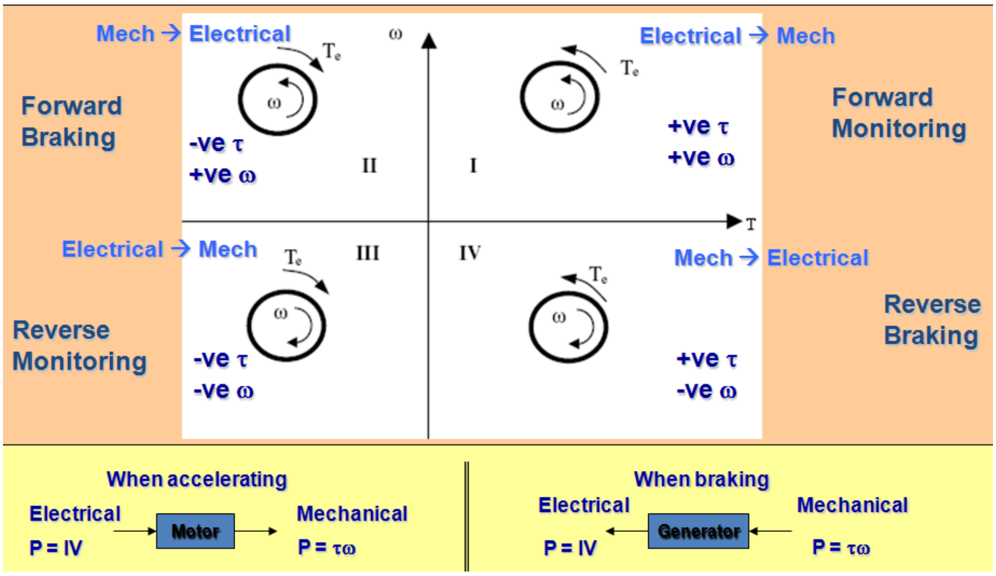


Figure 1: Regenerative Braking Concept

2.2 DC Motor

For this project, DC motor ceiling fan is used since it experienced regenerative braking concept. DC motor basically is a simple electric motor that uses electricity and a magnetic field to create torque where torque produced will be used to turn the motor. This torque actually produced from the repellent and attractive electromagnetic forces of two magnets with opposite polarity and an electric coil, which acts as an electromagnet [7]. A DC motor needs at least one electromagnet to operate. This electromagnet switches the current flow as the motor turns, changing its polarity to keep the motor running meanwhile the other magnet can be a permanent magnets. However there are two conditions necessary to produce a force on a conductor to create an electromagnet. The first one is the conductor must be carrying current and the conductor must be within a magnetic field [8]. Once this conditions is satisfied, there will be at least one electromagnet and DC motor can be modeled.

Fundamentally DC motor has six basic parts namely axle, rotor or armature, stator, commutator, field magnet and brushes [9]. Every part of the motor carries different functions. Two basic components are stator and rotor. The stationary part of the motor is called stator while the rotational part is called rotor. The rotor rotates with respect to the stator. It consists of windings where the windings being electrically connected to the commutator. These windings play the part of electromagnet in DC motor concept. Furthermore, the commutator segments are used as a contact point between the stationary brushes and the rotating armature [10]. As the power is applied, the polarities of the energized winding and the stator magnet are misaligned, and the rotor will rotate until it is almost aligned with the stator's field magnets [9].

There are various type of DC motor, each with different characteristics and features. Mainly there are three main types of DC motor which are Stepper DC Motors, Brushless DC Motors and Brushed DC Motors [11]. Stepper DC Motors are brushless, synchronous electric motors which depend on electromagnets to turn the internal shaft. It has an iron toothed cog connected around the internal rotating shaft. In addition, four toothed electromagnets are positioned at equal intervals around the cog. Second type is Brushless DC Motors. Since it eliminates the brushes, it increases their life span, survival without maintenances, power output and efficiency of the motor. Their essential working concept is to aid an outside commutator, which will reverse the direction of the current depending on the position of the rotor. The efficiency of a brushless motor is typically between 85 and 90 percent compared to a brushed motor's efficiency where it is usually about 75 to 80 percent [11]. Lastly is the Brushed DC Motors. Brushed DC Motors are the classic DC motors, which include a split ring commutator. It can be powered by any kind of DC battery. This motor is not so efficient due to friction where brushes will always be in contact with the commutator ring. Thus it is often considered to be limited, due to the friction reason. Brushes also scrape the ring, which will lead to replacement of the brushes and ring. However, there are advantages of Brushed DC motors compared to other types of motor. The initial cost for this motor is very low and that they have a very simple speed control system [11].

Basically there are three modes of motors application of operations. There are starting, speed control and lastly braking [12]. These three modes carry different function of operation depends on user needs. In order to operate a motor in operating speed, the motor need to increase it speed from zero to operating speed. This is called starting the motor. However, when the speed increases, it must comply with the requirements of the load. Thus users need to define a suitable speed and vary it in accordance to load requirements. This is called speed control. Finally, the motor need to stop when not in use thus is decelerating. This is called braking. In this project, braking applications is the main focus where a thorough research is done on this application.

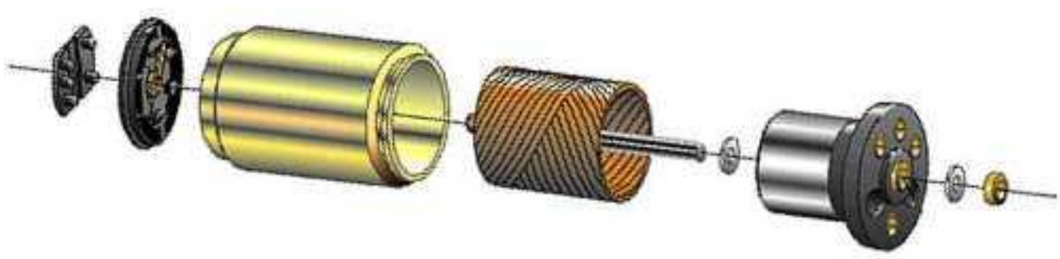


Figure 2: DC motor components

2.3 Thyristor DC Motor Drive

Complete system of regenerative braking concept is including a power electronic circuit. For this project, thyristor DC motor drive is used. Thyristor basically is a component which acts almost the same as a transistor. It is used to control the application of electrical power to a load. The construction is comprised of multiple layers of P-type semiconductor material and N-type semiconductor material. There are various types of thyristors for example triacs, silicon controlled rectifiers (SCRs), sidacs, and diacs. It is used as a switching technique for large capacity power such as motor control systems, high-voltage DC transmission, uninterrupted power supplies, induction heating, and others [13]. It permits large currents to be switched at high voltages where a small gate current pulse is injected. It operates when current pulse flows into the Gate (G), thus let a larger current to flow from the Anode (A) to the Cathode (C). The current flows to the gate act as a triggering pulse to the circuit. This means that even when the current into the gate stops, the thyristor continues to allow current to flow from anode to cathode. [14]

However, for this project, four thyristors are used. These thyristor are connected as a single phase bridge converter where it functions as a rectifier, which converts the incoming AC supply to produce a DC supply to the motor armature. With thyristor, the speed of the motor can be controlled by altering the firing angle of the thyristors. Thus the mean value of the rectified voltage can be varied, so allowing the motor speed to be controlled [15]. With this characteristic, it suits well with the function of the ceiling fan. In addition, four quadrant operations can be simulated with thyristor as the power electronic circuit.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

