Fuzzy Logic in Electrical Systems

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Abstract

With the advent of modern computer technology, the field of Artificial Intelligence is showing a definite utility in all spectrum of life. In the field of control, there is always a need for optimality with improved controller performance. In this paper, the feasibility of Fuzzy Logic as an effective control tool for DC motors is dealt with. The Fuzzy Logic Controller (FLC) is showing a better performance than conventional controllers in the form of increased robustness. In this paper, the role of Fuzzy Logic as a controller and its implementation is studied.

Keyword- Fuzzy Logic Controller (FLC), Fuzzification, DC Motors

I. INTRODUCTION

- Fuzzy logic is a powerful problem solving methodology introduced by Lotfi Zadeh in 1960's.
- It provides tools for dealing with imprecision due to uncertainty and vagueness, which is intrinsic to many engineering problems.
- It is a superset of Boolean or Crisp logic.
- It emerged into mainstream of information technology in late 1980's and early 1990

II. FUZZY LOGIC

- Fuzzy logic resembles human decision making with its ability to work from approximate data and find precise solutions.
- Classical logic or Boolean logic has two values or states. Eg. (true or false). It requires a deep understanding of a system, exact equations, and precise numeric values.
- Fuzzy logic is a continuous form of logic. eg (bad, very bad, poor, average). It allows modeling complex systems using a higher level of abstraction originating from our knowledge and experience.

III. WORKING OF FUZZY LOGIC

- The working of fuzzy logic can be understood by considering a simplified example of a thermostat controlling a heater fan.
- The room temperature detected through a sensor is input to a controller, which outputs a control force to adjust the heater fan speed.
- The first step in designing such a fuzzy controller is to characterize the range of values for the input and output variables of the controller.
- Labels such as cool for the temperature and high for the fan speed are assigned and a set of simple English-like rules to control the systems are written.

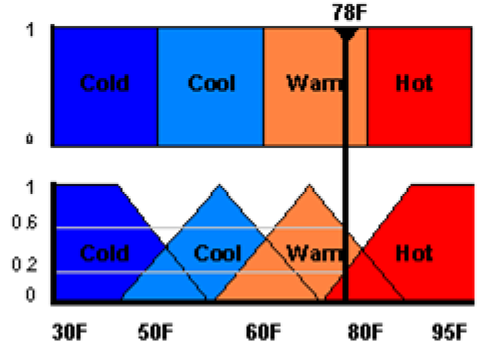

Figure2: Conventionnal and Fuzzy Sets

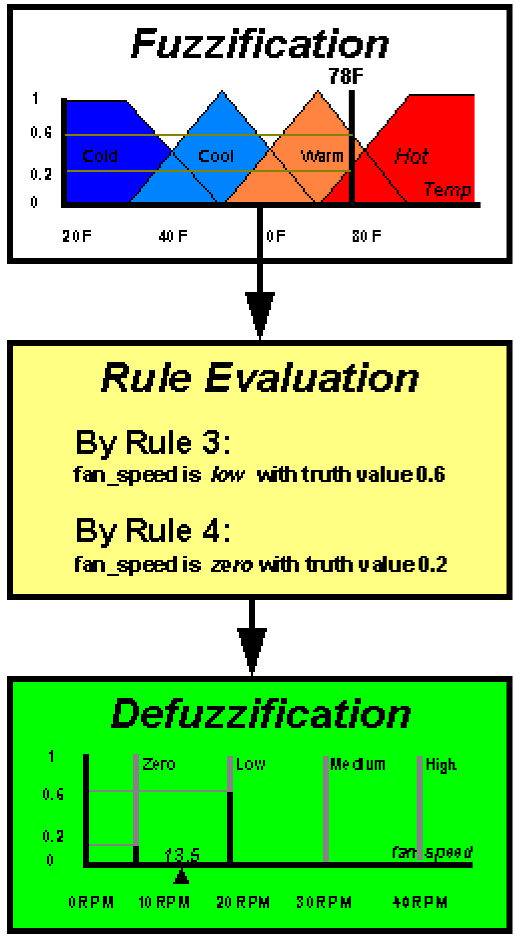

Figure 3 The Fuzzy Inference Process

- Inside the controller all temperature regulating actions will be based on how the current room temperature falls into these ranges and the rules describing the system behavior.

The controller's output will vary continuously to adjust the fan speed. The temperature controller described above can be defined in four simple rules:

IF temperature IS cold THEN fan_speed IS high
IF temperature IS cool THEN fan_speed IS medium
IF temperature IS warm THEN fan_speed IS low
IF temperature IS hot THEN fan_speed IS zero.

- Fuzzy controller accepts an input value, performs some calculations, and generates an output value. This process is called the Fuzzy Inference Process.

