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REVIEW ON SPEED CONTROL OF DC MOTOR USING PI & PI FUZZY LOGIC CONTROLLER

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ABSTRACT

DC Motors are widely used in many industrial applications, home appliances, robot manipulators, rolling mills and steel mills etc. Because of their high reliability, flexibility, efficiency, low electrical noise and low cost, where speed control of DC Motor is required. For the speed control of DC Motor, different controllers are used. This paper describes the speed control of DC Motor using conventional controllers and fuzzy logic controller based on Matlab Simulation Program. In comparison with the conventional controllers, fuzzy control gives efficient and effective speed response but conventional controllers provide better response with changing the load. This work includes the compar
ison between the conventional and fuzzy controller. MATLAB/ SIMULINK software has been used to develop the model and to investigate more about DC Motor.

Keywords: DC Motor, PI, Fuzzy Logic.

INTRODUCTION

DC Motors are widely used in many industrial applications, home appliances, robot manipulators, rolling mills and steel mills. Because of their high reliability, flexibility, efficiency, low electrical noise and low cost, where speed control of DC Shunt motor is required. For the speed control of DC Shunt Motor, different controllers are used. This paper describes the speed control of DC Shunt Motor using conventional controllers and fuzzy logic controller based on Matlab Simulation Program. This work includes the comparison between the conventional and fuzzy controller for which MATLAB / SIMULINK software has been used.

PI controllers are commonly used for motor control because of their simple structures and intuitionally comprehensive control algorithms. In process control, model based controls systems are mainly used to get the desired set points and reject small external disturbances. The internal model control (IMC) design is based on the fact that control systems contain some representation of the process to be controlled then a perfect control can be achieved. This work has compared the conventional methods with fuzzy logic control method.

At first, the concept of fuzzy logic was introduced by Lotfi Zadeh. He was a professor at the University of California at Berkeley, and it was not presented as a control methodology, but as a way of data processing. According to his observation, unlike other computers , fuzzy logic consists of a range of possibilities between T or F in human decisions. Fuzzy Logic Controllers were supposed to achieve the Speed control of a DC Motor using combined armature voltage and field current by varying the armature voltage in the constant torque region and the field current in the constant power region. Scientists prefer Fuzzy Logic Control over conventional controls because this system is easy to understand, gives most effective solutions to complex issues, helps in dealing with the engineering uncertainties. Also, this Fuzzy Logic Control System can be modified easily to improve or alter the performance of Machine.

HISTORY & INVENTION

This amazing piece of electrical equipment which is used in such a great manner all over every industry has been revolutionised our lives in many ways. But where this master piece came from? A very curious question must be in everyone's mind. As with all major innovations, there are many great people who had played a very great role in development of similar mechanisms. In US, Thomas Davenport is widely known as the inventor of the first electric motor. In 1837, he was the first to patent a useable electric motor which came a vast change in electrical world. In 1834, Moritz Jacobi had presented a motor that was three times as powerful as one patent by Davenport later. While, Sibrandus Stratingh & Christopher Becker was the first to demonstrate the practical application of an electric motor by running a small model car in 1835. The first practical DC Motor was invented some years later in 1886 by Frank Julian Sprague, whose invention lead to the first motor powered Trolley system in 1887 and the first electric elevator in 1892. Sprague's DC Motor was a hugely significant development, leading to a variety of applications which would reshape the face of industry and manufacturing.

DC MOTOR

A DC motor is any of a class of rotary electrical motors that converts the direct current electrical energy into mechanical energy through the interaction of two magnetic fields. One field is produced by a magnet of poles assembly, and other field is produced by an electric current flowing in the motor windings. These two fields result in a torque which tends to rotate the rotor.

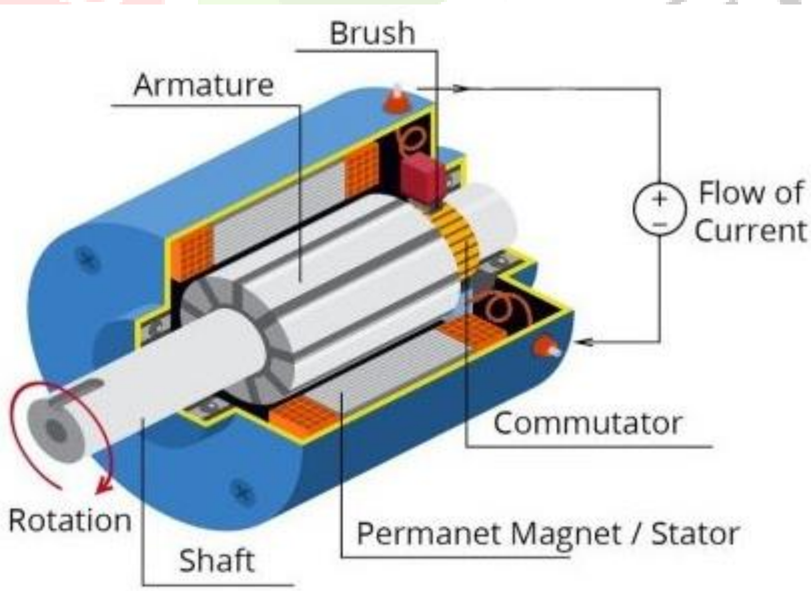


Fig. 1 – A DC MOTOR

WORKING PRINCIPLE:

A DC Motor works on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. In other words, when a magnetic field and an electric field interact, a mechanical force is produced. This is the basic working principle of DC Motor which is also known as Motoring Action.

