IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 3, March 2016

NFC Design using ANFIS for Power Electronics Circuits

Ms. K.J.Rathi[1], Dr. M.S.Ali[2]

Assistant Professor, Department of Electronics and Telecommunication,

Prof Ram Meghe College of Engineering & Management-Badnera, Amravati(M.S.), India [1]

Principal, Prof Ram Meghe College of Engineering & Management-Badnera, Amravati(M.S.), India [2]

Abstract*:* A Novel Neuro Fuzzy Controller (NFC) for performance enhancement of power electronics circuits(DC-DC, AC-DC) is proposed. The proposed controller which integrates the advantages of fuzzy logic and neural network into an intelligent control system has been designed and simulated.

Keywords*:* PID, IGBT, NNC, FLC, NFC, PWM, ANFIS.

1. INTRODUCTION

The classical control techniques using Proportional(P), Proportional-Integral(PI), PD(Proportional-Derivative) or Proportional-Integral-Derivative(PID) digital controllers are basically used in industry since they do not need too much expertise in order to be implemented and to be tuned on a real process. However, the performances of these controllers are very modest and are by construction non-optimal.

High performance control systems are needed mainly for two reasons. The first reason is concerned with the needs of the process, either in terms of steady state error or dynamic performance. The second one arises from the economic demand for the maximum utilization of costly power. Hence design of a novel controller can be considered as a challenging engineering problem.

In order that the regulated converter circuit has good transient and steady- state responses, a controller with the following properties are desirable:
1) it does not rely on an accurate model of the plant;
2) it is robust to the uncertainties of the plant parameters.

In general, the control of systems is difficult and mathematically tedious due to their high nonlinearity properties[1]. To overcome this difficulty, various advanced control techniques has been devised by various researchers based on the fuzzy logic , neural networks, or combination of both fuzzy logic and neural networks because of i) simplicity in controller development ii) possibility of automated control iii) need of less skilled labour[6-9].

In spite of the advantages in fuzzy control, the main limitations are the lack of a systematic design methodology and the difficulty in predicting stability and robustness of the controlled system. A trial-and-error iterative approach is taken for the controller design due to which we get sluggish response. At present a need arises for effective method to tune the membership function in order to minimize the output error measure to a considerable extent. Neural network controller have proved theoretically and experimentally their capacity for modeling nonlinear structures. Nevertheless, it is often necessary to run quite a long learning procedure, which can be an obstacle to gaining on-line control of the process.

Hence, a novel controller called Neuro Fuzzy Controller (NFC) is proposed to serve as a basis for constructing a set of fuzzy IF-THEN rules with appropriate membership functions to generate the stipulated input-output pairs. Thus, the learning ability of neural networks is integrated with fuzzy logic to afford a more promising method.

2. PROPOSED APPROACH

The Neuro Fuzzy Controller(NFC) is a combination of a fuzzy logic controller and a neural network, which makes the controller self tuning and adaptive. The basic concept of Neuro-Fuzzy control method is first to use structure - learning algorithm to find appropriate Fuzzy logic rules and then use parameter-learning algorithm to fine-tune the membership function and other parameters.

The Neuro Fuzzy Controller based on *Adaptive-Network-based Fuzzy Inference System (ANFIS),* is proposed. ANFIS is an adaptive network which permits the application of neural network topology together with fuzzy logic. In the fuzzy section, only the zeroth-order or first order Sugeno inference system or the Tsukamoto inference system can be used. For simplicity, we assume that the fuzzy inference system has two inputs (x, y) and one output (f). A typical rule set for a first-order Sugeno fuzzy model with fuzzy-based IF-THEN rules can be expressed as :

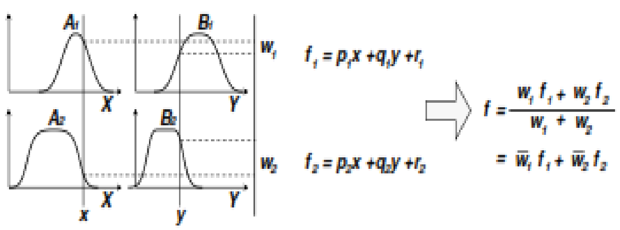


Fig1: A two-input first-order Sugeno fuzzy model with two rules

DOI 10.17148/IJIREEICE.2016.4303

Rule 1: If x is A_1 and y is B_1 , then $f_1 = p_1x + q_1y + r_1$
Rule 2: If x is A_2 and y is B_2 , then $f_2 = p_2x + q_2y + r_2$
where p_i, q_i , and r_i are linear output parameters (consequent parameters), where i = 1, 2.

