Design Of Fuzzy Logic Controller For A Non-Linear System

S.Amuthameena
Assistant professor, Dept of EIE,
M.Kumarasamy college of Engineering
Karur, India

S.Monisa
Assistant professor, Dept of EIE,
M.Kumarasamy college of Engineering
Karur, India

***Abstract*— In recent days, the major problem in the roads we face is due to lack of maintenance of traffic control. The traffic management in the urban communities requires appropriate arrangements and administration activity on the grounds that there is an enormous movement issue there. Lesser the streets and more are the vehicles. Along these lines activity is to be kept up in light of the fact that it influences the nation personals straightforwardly. There are numerous accidents and different sorts of lethal occurrences that are brought on by the inappropriate activity control framework. Keeping in mind the end goal to limit the street accidents and to protect the general population's lives, the traffic control system is intended to guarantee the security of the drivers and personals. This paper depicts a design of Fuzzy Logic Controller for a traffic control system. Finest signal settings can be fixed while fares of the trip and system flow are in balance. This problem can be considered as a nonlinear mathematical system with equilibrium constraints. Here, the performance of the system can be defined as a function of signal setting variables.In genuine figuring atmosphere, the data is not finished, exact and definite, creating extremely hard to infer a real choice. To manage handling and displaying data, fuzzy systems are connected to practice the correct termination. This manuscript concentrates on the essentials of Fuzzy Logic and its purpose in Rule Based Systems to make them proficient to hold this current certainty problems. In addition, a traffic activity control framework is projected and assessed utilizing MATLAB.**

Keywords*— *FuzzySets, Linguistic Variables,Fuzzy Logic, Traffic control system, Rule Based Fuzzy Systems, Inference systems.

I. INTRODUCTION

People are fit to utilize semantic data correctly in their basic leadership. Because of loose and unverifiable nature of the semantic data, machines are not competent to utilize them in basic leadership forms utilizing conventional techniques. To make the machines shrewd, similar to people in such manner, Fuzzy Methods [1,2] are utilized. Fuzzy Logic [3] is a type of multi-esteemed logic got from fuzzy set hypothesis to manage inexact thinking. It gives the way to speak to and handle the phonetic data and subjective characteristics of this present reality. Fuzzy Logic is the expansion of Crisp Logic to manage the idea of incomplete truth. Fuzzy Logic is connected in the quantity of territories, i.e. building applications, restorative applications, financial matters and administration, mechanical applications and some more. A Fuzzy Logic Controller (FLC) is projected because of its inherent advantages such as requirement of only approximate data, simple cost effective sensors and robustness. Fuzzy algorithms are quite understandable and healthy, in the sense that they are not very responsive to altering environments and incorrect or elapsed rules. Various misguided judgments have been made in the premature phase of the Fuzzy Logic. Several postulates indicates about fuzzy logic to make the idea lucid which states Fuzzy logic is not fuzzy and it is exact.

Rule Base Systems [4] are very pertinent in basic resolution make, control frameworks and forecasting. To manage vague, indecisive and inaccurate information, in frameworks that are rule based, fuzzy procedures are utilized. The best approach to speak to the mind boggling circumstances as far as basic regular dialects is the Fuzzy Logic. This manuscript presents the Rule Based Fuzzy Systems (FRBS) and its types. In second segment, the fundamental scientific idea of the Fuzzy Logic has been presented. The third segment presents the essential sorts of Rule Based Fuzzy Systems, Mamdani method and TAKAGI-SUGENO method. In fourth segment, a fuzzy logic controller for a movement control framework is demonstrated and assessed utilizing MATLAB. In segment 5, conclusion has been talked about.

II. FUZZY LOGIC CONTROL

Fuzzy Logic is a multi-esteemed logic which is like human speculation and elucidation. It has the capability of consolidating human heuristics into PC helped basic leadership. Fuzzy logic controller (FLC) is made of fuzzification, learning and inference unit and defuzzification are demonstrated in Fig.1. The fuzzy logic needs that variable utilized as a part of depicting the control rules ought to be communicated as far as fuzzy set variables with linguistic names. Behind the guidelines have been assessed, the final gait to finish the calculation is to figure the fresh result of the fuzzy calculation by means of defuzzification [5]

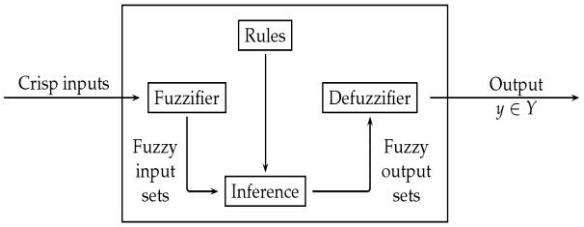


Fig.1. Structure of a Fuzzy Logic Control.