The direction of rotation of this motor is given by Flemming's Left Hand Rule, which states that if the index finger , middle finger, and thumb of your left hand are extended mutually perpendicular to each other and if the index finger represents the direction of the magnetic field, middle finger represents the direction of the current, then thumb will represent the direction in which force is experienced by the shaft of the DC Motor.Structurally and construction wise, a direct current motor is exactly similar to a DC generator, but electrically it is just the opposite. Here unlike generator, we supply electrical energy to the input port and derive mechanical energy from the output port.

DC Motor include two key components ; a stator and an armature. The stator is the stationary part of a motor, while the armature rotates. In a DC Motor, the stator provides a rotating magnetic field that drives the armature to rotate. A simple DC Motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the center of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field. The windings of insulated wire are connected to a commutator that applies an electric current to the windings. The commutator allows each armature coil to be energised in turn, creating a steady rotating force known as torque.

When the coils are turned on and off in sequence, a rotating magnetic field is created that interacts with the differing fields of the stationary magnets in the stator to create torque, which causes it to rotate. These key principles of DC Motor allow them to convert the electrical energy from direct current into mechanical energy through the rotating movement, which can then be used for the propulsion of objects

DETAILED DESCRIPTION OF A DC MOTOR:

Main parts of a DC Motor are Armature or Rotor, Field coil or Stator, Commutator and Brushes.

Armature or Rotor: A DC Motor has coils of wire mounted in slots on a cylinder of ferromagnetic material which is termed as **Armature.** It's a cylinder of magnetic laminations that are insulted from each other. Armature is perpendicular to the axis of the cylinder It is mounted on bearings, free to rotate and rotates on it's axis. Armature is separated from the field coil by an air gap.

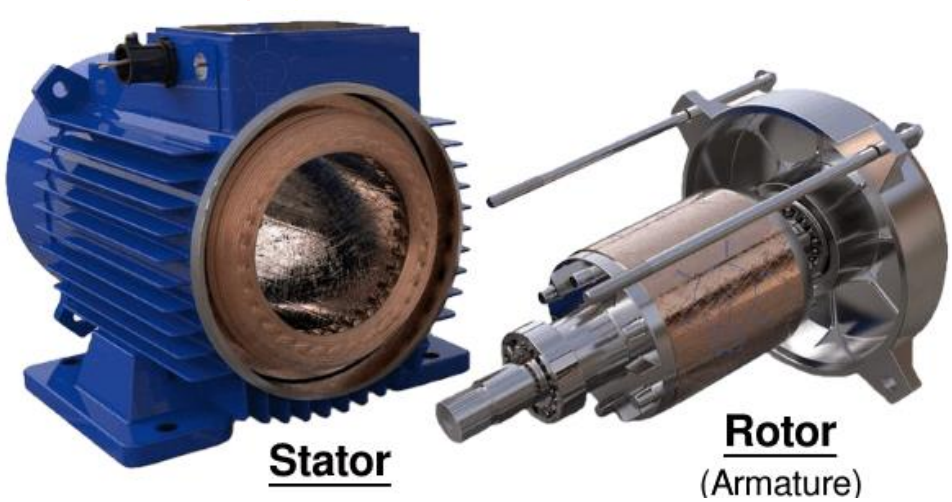


Fig. 2 – ROTOR AND STATOR

Field Coil or Stator: A DC Motor field coil is a non-moving part on which winding is wound to produce a magnetic field. It has a cylindrical cavity between it's poles.

Commutator: The commutator of a DC Motor is a cylindrical structure that is made up of copper segments stacked together but insulated from each other using mica. The primary function of commutator is to supply electrical current to the armature winding.

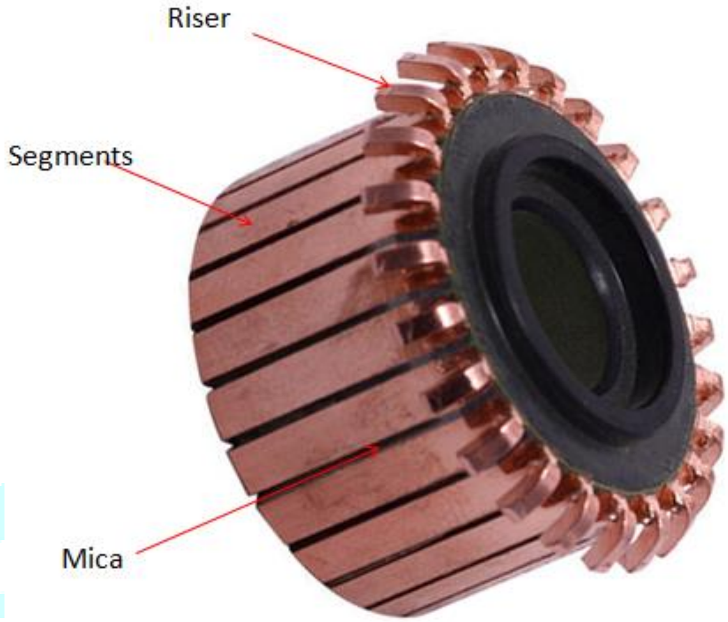


Fig. 3- COMMUTATOR OF DC MOTOR

Brushes: The brushes of a DC Motor are made with graphite and carbon. These brushes conduct electric current from the external circuit to the rotating commutator. Brushes and Commutator together transmit the power from the static electrical circuit to the mechanically rotating region or the rotor.

