

DEVELOPMENT OF P-RESONANT VOLTAGE CONTROL FOR DC MOTOR
USING ARDUINO

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ABSTRACT

This project described about to design and to development of P-Resonant voltage control for DC motor. The objective of P-Resonant controllers is applied to control the output voltage of the DC motor. An Arduino board device is used as a medium for the implementation of the control system design. The P-Resonant controller is developed and simulates using MATLAB/Simulink software. MATLAB block diagram is downloaded into Arduino which will generate the PWM signal. The signal is transmitted from the gate driver to the three phase rectifier to produce a direct current voltage for the motor. The voltage produced is in accordance with the specified value at the reference voltage. The actual voltage will try to reference voltage with the comparison method and control of the ' P-Resonant '. The difference is then corrected to minimize the voltage error. A simple hardware implementation of the PR voltage controller is designed and the experimental results are presented to demonstrate the validity of this approach. The results are observed in two main part; simulation and hardware. Each part has an open loop control and close loop control. It has been observed that the designed system has been successfully implemented.

ABSTRAK

Projek ini menerangkan tentang reka bentuk dan pembangunan kawalan 'P-Resonant' voltan bagi motor arus terus. Objektif pengawalan 'P-Resonant' digunakan untuk mengawal voltan keluaran Motor arus terus. Arduino digunakan sebagai perantaraan untuk melaksanakan reka bentuk sistem kawalan. Pengawal 'P-Resonant' dibangunkan dan disimulasi menggunakan perisian MATLAB/Simulink. Rajah blok MATLAB dimuat-turun ke dalam Arduino yang akan menjanakan isyarat PWM. Isyarat dihantar daripada pemandu pintu kepada penerus tiga fasa untuk menghasilkan voltan berbentuk arus terus kepada motor DC. Voltan yang dihasilkan adalah mengikut nilai yang ditetapkan pada voltan rujukan. Voltan sebenar akan cuba mengikut voltan rujukan dengan kaedah perbandingan dan kawalan daripada 'P-Resonant'. Perbezaan kemudian diperbetulkan dengan itu meminimumkan ralat voltan. Perkakasan mudah pelaksanaan pengawal voltan 'PR' adalah direka dan keputusan eksperimen dibentangkan untuk menunjukkan kesahihan pendekatan ini. Keputusan dipatuhi dalam dua bahagian utama; Simulasi dan perkakasan. Setiap bahagian mempunyai kawalan gelung terbuka dan kawalan gelung rapat. Ianya telah diuji dan sistem yang direka telah berjaya dilaksanakan

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LIST OF SYMBOLS AND ABBREVIATIONS

<i>AC</i>	-	Alternating Current;
<i>DC</i>	-	Direct Current;
<i>PID</i>	-	Proportional Integral Derivative;
<i>IM</i>	-	Induction Motor;
<i>PWM</i>	-	Pulse Width Modulation;
<i>PR</i>	-	Proportional Resonant;
<i>FLC</i>	-	Fuzzy Logic Controller

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CHAPTER 1

INTRODUCTION

1.1 Background

The direct current (DC) motor is a device that used in many industries in order to convert electrical energy into mechanical energy. There are several kinds of DC motors; examples are stepper motors, servos, brushed/brush-less motors. These all results from the availability of speed controllers is wide range, easily and many ways. In most applications, speed control is very important [1]. Speed of dc motor is controlled by increasing or decreasing the voltage or current. This will affect the speed of the dc motor. So, it is important to make a controller to control the speed of DC motor in desired speed.

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems. Rectification may serve in roles other than to generate direct current for use as a source of power. As noted, detectors of radio signals serve as rectifiers. In gas heating systems flame rectification is used to detect presence of flame [2].

There are different types of controller that can be used to control the speed of a dc motor, for example PI, PID, Fuzzy Logic, Repetitive, Time Delay and PR. The recently introduced proportional-resonant (PR) controllers and their suitability for

current or voltage control of grid-connected converters. Using the PR controllers, the converter reference tracking performance can be enhanced and previously known shortcomings associated with conventional PI controllers can be alleviated. These shortcomings include steady-state errors in single-phase systems in three-phase systems. PR control theory is revised in detail with a number of practical cases that have been implemented previously, described clearly to give a comprehensive reference on PR control [3].

Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can be communicating with software running on your computer such as MATLAB. The boards can be assembled by hand or purchased preassembled.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research [4].