The thermostat works in three steps
Fuzzification
Rule evaluation
Defuzzification

IV. Conventional and Fuzzy Design-A Comparison

- The conventional design requires more number of steps than Fuzzy design.
- Fuzzy logic reduces the design development cycle.
- It simplifies design complexity.
- It improves time to market.
- It reduces hardware cost.
- It simplifies implementation.
- It improves control performance.

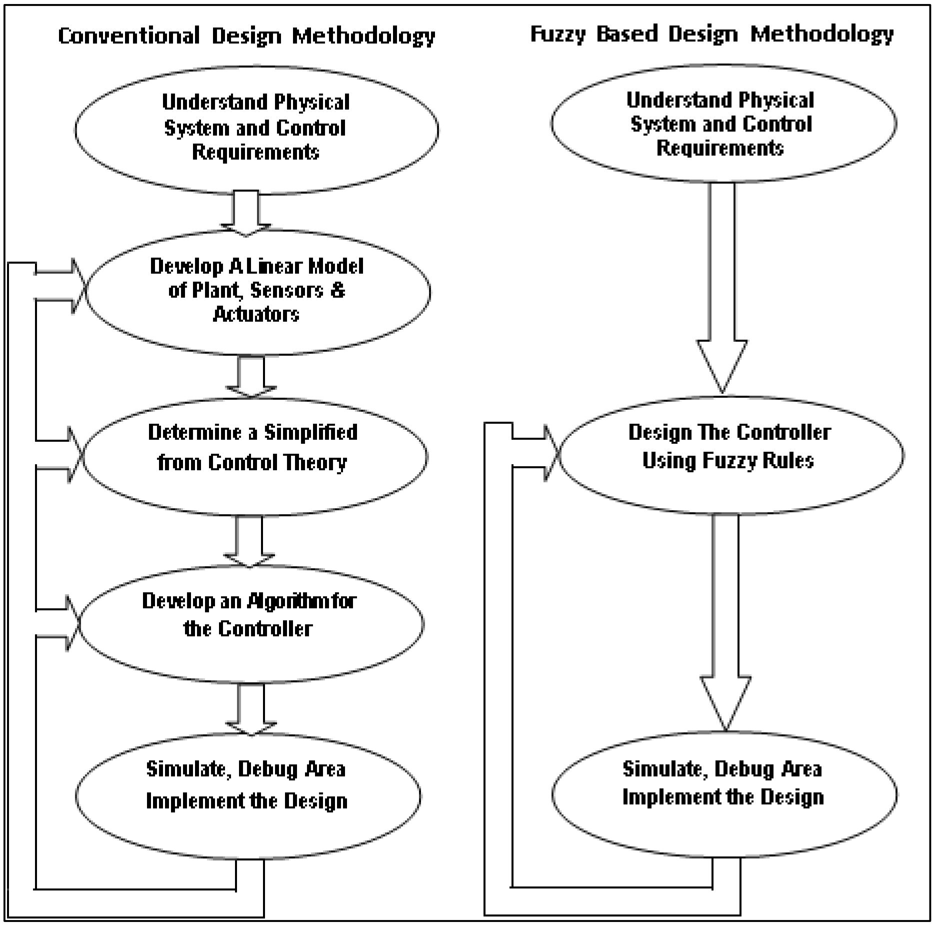

Fig. 4: Conventional and Fuzzy Design

A. Real Time Speed Control of Motor using Fuzzy Logic

- Fuzzy logic control (FLC) technique has become an active area of research in the application of industrial processes, which are not amenable to conventional control techniques.
- It attempts to emulate human mind for monitoring the process parameters and to take decisions regarding the control action.
- The four principal components of FLC include:

Fuzzification interface
Knowledge base
Decision making logic
Defuzzification interface.

1) Fuzzification

- Fuzzification converts the input data namely error, e(t) and change in error, ce(t) into suitable linguistic variables.
- A scale mapping is performed using triangular membership function, which transfers the range of input variables into corresponding universe of discourse.

2) Knowledge Base

- Knowledge base consists of database and rule base.
- Data base provides necessary definitions that are used to define linguistic control rules with a syntax, such as: IF < fuzzy proportion > THEN < fuzzy proportion >
- The 'IF' part is called the 'antecedent' and the 'THEN' part is called the 'consequent'.
- In control applications the antecedents are 'error' and 'change in error' and the consequent is the 'control command'.

3) Decision Making Logic

- Decision making logic infers a system of rules through the fuzzy operators namely 'AND' and 'OR' and generates a single truth value which determines the outcome of rules (inferred fuzzy control action).

4) Defuzzification

- Defuzzification yields a crisp, non-fuzzy control action from an inferred fuzzy control action.

- In the present work, the center of area method is used as the defuzzification strategy.

