COMPREHENSIVE REVIEW: SPEED CONTROL OF DC MOTOR USING FUZZY LOGIC CONTROL

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Abstract: The consistency and presentation of the AC drives depends on the development in different methods likes microelectronics, power electronics, control methods, artificial intelligent techniques and so on. FLC (Fuzzy Logic Concept) is one of the Artificial Intelligent methods have found high applications in most of the nonlinear systems like the electric drive motors. Fuzzy Logic Concept can be used while any system controller without necessity of the system mathematical model unlike that of the conventional electrical drive control, which uses the mathematical model. Because of the usage of the FLC concept, the reliability, efficiency & performance of the AC drives are increases. In vision of the previously mentioned concepts, this paper describe basic concept of fuzzy logic controller scheme designed and apply for the speed control of a DC motor by using the PID (Proportional-Integral-Derivative) controller and PSO (particle swarm optimization) approach for formative optimal PID controller tuning parameters. The proposed approach has better feature, stable convergence characteristics, easy implementation and very good computational performances efficiency.

Keyword-Artificial Intelligence, Electric drive, Induction machine, Space vector pulse width modulation, Fuzzy logic control, PID controller.

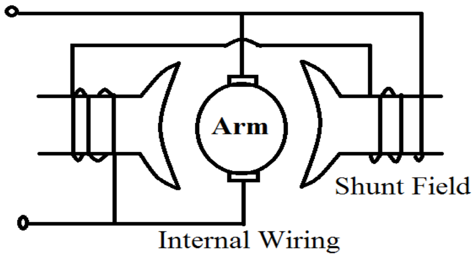
I. INTRODUCTION

Resent year PID (Proportional-Integral Derivative) controllers are widely used in industrial plants since it is robust and simple. Processes of Industrial are subjected to difference in parameters and parameter perturbations, which while significant makes the system unstable. Consequently the engineers are on look for automatic tuning procedures. From the control point of view, DC motor characteristics are show excellent control because of the decoupled nature of the field. Newly, many modern control methodologies like nonlinear control, optimal control, variable adaptive control and structure control have been broadly proposed for DC motor. Though, these approaches are either difficult in theoretical bases or complex to implement. Proportional-Integral Derivative control among its three term functionality casing action to both steady-state and transient response, offers the simplest and yet most efficient solution too various real world control problems. In the simple structure and robustness of this method, optimally tuning gains of Proportional-Integral Derivative controllers have been quite difficult. Now a day, the fuzzy logic approach offers a quicker, simpler and more reliable solution that is advantage over conventional techniques. Fuzzy logic may be seen as set theory from [10]. While compared to the conventional controller, the major advantage of fuzzy logic is that no mathematical modeling is necessary. Seeing as the controller system are especially based on the knowledge of the system behavior and experience of the control engineer, the fuzzy logic concept requires less complex mathematical modeling than other classical controller does.

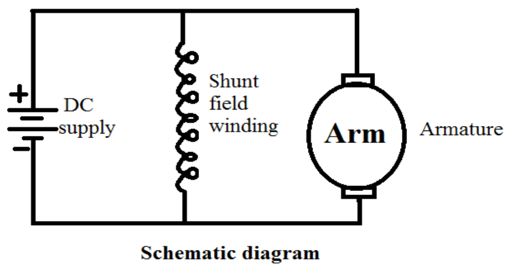
II. THE INTRODUCTION of DC MOTOR

Usually an electric motor transfer electric energy to mechanical energy by using interacting magnetic fields. Basically, Electric motors are used for a extensive variety of commercial, residential and operations of industrial. As situation the connection for a DC motor is illustrated in Figure (1) and DC motor consists of a shunt field connected in parallel with the armature. The shunt field winding is prepared up of many small-gauge wire turns and has a much higher resistance and lower current flow compared to a series field winding. Accordingly, these types of motors have excellent speed and position control. Therefore DC shunt motors are characteristically used applications that need five or more horse power. The dynamic behavior equations describing of the DC motor based on the schematic diagram illustrate on (2) are given by the following equations:

$$Va = Ra.ia(t) + La.\frac{dia\,(t)}{dt} + eb(t) \qquad ....1$$



(a)



