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Design Algorithm of Artificial Intelligence for Speed Control of 3-phase Squirrel-Cage Induction Motor (SCIM)

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Abstract—*Design a " fuzzy logic controller" for Speed control of 3-phase Squirrel Cage Induction Motor (SCIM) for various application.*
In the designing of a controller, the main criterion is the controllability of torque in an induction motor with good transient and steady state responses, these characteristics which can be achieved by PI controller but with certain drawbacks.
Fuzzy logic controller is controlling system based on fuzzy logic concepts. It is a non-linear mapping between input & outputs. It takes decisions depending on if-then rules and fuzzy sets.

Keywords: *Artificial intelligence techniques, Fuzzy logic, induction motor drive, Electrical, Power Electronics..*

1. INTRODUCTION

Recently soft computation is used widely in electrical drives, like;
1. Artificial Neural Network (ANN)
2. Fuzzy Logic Set (FLS)
3. Fuzzy-Neural Network (FNN)
4. Genetic Algorithm Based system (GAB)
5. Genetic Algorithm Assisted system (GAA)
6. Expert system (ES). [11]

In the designing of a controller, the main criterion is the controllability of torque in an induction motor with good transient and steady state responses. With certain drawbacks, PI controller is able to achieve these characteristics, but the main draw-backs are ;

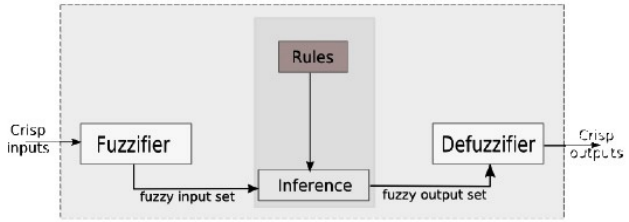
(1) The gains cannot be increased beyond certain limit.
(2) Non linearity is introduced, making the system more complex for analysis.

2. THEORY OF FUZZY LOGIC

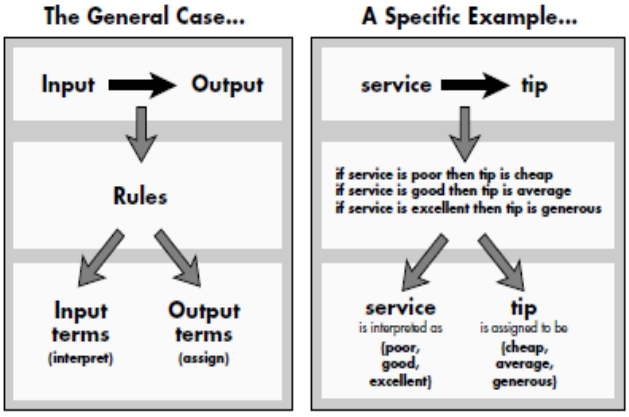
Fuzzy logic to give crisp (Boolean logic i.e.0 or 1) outcomes from fuzzy input variable (linguistic i.e. slow, moderate, fast,wet, cold, hot, dry) called FL.

- Boolean logic: 1 or 0 (Yes or No/ True or false)
- Trivalent logic: 0- 0.5 -1 (three definite answers)
- Fuzzy Logic/ multi valued logic: (0 to 1 i.e. many points can consider)

(i) FLC consists of four main parts



The fuzzification technique involves outlining the membership functions for the inputs. each MFs represents a fuzzy set or a linguistic variable.

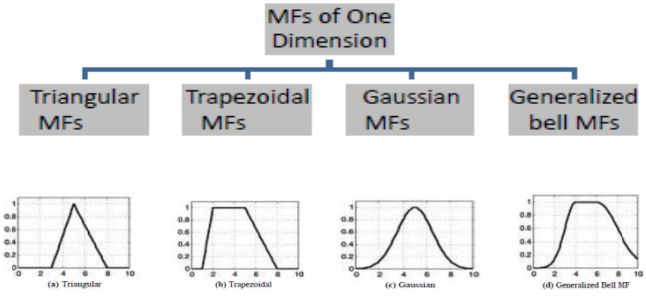


(ii) Membership Function

The fuzzification technique involves outlining the membership functions for the inputs. each MFs represents a fuzzy set or a linguistic variable. Linguistic variables are represented by MFs.