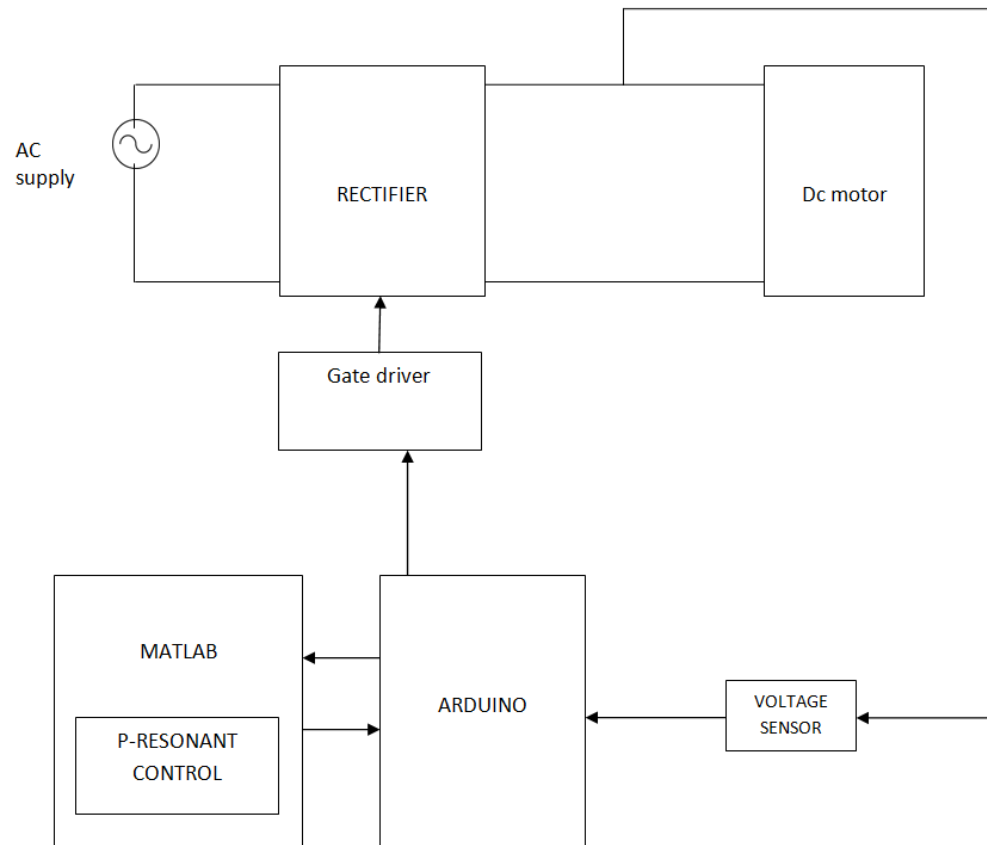


Figure 1.1: Block diagram of the project

Figure 1.1 shows the block diagram of this project. This component is important to keep this project running smoothly. An overview of the beginning is necessary to ensure that each component be able to communicate with each other. The use of appropriate components is also essential to develop this system especially at control part.

1.2 Problem statement

In the industry, universal Motors which are essentially DC motors are widely used in applications where the speed of a process needs to be controlled. Such applications are encountered frequently in our daily lives such as controlling the speed of fans or controlling the speed of hand-held tools such as drills, and in industrial automation applications such as controlling the speed of conveyor belt. Many such applications

which utilize DC motors have requirements associated with the steady-state speed and/or a ramp up time for the motor to reach this speed.

Some of the most common problems with the dc motors include its inefficiency to start immediately. There are many reasons for its incapability to start such as low voltage supply, wrong connection, excessive load, frozen bearing, ground fault and so forth. Sparks in the brushes is another problem associated with the dc motors. Sparks may be caused due to insufficient contact and inappropriate size of the brushes.

The most issue discusses in speed controller is regarding their efficiency and reliability. The efficiency element is important in order to save cost. The efficiency of speed controller is depending on method control system. The speed controller usually control in analog system.

Manual controller is also not practical in the new technology era because it wasting time and cost. Operation cost regarding controller is got attention from industrial field. In order to reduce cost and time, we suggest making a controller based on computer because it is portable. The user can monitor their system at certain place without need to going the plant (machine) especially in industrial implementation. From that, the man power can be reduced and reserve with computer which is more precise and reliable.

1.3 Objective

Basically, this project is listing four main objectives. The objectives are a guideline and goal in order to complete this project. This project is conducted to achieve the following objectives:

- To integrate communication between MATLAB and Arduino software.
- To develop a proportional resonant (P-Resonant) voltage controller for DC motor control.
- To design gate driver for converter circuit.
- To design the three phase rectifier circuit for dc motor.

1.4 Scope

The scope of the project based on the objectives of the project that focuses on the development of hardware and software.

- This project a use MATLAB R2013b to communicate with the Arduino Uno Rev3 microcontroller based board. Arduino has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.
- To using MATLAB simulation toolbox to develop and produce a proportional resonant voltage controller block diagram to create PWM output signal.
- To developed a gate driver circuit with six (6) outputs to accommodate the number of MOSFET used in the rectifier circuit.
- Meanwhile, the project will proceed with design the rectifier for dc motor. The rectifier will be utilized for converting the AC source supply to the DC source supply. The power rating of DC multifunction machine for motor is 0.3kWatt. The output current and voltage will be 1.8A and 220VDC.

CHAPTER 2

LITERATURE REVIEW

2.1 Dc motor

A DC Motor in simple words is a device that converts direct current (electrical energy) into mechanical energy. It's of vital importance for the industry today, and is equally important for engineers to look into the working principle of DC motor. In order to understand the operating principle of dc motor we need to first look into its constructional feature in figure 2.1 [5].

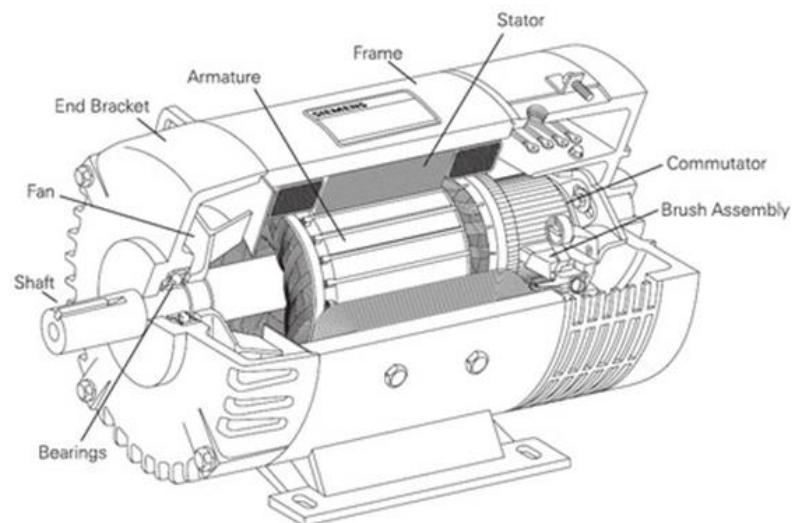


Figure 2.1: constructional of DC motor

DC motor is considered a system having torque/speed characteristics compatible with most mechanical loads. This makes a DC motor controllable over a wide range of speeds by proper adjustment of the terminal voltage. Now days

induction motors, Brushless DC motors and Synchronous motors have gained widespread use in electric traction system. Hence dc motors are always a good option for advanced control algorithm because the theory of dc motor speed control is known more than other types. Speed control techniques in separately excited dc motor by varying the armature voltage for below rated speed [6].