Fig. 4 – CARBON BRUSH OF DC MOTOR

A magnetic field arises in the air gap when the field coil of the DC Motor is energised. The created magnetic field is in the direction of the radii of the armature. The magnetic field enters the armature from the North pole side of the field coil and "exists" the armature from the field coil's South pole side. The conductors located on the other side pole are subjected to a force of the same intensity but in the opposite direction. Theses two opposing forces create a torque that causes the motor armature to rotate.

TYPES OF DC MOTOR:

There are mainly four types of DC Motor: Permanent Magnet DC Motor, Series DC Motor, Shunt DC Motor and Compound DC Motor.

Permanent Magnet DC Motor: The Permanent magnet motor uses a permanent magnet to create field flux. This type of DC Motor provides great starting torque and has good speed regulation, but torque is limited so they are typically found on low horsepower applications.

Series DC Motor: In a series DC Motor, the field is wound with a few turns of a large wire carrying the full armature current. Typically, series DC Motor creates a large amount of starting torque but cannot regulate speed and can even be damaged by running with no load. These limitations mean that they are not a good option for variable speed drive applications.

Shunt DC Motor: In Shunt DC Motor, the field is connected parallel to the armature windings. These motors offer great speed regulation due to the fact that the shunt field can be excited separately from the armature windings, which also offer simplified reversing controls.

Compound DC Motor: DC Motor having both series and shunt field windings is known as Compound DC Motor. Theses also have a separately excited shunt field. They have good starting torque but may experience control problems in variable speed drive applications.

APPLICATIONS OF DC MOTOR:

(1) Series dc motors are used in cranes, air compressors, vaccum cleaner, sewing machine, etc.
(2) Shunt dc motors are used in Lathe machines, Fans, Blowers, Conveyors, Lifts, Spinning Machines, Weaving Machines, etc.
(3) DC Motors are used in Presses and Shears.
(4) DC Motor of Compound type are used in Elevators and Heavy Planners.
(5) DC Motors are used in Rolling and Steel Mills.
(6) DC Motors are used to power those hydraulic pumps which are essential in almost every industry including construction, mining, manufacturing and steel.
(7) They are different types of motor which are used in electric cars and other vehicles.
(8) DC Motor for toys are a popular choice for manufacture, with these 'toy motors' often used in children's toys such as remote control cars and trains where small DC Motor works well.

NECESSASITY OF SPEED CONTROL OF DC MOTOR

Speed Control in the DC Machine shows an impact on the speed of rotation of the motor where this direct influence on the machine functionality and is so important for the performance and outcome of the performance. At the time of drilling, every kind of material has it's own rotational speed which changes depending upon the drill size. It is a machine which converts electrical energy into mechanical energy. In a mechanical system, speed varies with the number of tasks so speed control becomes necessary here for the machine to do mechanical work in a proper way. It makes motor to operate properly.

DC Motor speed control is done either manually by the worker or by using any intelligence techniques. This seems to be in contrast to speed limitation where there has to be speed regulation opposing the natural variation in the speed because of the variation in the shaft load. In this research paper we have discussed the PI Controller method and then Fuzzy Logic Controller Method. We have done a comparative analysis between PI and FLC.

PROPORTIONAL INTEGRAL (PI) CONTROLLER

Proportion Integral controller sometimes also known as Proportional plus integral (PI) controller. It is a type of controller formed by combining proportional and integral control action. Thus, it is known as PI controller. It is a type of feedback control. In this project, a one quadrant GTO chopper has been used as power conditioning unit in the experimental setup using a separately excited DC Motor. Most DC motor drives are operated as closed – loop speed control system. In the proportional – integral controller, the control action of both proportional as well as the integral controller is utilized. The combination of two different controllers produces a more efficient controller which eliminates the disadvantage associated with each one of them.

A simple proportional gain in the speed loop may not be sufficient to provide a precise control on the speed of drives. This may result in the high overshoot and also an undesirable steady state error in speed. Therefore, some kind of compensation technique has to be employed to improve the performance of the drive. The mostly used compensation method for DC Motor drive is Proportional plus integral (PI) Control.

Advantages of PI Controller

- Due to presence of the integral term, steady state error in speed is zero, making the system more accurate.
- It provides a faster response than I–only Control due to the addition of proportion action.
- PI control stops the system from fluctuating.
- It is able to return the system to the initial set points.
- No steady state error.
- It is quite satisfactory and robust.
- It is not necessary to use such high gains as required in proportional gain controller.

Disadvantages of PI Controller

- If a very fast response is desired, then there will be a penalty in the form of higher overshoot in speed, which is not desirable.
- Narrower range of stability.
- A high gain cannot be used because that will result in high overshoot.
- If one would like to design it without any overshoot then response to the load change will become slow.

Theory of PI Controller

The block diagram of the motor drive with the PI Controller has one outer speed loop and one inner current loop. K_P and K_I are the proportional and integral gains of the PI controller. The output of the PI controller E_1 acts as a current reference command to the motor, C_1 is a simple proportional gain in the current loop and K is the gain of the machine. For analysis, the electrical time constant can be neglected, since it is very small as compared to the mechanical time constant of the motor.