The primary favorable position of FLC is that Fuzzy Logic portrays frameworks regarding a mix of numerics and etymology (symbolics). This has points of interest over immaculate scientific (numerical) approaches or unadulterated typical methodologies in light of the fact that all the time framework information is accessible in such a mix and furthermore fuzzy logic some of the time utilizes just

estimated information, so basic sensors can be utilized. Besides, the calculations can be portrayed with little information, so little memory is required and are frequently very justifiable. Fuzzy calculations [6] are regularly hearty, as in they are not extremely delicate to changing situations and wrong or overlooked principles.

III. Rule Based Fuzzy Systems

Rule Based Systems for fuzzy logic comprise an addition to set up control dependant structures, since they oversee IF – THEN rules whose antecedants and consequents are made out of fuzzy logic declarations, set up conventional reliable ones. The most generally perceived employments of Rule Based Fuzzy Systems consolidates, Fuzzy Classification [7], Fuzzy Modelling [8] and Fuzzy Control [9] . In a Rule Based Fuzzy Systems, fuzzy logic is used to play out the functions like, illustration of various sorts of learning, showing the participations and associations. The rule components of the learning got by fuzzy sets incorporate treatment of helplessness. Because of this, Fuzzy Logic enlistment procedures have ended up being all the more intense and versatile with the assessed thinking systems. Phonetic elements and qualities are used for the change of the Knowledge Representation. These elements and their qualities are portrayed by the setting subordinate fuzzy sets whose suggestions are shown by dynamic enlistment work. Two vital sorts of Rule Based Fuzzy Systems proposed are, Mamdani Rule Based Fuzzy Systems [10] and Takagi-Sugeno-Kang Rule Based Fuzzy Systems [11].

A. Mamdani Fuzzy Rule – Based Systems

Fuzzy Logic Controllers (FLC) are the Rule Based Fuzzy Systems with fuzzifier and defuzzifier. The chief elements of the Mamdani method are shown in Fig.2.

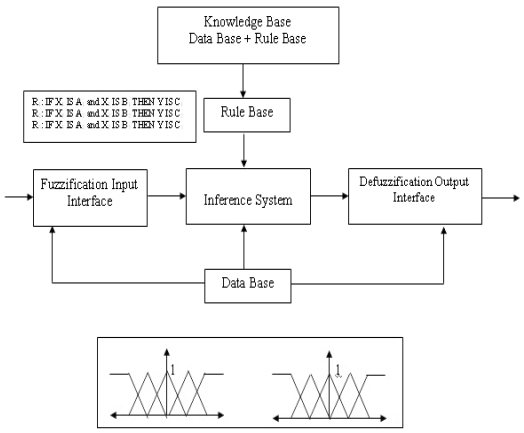


Fig 2. Mamdani method for fuzzy logic control

B. TAKAGI-SUGENO Rule Based Fuzzy Systems

Another Fuzzy lead based framework demonstrate (Fig.3) is anticipated, in light of principles whose antecedant is made out of the linguistic names and the consequent is spoken to by an element of the input functions.

$$\text{IF } A_1 \text{ is } X_1 \text{ and} \ldots \text{and } A_n \text{ is } X_n \quad \text{THEN}$$
$$B=a_1.A_1 \ldots + a_n.A_n + a_0$$

Here, Ai is the framework input variable, B as the yield variable a= (a0, a1…. … … an) is a vector of true parameters. Xi is the immediate detail of a etymological mark that focuses to a one specific individual from a fuzzy parcel of a semantic changeable.

For a Sugeno model of zero-order, the output z is a constant ($a = b = 0$).

Output level is denoted as, z_i, in each rule,whereas w_i represents the firing strength of the rule. For an AND rule with Input 1 = c and Input 2 = d, the firing strength is

$$w_i = AndMethod(F_1(c), F_2(d))$$

where $F_{1,2}(.)$ are the membership functions for Inputs 1 and 2.The final output of the system is the weighted average of all rule outputs, computed as

$$\text{Final Output} = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i}$$

where N is the number of rules.