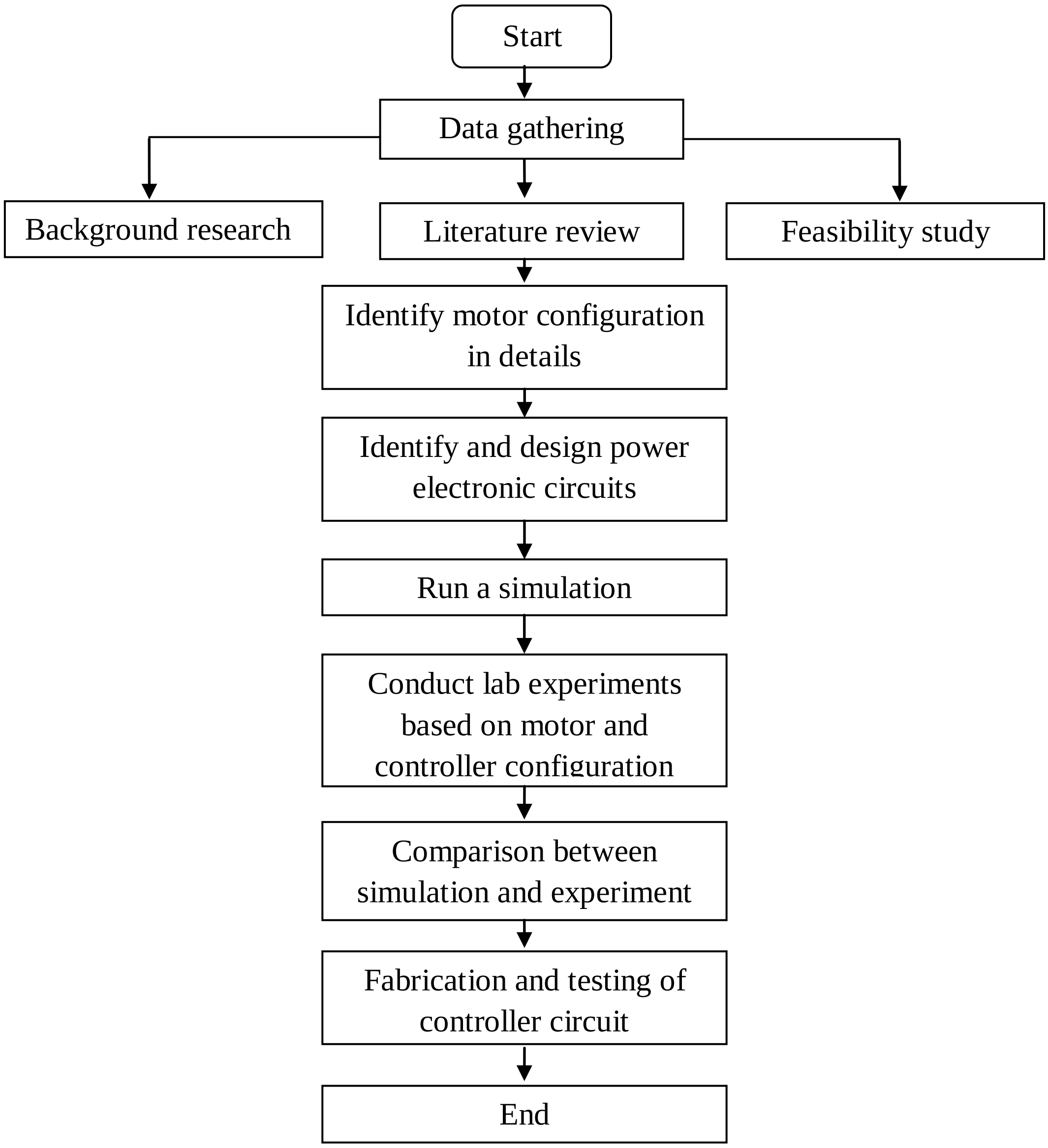


Figure 3: Flow chart of the project

3.2 Details of the procedure

3.2.1 Data gathering

Data gathering involved research on regenerative braking and AC induction motor, literature review of these two topics and feasibility of the project. It is done in order to understand in depth the project's concept topology, configuration and other important information.

3.2.2 Identify motor configuration

Since this project is using DC motor of a ceiling fan, the configuration of the motor such as voltage, current, power, speed and other parameters need to be identified before proceeding with the next stage of project.

Table 1: Motor characteristic

Voltage	24 V
Rating Speed	185 rpm
Rating Power	39 W
Rating Current	1.65 A

3.2.3 *Power electronic circuits*

Thyristor Converter-Based DC Motor Drive is used in this part. The setup can simulate the operation of the four quadrant operation. Operation in quadrants II and IV corresponds to forward and reverse braking, respectively.

3.2.4 *Run a simulation*

The simulation will use MATLAB Simulink since it has the DC Drive Library Configuration. In addition, the software has the setup of Thyristor Converter-Based DC Motor Drive. However, the simulation cannot be done exactly the same as experimental work since few parameters in MATLAB Simulink is fixed

Table 2: Specifications of DC motor

Specifications	Value
• Rating Power	• 5 hp
• Nominal Speed	• 1500 rpm
• Voltage	• 240 V
• Armature resistance	• 0.78 Ω
• Armature inductance	• 0.016 H
• Field resistance	• 150 Ω
• Field inductance	• 112.5 H
• Power Supply	• 240 V 50 Hz

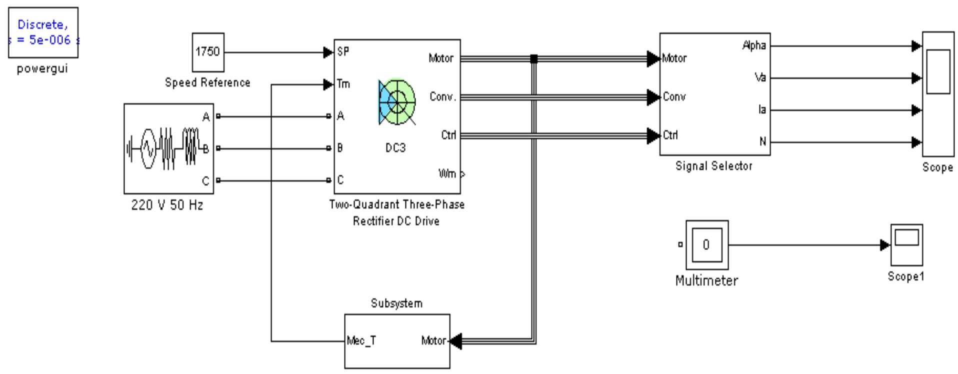


Figure 4: Simulation setup in MATLAB Simulink

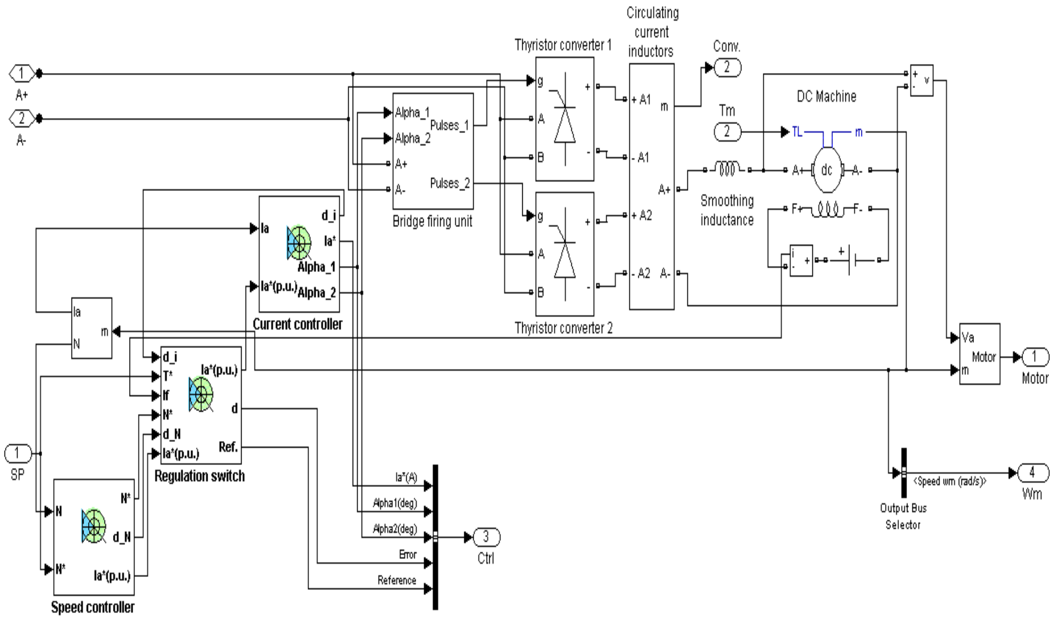


Figure 5: Subsystem of Simulink Setup

The machine is separately excited with a steady DC field voltage source. From the schematic, it is observed that the circulating current formed by the instantaneous voltage difference at the terminal of both converters is restricted by inductors connected between these terminals. Furthermore, armature current oscillations are reduced by a smoothing inductance connected in series with the armature circuit. Meanwhile, the converter outputs a continuous voltage value which is equal to the average-value of the rectified voltage. The input currents have the frequency and amplitude of the primary current component of the input currents. Simulation results have been obtained with a 4 µs time step, as shown in Result and Discussion chapter.

