

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

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This is special dedicated to my family for their continue love and prayers, to all my friends for their understanding support and cooperation



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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

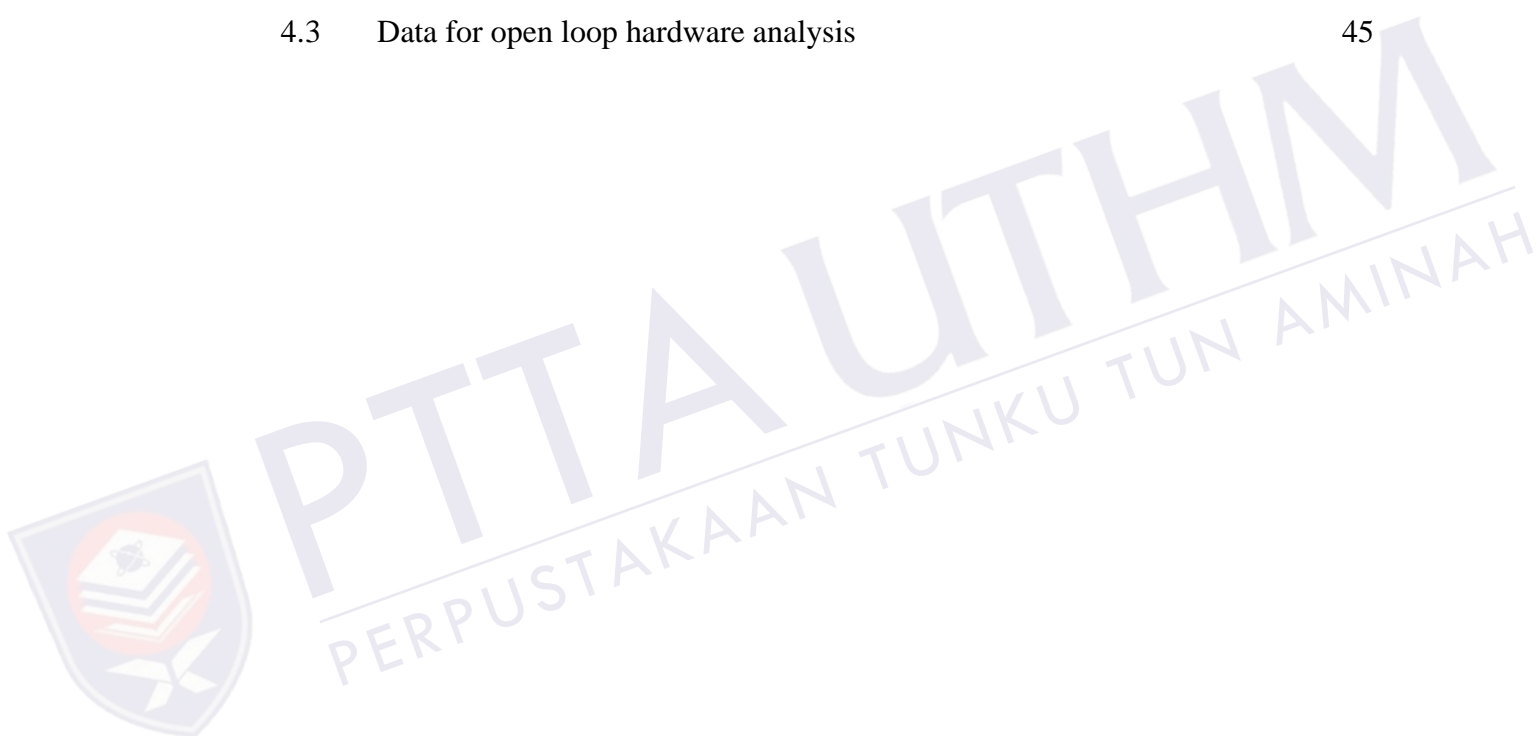
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LIST OF SYMBOLS AND ABBREVIATIONS

<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].