PI Controller Model

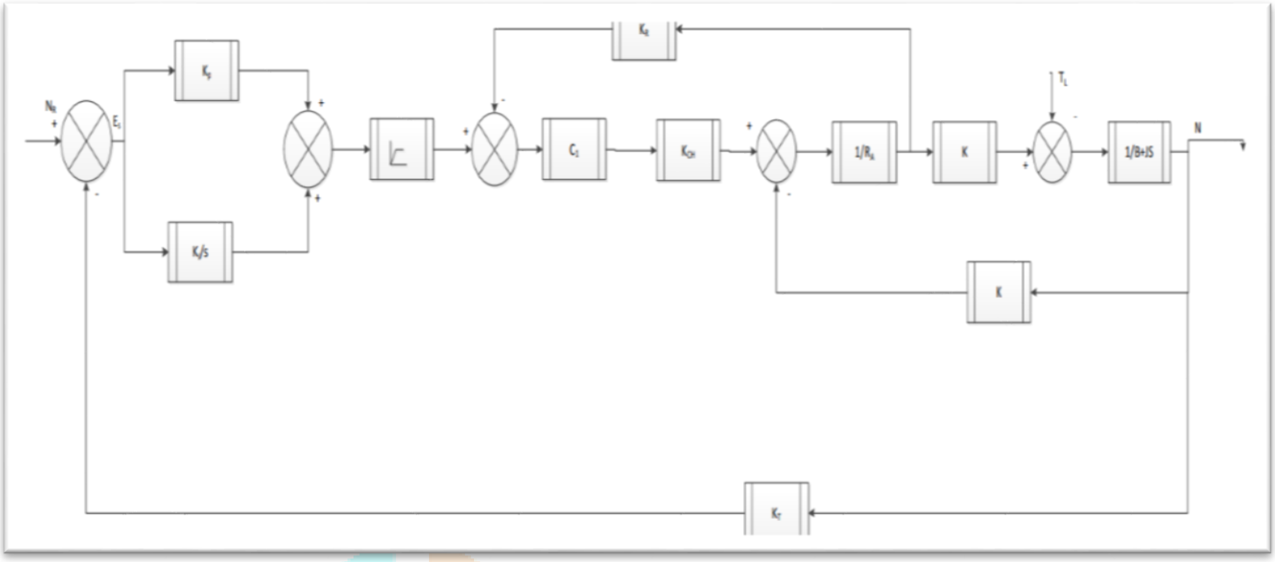
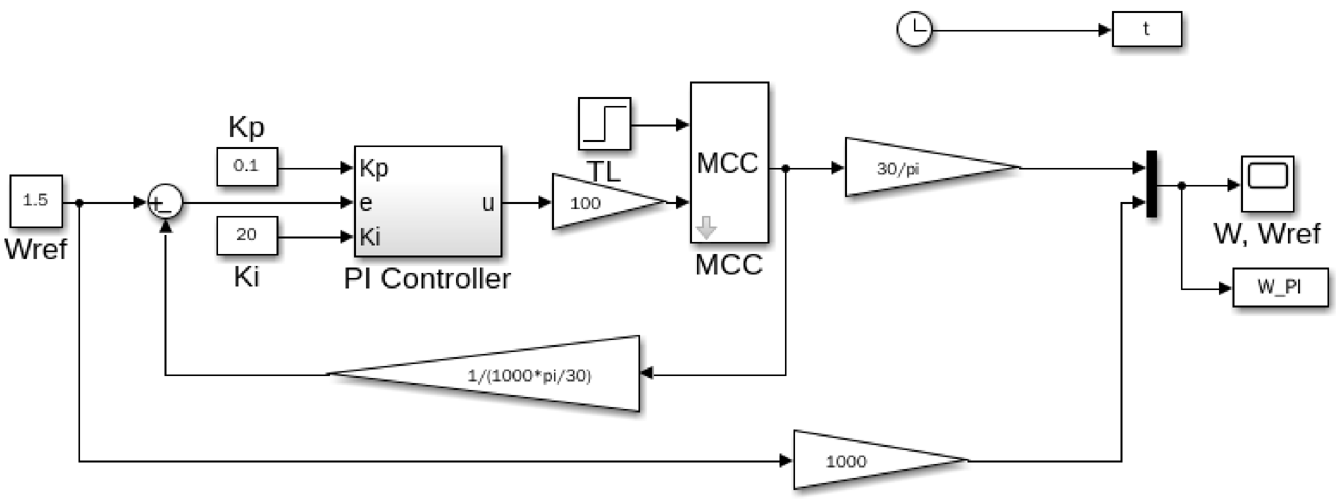
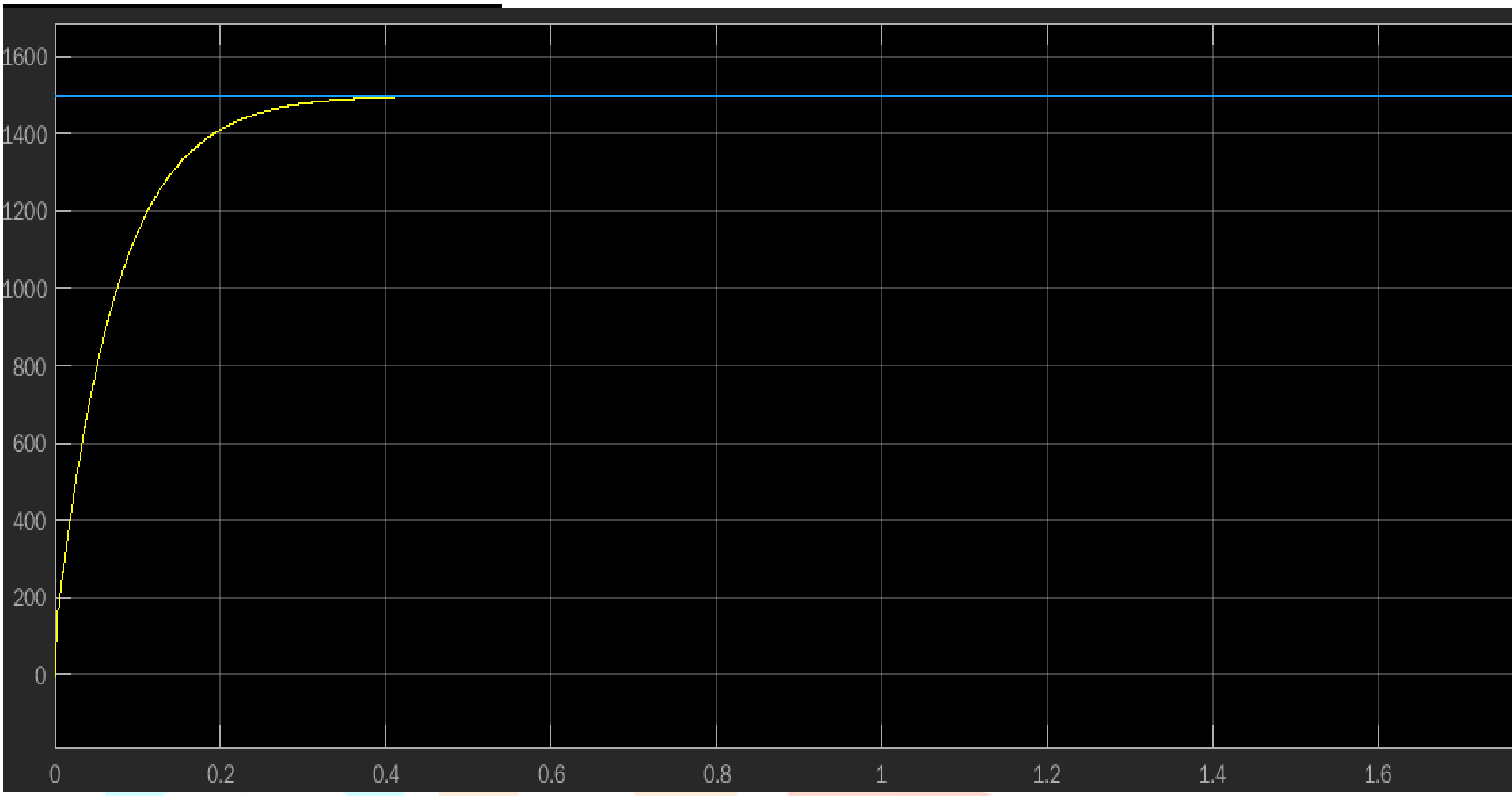