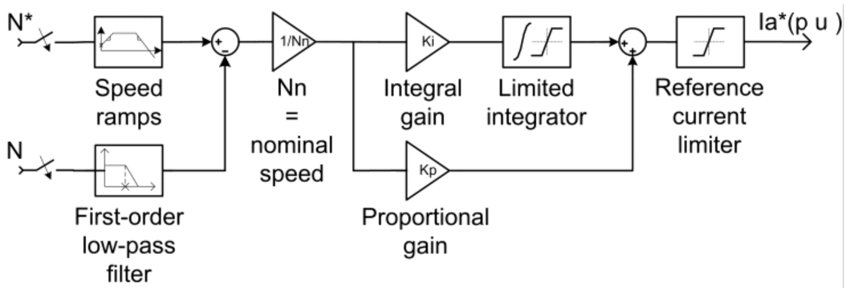


Figure 6: Speed Controller

PI controller embedded in the system is used as speed regulator in the above diagram. Thus the electromagnetic torque needed to reach the desired speed used current controller in order to obtain the speed where the current controller is derived from the controller outputs. Later the controller takes the speed reference and the rotor speed of the DC machine as inputs. However, the speed reference will follow user-defined acceleration and deceleration ramps in order to avoid sudden reference changes. This is due to the fact that armature over-current may occur from the changes and destabilize the system.

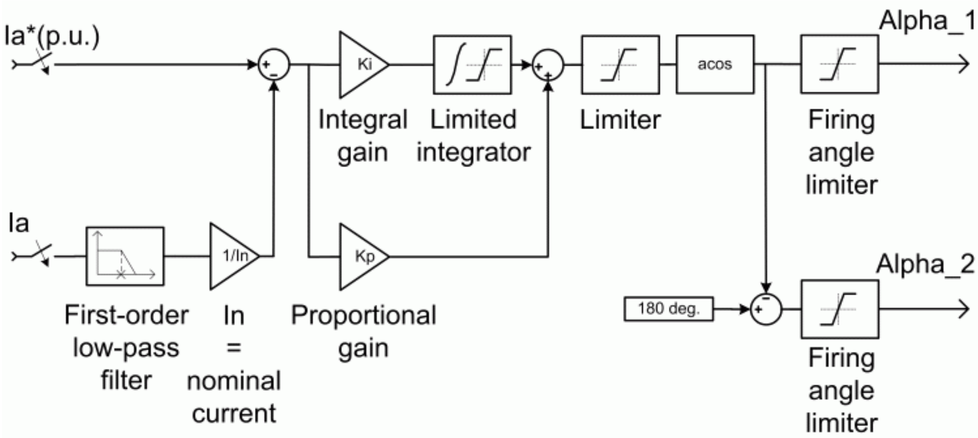


Figure 7: Current controller

Next is current controller where the armature current regulator is based on a second PI controller build in the system. Armature current is controlled by a regulator where it calculate the appropriate thyristor firing angles then generates the converter output voltages needed to acquire the desired armature current. In addition, the controller takes the current reference and the armature current flowing through the motor as inputs of its system. This work is done by the regulation switch block in the subsystem. From the calculation, the firing angle can vary between 0 and 90 degrees. This variation is due to the circuit which is single phase circuit. Then it creates opposed average voltages at the converter DC output terminals and thus equal average voltages at the DC motor armature.

3.2.5 Lab experiments

The experiments involve a power electronic called thyristors and a motor. Three experiments will be carried out on order to identify the motor operations. First is to measure circulating current in a four quadrant converter. Second is to verify and observe the operation of the circuit in each quadrant and the last one is to verify and observe four quadrant operation by using the circuit to drive a DC motor and generator. Listed are the equipments used in the lab experiments.

- Mobile Workstation
    1. Power Supply
    2. DC Motor/Generator
    3. Smoothing Inductor
    4. Power Thyristor
    5. DC Voltmeter and Ammeter
    6. Wires/Connectors
    7. Tandem Rheostat
- EMS Data Acquisition and Management LVDAM-EMS
- Step Down Transformers

3.2.6 Comparison

Next comparison is done between the experiments and the simulation results. With this comparison, one can identify and observed the operations of DC motor ceiling fan in four quadrant operations.

3.2.7 Fabrication and testing of controller circuit

Final stage is on fabricating the new control circuit. New control circuit comprises the switching and storing devices. This stage take a lot of time since several testing to ensure the new circuit can work properly is carefully done. Based on Design Concept chapter, a charging circuit is needed in order to charge the battery. Two circuits are needed, the first circuit is step down converter and the second circuit is voltage regulator.

3.2.7.1 Step down Converter

Regenerative breaking from motor produce high values of voltage and it is not suitable to charge a battery. Thus step down transformers are needed to lower down the values before being feed to voltage regulator. Step down transformer is designed to reduce electrical voltage where primary voltage is greater than secondary voltage. It converts electrical voltage from one level usually down to a lower level. In addition, step down transformers typically rely on the principle of magnetic induction between coils to convert voltage levels [16].

3.2.7.2 Voltage Regulator

Voltage regulators are components that retain a constant voltage output. For a battery that need to charge, it need a constant voltage input. Thus using voltage regulators, it is responsible for maintaining a voltage within the range that the battery can safely accept [17]. In addition, voltage regulator maintains the voltage of a power source within acceptable limits [18]. Thus it is suitable for a battery to have a voltage regulator for constant charging during braking.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Design Concept

Main concern of this project is the single phase motor where the speed variation of the motor is the essential parameter. According to study by Richard Torrens (1996), there are many motor that can apply regenerative braking concept and it includes DC motor. Basically a motor can be applied the regenerative braking concept if the motor maintain a magnetic field as the armature current passes through zero. Then, as the armature back emf decreases below the applied drive voltage, the armature current will reverse.

For this project, the author is comparing the concept in the hybrid car with the concept that may be applied to ceiling fan. Since the motor used by the ceiling fan can experience regenerative braking concept, the author can focused on the whole project construction. For a hybrid car, it has an engine that powered up the motor. Then it has clutch to control the motor, whether to engage or disengage the motor. For a car, regenerative braking occurs when the throttle is at idle, while coasting, or while pressing the service brake. At this time, the motor/generator will switch to generator mode to charge the hybrid battery system. Based on this equipment, the same concept can be applied to ceiling fan. The construction of this project may differ from the hybrid car but the function is still the same.

