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Closed Loop Control of PV Based Embedded Z-Source Inverter Based Induction Motor Drive (Ezsibimd) with Fuzzy Logic Controller

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ABSTRACT

This paper presents the Fuzzy Logic Controlled (FLC) Photovoltaic Based Embedded Z-Source Inverter fed Induction Motor Drive System. The system is designed and simulated using MATLAB/SIMULINK and the simulation results are presented. To enhance the system robustness to external load disturbance and improve the dynamic response, a Fuzzy Logic Controller(FLC) is incorporated in the outer loop. FLC can handle a complicated nonlinear system which has a degree of uncertainty. It doesn't require exact system modeling and parameters; this makes FLC very suitable for motor drive control.

1.Introduction

The conventional controllers are implemented for better track performance, robustness and stability and have been proved the best controllers for motor drives. the designing of PI and PID controllers require the precise mathematical model of the actual system to be controlled, moreover the classical controllers cannot cope up with the system nonlinearities and uncertainties, Heng Deng et al. (2006) , 'Modelling and control of single-phase ups inverter: a survey', in proc. Peds-kualalumpur, Kualalumpur, pp. 848-853, 2005.

But fuzzy controller is a non-linear controller that does not require a precise mathematical model for its design. Perry.A.G et al. (2004)85 , 'A new design method for pi-like fuzzy logic controllers for dc-to-dc converters', in proc. pescaachen, Aachen, vol. 5, pp. 3751-3757,2004.

To enhance the system robustness to external load disturbance and improve the dynamic response, a Fuzzy Logic Controller(FLC) is incorporated in the outer loop. FLC can handle a complicated nonlinear system which has a degree of uncertainty. It doesn't require exact system modeling and parameters; this makes FLC very suitable for motor drive control. A classical FLC is composed of three parts: fuzzification of input variables, fuzzy reasoning and defuzzification.

2. FLC Controller

The basic structure of a Fuzzy Logic Controller shown in Figure 6.13 shows the basic structure of a Fuzzy Logic Controller. The main building units of FLC are Fuzzification unit, a Fuzzy Logic reasoning unit, a knowledge base and a defuzzification unit. De-fuzzification is the process of converting inferred Fuzzy Control actions into a crisp control signals.

Fuzzy Logic Controller

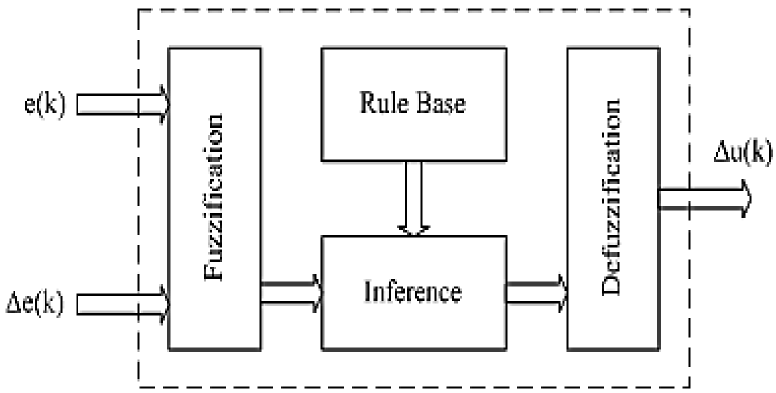

Figure.1. Basic Structure of Fuzzy Logic Controller

3. Fuzzification

The first block inside the controller is fuzzification block which converts each piece of input data to degrees of membership function by a lookup table in one or several membership functions. The fuzzification block matches the input data with the conditions of the rules to determine. There is a degree of membership for each linguistic term that applies to the input variable. The inputs and output of the Fuzzy Controller are not quantized in the classical sense that each input or output is assigned a 'membership grade' (to each Fuzzy set).

The universe of discourse (range) of the inputs is divided into several Fuzzy sets of desired shapes. The output is also mapped into several Fuzzy regions of desired shapes. Mamdani type input and output membership functions are used in this work to control. The number of Fuzzy levels is generally not fixed and depends on the resolution needed in an application.