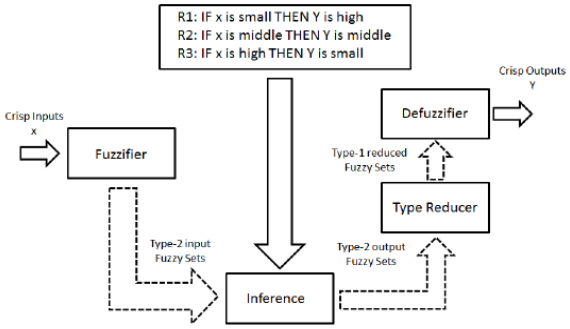


Fig.3. TAKAGI-SUGENO method

IV. DESIGN OF FUZZY LOGIC CONTROLLER FOR A TRAFFIC CONTROL SYSTEM

A fuzzy logic controller for a nonlinear traffic system has been proposed and implemented using the fuzzy logic techniques. The overall scheme is defined as follows.

A. Fuzzification

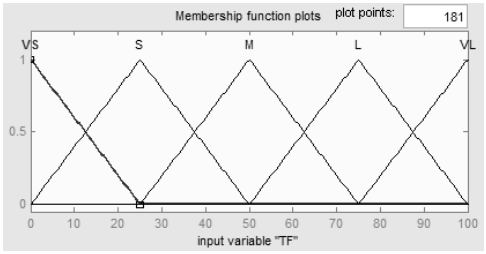
Fuzzification[12] is a process of making a crisp quantity into fuzzy quantity. The definition of linguistic variables and terms is needed before this process takes an action. Asset of linguistic terms are decomposed from a linguistic variable. Membership functions are used to relate the crisp or non-fuzzy input to fuzzy linguistic terms. In other words, a membership function is an important feature of fuzzy logic [13], a value can belong to multiple sets at the same time that is a numerical value does not have to be fuzzified using only one membership function. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. There are different forms or shapes of membership functions such as Triangular, Gaussian, Ttrapezoidal, Generalized Bell and Sigmoidal.

B. Membership Variables

Simulation of the proposed traffic control systems using MATLAB is done using, three input fuzzy membership functions and one output fuzzy membership functions[14] are developed. Here, the input membership functions

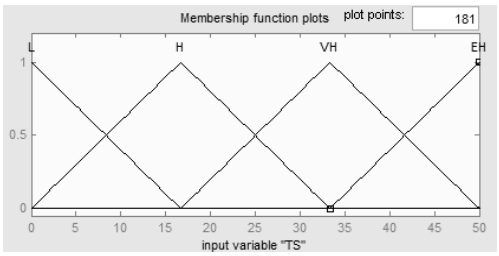
are the Travel Flow (TF), Travel Stand in line (TS) and Inward Flow (IF) and On Time (OT) as the at output membership function . The input variable Travel flow is shown in Fig.4 , Travel Stand in line in Fig.5, Inward flow is revealed in Fig.6. The output variable is ON time which is revealed in Fig.7.

(i) *Input Membership Functions*



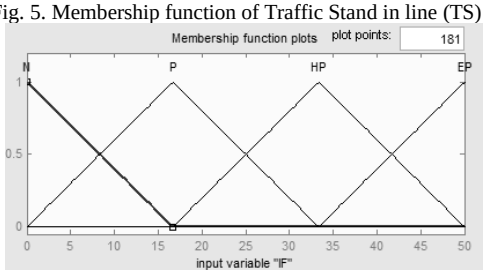
VS-Very small, S-Small, M-Medium, L-Large, VL-Very Large

Fig. 4. Membership function of Travel Flow (TF) Variable



L-Low, H-High, VH- Very High, EH-Extremely High

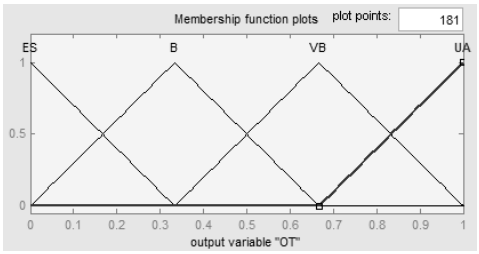
Fig. 5. Membership function of Traffic Stand in line (TS)



N-Negative, P-Positive, HP- Highly Positive, EP-Extremely Positive

Fig. 6. Membership function of Inward Flow (IF)

(ii) *Output Membership Functions*



ES-Extremely Small, B- Big, VB-Very Big, UA-Unacceptable

Fig.7. Membership Function of the On Time (OT)

C. Knowledge base Definition:

A fuzzy rule is built to direct the output variable in a fuzzy logic control framework. A fuzzy rule is a basic IF-THEN rule with a clause and termination. It can be spoken to by the inference table[15]. The input factors input1 and input2 are laid out along the axis, and the conclusions are inside the table. (Jantzen, 2007) .