Comparison between regenerative braking concept in hybrid car and ceiling fan

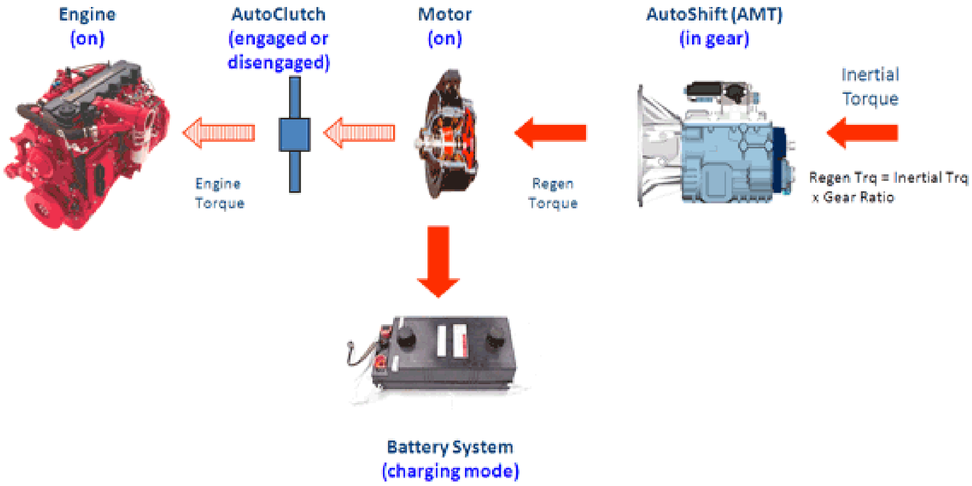


Figure 8: Regenerative Braking concept in hybrid car

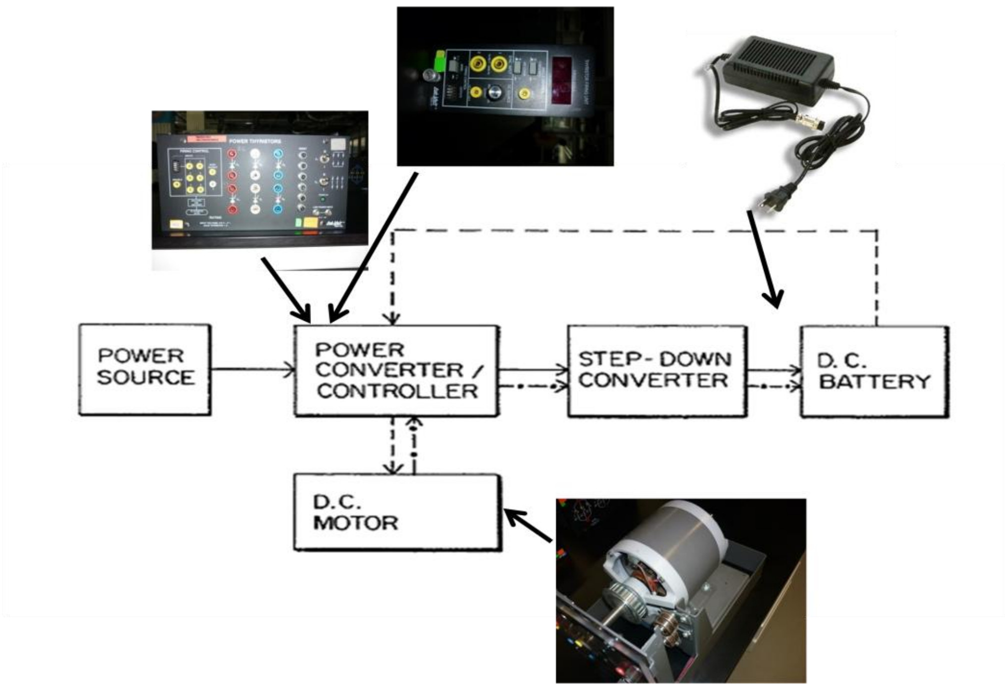


Figure 9: Regenerative braking concept in ceiling fan

4.2 Simulation of DC Motor Drive

For simulation, setup which is similar to experimental works was chosen. The setup is Thyristor Converter-Based DC Motor Drive. This setup can simulate the operation of the four quadrant operation. Operation in quadrants I and II corresponds to forward and reverse braking, respectively. However, the simulation cannot be done exactly the same as experimental work since few parameters in MATLAB Simulink is fixed.

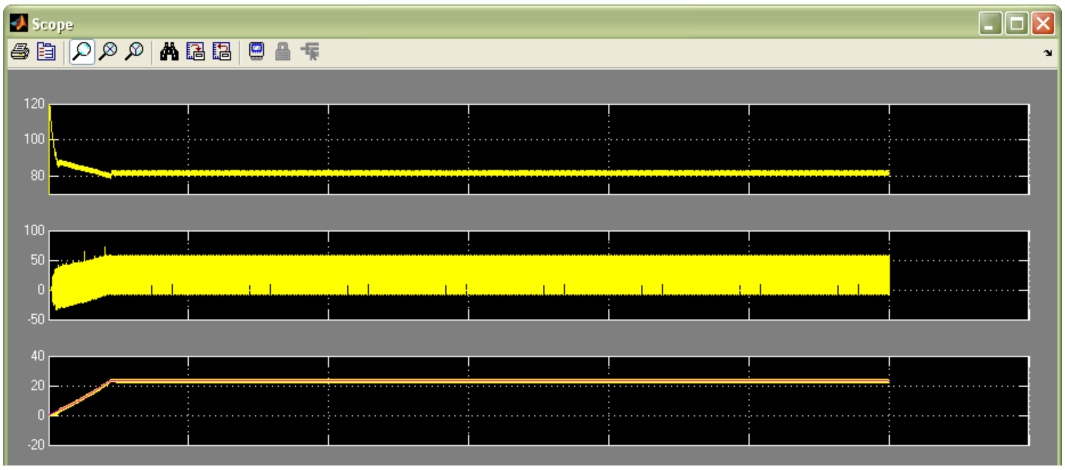


Figure 10: Results of Simulation

Due to parameter differences in simulation and experimental works, the result for this simulation is observed for its trend only. For Alpha or firing angle, as it decreases, the value of voltage increases. This is the same as we plotting the results of experimental works. The speed reached it nominal speed once the voltage start to increases. Although there are differences in value, the trend of simulation is the same as experimental work where this setup can simulate the operation of the four quadrant operation. Operation in quadrants II and IV corresponds to forward and reverse braking, respectively. For the DC models of the Electric Drives library, this braking is regenerative, meaning that the kinetic energy of the motor-load system is converted to electric energy and returned to the power source. This method allows inverting the motor current in order to create an electric torque opposite to the direction of motion. Thus it verified that regenerative braking concept can be obtained using thyristor controller circuit.

4.3 Lab Experiment

The experiment for this project is done based on a subject called Power Electronic. It involves a power electronic called thyristors and a motor. The operation of four quadrants can be demonstrated by playing around with the firing angle, α. For α less than 90’, it produced positive voltage which is motoring mode. Meanwhile for α more than 90’ but less than 180’, it produced negative voltage which is breaking mode. In order to demonstrate this condition, three experiments were carried out. These experiments carry different objectives for this project.

4.3.1 First Experiment - To measure circulating current in a four quadrant converter

Table 3: Result of Circulating current and voltage output

Firing angle, α	**Circulating current, mA**	**Output voltage, V**
15	68	250.5
30	257	223.5
45	381	181.8
60	543	128.8
75	471	64.8
90	432	-1.2
105	474	-68.86
120	522	-128.8
135	414	-167.22
150	241	-222.68
165	59	-248.82

4.3.2 *Second Experiment - To verify and observe the operation of the circuit in each quadrant*

Table 4: Result of respective current sign

	Sign			
	A	B	C	D
Current, I	+	-	+	-
Voltage, E	+	-	-	+
Power, P	+	+	-	-
QUADRANT	**1**	**3**	**4**	**2**

4.3.3 *Third Experiment - To verify and observe four quadrant operations by using the circuit to drive a DC motor and generator*

Table 5: Result of Experiment 3

Firing Angle	Power	Torque	Rotation	Operation	Quadrant	Speed
90 to 30	+	+	+	Motoring	1	1250 rpm
30 to 75	-	-	+	Generating	2	350 rpm
75 to 150	+	-	-	Motoring	3	-1250 rpm
150 to 105	-	+	-	Generating	4	-350 rpm

From the results, it is known that DC motor is naturally a bidirectional energy converter. Based on Experiment 1, by applying a positive voltage V, greater than E, current flows into the armature and the machine runs as a motor. Then if V is reduce to less than E, the current, torque and power automatically reverse direction, and the machine acts as a generator. Thus it is proven that from the experiment, DC motor is experiencing regenerative braking by using thyristor circuit. For normal motoring where the output voltage is positive, the firing angle α will be up to 90°. When α is greater than 90°, yet, the output voltage is negative, as shown by the results from Experiment 1.

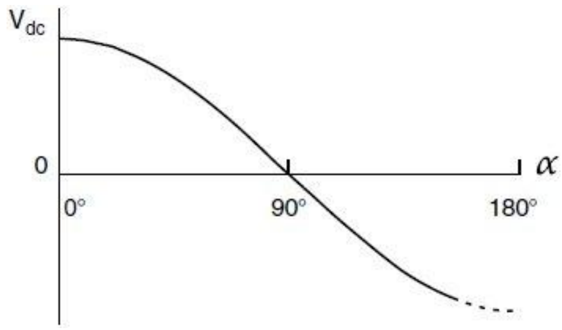


Figure 11: Average DC output voltage

Since DC motor ceiling fan need to operate in positive direction only, the firing angle α will be up only to 90°. As shown in Experiments 3, with rotation positive the motor can experience motoring and generating operation. However, due to the converter current is still positive, but the converter voltage is negative, and power is thus flowing back to the source. This situation is quadrant 2 operation and the motor are decelerating because of the negative torque. As the speed falls, E reduces, and so V must be reduced progressively to keep the current at full value. The current needs to be kept negative in order to run up to speed in the reverse direction. Thus thyristor is successfully conducting the motor to operate only in quadrant 1 and 2 only.