(b)

Figure 1: Diagram of DC Shunt Motor (a)basic diagram (b)schematic diageam

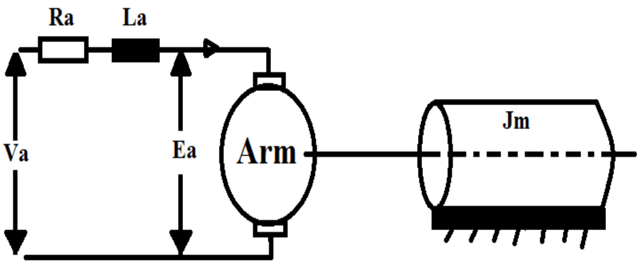


Figure 2 Schematic Diagram of DC Motor

$eb(t) = Kb.w(t)$ ….2
$Tm(t) = KT.ia(t)$ ….3
$Tm = jm.\frac{dw(t)}{dt} + Bm.w(t)$ ….4
$Tm = jm.\frac{d\theta 2(t)}{dt} + Bm.\frac{d\theta(t)}{dt}$ ….5

After simplification and get the ratio of θ(s)/v(s).
The transfer function will be given below:

$\frac{\theta(s)}{v(s)} = Kb/[JLaS3 + (RaJ + BLa)S2 + (Kb2 + RaB)s]$ ….6

Here: va= armature voltage(v), Ra= armature resistance(Ω), La=armature inductance (H),Ia=armature current (A),Jmjm=rotorinertia , Bm=viscousfriction coefficient (Nms/rad). KT=torque constant, Kb=back emf constant (Vs/rad).

III. BASIC DESCRIPTION OF THE PID CONTROLLER

Basically, the development of Proportional-Integral Derivative control theories has already been from 60 years ago. Proportional-Integral Derivative control has been one of the control system methods of the longest history. Though this method is now a day widely used [4] [5]. Proportional-Integral Derivative controller is essentially to adjust an appropriate proportional gain (Kp), integral gain (Ki), and differential gain (Kd) to get the optimal control performance. These functions have been sufficient to the most control processes. The Proportional-Integral Derivative (PID) controller system block diagram is shown in Figure 3:

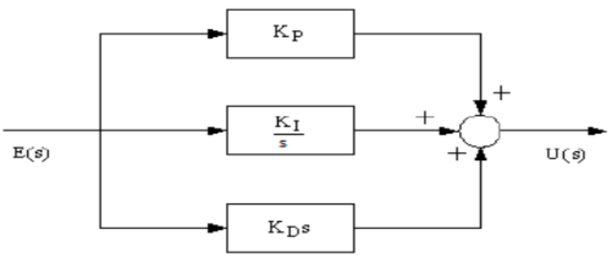


Figure 3: PID controller system block diagram.

The association between the input e(t) and ouput u(t) can be formulated in the following:

$U(t) = Kpe(t) + Ki\int_0^t e(t)dt + KD\frac{de(t)}{dt}$ …. 7

The transfer function is expressed as:

$C(s) = Kp + \frac{Ki}{s}{}_{kDs} = \frac{U(s)}{E(s)}$ ….8

The DC motor speed control system using PID control system block diagram is illustrated in Figure 4:

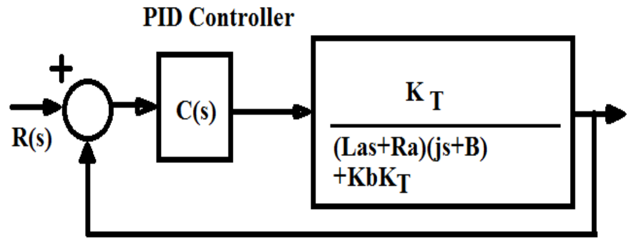


Figure 4 Speed control of DC motor using PID controller

There are various types of tuning method of PID controller like PSO Particle Swarm Optimization, ziegler-nichols tuning method, Fuzzy Logic method etc. In this paper Fuzzy Logic Control system is explained.