The most unique connective is the "and" connective, frequently actualized as increase rather than least. For instance 'If input1 is Neg and input2 is Pos then output1 is Zero'. By and large, derivation is a procedure of acquiring new learning through existing information. It can be characterized as a procedure to acquire the last aftereffect of mix of the consequence of every manage in fuzzy esteem with regards to fuzzy logic control framework.

There are numerous techniques to carry out fuzzy inference[16] strategy and the most widely recognized two of them are Takagi-Sugeno-Kang and Mamdani strategy. Mamdani technique was projected by Ebrahim Mamdani as an endeavor to manage a vapor motor and heater in 1975. It depends on fuzzy calculations for complex framework and choice procedures by Lofti Zadeh. Assume a rule base is given in the accompanying structure;

In the event that input a = X AND input b = Y THEN output c= Z

Later than the total procedure, a fuzzy set exists for every output membership that necessities defuzzification. It is conceivable and by and large significantly more productive, to utilize a solitary spike as the output membership works as opposed to a dispersed fuzzy set, improves the productivity of defuzzification process since it significantly disentangles the calculation requisite by the more broad Mamdani technique. Henceforth, Mamdani strategy is utilized here.

The following rule table proposed the Knowledge base [17] of the proposed system which is given in the Table 1.

TABLE 1. FUZZY RULE TABLE FOR TRAFFIC CONTROL SYSTEM

Travel flow (TF)	**Inward flow (IF)**	**On Time (OT)**
VS	N	ES
S	VL	ES
L	N	B
M	N	ES
L	N	B
M	P	ES
S	HP	VB
S	P	B
VS	HP	VB
VL	P	B
VL	P	UA

The stage series change is realized by the Traffic Stand in line statistics on the residual stages, as shown in Table 2. S1, S2 and S3 are the stages, where as the stage S4 is assumed to be fixed.

TABLE 2. FUZZY RULE TABLE FOR STAGE SERIES CHANGE

TS1	TS2	TS3	NEXT STAGE
L	L	L	S1
L	H	L	S2
L	L	H	S3
H	L	L	S1
H	VH	H	S2
VH	H	L	S1
H	L	VH	S3
L	VH	H	S2
VH	H	H	S1
VH	VH	H	S1
H	VH	L	S2

D. FUZZY LOGIC CONTROLLER FOR THE PROPOSED SYSTEM

Firstly, a fresh arrangement of information are assembled and changed over to a fuzzy set utilizing fuzzy etymological factors, membership functions and fuzzy linguistic terms. This progression otherwise called fuzzification. A short time later, a derivation is made base on an arrangement of standards. Ultimately, utilizing the membership functions, the subsequent fuzzy output is mapped to a fresh output, in the defuzzification step.

The proposed framework has been executed utilizing MATLAB. The framework is recreated with two input and one output membership functions. The framework is produced utilizing Mamdani Type Fuzzy System. It is utilized to build up the framework with fuzzy govern base, appeared in Fig.8