4.4 Discussion

From the simulation part, it is clear that with thyristor converter, DC motor can operates in motoring and generating modes. However, for DC motor of a ceiling fan, it is necessary only to operate in two quadrants since the rotation always positive. In addition, the result in simulation is not actually the same as in experiment since few parameters in simulation cannot be changed according to design of circuit. Therefore it is essential only to observe the trend of the graph to identify the projects results. From the simulation, it is clear that the data obtained can be used in further experiment.

Next is on the experiments part where three experiments were carried out. Power electronic used is thyristor converter circuit. It can deliver either positive or negative voltage. However it can only supply a positive current. For ceiling fan motor, it is sufficient to operate in quadrant I and II only for motoring and generating mode. In this case, the converter can be used so the motor can act as a generator. The electrical energy from the generator is feed to the charger circuit to charge the battery for other appliances used.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Regenerative braking is relatively a new concept in world of motor and generator. Most application of regenerative braking normally involved in hybrid transportation but for this project, it is applied on a ceiling fan. Literature review has been conducted for different type of motor such as DC motor, AC three phase motor, AC single phase induction motor and others. Specifically, literature review was focusing more on DC motor since ceiling fan is using that type of motor. In addition, testing of current motor of ceiling fan has been conducted. The testing involved solely on motor of the ceiling fan is done successfully. The result of the testing is very encouraging for completion of this project. With the results, a control circuit was designed and run perfectly. The control circuit which is Thyristor Converter DC Motor Drive can be used together with ceiling fan to illustrate the regenerative braking concept. With this, the project is done successfully.

5.2 Recommendations

With the current technology, motor drive more accurate by using microprocessor based DC motor drive. This is due to the fact that microprocessor-based control systems carry many significant advantages they compare to analog system. The advantages are such as easy hardware configuration, ease of shifting the control strategy and parameters, less effect from temperature variations and finally cheap in cost. Moreover microprocessors offer more flexibility and economy than the analog circuits; their relatively limited real-time capabilities restrict their functions to table lookups and simple arithmetic operations. As a result, controllers designed for microprocessor implementation is very efficient and reliable.

As for microprocessor based DC motor drive, it must have the functions of monitor and takes the reading of speed and current signals of the motor. The current signals and speed signals obtained from Tachometer is processed in the microprocessor. Later the processor and interfacing circuit interacts with the system. To perform several task. The tasks include selection and sampling of signals, mathematical computation to implement control, the necessary A/D or D/A conversion and others. This task is defined by the user using programmer languages such as C++. After being processed, the outputs of the micro-processor are fed into the firing circuitry where the circuitry generates gate drive signals and sends them to the motor for control purpose. Thus accurate control of motor can be obtained.

REFERENCES

[1] Ceiling fan. (n.d) in Wikipedia. Retrieved February 21, 2010, from http://en.wikipedia.org/wiki/Ceiling_fan

[2] Peterman, Terry. (2009, June 19). *How to Select a ceiling fan*. Retrieved March 15, 2010, from http://www.electrical-online.com/ceilingfanselection.htm

[3] Aire, Minka. (2007, April 19). *Ceiling fan rating system*. Retrieved March 15, 2010, from http://www.delmarfans.com/product_rating.cfm

[4] Pollick, Michael. (2009, March 16). *What is Regenerative braking?*. Retrieved February 4, 2010, from http://www.wisegeek.com/what-is-regenerative-braking.htm

[5] Vo*ltage rise due to regenerative braking of dc machines associated with gantry cranes at kaohsiung harbour*. (2006, June). Retrieved May 3, 2010 from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4520374

[6] *Transmissions articles: what is regenerative braking?*. (2009, April 26). Retrieved February 4, 2010, from http://www.blogcatalog.com/blog/transmission-repair-blog

[7] Petersen J.S, Foster, Niki. (2009, October 19). *What is a DC Motor?*. Retrieved February 9, 2010 from http://www.wisegeek.com/what-is-a-dc-motor.htm

[8] DC Motor Theory Summary. (n.d) Integrated Publishing. Retrieved February 9, 2010 from http://www.tpub.com/content/doe/h1011v2/css/h1011v2_111.htm

[9] Seale, Eric. (2003, July 10). *DC Motor, Principle of Operation* Retrieved February 9, 2010 from http://solarbotics.net/starting/200111_dcmotor/200111_dcmotor2.html

[10] *DC Motor Components* (2006, September 26). Retrieved February 9, 2010 from http://zone.ni.com/devzone/cda/ph/p/id/50

[11] *Types of Motor* (2009, April 1). Retrieved February 9, 2010 from http://www.dcmotorguide.com/1103/TypesofDCMotor.html

[12] *Electrical Machines I, DC Motor Configuration Lecture Notes*
Prof. Krishna Vasudevan, Prof. G. Sridhara Rao, Prof. P. Sasidhara Rao
Indian Institute of Technology Madras

[13] *Thyristor* (2007, April). Retrieved March 13, 2010 from http://www.electronics-manufacturers.com/products/electrical-electronic-components/thyristor/

[14] Ryan, V. (2002, October 19). *The Thyristor* Retrieved March 13, 2010 from http://www.technologystudent.com/elec1/thyris1.htm

[15] Hughes, Austin. (2008, October 21). *DC Motor Drive Basics – Part 1: Thyristor Drive Overview* Retrieved March 13, 2010 from http://www.eetimes.com/design/industrial-control/4014215/DC-Motor-Drive-Basics--Part-1-Thyristor-Drive-Overview?pageNumber=0

[16] *Step down Transformers* (2009, May). Retrieved March 13, 2010 from http://www.electricityforum.com/electrical-transformers/step-down-transformers.html

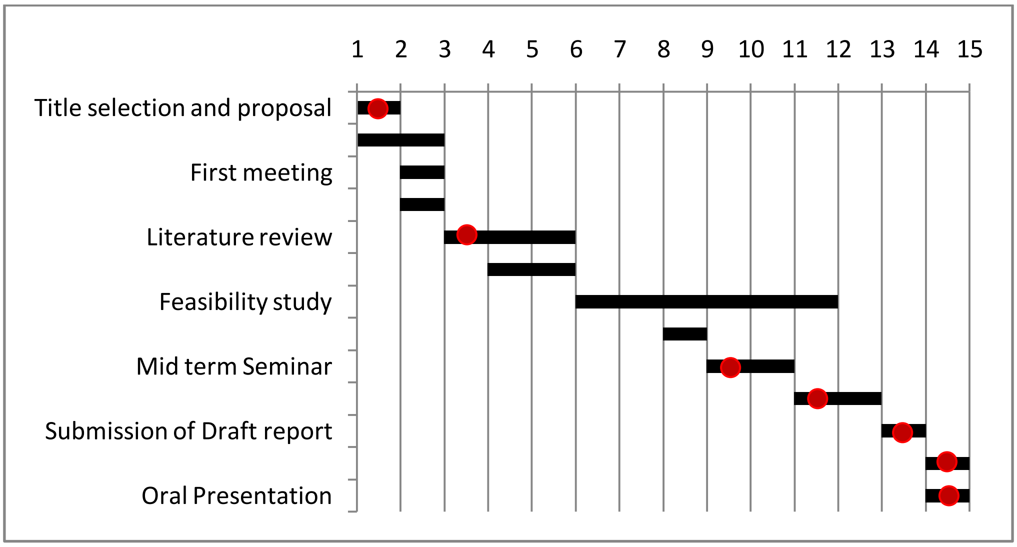
[17] Swan, Katherine. (2010, August 20). *What are voltage regulators?* Retrieved September 21, 2010 from http://www.wisegeek.com/what-are-voltage-regulators.htm

[18] *Voltage Regulator* (2006, June). Retrieved June 2010 from http://www.britannica.com/EBchecked/topic/632467/voltage-regulator