Fig. 5 - PI Controller Model

PI Controller MATLAB/SIMULINK Model:



Matlab Result of PI Controller:



FUZZY LOGIC CONTROLLER (FLC)

Fuzzy Logic Control is one of the control algorithm based on a linguistic control strategy, which is being derived from expert knowledge into an automatic control strategy. Fuzzy logic control does not need any kind of difficult mathematical calculations like other controls. While the other types of control systems use difficult mathematical calculations to provide a model of the controlled plant, fuzzy uses only simple mathematical calculations to simulate the expert knowledge. Although it does not need any difficult mathematical calculations, but it gives good performance in a control system. Thus, it can be one of the best available answers today for a broad class of challenging control problems.

Principle Elements to a Fuzzy Logic Controller:

Fuzzy Logic Controller basically has four components:
(1) Fuzzification
(2) Interference engine
(3) Rule bases and data bases
(4) Defuzzification

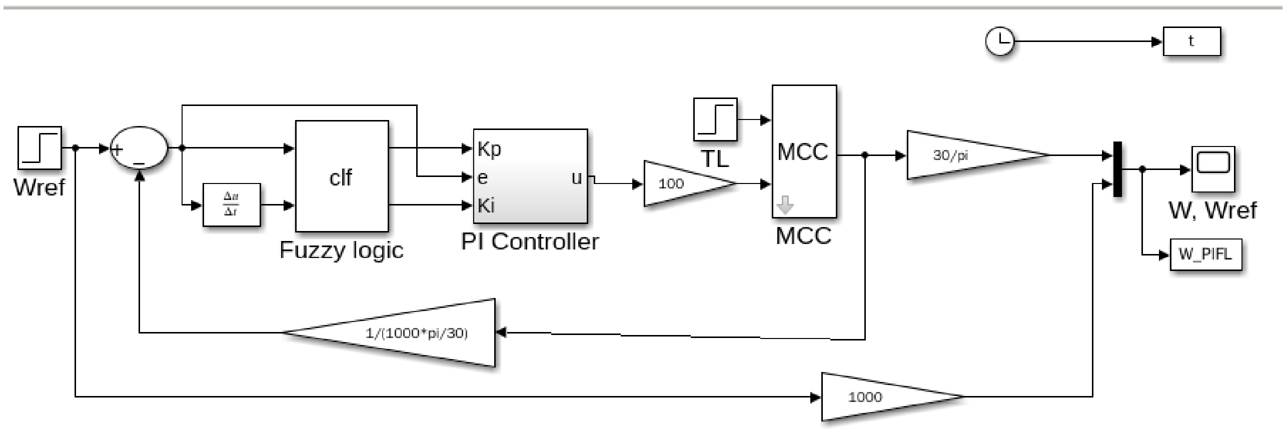
Fuzzification: This is the first block of the controller which converts the measured inputs into the fuzzy linguistic values. The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to the controller. Usually, Fuzzy Logic uses linguistic variables instead of any precise or numerical variables. The process of transforming a numerical value into a linguistic variable is called fuzzification. It measures the input variables. It also performs a scale mapping that transfers the range of input variables into corresponding universe of discourse. Here, speed error and it's derivative that is change in speed error are chosen as the input variables.