A series dc motor gets its name from the fact that the field winding in this case is connected internally in series to the armature winding such as figure 2.2. Thus the field windings are exposed to the entire armature current unlike in the case of a shunt motor. A dc series motor is usually built for fractional. Horse power sizes. It is normally used to drive portable apparatuses. Series dc motors are extensively used in many applications that require high starting torque such as cranes, hoists, electric traction, etc [7].

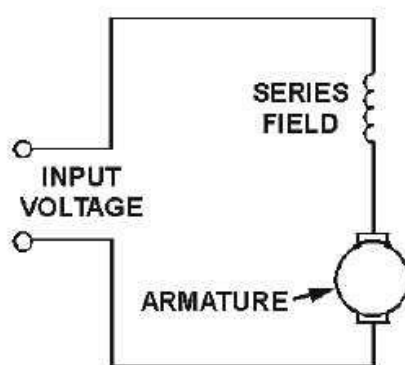


Figure 2.2: Series DC motor schematic diagram

A shunt DC motor connects the armature and field windings in parallel or shunt with a common DC power source in Figure 2.3. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor. It is typically used for industrial, adjustable speed applications, such as machine tools, winding/unwinding machines and tensioners [8].

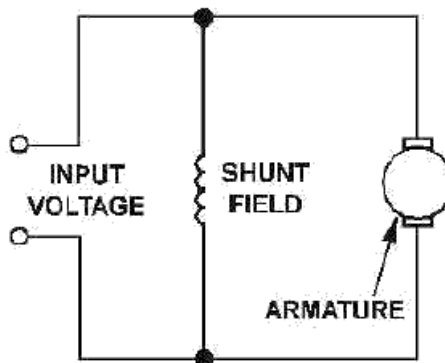


Figure 2.3: Shunt DC motor schematic diagram

A compound DC motor connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor. This motor is used when both a high starting torque and good speed regulation is needed. The motor can be connected in two arrangements: cumulatively or differentially. Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation. In figure 2.4, differential compound DC motors have good speed regulation and are typically operated at constant speed. In a compound motor the magnetizing flux consists in two parts, one depending on the parallel or shunt current and one function of the armature current that flows through the coils in series of the motor armature [9].

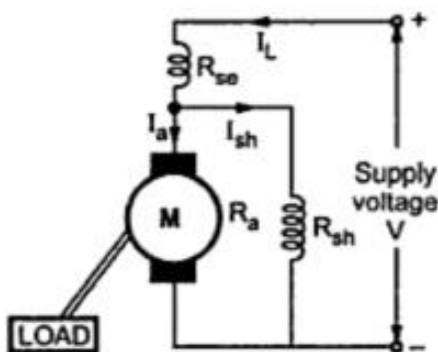


Figure 2.4: Compound DC motor schematic diagram

As the name suggests, in case of a separately excited DC Motor the supply is given separately to the field and armature windings. The main distinguishing fact in these types of dc motor is that, the armature current does not flow through the field

windings, as the field winding is energized from a separate external source of dc current as shown in the Figure 2.5.

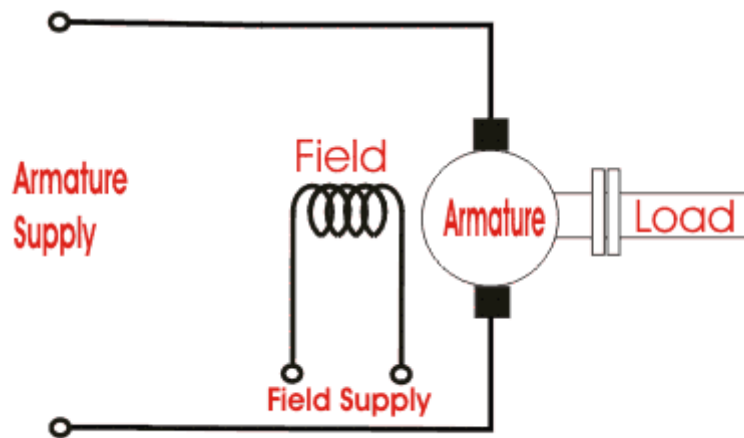


Figure 2.5: Separately Excited DC motor schematic diagram.

2.2 MATLAB

The name MATLAB stands for Matrix Laboratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research [4].

MATLAB has many advantages compared to conventional computer languages for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering.

2.3 Arduino

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter [10].

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing, MaxMSP) [11].

Arduino is composed of two major parts: the Arduino board, which is the piece of hardware you work on when you build your objects; and the Arduino IDE, the piece of software you run on your computer. You use the IDE to create a sketch (a little computer program) that you upload to the Arduino board. The sketch tells the board what to do [12].

2.4 Control Method

Many controllers have been developed, that can be divided into two classifications, passive and adaptive power controller. The example for passive power controller relay and sliding mode control and for adaptive power controller is PID, fuzzy, Repetitive and P-resonant controller. Each of them has their advantages, such as simple structure and low maintenance cost.

2.4.1 PID controller

The Proportional(P)+Integral(I)+Derivative(D), i.e. PID control algorithm is most widely used in industrial applications. We have implemented a PID controller to control the motor speed. The error between the reference speed and the actual speed is given as input to a PID controller. The PID controller depending on the error changes its output, to control the plant input such that the error is minimized [13].

$$C_{(s)} = K_p \left(1 + \frac{1}{T_i * s} + T_D * s \right) \quad (2.1)$$

The proportional control (K_p) is used so that the control signal $u(t)$ responds to the error immediately. But the error is never reduced to zero and an offset error is inherently present. To remove the offset error the Integral control action (TI) is used. To Derivative control (TD) is used to dampen out oscillations in the plant response. Also, the presence of derivative control reduces the need of K_p being large to achieve stability. PID controller was implemented and the performance of the system was evaluated. The control algorithms were implemented using OP-AMPS. The details of implementation are given in the following sections. Proportional-Integral Derivative (PID) controllers have been widely used for speed and position control of DC motor [14]. A PID (proportional-integral-derivative) controller is one of the most commonly used controllers because it is simple and robust. Also, it is suitable for use in a control system where the transfer function of the plant has not been completely defined [15].