IV. FUZZY LOGIC CONTROL DESCRIPTION

The fuzzy logic establishment is based on the simulation of people's opinions and perceptions to control any required system. One of the methods to make simpler complex systems is to accept to vagueness, precision and uncertainty up to some extent [11]. Fuzzy control is provides a really simple way to draw specific conclusions from vague ambiguous or imprecise information. Fuzzy logic is appropriate for applications such as the speed control of dc motor which has non-linear characteristics. A fuzzy logic control system is a system in which a analyzes the mathematical system that analog input values in terms of logical variables that obtain on continuous values between 1 and 0, in contrast to classical or digital logic, which operates on discrete values of either 0 or 1 (false or true, respectively). FLC (fuzzy Logic Concept) provides a easy way to appear at a definite conclusion based upon noisy, vague, ambiguous, imprecise, or missing input information. FL's approach to control problems mimics how a person makes decisions, only much faster. Fuzziness function is related with the degree to which events occur rather than likelihood of their occurrence. Fuzzy Logic have some advantages compared to other classical controller such as low cost and the possibility to design without knowing the precise mathematical model of the process. FL (Fuzzy Logic) incorporates an alternative way of thinking which allows complex design systems using higher level of abstraction originating from the knowledge and experience.

Characteristic Components of a Fuzzy Logic Controller are:

- Preprocessing
- Fuzzification
- Rule Base
- Defuzzification
- Post processing

A. Preprocessing:

The inputs of fuzzy logic are mainly often hard or crisp measurement from some measuring equipment rather than linguistic. A pre-processor block is illustrated in Figure: 5 the measurements conditions before enter the controller.

B. Fuzzification:

The first block inside the controller is fuzzification which converts each part of input data to degrees of membership by a lookup in more than one membership functions.

C. Rule Base:
The rule base is define as the collection of rules. The rules base are in “If Then” format. Formally the ‘If’ side is called the conditions and the ‘Then’ side is called the conclusion. Basically the computer is capable to perform the rules and compute a control signal depending on the measured inputs error (e) and change in error (Ce).

D. Defuzzification:
Defuzzification is while all the procedures that have been activated are converted and combined in to a single non-fuzzy output signal which is the control signal of the system. The output values are depending on the rule base that the systems have and the positions depending on the non-linearity’s offered to the systems. To accomplish the results, develop a system control curve representing the I/O relation of the system, and based on the information describe the output degree of membership function with the aim to minimize the effect of non-linearity.

E. Post processing:
The post processing is often contains an output gain that can be tuned and also become as an integrator. An skilled operator develops flexible control mechanism using words like "not very suitable, suitable, high, little much high.”. Figure 5 illustrate process blocks for a fuzzy controller.

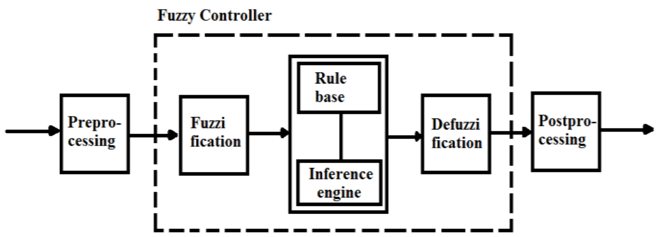


Figure 5: Process Blocks for a Fuzzy Controller.

Though the classic controllers depend on the accuracy of the system model and parameters, Fuzzy Logic Concept uses different strategies for motor speed control. Generally, fuzzy logic concept process is based on linguistic and experiences definitions as a replacement for of system model. It is not required to recognize exact system model to design fuzzy logic concept. Furthermore, if there is not enough knowledge about control process, fuzzy logic concept may not give satisfactory results [9].