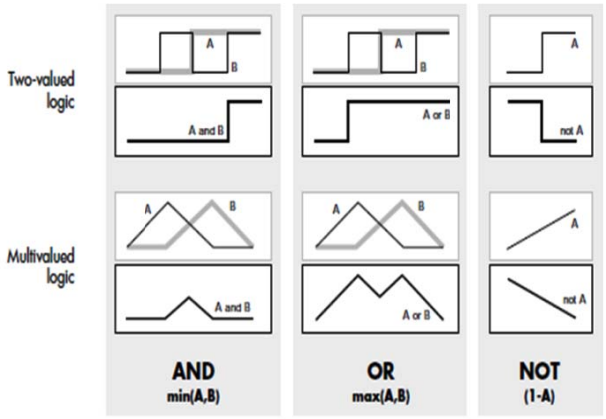
- Triangular MF
- Trapezoidal MF
- Bell MF
- Generalized Bell MF
- Sigmoidal MF [14]

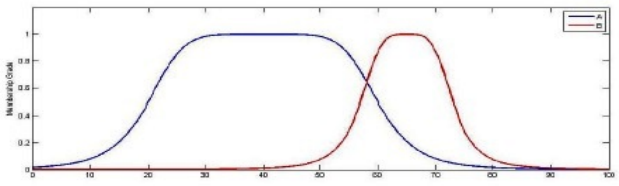
The crisp inputs are thus transformed into fuzzy sets. Triangular, MF, Trapezoidal MF, Bell MF, Generalized Bell MF or Sigmoidal MF [14] can be used. Even a hybrid of any of the above Membership Functions can be used for fuzzification.



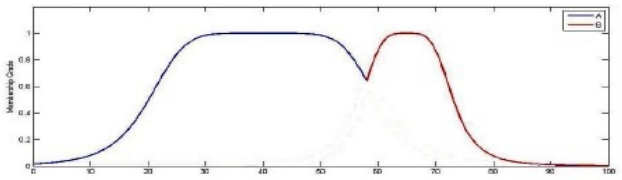
(iii) Fuzzy Rule Base.

Rule based on ; AND logic, OR logic & NOT logic.

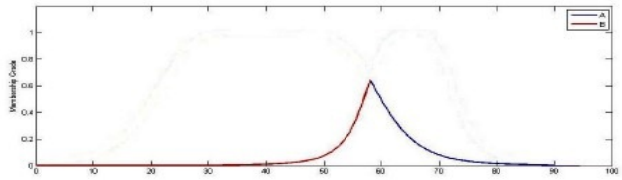




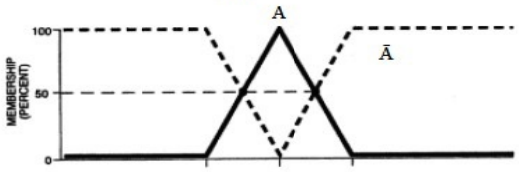
(a) Two Fuzzy sets A and B



(b) A ∪ B



(c) A ∩ B



(d) Fuzzy set A and its Complement Ā

3. ADVANTAGES OF FUZZY LOGIC CONTROLLER

- It is simple to design.
- It provides a hint of human intelligence to the controller.
- It is cost effective.
- No mathematical modeling of the system is required.
- Linguistic variables are used instead of numerical ones.
- Non-linearity of the system can be handled easily.
- System response is fast.
- Reliability of the system is increased.
- High degree of precision is achieved

4. HOW TO DESIGN FUZZY LOGIC CONTROLLER

Steps for design FLC are as following;

- The selection of appropriate inputs and their fuzzification.
- The definition of the input and output membership functions.
- The definition of the Fuzzy Rule Base.
- The de-fuzzification of the output obtained after the processing of the linguistic variables with the help of a proper de-fuzzification technique.
- Membership Function Design: Triangular MF is easy to represent the Input linguistic variables;
  - Speed Error (e):- e=wm-wr
  - Change in Error (Δe):- derivative of speed error.
  - Change of Control (Wsl):-

$$We^* = W_{sl} + W_m$$

(i)Fuzzy Rule Table for Output (Wsl)