2.4.2 Fuzzy logic controller

A fuzzy logic model is a logical-mathematical procedure based on an “IF-THEN” rule system that mimics the human way of thinking in computational form. Generally, a fuzzy rule system has four modules [16].

- Fuzzification
- Fuzzy Inference
- Rule base
- Defuzzification

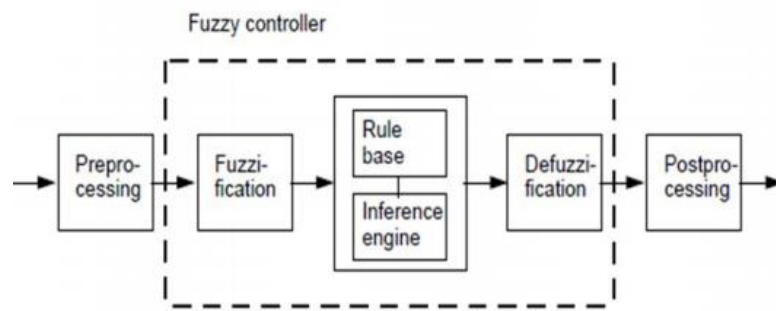


Figure 2.6 Structure of fuzzy logic controller

Fuzzy logic controllers have certain advantages compared to classical controllers such as simplicity of control, low cost, and the possibility to design without knowing the exact mathematical model of the process. They are used in several applications ranging from the control of power converters to speed control of motors. They are suitable for applications such as the speed control of a dc motor which has nonlinearities. In designing a fuzzy logic controller (FLC), the derivation of the rule-base and the defuzzification are important factors [17].

A fuzzy control system is a control system in which a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively).

Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy Logic's approach to control problems mimics how a person makes decisions, only much faster. Fuzziness is connected with the degree to which events occur rather than likelihood of their occurrence. FLC have some advantages compared to other classical controller such as simplicity of control, low cost and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic incorporates an alternative way of thinking which allows modeling complex systems using higher level of abstraction originating from the knowledge and experience [18].

2.4.3 Repetitive controller

Repetitive controller is a specialized control scheme for tracking periodic reference commands and rejecting periodic disturbances with a known period. The advantage of repetitive control is that the tracking error decreases with increasing number of periodic motion. However, the positive feedback loop used to generate the periodic signals which affect the stability of the system. In the end, the repetitive controller is likely to make the system unstable. Therefore, the trade-off between stability and tracking performance has been considered to be an important factor in the repetitive control system [19].

2.4.4 Proportional-resonant controller

The proportional-resonant control is used in voltage control loop to achieve steady-state accuracy and the ability to cancel the disturbances of load currents simultaneously. The discrete domain control system analysis shows that the whole system can obtain high quality steady-state compensation accuracy and fast dynamic response [20].

PR controller has much in common with a common PI controller. The difference consists only in the way the integration action takes part. The integrator will only integrate frequencies very closed to the resonance frequency and will not introduce stationary error or phase shift [21].

Proportional-resonant (PR) controller, which introduces an infinite gain at a selected resonant frequency for eliminating steady state error, constituted by the proportional regulator and resonant controller. The controller can be used to control the DC signals, thus eliminating the need for coordinate system transformation, and these advantages make it suitable for the power quality control applications with high performance [20]. The PR controller $G_{PR}(s)$ is defined as:

$$G_{PR}(s) = K_P + \frac{K_r s}{s^2 + \omega_0^2} \quad (2.2)$$

Where: k_p and k_r are the controller coefficients, and ω_0 is considered as the cut-off frequency.

The PR controller has been designed based on the frequency output of the I_L . As known the output is 50Hz. The aim of this controller is to control the sinusoidal variable which has resonant frequency at 50Hz and in the same time reject others frequencies. The PR controller is used where it has high gain at the resonant frequency. Figure 2.7 shows the PR controller block. This controller needs to have two controllers side which response to d and q components. The references values for d and q are 1 and 0. At the end of this control process the d and q can be sum together to generate the periodic signal that is used to generate the PWM signal to the inverter [22].

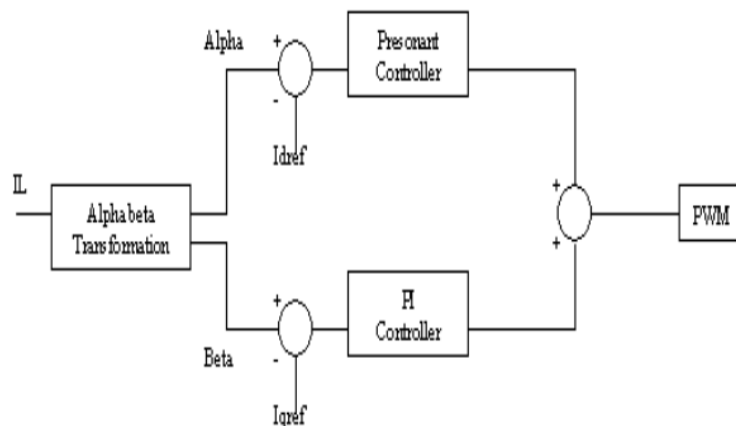


Figure 2.7: Proportional Resonant controller block

Advantages of the PR controllers include the possibility of tuning their individual resonant peaks to the grid frequency for precise fundamental reference tracking and to some low-order harmonic frequencies for selective harmonic compensation, and the possibility of implementing harmonic reference generator in the stationary frame needed for active filters.

Implementation wise, the PR technique requires lesser computational overhead and does not require an explicit grid voltage feed forward control path, while still achieving the same performance as a synchronous PI controller. For three-phase systems, the PR technique also has the unique feature of compensating for both positive- and negative-sequence components simultaneously, unlike synchronous PI where separate frame transformations are needed. Given these advantages, PR controllers can certainly replace their PI counterparts [23].