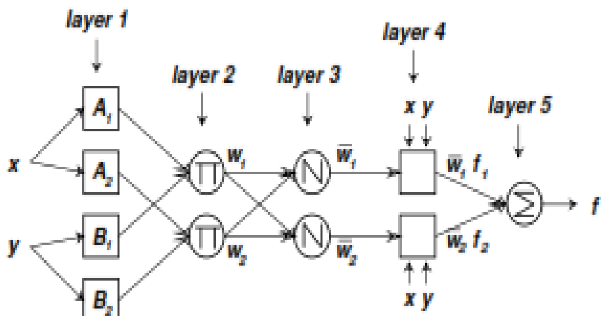


Fig2 : Equivalent ANFIS architecture

There are five layers in the ANFIS structure.

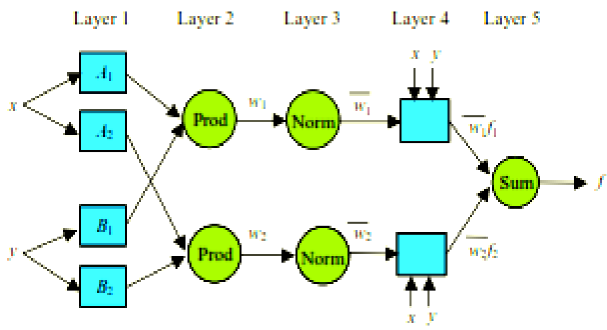


Fig3: ANFIS architecture based on Sugeno

In layer1 every node is an adaptive node with a node function

$$O_{1,i} = \mu_{Ai}(x), \qquad i = 1, 2, \ldots,$$

$$O_{1,i} = \mu_{Bi-2}(y), \qquad i = 3, 4, \ldots,$$

where i is the membership grade of a fuzzy set (A_1, A_2, B_1, B_2) and $O_{1,i}$ is the output of the node i in layer l. The membership function that has been used in this study is the Gaussian function given by

$$\mu_A(x) = \exp\left(\frac{-0.5(x-c)^2}{\sigma^2}\right)$$

where c and σ are referred to as premise parameters. In layer2 each node is a fixed node and calculates the firing strength of a rule via multiplication. The outputs are given by

$$O_{2,i} = w_i = \mu_{Ai}(x).\ \mu_{Bi}(y), \quad i = 1, 2.$$

In general, any other T-norm operator performing fuzzy AND method can be used as the node function in this layer. In layer3 every node is also fixed and performs a normalization of the firing strength from the previous layer. The outputs of this layer are called normalized firing strengths and are given by

$$O_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2}, \qquad i = 1, 2,$$

where $O_{3,i}$ the output of layer3. In layer4, all nodes are adaptive, and the output of a node is the product of the normalized firing strength and a first-order polynomial given by

$$O_{4,i} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i), \quad i = 1, 2$$

where $\overline{w_i}$ is the output of layer3, and (p_i, q_i, r_i) is the parameter set.

The parameters in this layer are referred to as the consequent parameters. There is a single node in layer5 which is a fixed node and computes the overall output as the summation of contribution from each rule:

$$O_{5,1} = \sum_i \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}, \qquad i = 1, 2$$

where $O_{5,1}$ denotes the output of layer5.

A hybrid learning algorithm is used for ANFIS training. It consists of two stages, forward pass and backward pass. In the forward pass, the consequent parameters are identified by the least squares estimation, and in the backward pass, the premise parameters are updated by the gradient descent. After optimizing the proposed ANFIS structure, all parameters of Gaussian input membership functions and linear output parameters are obtained.

The firing strength of each rule can be calculated via multiplication of the Gaussian input membership functions (fuzzy AND), and the final output of the model (drain current) is calculated as the summation of the contribution from each rule[2-5]. These equations are implemented in MATLAB. Finally, the ANFIS model is imported into the circuit simulator software as a subcircuit called as Neuro Fuzzy Controller for the power electronics circuits.

3. DESIGN OF CONVERTER CIRCUIT

To obtain high performance control of a system, a good model of the system is needed. It is desirable that the conversion be made with low losses in the converter. To obtain low losses, resistors are avoided in the power electronics converter circuits. Capacitors and inductors are used instead since ideally they have no losses.