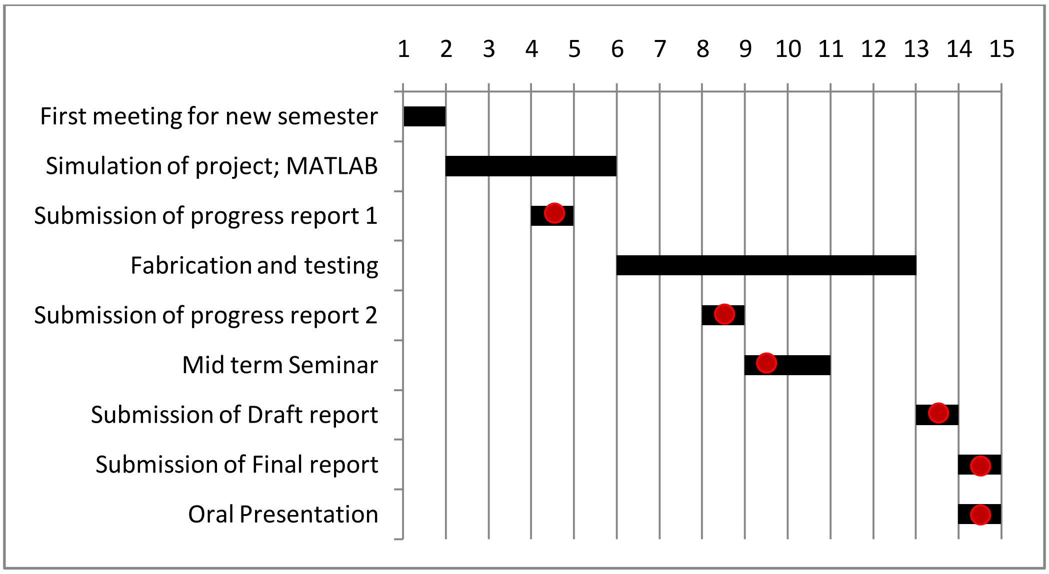
APPENDICES

APPENDIX A

GANTT CHART



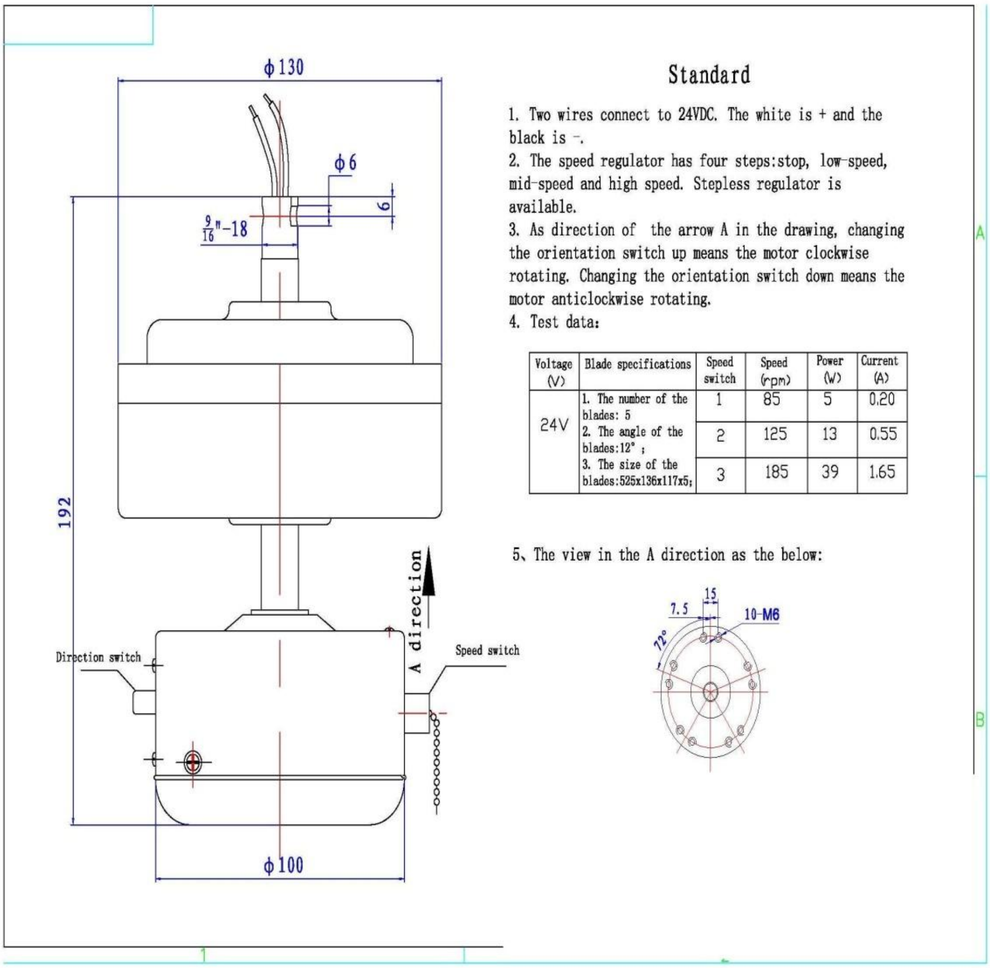
Final Year Project I



Final Year Project II

APPENDIX B

DC MOTOR CEILING FAN DATASHEET



Standard

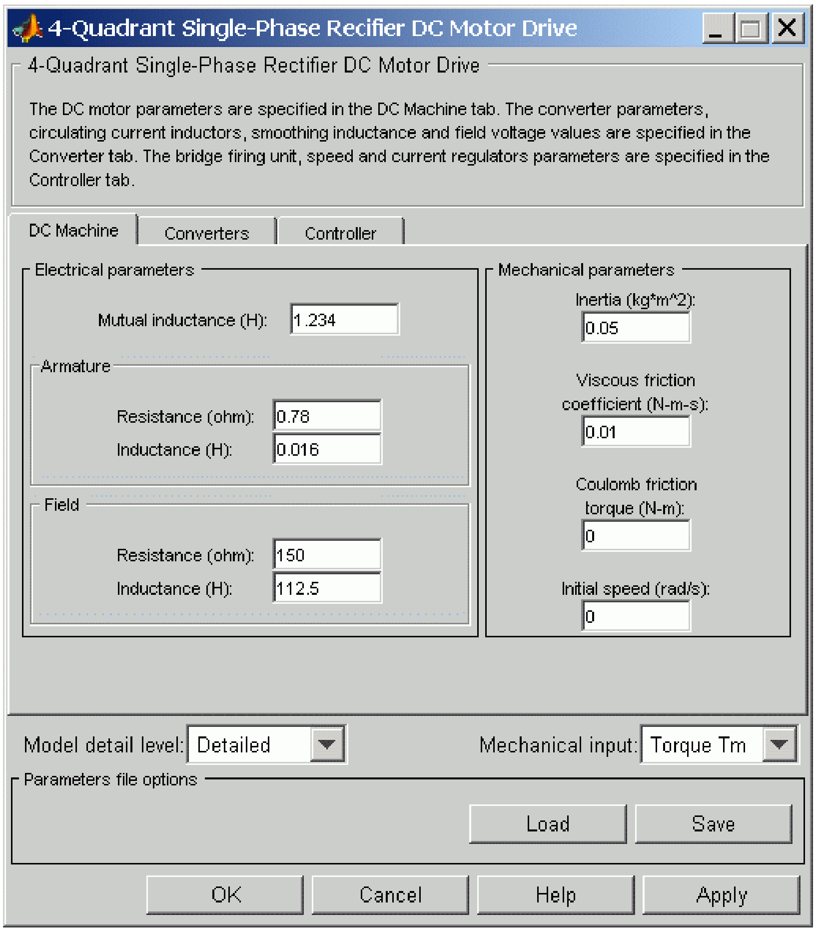
1. Two wires connect to 24VDC. The white is + and the black is -.
2. The speed regulator has four steps:stop, low-speed, mid-speed and high speed. Stepless regulator is available.
3. As direction of the arrow A in the drawing, changing the orientation switch up means the motor clockwise rotating. Changing the orientation switch down means the motor anticlockwise rotating.
4. Test data:

Voltage (V)	Blade specifications	Speed switch	Speed (rpm)	Power (W)	Current (A)
24V	1. The number of the blades: 5	1	85	5	0.20
	2. The angle of the blades:12° ;	2	125	13	0.55
	3. The size of the blades:525x136x117x5;	3	185	39	1.65

5、The view in the A direction as the below:

APPENDIX C

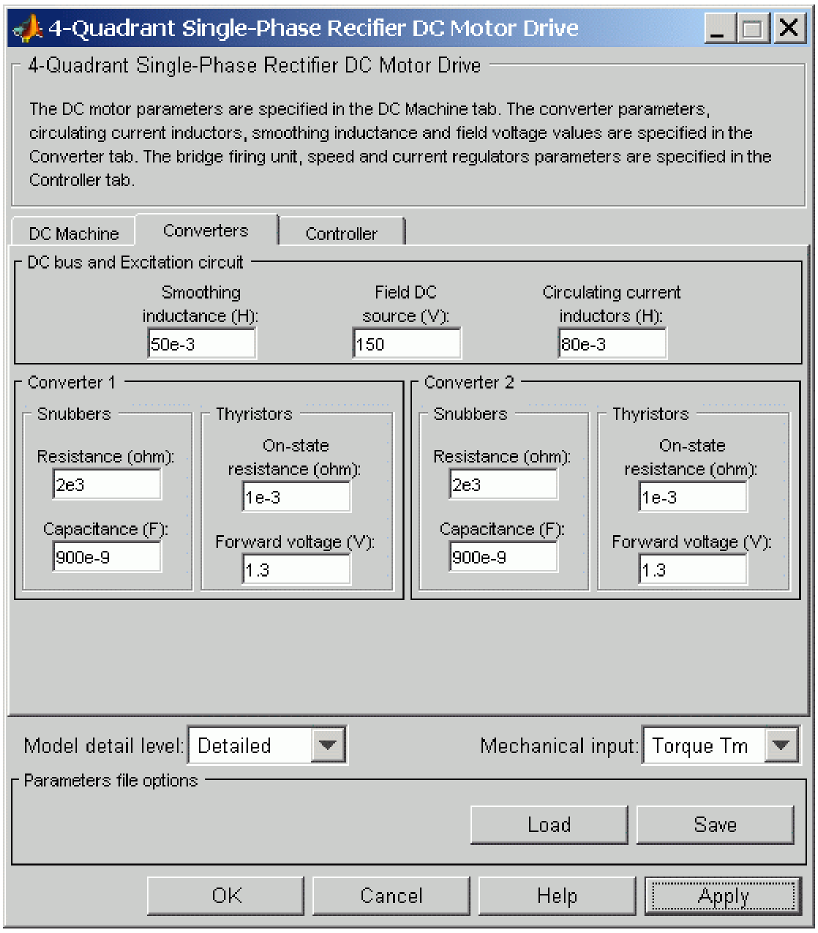
MATLAB SIMULINK DIALOG BOX A



DC Machine Tab

APPENDIX D

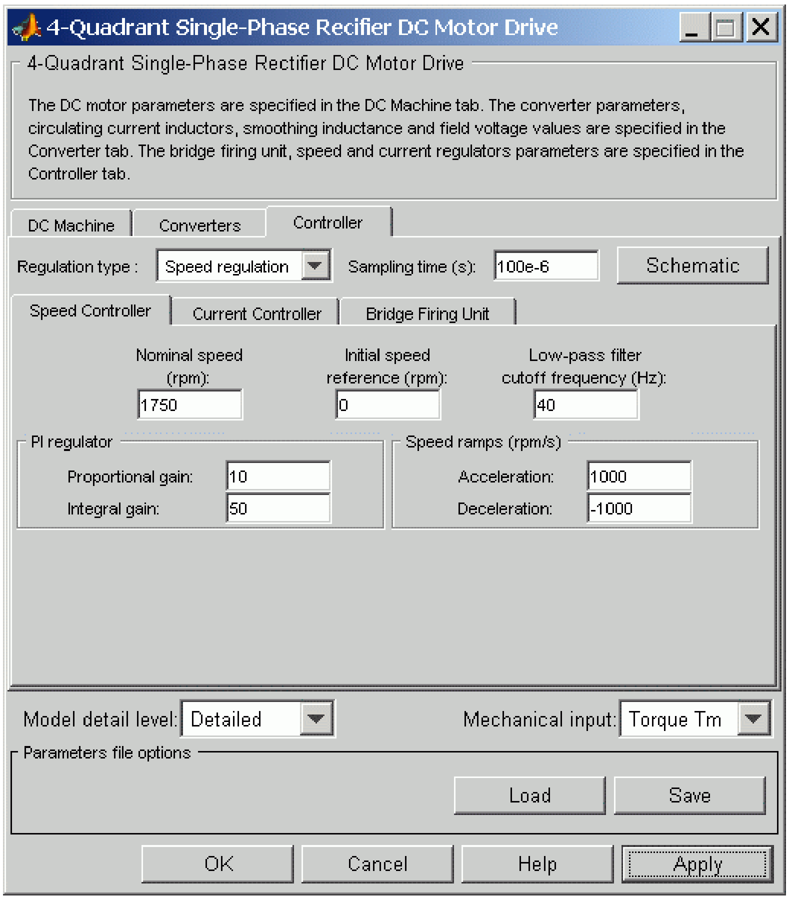
MATLAB SIMULINK DIALOG BOX B



Converter Tab

APPENDIX E

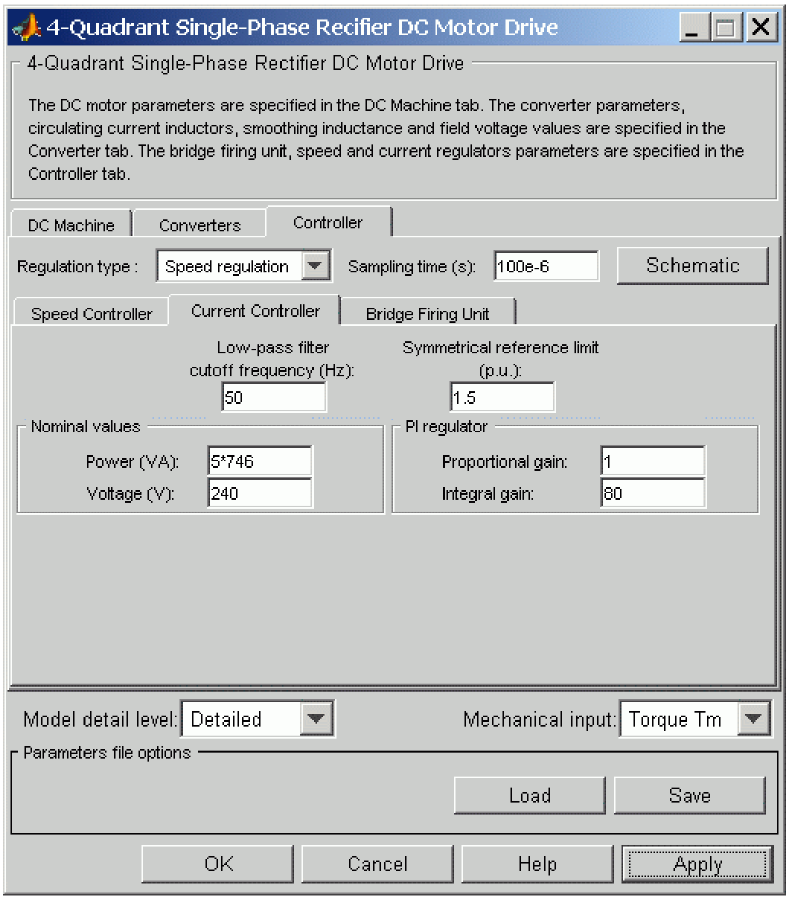
MATLAB SIMULINK DIALOG BOX C



Controller Tab

APPENDIX F

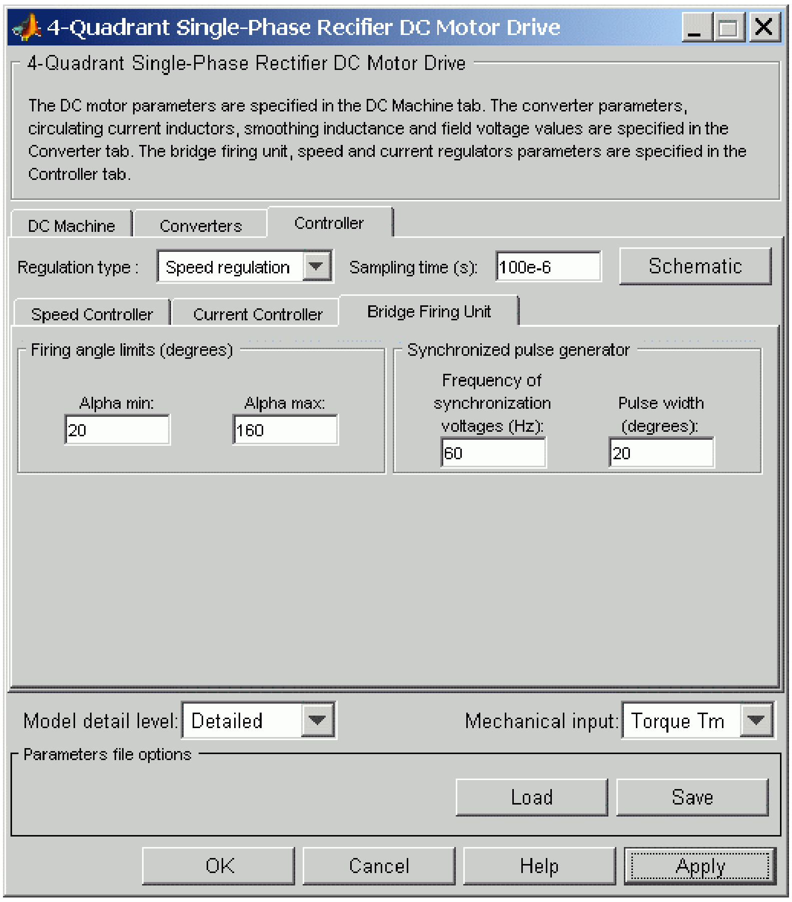
MATLAB SIMULINK DIALOG BOX D



Controller - Current Controller Sub tab

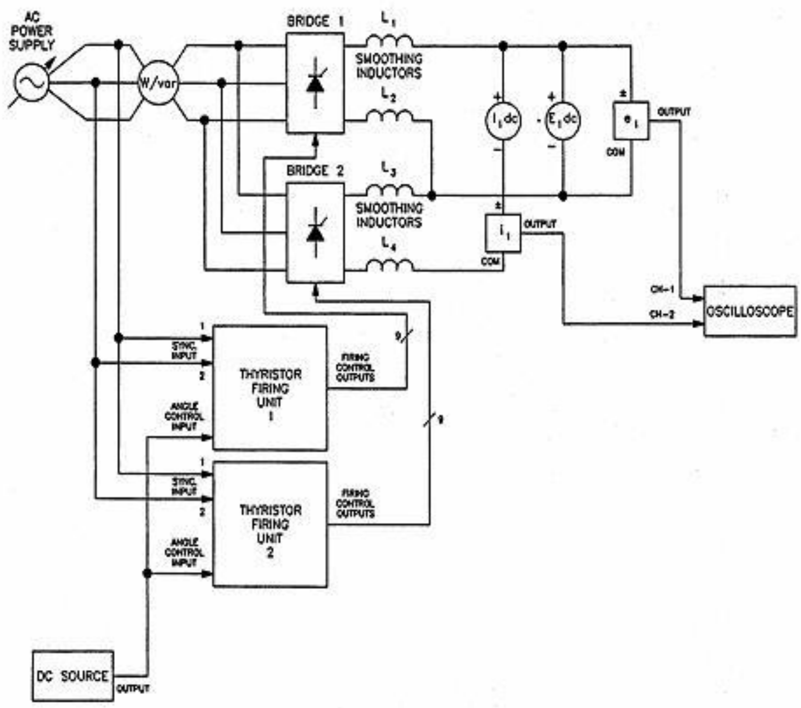
APPENDIX G