2.5 Gate Driver

Gate drivers are electronic circuits that apply correct power levels to metal-oxide field-effect transistors (MOSFETs) and insulated gate bipolar transistors (IGBTs). With IGBTs, gate drivers serve as isolation amplifiers and often provide short-circuit protection. Because of their insulated gates, IGBTs require a continuous gate circuit in order to sustain gate current. Solid state switching technology has enhanced pulsed power applications by extending capability in a mentioned area.

With power-MOSFETs, gate drivers can be implemented as transformers, discrete transistors, or dedicated integrated circuits (IC). They can also be integrated within controller ICs. Partitioning the gate-drive function of controllers that use pulse width modulation (PWM) improves controller stability by eliminating the high peak currents and heat dissipation needed to drive power-MOSFETs at very high frequencies [24].

It's specially designed to handle significant power levels. They're only used in "on" or "off" states, which has resulted in their being the most widely used low-voltage switch. When compared to the IGBT, a power MOSFET has the advantages of higher commutation speed and greater efficiency during operation at low voltages. What's more, it can sustain a high blocking voltage and maintain a high current. This is because most power MOSFETs structures are vertical (not planar). Its voltage rating is a direct function of the doping and thickness of the N-epitaxial layer, and its current rating is related to the channel's width (the wider the channel, the higher the current). Due to its efficiency, power MOSFETs are used in power supplies, dc/dc converters, and low-voltage motor controllers [25].

Driving power MOSFET at high switching frequency may induce significant switching power losses. A gate driver with low energy consumption is proposed for power MOSFET in switching power conversion applications. The proposed gate driver regulates the output gate driving voltage for minimizing the loss of charging and discharging the gate capacitor [26].

Among these technologies, semiconductors such as MOSFETs and IGBTs have drawn attention in high frequency applications.

CHAPTER 3

METHODOLOGY

3.1 Block diagram

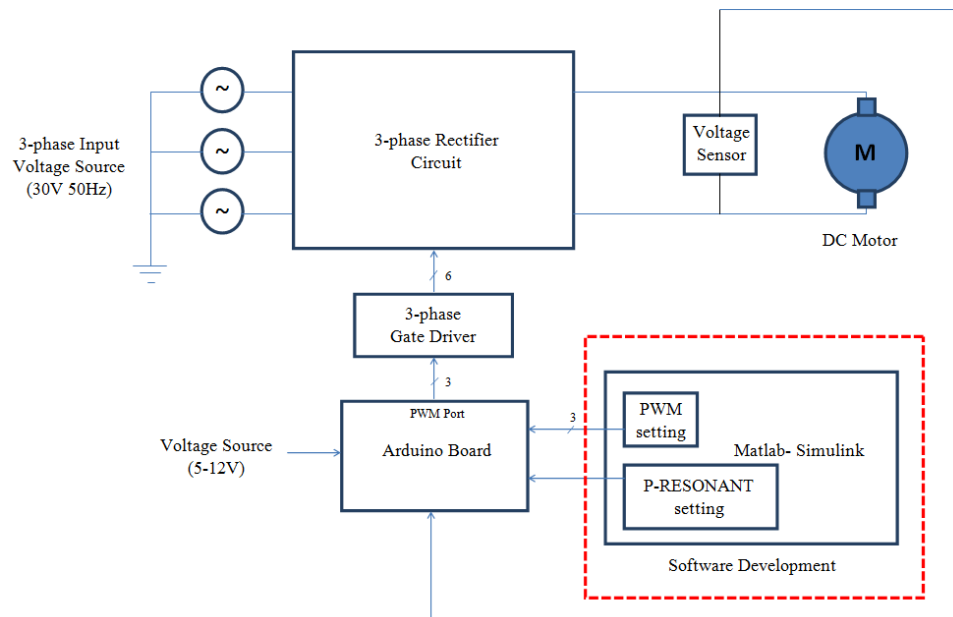


Figure 3.1: The project block diagram

Figure 3.1 shows the block diagram of the project. This project have 6 mains parts which are the three phase input voltage, three phase rectifier, three phase gate driver, dc motor as a load, voltage sensor as a feedback and the controller to control the voltage.

The three phase input voltage applied to the source is from 0 to 40V with frequency 50Hz. The second part is the rectifier. Rectifier will be used to convert alternating current (AC) to direct current (DC) power supply. The system need because the three phase dc motor as a load. The three phase rectifier also known as the six switch rectifier type or full bridge rectifier and will receive the output PWM from the gate driver.

For the third part, gate driver circuits are function to step up the signal PWM from the arduino. The gate driver will step up the number and the amplitude of the signal PWM to the three phase rectifier. The gate driver will produce six PWM signal.

The DC motor was used as a load. The rating of the DC motor is 0.3kW, 220V, and 1.8A. DC multi-function machine for motor and generator operation, can be used as shunt, series, separately excited, or compound wound machine, series and shunt winding with tap for compounding, with commutating winding and compensation winding. All windings are separately connected to 4 mm safety sockets. When separately excited DC motor running, the sensor voltage will be detected. Sensor voltages are used to send data to the Arduino. The output of the voltage sensor will be used as a feedback to the controller.

The important part of the system is the controller. This project is to develop a control voltage through P-resonant method for controlling the speed of a dc motor. The controller will compare the motor voltage with the reference voltage and if there is an error, the controller will generate the pulse width modulation to fed into the three phase rectifier. By feeding the PWM to the rectifier, it will rescale the output to power up the load. This process will continuous in the feedback until the error approximately to zero.

3.2 Project design

To achieve the project, hardware designs have been made. In hardware development, two main part which rectifier and their gate driver are the first to be design. Then the other part is software for the controller design.

3.2.1 Rectifier design

In the three-phase rectifiers, MOSFETs are needed to produce power switching. In this project, MOSFET IRF840 is used. For the six MOSFET, the circuit again has a pulse number of six. For this reason, it is also commonly referred to as a six-pulse bridge. Each gate of the MOSFET needs to give a signal to switching and finally 6 PWM must be built to give signal to the gate of MOSFET. Figure 3.2 shows the circuit arrangement of three phase inverter in PROTEUS software.