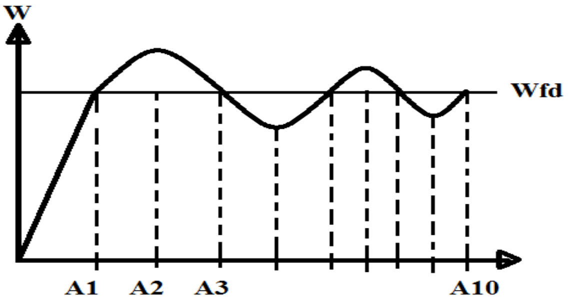
Defining Input and Output:
The aim of designed fuzzy logic control in this study is to control speed. Additionally, the change of error plays an important role to describe controller input. As a result fuzzy logic control uses error (e) and change of error (Ce) for variable of linguistic which are generated from the control rules. Equation (9) and Equation (10), determines required system equations as:

$e(t) = r(t) - u(t)$ ….9

$\acute{e}(t) = e(t) - e(t-1)$ ….10

Here, r(t) is desired speed and u(t) is actual speed.

Defining membership functions and rules:
Fuzzy logic system speed comes to reference value by means of the defined rules. For example, first basic rules is, ‘if e(t) is NA then u(t) is DM’. According to this rule, if value of error is negative large then output will be negative large. To calculate FLC (Fuzzy logic concept) output value, the output and inputs must be transformed from ‘crisp’ value into linguistic from. Fuzzy logic membership functions are used to perform this conversion.



	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9	A1 0
ea	+	-	-	+	+	-	-	+	+	-
Ce a	-	-	+	+	-	-	+	+	-	-

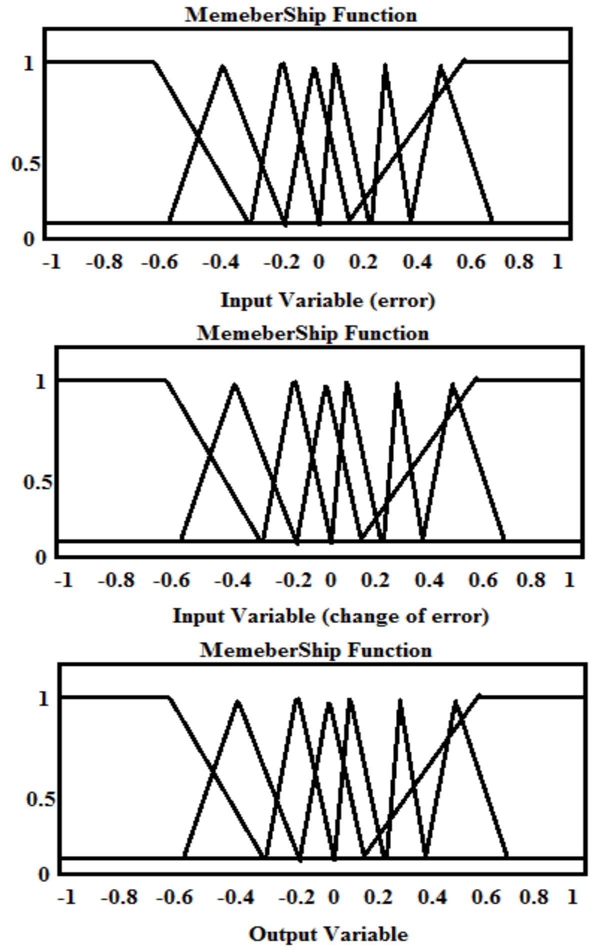


Figure 6: Linguistic for angle determination of the drive circuit (a) Speed error (b) change of speed error (c) change of alpha

Basically fuzzy membership functions convert into crisp are used to perform this conversion. Therefore, while simple numbers are now processed in controller after scaling, fuzzy computation is performed in a shorter time. The linguistic terms for output and input values are represented by seven membership functions as illustrate in Fig. 6.

V. CONCLUSION

Speed control of the DC motor system using both fuzzy logic control system and PID control system has been presented in this paper. Comparison of both control systems PID and fuzzy logic control system, fuzzy logic control system is better than PID control system. In the fuzzy logic control system is not required to mathematical model like PID controller and fuzzy control work with few input data. Therefore, fuzzy logic control system is easy to implementation, easy to control of DC motor. We were able to construct a well performed fuzzy logic logic controller based on the experience about the position controller.

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