MATLAB SIMULINK DIALOG BOX E



Controller - Bridge Firing Unit Sub tab

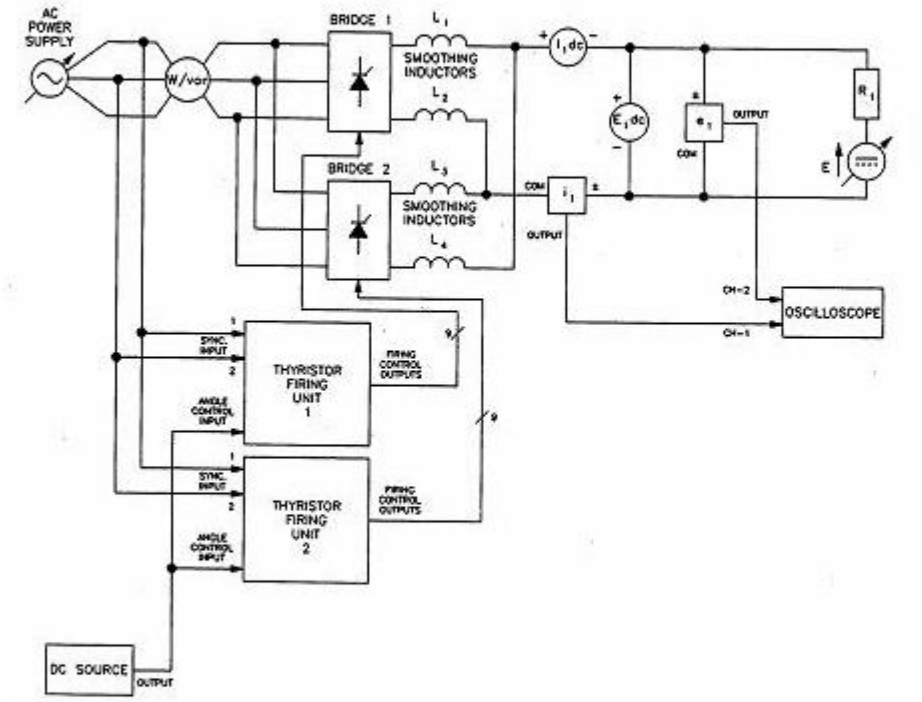
APPENDIX H
SETUP FOR FIRST EXPERIMENT



To measure circulating current in a four quadrant converter

APPENDIX I

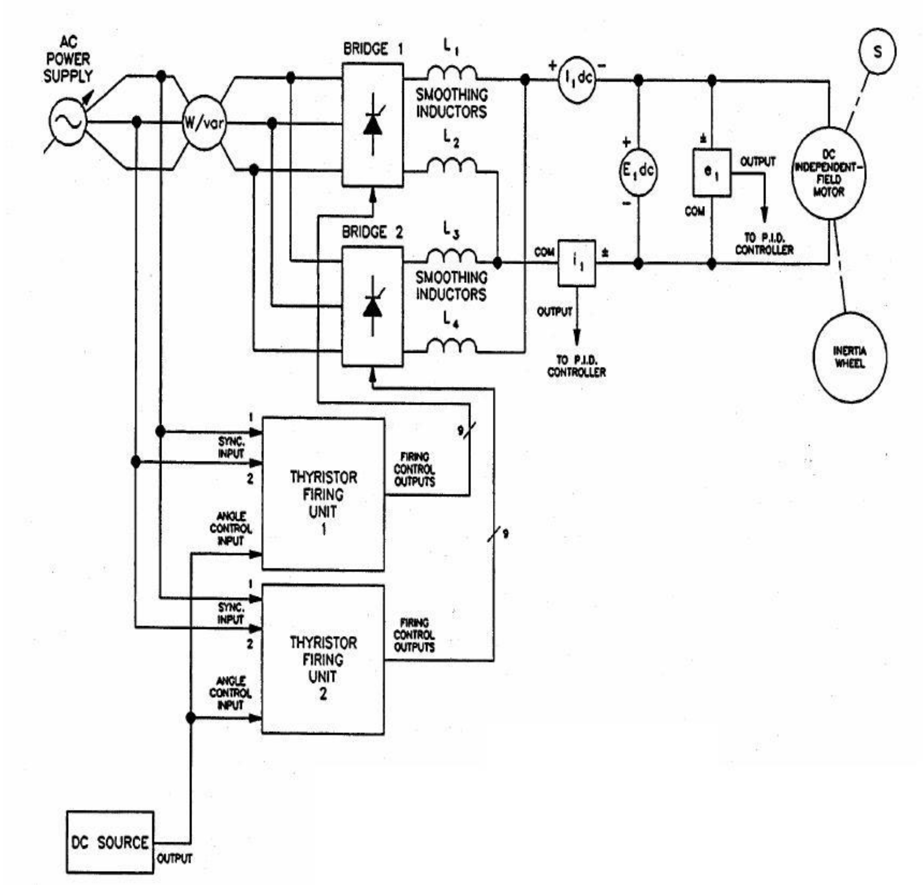
SETUP FOR SECOND EXPERIMENT



To verify and observe the operation of the circuit in each quadrant

APPENDIX J

SETUP FOR THIRD EXPERIMENT



To verify and observe four quadrant operations by using the circuit to drive a DC motor and generator