Interference Engine: The fuzzy interference engine is the kernal of a FLC. It has a capability of making human decisions based on fuzzy concepts or inferring fuzzy control actions employing fuzzy implantation.

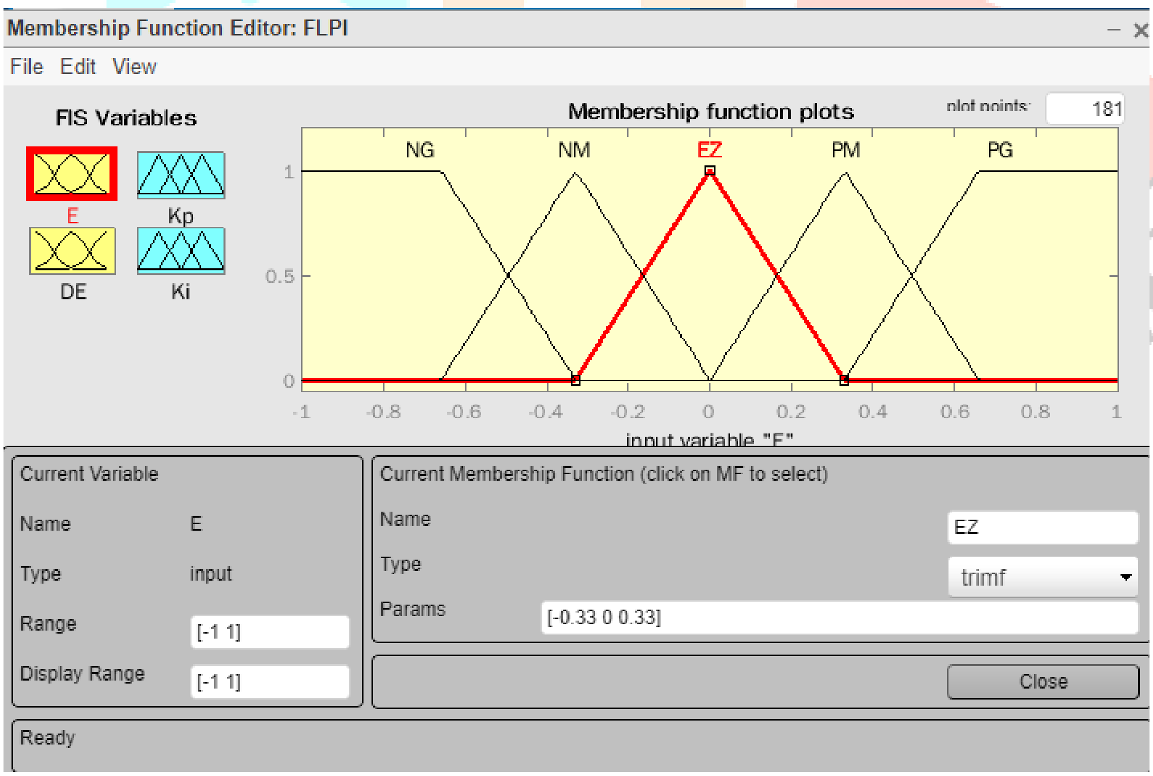
Rule Base: The collection of rules is called rule base. In this, if- side is called condition and then – side is called as conclusion. The rule reflects the strategy to control signal should be a combination of reference error and change in error. It comprises of knowledge of application domain. It consists of data base and linguistic control rule base.