A. Design of Fuzzy Sets and MFs for Input Variable Speed Error (e)

Fuzzy set or label	Set Description	Range	Membership Function
NL (Negative Large)	Speed error is high in the negative direction.	-1.0 to -1.0 -1.0 to -0.8 -0.8 to -0.5	Trapezoidal
NM (Negative Medium)	Speed error is medium in the negative direction	-0.8 to -0.5 -0.5 to -0.2	Triangular
NS (Negative Small) -	Speed error is small in The negative direction	-0.5 to -0.2 -0.2 to 0	Triangular
ZE (Zero)	Speed error is around zero	-0.2 to 0 0 to 0.2	Triangular
PS (Positive Small)	Speed error is small in the positive direction.	0 to 0.2 0.2 to 0.5	Triangular
PM (Positive Medium)	Speed error is medium in the positive direction.	0.2 to 0.5 0.5 to 0.8	Triangular
PL (Positive Large)	Speed error is high in the positive direction.	0.5 to 0.8 0.8 to 1.0 1.0 to 1.0	Trapezoidal

B. Design of Fuzzy Sets and MFs for Input variable Change in Error (Δe)

Fuzzy set or label	Set Description	Range	Membership Function
NL (Negative Large)	Speed error is high in the negative direction.	-1.0 to -1.0 -1.0 to -0.8 -0.8 to -0.5	Trapezoidal
NM (Negative Medium)	Speed error is medium in the negative direction	-0.8 to -0.5 -0.5 to -0.2	Triangular
NS (Negative Small)	Speed error is small in The negative direction	-0.5 to -0.2 -0.2 to 0	Triangular
ZE (Zero)	Speed error is around zero	-0.2 to 0 0 to 0.2	Triangular
PS (Positive Small)	Speed error is small in the positive direction.	0 to 0.2 0.2 to 0.5	Triangular
PM (Positive Medium)	Speed error is medium in the positive direction.	0.2 to 0.5 0.5 to 0.8	Triangular
PL (Positive Large)	Speed error is high in the positive direction.	0.5 to 0.8 0.8 to 1.0 1.0 to 1.0	Trapezoidal

C. Design of Fuzzy Sets and MFs for Change of Control (Wsl)

Fuzzy set or label	Range	Membership Function
NL (Negative Large)	-1.0 to -1.0 -1.0 to -0.8	Triangular
NML (Negative Large Medium)	-1.0 to -0.8 -0.8 to -0.6	Triangular
NM (Negative Medium)	-0.8 to -0.6 -0.6 to -0.4	Triangular
NMS (Negative Medium Small)	-0.6 to -0.4 -0.4 to -0.2	Triangular
NS (Negative Small)	-0.4 to -0.2 -0.2 to 0	Triangular
ZE (Zero)	-0.2 to 0 0 to 0.2	Triangular
PS (Positive Small)	0 to 0.2 0.2 to 0.4	Triangular
PMS (Positive Medium)	0.2 to 0.4 0.4 to 0.6	Triangular
PM (Positive Medium)	0.4 to 0.6 0.6 to 0.8	Triangular
PML (Positive medium Large)	0.6 to 0.8 0.8 to 1.0	Triangular
PL (Positive Large)	0.8 to 1.0 1.0 to 1.0	Triangular