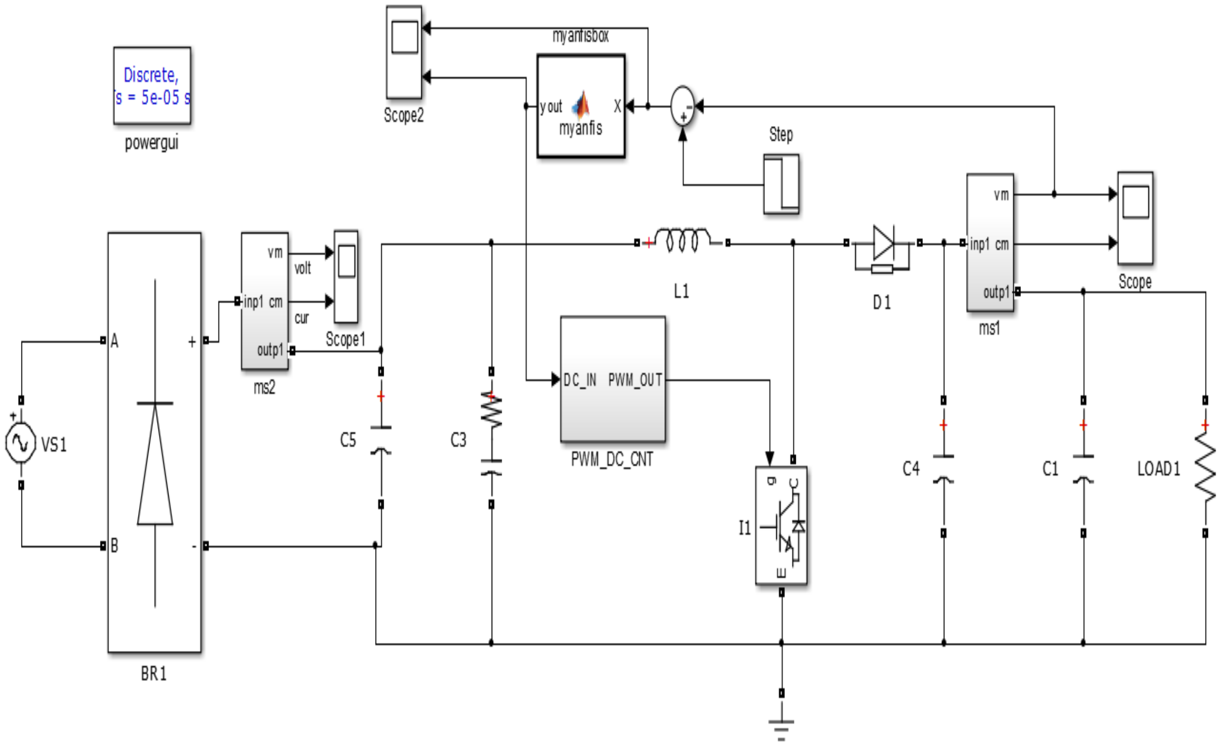
The electrical components can be combined and connected to each other in different ways, called different converter (DC-DC, AC-DC) topologies, each one having different properties. By using pulse-width modulation (PWM) control, regulation of output voltage is achieved by varying the duty cycle of the switch. Duty cycle refers to ratio of the period where power semiconductor is kept ON to the cycle period[10].

The proposed converter circuit uses IGBT as the switching device. Use of IGBTs allow to build cheaper and better converters.

They have three attractive advantages: higher switching frequency, easy and simple gate control and no need for snubber circuits. IGBTs are continuously controllable during turn on and turn off. This makes overcurrent limitation much easier and allows dV/dt control to reduce the and dV/dt stresses.

IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 3, March 2016

Fig4: Neuro Fuzzy Controller for DC-DC(Boost) Converter circuit



4. SIMULATION RESULTS

The output of Neuro Fuzzy Controller, i.e ANFIS block in circuit shown above generates a PWM signal which drives switching IGBT. The simulink model of the converter circuit is simulated in MATLAB[11]. Simulation results show that there is an excellent agreement between the numerical and predicted values with the least errors. Thus, the designed ANFIS model (for NFC) could significantly reduce the output errors in comparison with the Neural Network Controller(NNC) and Fuzzy Logic Controller(FLC).