V. OPEN LOOP INVESTIGATION

- The d.c. motor being controlled, is a 12V, 1.5amp, 20 watts armature controlled permanent magnet motor.
- The motor has a maximum speed of 2500 rpm and drives an output shaft with a 9:1 reduction, achieved through two stages of belt drive.
- A tacho generator is fixed on the motor shaft.
- It produces a d.c voltage in the range of + 5 volts depending on the magnitude of the speed and the direction of rotation of the motor.
- The motor is loaded using an eddy current brake
- The d.c motor experimental set-up is interfaced to the process computer through signal conditioning module and control module.
- The signal-conditioning module consists of ADAM 4012 A/D input module, ADAM 4021 D/A output module and ADAM 4520 communication module (which converts RS 485 protocol to RS 232 protocol before being fed to the computer).
- Open loop studies are carried out on the experimental set-up of the d.c motor.
- A step change in the input voltage is given to the motor.
- The variation of speed is recorded and plotted.
- The d.c. motor parameters are calculated from the open loop response of the motor obtained from the experimental data using reaction curve method.
- The d.c motor is modeled as a first order system with dead time as given below:

$$Gp(s) = \underline{Kp\ e}\ {-}^{\theta s}(1+Ts)$$

With process gain, Kp = 0.88
Dead time, θ = 0.2714 seconds
Time constant, T = 0.04285 seconds

VI. PID CONTROLLER DESIGN

- The PID controller is represented in the velocity form of discrete algorithm as given below:

$$\Delta Un = KC\ [1 + T/TR + TD/T]\ en\text{-}KC\ [1+2TD/T]en\text{-}1+KC\ (TD/T)en\text{-}2$$

- The tuning of controller is carried out using Ziegler Nicholo's tuning rule.
- The controller settings of PID controller thus obtained are given as follows:

K_c = 16.8; T_R = 0.0257 Seconds and T_D = 0.02143 Seconds

VII. FLC DESIGN

- During fuzzification, the fuzzy input variable, error, e(t) ranging from -5V to +5V is converted into five linguistic levels namely Negative large, Negative medium, Zero, Positive medium, and Positive large.
- Similarly, the other fuzzy input variable, change in error; ce(t), ranging from -5V to +5V is converted into five linguistic levels namely Negative large, Negative medium, Zero, Positive medium, and Positive large.
- The triangular membership function is used to perform the scale mapping.
- The membership functions of the three fuzzy variables of the d.c motor system is shown
- The variation of controller output with error and change in error is shown.

VIII. RULE BASE

- The behaviors of the control surfaces are defined by the rules that tie together the fuzzy variables. In the present case 21 Rules are framed.
- All the rules are represented in the form of a rule base matrix.
- In the matrix, the antecedents are the error and change in error. The consequent of the rules are the manipulated variables, given in the box. The outcome of the rules namely the truth-value is obtained using max-min criteria.
- The non-fuzzy crisp output from the FLC is obtained by carrying out defuzzification using the center of area method.
- The crisp output thus obtained is given below:

$$Z_0 = \frac{\sum_{j=1}^{N} \mu z\ (Wj)\ (Wj)}{\sum \mu z\ (Wj)}$$

Where j= 1 to N, the number of quantization levels

Wj is the support value at which the membership function reaches the maximum value.
(μz Wj) maximum value of membership function corresponding to the quantization level.

IX. RESULTS AND DISCUSSIONS

A. PID Scheme Simulation

- After tuning the PID controller, its performance for set-point tracking is studied.
- The closed loop response with the PID controller for set-point tracking is displayed.
- The response shows overshoot.
- The oscillations before reaching the set point would affect the life of the controller.

B. FLC Scheme and Description

- After tuning the FLC, its performance for set-point tracking is studied.
- The closed response of the motor with a Fuzzy Logic Controller is given
- It can be seen from the response that, the motor reaches the set point without oscillations and overshoot.
- There is also improvement in both the rise time and settling time.

X. REAL TIME CONTROL OF DC MOTOR USING PID CONTROL

- The PID control scheme is implemented on the d.c motor.
- The controller output is given to the motor through ADAM 4021 D/A output module.
- The real time closed loop response of PID controller set-point tracking is shown

XI. REAL TIME CONTROL OF DC MOTOR USING FUZZY LOGIC CONTROL

- The FLC scheme is implemented on the d.c motor using 7 quantization levels and 21 rules.
- Tuning is carried out by adjusting the membership values and rule sets.
- The real time closed loop response of the FLC scheme for set-point tracking is displayed
- FLC performs well compared to PID controller.
- The response does not show much overshoot and settled quickly without any oscillations.
- Also there is no offset in the closed loop response.

XII. CONCLUSION

- The present work brings out the potential advantages of applying FLC technique for speed control of d.c. motor.
- The FLC performance has good set-point tracking.
- Moreover, because of their reliance on rules based on expert knowledge, they provide their environment, a higher machine intelligent quotient.
- The center of area method takes the center of gravity of final fuzzy space and produces a result that is sensitive to all the rules in particular.
- The results tend to move smoothly across the control surface.
- The comparison of closed loop performance of both the schemes show the superiority of FLC scheme over PID control.
- FLC can therefore be an effective control strategy for the speed control of d.c. motor.

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