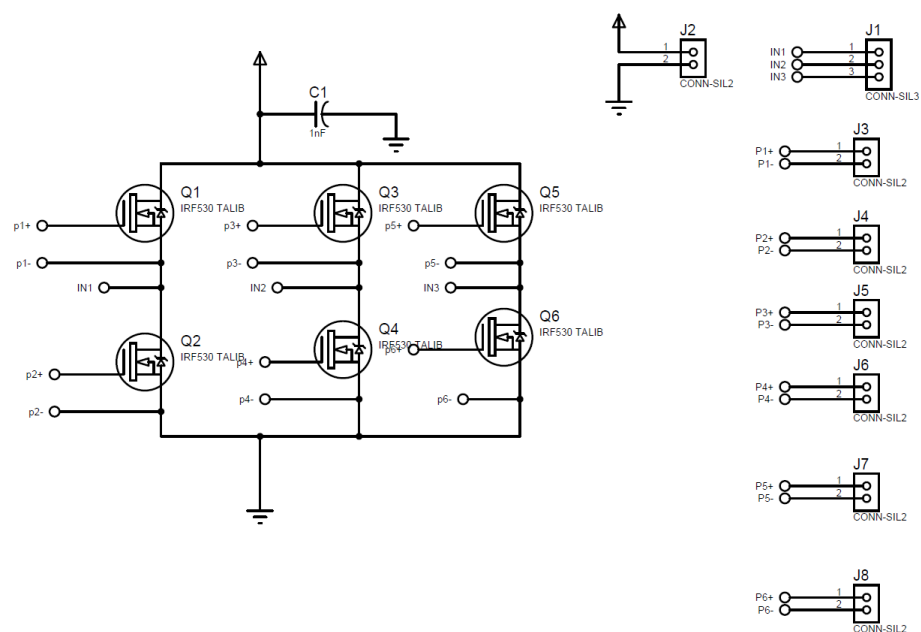


Figure 3.2: Three Phase Rectifier circuit diagram

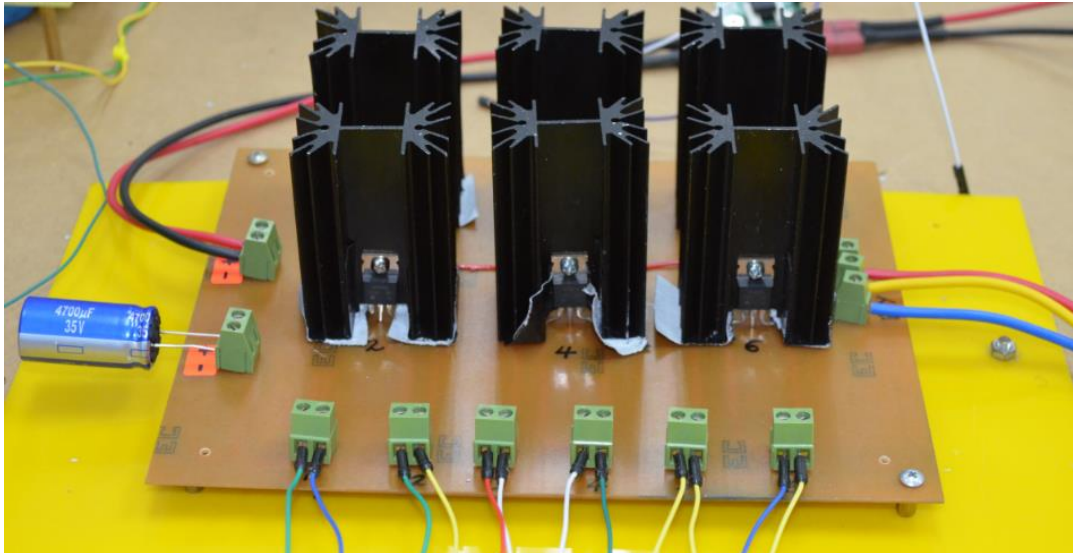


Figure 3.3: The hardware of three phase rectifier

Figure 3.3 shows the hardware of the three phase rectifier. At the right hand side is the incoming with 23Vac supply from phase A, B and C in. The six positive and negative (in front of MOSFET) is the PWM switching signal from gate driver. While the left hand side is the Vdc input terminal block and connect to the dc motor.

3.2.2 Gate driver design

Figure 3.4 shows the gate driver for three phase rectifier. The function of the gate driver is to produce 6 pulse PWM signal from three different phase inputs from Arduino. In this project, the gate driver will step up the voltage from 5V to 15V by voltage regulator IL0515S before sending it to the three phase rectifier.