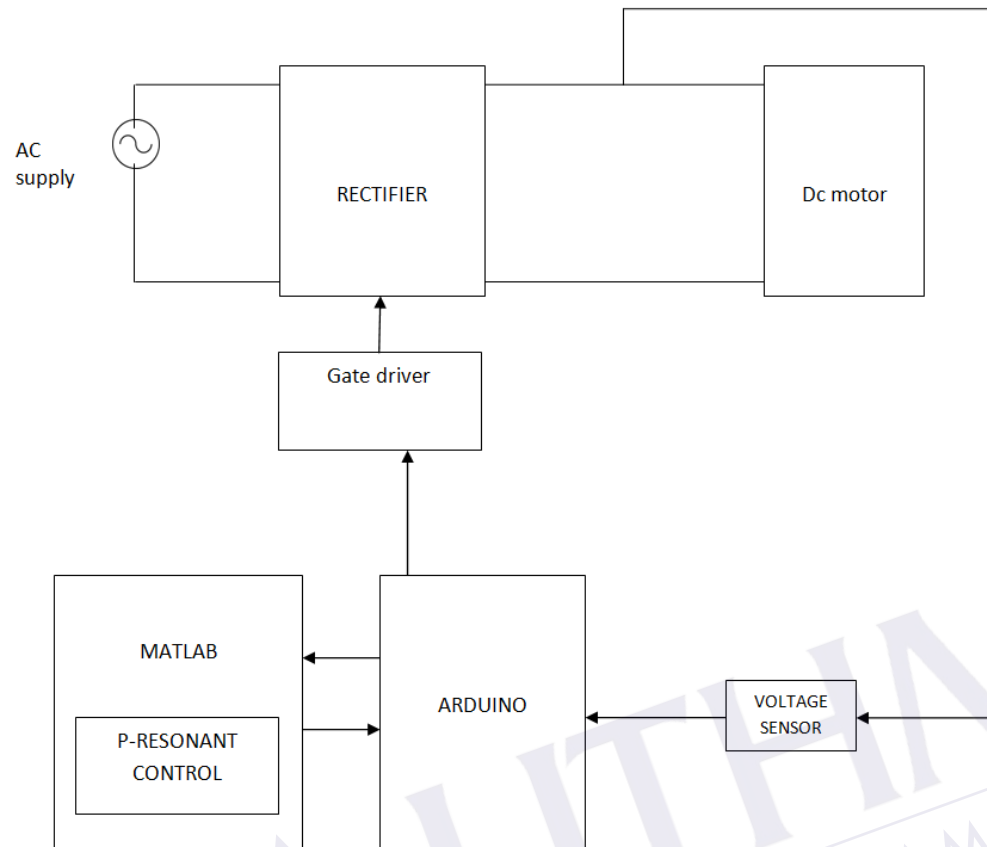


Figure 1.1: Block diagram of the project

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].

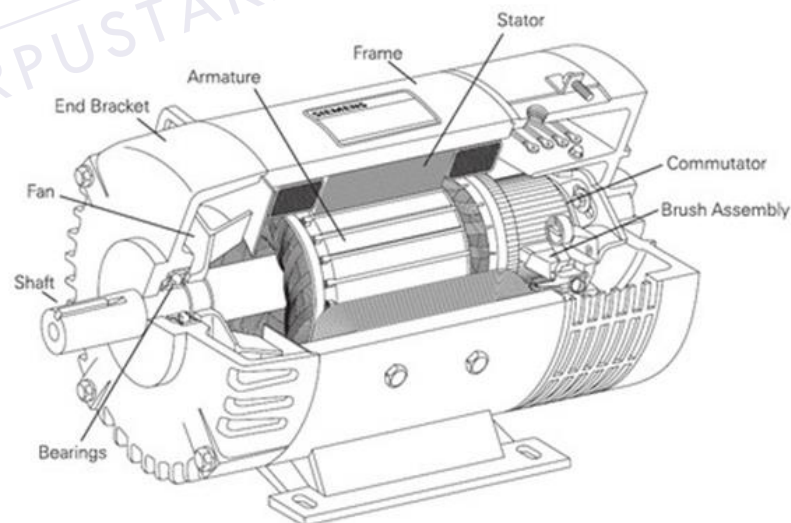


Figure 2.1: constructional of DC motor

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].