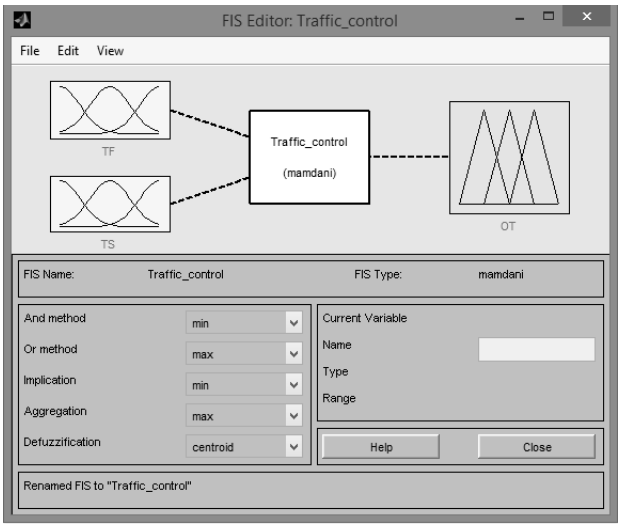


Fig.8. Fuzzy Inference System (FIS) using MATLAB

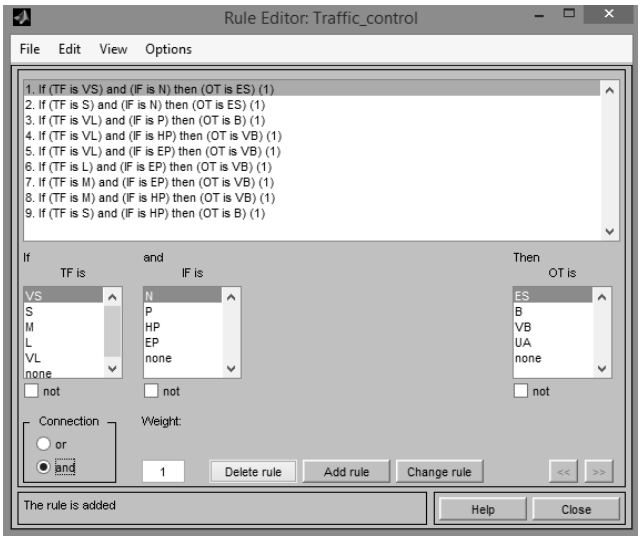


Fig.9. Rule Editor in MATLAB for Proposed System

E. Simulation Results

The accompanying outcomes have been gotten by doing simulation in MATLAB and the outcomes are discovered appropriate. The Travel Flow, Inward Flow and On Time are talked about and acknowledged in Table 3.

TABLE 3. SIMULATION RESULTS

S. No.	Input1 [Travel Flow]	Input2 [Inward Flow]	Output [On Time]
1	9	4	19
2	9	9	30
3	19	16	49
4	29	24	99
5	49	60	119
6	59	70	159
7	69	70	169
8	79	71	241
9	89	98	269
10	99	109	319

Fig. 10 shows the relation between the input variables, Travel flow and Inward flow and output variable ON time. Hence the results are obtained and studies were performed.

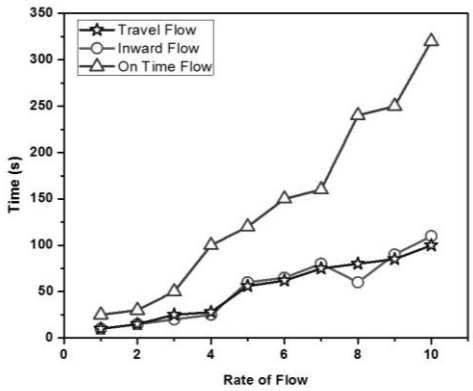


Fig.10. Simulation result graph showing the fuzzy logic controller output

The stage arrangement change is acknowledged in Table.4 which depends on the principles of Information Base.

TABLE. 4. SIMULATION RESULT FOR PHASE SEQUENCE CHANGE

TS1	TS2	TS3	NEXT STAGE
7	7	7	S1
9	16	9	S2
10	8	19	S3
26	22	20	S1
22	60	22	S2
55	11	24	S1
16	44	76	S3
31	76	41	S2

V. CONCLUSION

Current engineering, business applications and medicinal applications are in need to upgrade their capacity to manage loose and questionable data, empowering them to have a solid thinking and choice power. It has made them to hold more perplexing and semantic calculations effectively and proficiently. Every one of these necessities prompt to quick improvement and joining of FLC based control frameworks. In prospect, creators might want to actualize the answers for the issues by Evolutionary Computation methods. The utilization of Memetic Genetic Algorithms and Evolutionary Algorithms[18] will be favored.