C. Fuzzy Rule Table for Output (W_{sl})

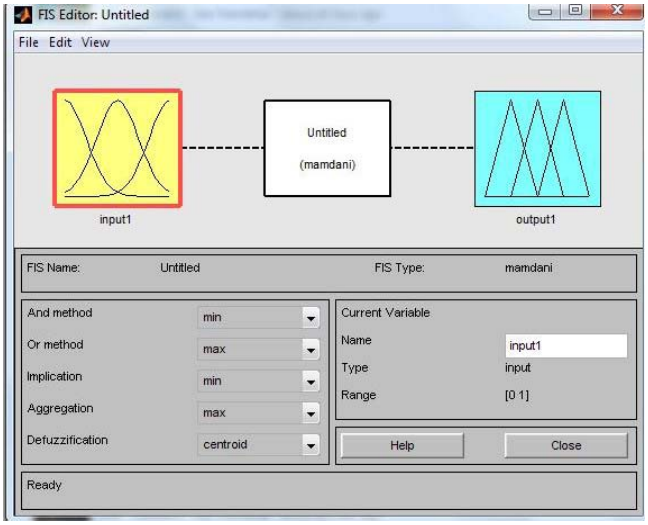
e Δe	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NLM	NM	NMS	NS	ZE
NM	NL	NLM	NM	NMS	NS	ZE	PS
NS	NLM	NM	NMS	NS	ZE	PS	PMS
ZE	NM	NMS	NS	ZE	PS	PMS	PM
PS	NMS	NS	ZE	PS	PMS	PM	PLM
PM	NS	ZE	PS	PMS	PM	PLM	PL
PL	ZE	PS	PMS	PM	PLM	PL	PL

Steps 2

- The program for designing of the Fuzzy Logic Controller is written in a word file.
- The definitions for all the shown membership functions are written in the program.
- The 49 rules shown above in tabular form are written in the program/ word file according to the syntax provided by MATLAB. Word file saved in. fis.

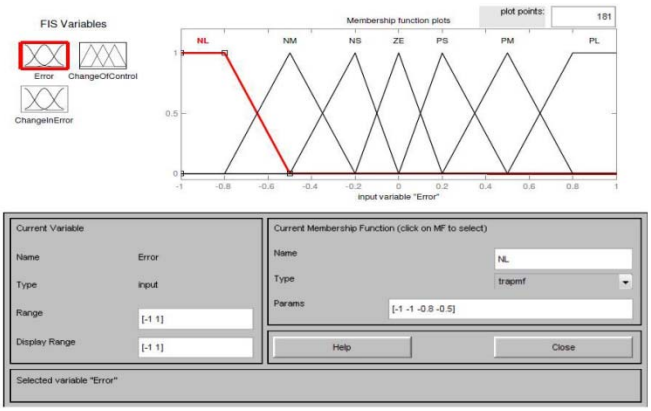
Step 3: The **.fis** file is now to be loaded in the FIS editor to view the membership functions, the rules and the rule surface plot.

On the command window of MATLAB **fuzzy** is typed to open the FIS editor.



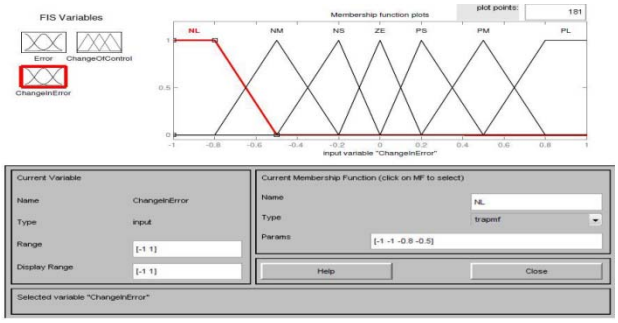
Step 4:

Click on any of the input or output to view the respective membership functions. The membership functions for inputs Error and Change in Error and for output Change in Control.



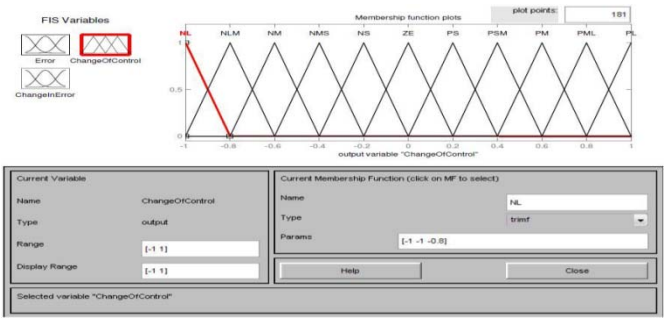
Step 5:

Membership function for the input Error (e)



Step 6:

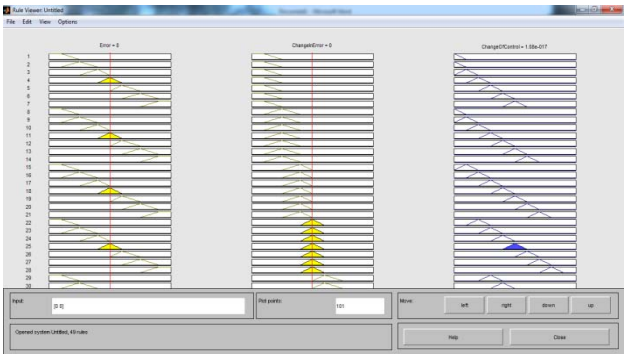
Membership function for the input Change in Error (Δe)



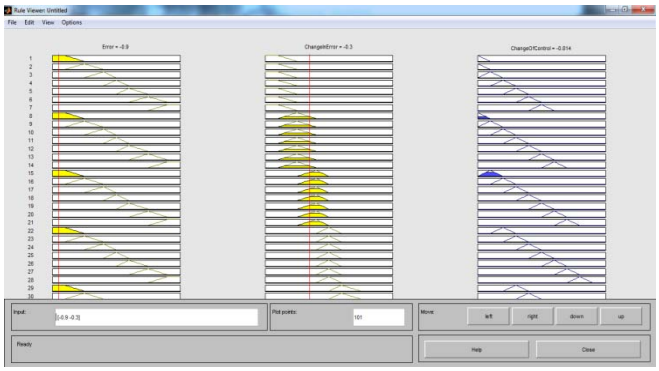
Step 7:

Membership function for the output Change of control (ωSl)

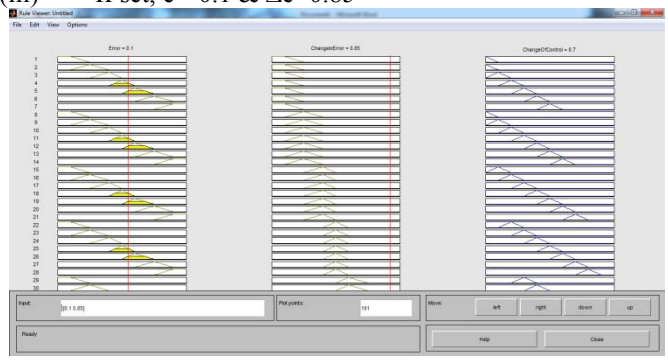
(i) Rule viewer with input e=0 & Δe=0



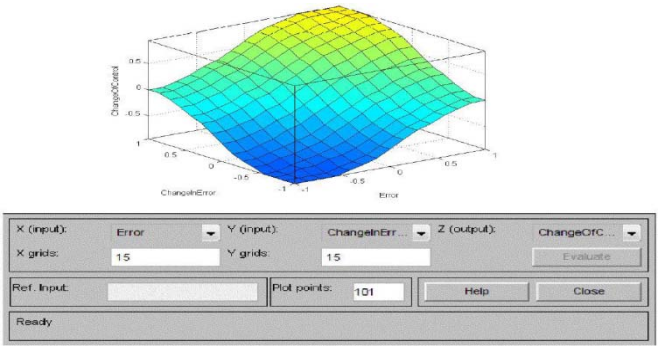
(ii) et, e=-0.9 & Δe=-0.3



(iii) If set, e=-0.1 & Δe=0.85



(iv) Three dimensional plot of the control surface



5. CONCLUSION

This paper has described the design, simulation and test of a simple but effective fuzzy logic controller for Induction motor (IM) drives.

From the above simulation results it was observed that the current waveforms are smoother as well as very less distortion, Moreover the torque waveforms are also better. Therefore it can be concluded that FL is an powerful means for designing intelligent systems.

Domain knowledge can be put into a fuzzy system by human experts in the form of linguistic variables and fuzzy rules.

Since these approaches doesn't require the knowledge of a mathematical machine model.

6. RESULT

Application of FLC is favored since it has simple architecture, ease of training algorithm, its ability to approximate the non-linear functions and insensitivity to disturbances makes it suitable for inherently non-linear IM as compare to conventional controllers like PI etc

It is observe that the designing a Fuzzy Logic Controller using the Mamdani Fuzzy Model is quite convenient and does not require any complex procedures or mathematical calculation.

7. ACKNOWLEDGEMENTS

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