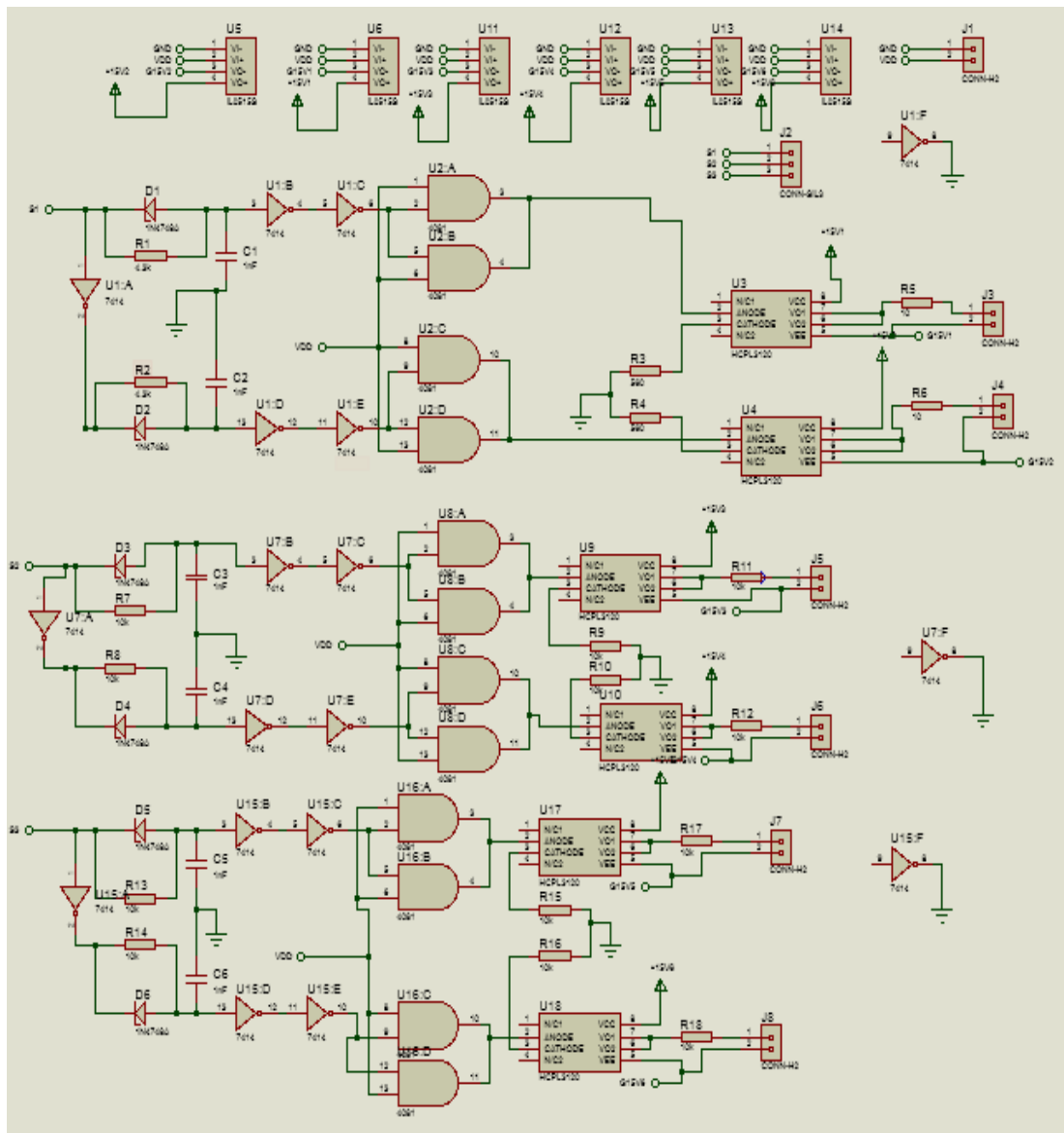


Figure 3.4: Gate driver circuit diagram

The other main component in the gate driver is Gate Drive Optocoupler HCPL3120. This optocoupler is ideally suited for driving power IGBT's or MOSFET's used in motor control inverter application. The minimum supply voltage of this optocoupler is 15V that are taken from the IL0515S which are the DC-DC converter. The picture of the gate driver hardware is shown in Figure 3.5.

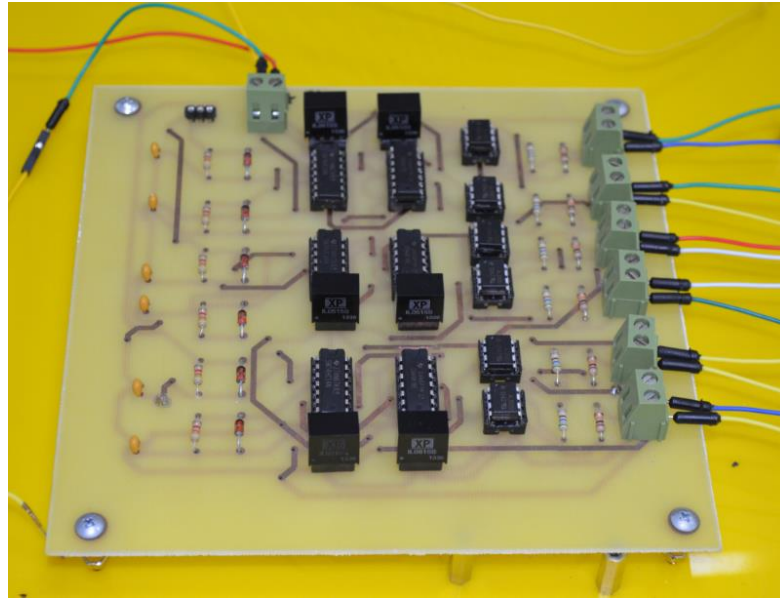


Figure 3.5: The hardware of gate driver

3.2.3 Controller design

Figure 3.6 shows the detail of P Resonant controller. The PR controller divides by a grouping of proportional gain and integration gain. For the integration gain, ideal controller transfer function is used.

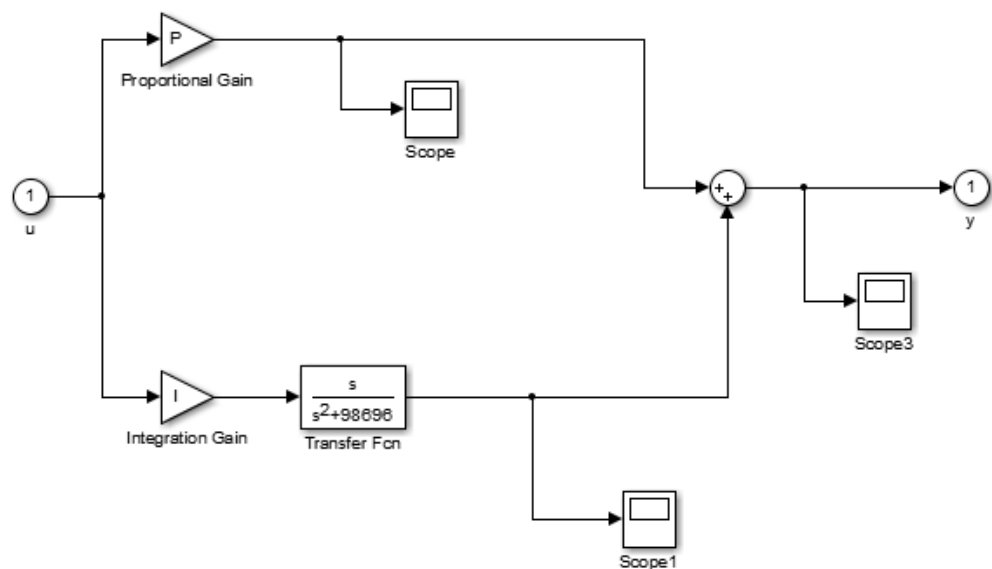


Figure 3.6: P-Resonant controlled diagram

The value of 98696 is represents the sign of ω_0^2 in Equation 2.2. It is based on the calculation:

$$\omega_0^2 = (2\pi f)^2 \quad (3.1)$$

$$\omega_0^2 = (2 * \pi * 50)^2$$

$$\omega_0^2 = 98696$$

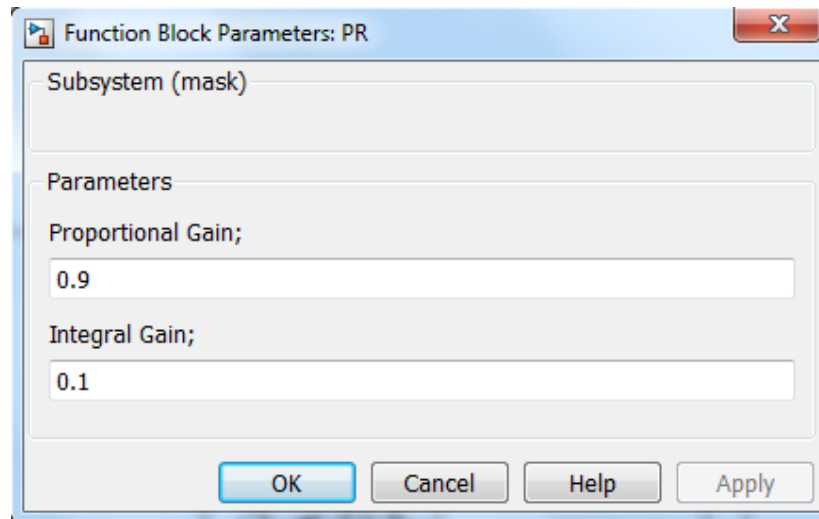


Figure 3.7: P-Resonant block parameter

The key component is the Arduino microcontroller. It is the control center of the entire system. It contains all the software design for this project. The microcontroller will receive signals from the voltage sensor. Then, the microcontroller will send another signal to the motor based on the signal it receives. After the motor receives the signal from the microcontroller, it will start rotate and push a lever trigger.

The available data will be processed in MATLAB with P-Resonant method. PR controller is used for controlling the voltage. Transfer function of a PR controller is given by:

$$G_{PR} = K_p + \frac{K_i S}{s_i + \omega_0^2} \quad (3.2)$$

Where ω_0 , k_p and k_i are resonant frequency, proportional and integral gains of controller, respectively. According to internal model principle, if the resonant

frequency of the PR controller is equal to the frequency of a sinusoidal reference voltage, then the controller introducing an infinite gain at this frequency makes the output voltage track the reference command. For achieving the control objectives and modeling the rectifier and its PWM modulator as a constant gain, the control voltage loop band-width is chosen much lower than the switching frequency of the rectifier. Figure 3.8 shows the stationary PR block diagram for voltage controller.

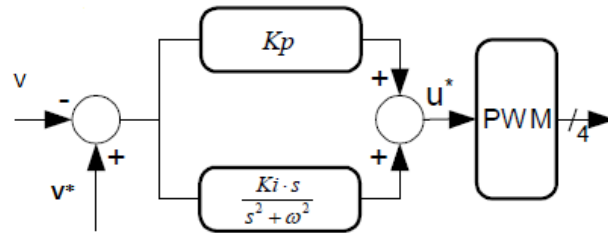


Figure 3.8: Block Diagram of PR voltage controller

MATLAB simulation toolbox is using to develop and produce a proportional resonant voltage controller block diagram to create PWM output signal. The communication between MATLAB and Arduino will produce for controlling the speed of a dc motor. Arduino will be sent data to a gate driver in Pulse Width Modulator (PWM).

Then, Arduino will transmit data to gate driver. A gate driver' is a power amplifier that accepts a low-power input from a voltage controller and produces a high-current drive input for the gate of a high-power transistor that MOSFET. In essence, a gate driver consists of a level shifter in control the switching.

This project will use DC multifunction machine as shown Figure 3.9. DC multi-function machine for motor and generator operation, can be used as shunt, series, separately excited, or compound wound machine, series and shunt winding with tap for compounding, with commutating winding and compensation winding. All windings are separately connected to 4 mm safety sockets.

The basic principle behind DC motor speed control is that the output speeds of DC motor can be varied by controlling decreasing and increasing voltage to rated speed keeping field voltage constant. The output speed is compared with the reference speed and error signal is fed to speed controller. Controller output will vary

whenever there is a difference in the reference speed and the speed feedback. The output of the speed controller is the control voltage that controls the operation duty cycle. The converter output give voltage required to make the motor return to the desired speed. The reference speed is provided through a potential divider because the voltage from potential divider is linearly related to the speed of the DC motor. Therefore, a dc motor can control by a modern computerized control system.



Figure 3.9: DC multi-function machine

3.2.4 Voltage sensor design

A voltage sensor (also known as a voltage divider) is a simple linear circuit that produces an output voltage (V_{out}) that is a fraction of its input voltage (V_{in}). Voltage division refers to the partitioning of a voltage among the components of the divider. The formula governing a voltage divider is similar to that for a current divider, but the ratio describing voltage division places the selected resistance in the numerator.

In this project, a voltage sensor consists of two resistors in series or a potentiometer. Voltage sensor should be set so as to be read by the Arduino and use feedback as a reference voltage. Figure 3.10 shows the circuit diagram of voltage sensor. Two resistors, 2500 ohm for R1 and 370 ohm for R2, was chosen so that the

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