The calculations speed of the proposed ANFIS model to obtain the results is extremely high with higher accuracy. Number of epochs needed to reach convergence (1,000 in comparison with 10,000)is lower in ANFIS model as compared to the NNC model. Hence, the training time for the ANFIS model is definitely less than the required time for designing similar models using pure neural networks. It means that the ANFIS model is better than Artificial Neural Network(ANN) for redeveloping the model and increasing the input parameters. Also for an ANN model, we have to perform a trial and error process to develop the optimal network architecture, while the ANFIS model does not require such a procedure. This is because the ANFIS is more transparent, and it is possible to obtain input output relationships from membership functions and IF-THEN rules. Simulation results show that the designed ANFIS model (for NFC) could significantly reduce the output errors in comparison with the NNC and FLC.

5. CONCLUSION

The proposed Neuro Fuzzy Controller can be used for any converter topology. The proposed novel controller is adaptive and its analysis shows significant enhancement in performance of power electronics circuits. Thus, we have proposed the ANFIS model as an improved approach over the NNC and Fuzzy Logic controllers for power electronics circuits.

REFERENCES

1. B.K.Bose,"Expert system, fuzzy logic and neural network applications in power electronics and motion control," Proc. IEEE, vol. 82, no. 8, pp. 1303-1323, 1994.
2. Jyh-Shing Roger Jang, "ANFIS: Adaptive-Network-Based Fuzzy Inference System", IEEE Trans. on Systems, Man. and Cybernetics, vol.23, no.3, pp.665-684, 1993.
3. Jyh-Shing Roger Jang, Chuen-Tsai Sun, "Neuro-Fuzzy Modeling and Control", IEEE Proc., pp. 1-29, March 1995.
4. Detlef Nauck, "Neuro-Fuzzy Systems: Review and Prospects", IEEE Trans. Autom. Proc. Fifth European Congress on Intelligent Techniques and Soft Computing", pp. 1044-1053, Sep8-11 1997.
5. P.J.Werbos, "Neurocontrol and Fuzzy Logic: Connections and Designs", International Journal of Approximate Reasoning, vol. 6, pp. 185-220, Feb. 1992.
6. L.K.Wong, F.H.F.Leung, P.K.S.Tam, "A Neuro-fuzzy Controller Applying to a Cuk Converter," IEEE Explore pp. 446-450, 1995.
7. S.Joseph Jawhar, N.S. Marimuthu, S.K.Pillai, N.Albert Singh, "Neuro-Fuzzy Controller for a Non Linear Power Electronic Buck & Boost Converters", Asian Power Electronics Journal, vol. 1, no.1, pp. 111-115, Aug 2007.
8. S.Joseph Jawhar, N.S. Marimuthu, N.Albert Singh, "An Intelligent Controller for a non Linear Power Electronic Buck Converter", International Journal of Electrical and Power Engineering, vol. 1, no.1, pp. 43-46, 2007.
9. A. Rameshkumar, S. Arumugam, "A Neuro-Fuzzy Integrated System for Non-Linear Buck and Quasi-Resonant Buck Converter", European Journal of Scientific Research, vol. 51, no. 1, pp. 66-78, 2011.
10. Mohan, Undeland and Robbins, "Power Electronics: Converters, Applications and Design", Wiley, 1989.
11. Hemant Mehar, "MATLAB Simulation Techniques in Power Electronics", IEEE Technology and Engineering Education, vol. 7, no. 4, pp. 62-65, 2012

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 3, March 2016

BIOGRAPHIES

Ms. K.J.Rathi is a Assistant Professor in Electronics and Telecommunication Department of Prof.Ram Meghe College of Engineering & Management, Badnera-Amravati. She completed her B.E.(Industrial Electronics) and M.E.(Electronics) from Dr.B.A.M.U, Aurangabad in 1999 and 2009 respectively. Her research interests are Power Electronics Systems, Artificial Intelligence and VLSI Design.

Dr. M. S. Ali is a Professor and Principal of Prof RamMeghe College of Engineering & Management, Badnera – Amravati. He obtained his B.E.(Electronics& Power) and M.Tech.(Power Electronics) from Nagpur University and I.I.T. Powai, Mumbai in 1981& 1984 respectively He obtained his Ph.D. from SGB Amravati University in 2006. He has been on the SGBUniversity's various bodies like Board of Studies, Faculty of Engineering &Technology and Academic Council since last fifteen years. He is Hon'ble Chancellors nominee on the senate of RTM Nagpur University. His research interests are Operating Systems, Artificial Intelligence and Java Technologies.