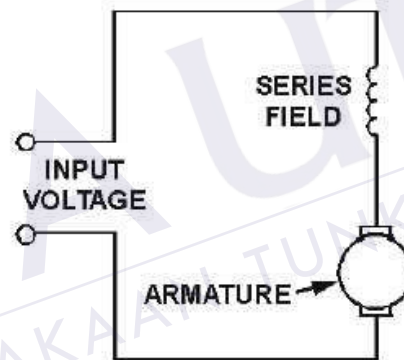


Figure 2.2: Series DC motor schematic diagram

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].

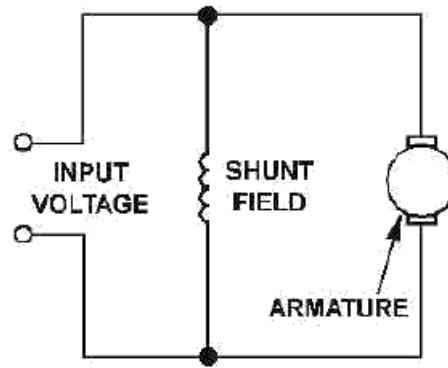


Figure 2.3: Shunt DC motor schematic diagram

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].

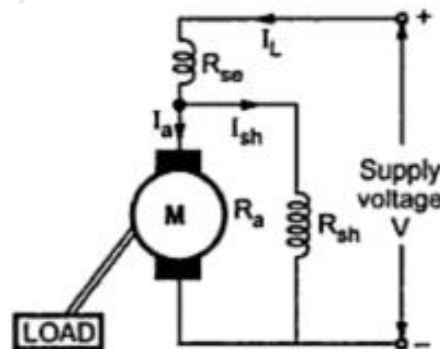


Figure 2.4: Compound DC motor schematic diagram

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.

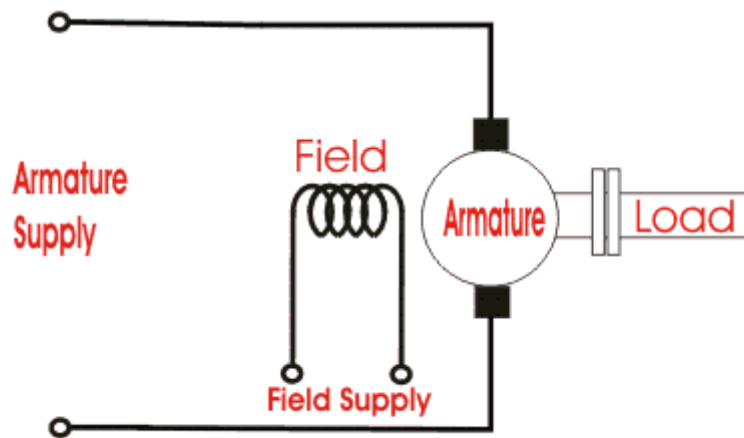


Figure 2.5: Separately Excited DC motor schematic diagram.

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

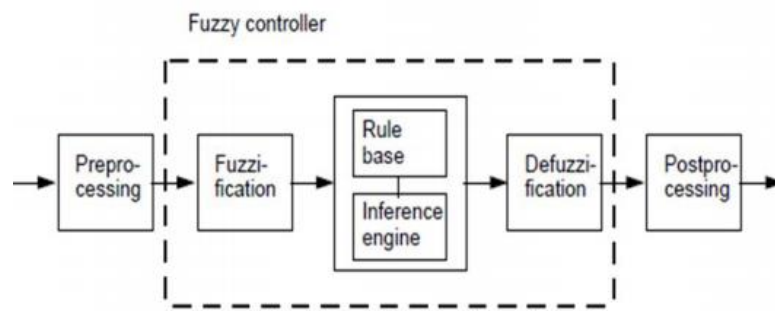


Figure 2.6 Structure of fuzzy logic controller

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].

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