REFERENCES

[1]. L. A. Zadeh, "Fuzzy Sets", Information and Control, vol. 8, (1965), pp. 338-353.
[2]. L. A. Zadeh, "Fuzzy sets as a basis of possibility", Fuzzy Sets Systems, vol. 1, (1978), pp. 3-28.
[3]. T. J. Ross, "Fuzzy Logic with Engineering Applications", McGraw-Hill, (1995).
[4]. L. M. Pant and A. Ganju, " Rule Based Fuzzy Systems for prediction of direct action avalanche", CurrentScience, vol. 87, no. 1, (2004) July.
[5]. AmirGheibi, S.Mohammad Ali Mohammadi, Malihe M. Farsangi, "Comparing performance of PID and fuzzy controllers in the present of noise for a Photovoltaic System" Journal of mathematics and computer science (2014), 69-76.
[6]. Balraj B, Arulmozhi M, 2015, 'Enhanced control strategy for lab scale fermentation process of actinomycetes sp. and its antibacterial activity,' 2015 Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, pp. 1-5, doi: 10.1109/GET.2015.7453792.
[7]. Sena TEMEL, Semih YAĞLI,Semih GÖREN ,"P, PD, PI, PID CONTROLLERS" Discrete Time Control Systems Recitation Report .
[8]. W. Pedrycz (Eds.), "Fuzzy Modelling: Paradigms and Practice", Kluwer Academic Press, (1996).
[9]. D. Drainkov, H. Hellendorn and M. Reinfrank, "An introduction to Fuzzy Control", Springer-Verlag, (1993).
[10]. Z. Chi, H. Yan and T. Pham, "Fuzzy Algorithms: With applications to image processing and pattern recognition", World – Scientific, (1996).
[11]. E. H. Mamdani and S. Assilian, "An experiment in linguistic synthesis with fuzzy logic controllers",International Journal of Man-Machine Studies, vol. 7, (1975), pp. 1-13.
[12]. T. Takagi and M. Sugeno, "Fuzzy identification of systems and its applications to modeling and control", IEEE Transactions Systems, Man and Cybernetics, vol. 15, no. 1, pp. 116-132.
[13]. A. Fernandez, S. Garcia, M. J. del Jesus and F. Herrera, "A study of the behavior of linguistic fuzzy rule based classification system in the framework of imbalanced data sets", Fuzzy Sets and Systems, vol. 159, (2008), pp. 2378-2398.
[14]. O. Cordon, F. Herrera, F. Hoffmann and L. Magdalena, "Genetic Fuzzy Systems: Evolutionary Tuning and Learning of Fuzzy Knowledge Bases", Advances in Fuzzy Systems-Applications and Theory, vol. 19, World Scientific, (2001).
[15]. H. Ishibuchi, T. Murata and I. B. Tarksen, "Single objective and two objective genetic algorithms for selecting fuzzy rules for pattern classification problems", Fuzzy Sets and Systems, vol. 89, no. 2, (1997), pp. 135-150.
[16]. H. Isibuchi, K. Nozaki, N. Yamamoto and H. Tanaka, "Selecting fuzzy if then rules for classification problems using genetic algorithms", IEEE Transactions on Fuzzy Systems, vol. 3, no. 3, (1995), pp. 260-270.
[17]. A. Fernandez, M. J. del Jesus and F. Herrera, "Analyzing the hierarchal fuzzy rule based classification systems with genetic rule selection", International workshop on genetic and evolutionary fuzzy systems, Spain, (2010) March, pp. 69-74.
[18]. M. J. Gacto, R. Alcala and F. Herrera, "Integration of an index to preserve the semantic interpretability with multi-objective evolutionary rule selection and tuning of linguistic fuzzy systems", IEEE Transactions on Fuzzy Systems, vol. 18, no. 3, (2010) June, pp. 515-531.
[19]. O. Cordon, F. Herrera and P. Villar, "Analysis and guidelines to obtain a good uniform fuzzy partition granularity for Rule Based Fuzzy Systems using simulated annealing", International Journal of Approximate Reasoning, vol. 25, (2000), pp. 187-215.
[20]. Uma, J, Jeevanandham, A, Muniraj, C, 2016, Implementation of Real Coded GA based Fuzzy Controller for Sensorless SR Motor Drive, International Journal of Fuzzy System, Vol. 18(5), pp 751–762.
[21]. Uma, J, Jeevanandham, A, 2014, 'Study of Intelligent PI-Fuzzy supervisory speed control scheme for 4 Phase Sensorless SRM drive', International Journal of Applied Engineering Research, Vol. 9, no. 22, pp. 16581-16594.
[22]. Uma, J, Jeevanandham, A 2016, 'Investigations of Fuzzy Logic Controller for Sensorless Switched Reluctance Motor Drive', IOSR Journal of Electrical and Electronics Engineering, Vol. 11, Issue.1, pp. 30-35
[23]. V.R. Ravi, M. Monica, S. Amuthameena, S.K. Divya, S. Jayashree, J. Varshini, 2014 "Sliding Mode Controller for Two Conical Tank Interacting Level System", Applied Mechanics and Materials, Vol. 573, pp. 273-278.
[24]. Amuthameena S, 2016, A novel strategy for blood glucose control in human body using PID-Fuzzy Logic Controller, Journal of Chemical and Pharmaceutical Science, Special issue 8, pp. 88-92.
[25]. Amuthameena, S., Amuthan, G. and Ganesan, L. (2017) 'Comparative analysis of unity power factor grid-connected PV system with PI and fuzzy-based controllers', Int. J. Power Electronics, Vol. 8, No. 2, pp.159–177.