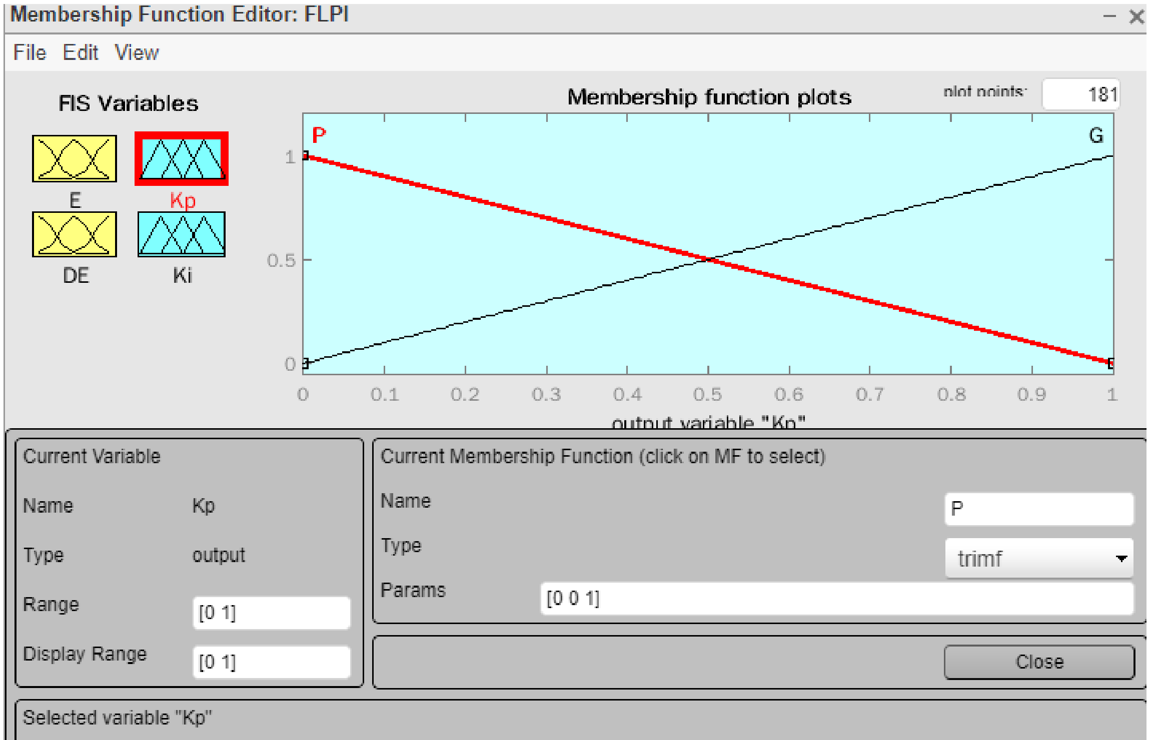
Defuzzification: The reverse of fuzzification is called defuzzification. It is the transformation of a fuzzy quantity into a precise quantity, just like fuzzifications is the conversion of a precise quantity into a fuzzy quantity.

PI Fuzzy Logic MATLAB/SIMULINK Model



PI Fuzzy Logic Simulink Result

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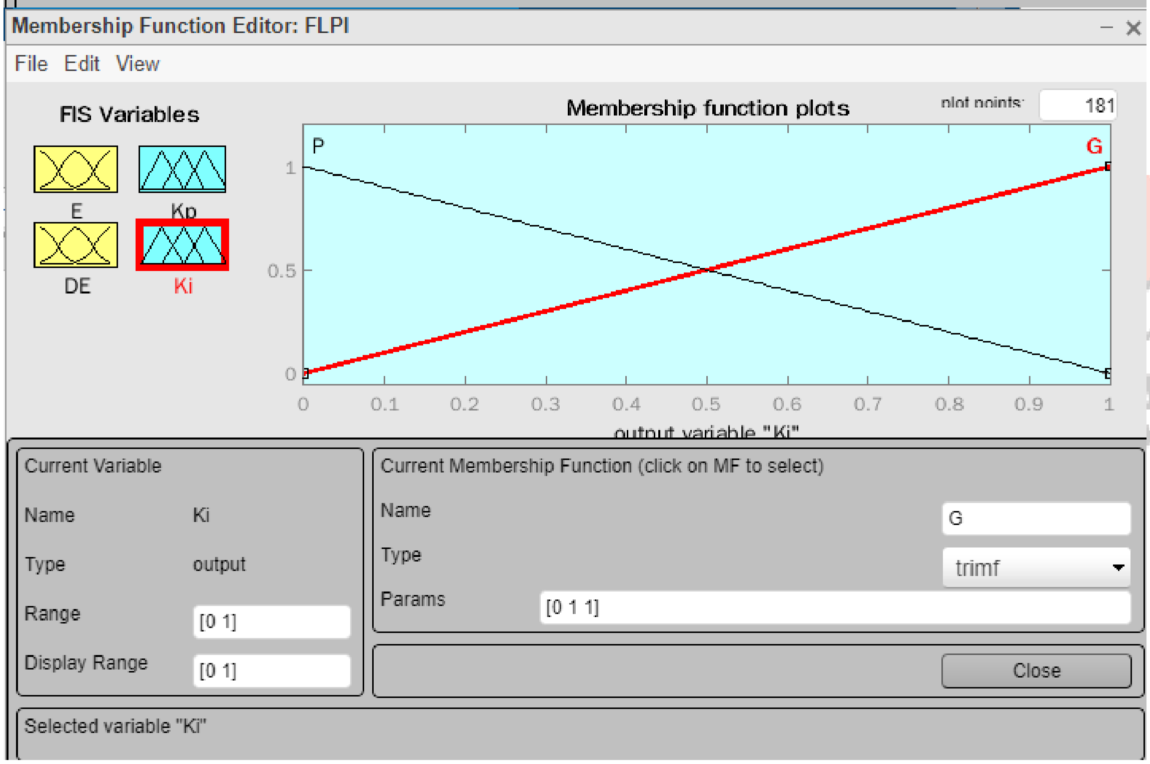
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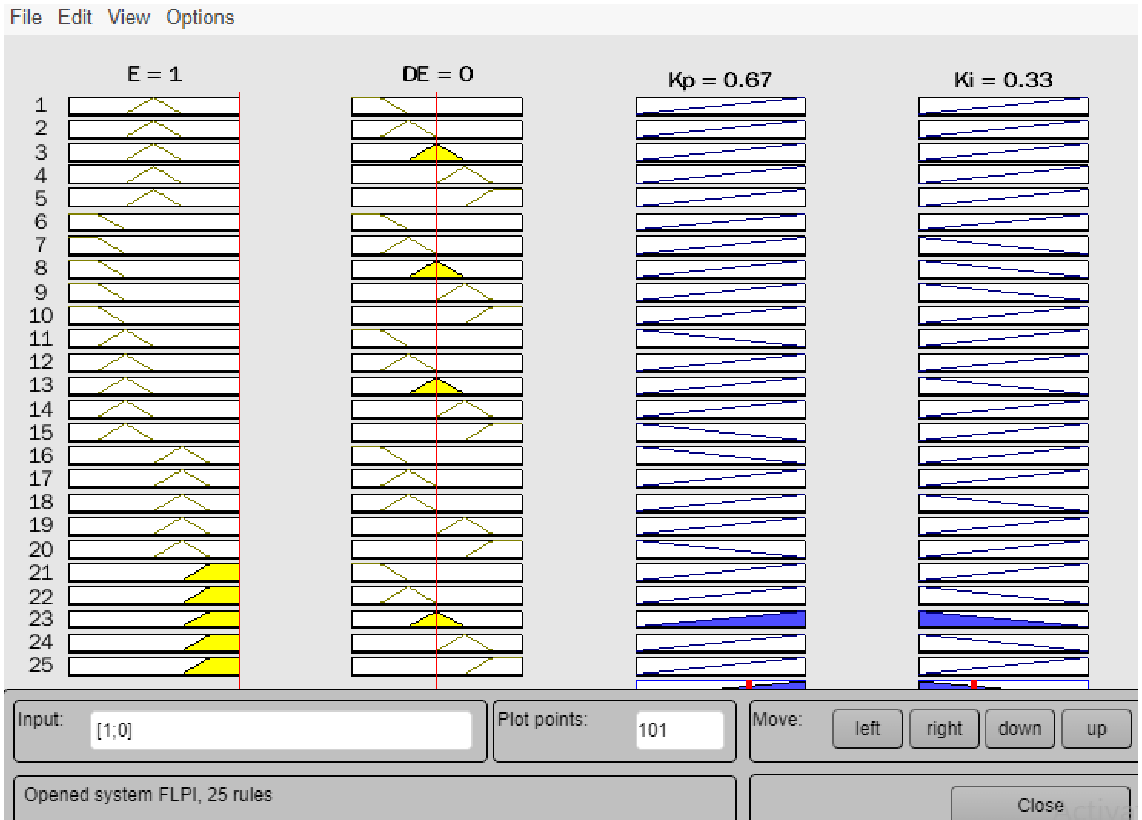

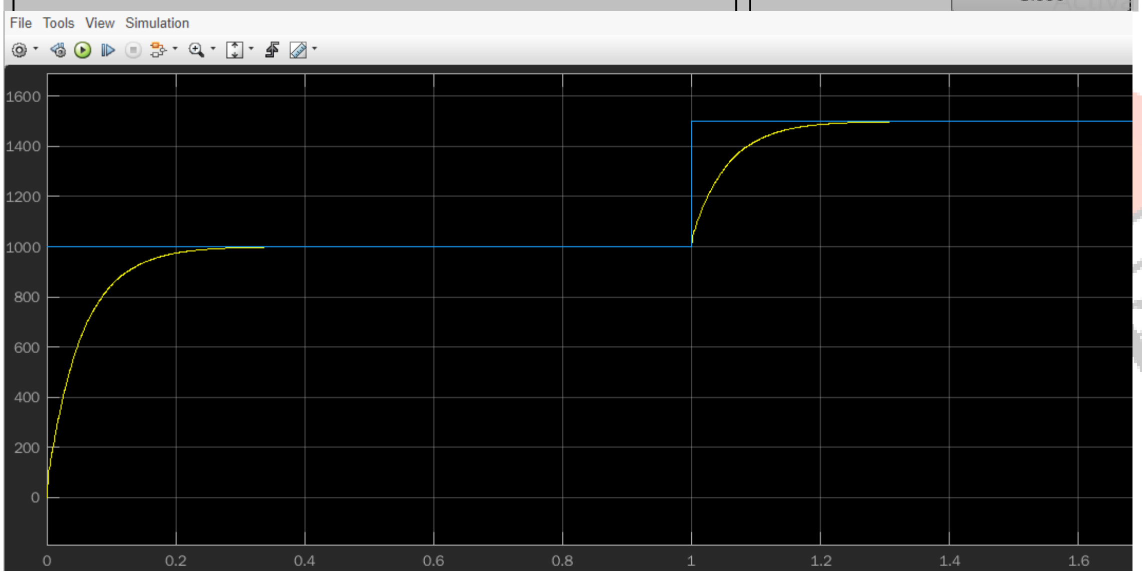

Conclusions:

The background of DC Motor is studied in this project. Most importantly, speed control of a DC Motor has been studied by PI Controller and Fuzzy Logic Controller method. The speed control of DC Motor has been done in MATLAB/SIMULINK because they allow various dynamic characteristics such as phase current, voltage, rotor speed and mechanical torque are considered. Here, MAMDANI algorithm has been used in fuzzy logic. Also, simulation is cheaper than actual experiments models and gives more accurate values. We have made a comparison between PI and Fuzzy Logic in which we found that Fuzzy systems given the better performance than other conventional controllers with less overshoot and no oscillations. Graph for the speed response of a DC Motor using fuzzy logic controller is compared with the graph for the speed response of a DC motor without fuzzy logic. Controller. Through our research, we have tried to build up a great idea for DC Motor and basis of it's control systems.

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