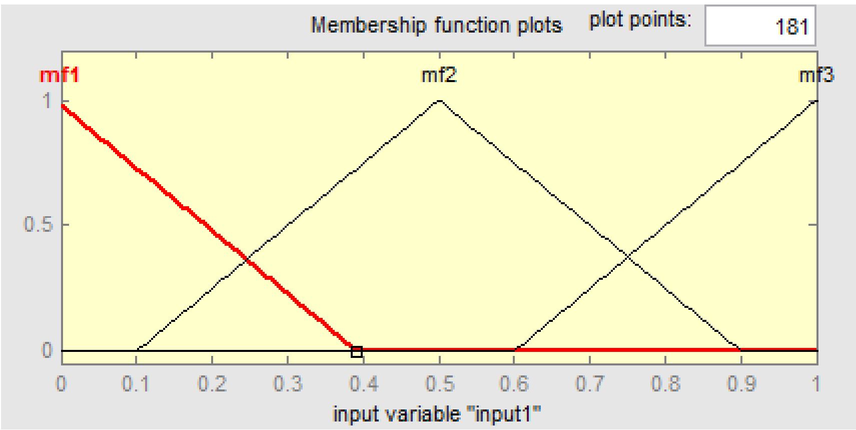

Figure .2. Input variables

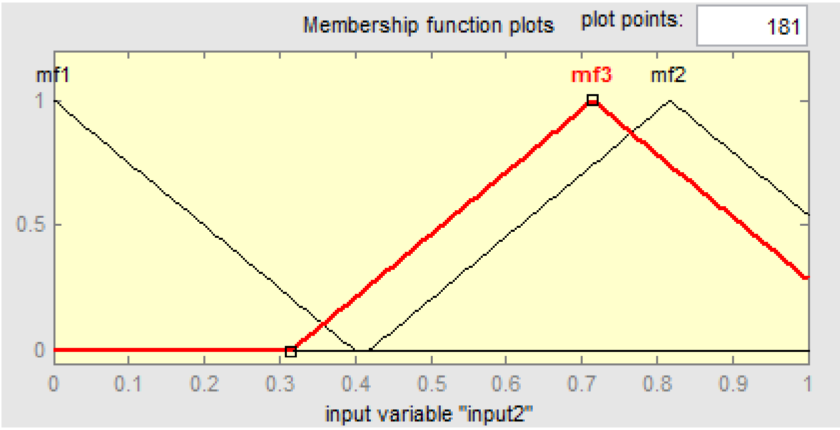

Figure 3. Input

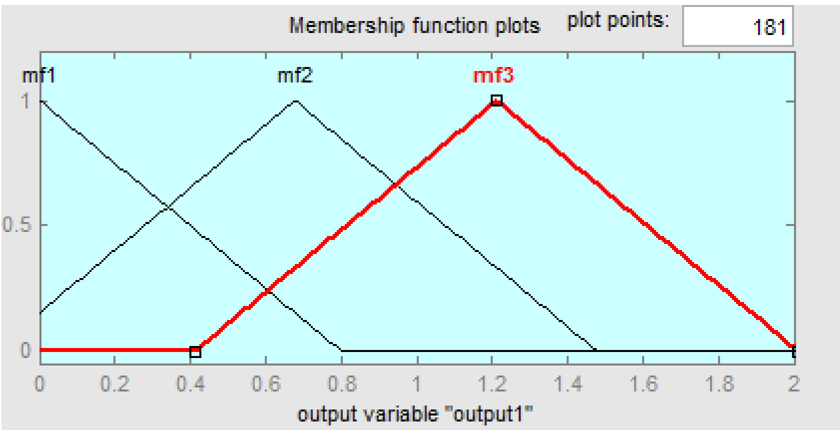

Figure .4. Membership functions

The larger number of Fuzzy levels, the higher is the resolution. In the present work, three triangular Fuzzy sets are chosen as shown in Figures6.14 and 6.16 and are defined by the following library of Fuzzy set values for the error Ve, change in error Vce and for the change in duty cycle δdk.

NL Negative Large
NS Negative Small
Z Zero
PS Positive Small
PL Positive Large

Trapezoidal or bell shaped membership function may also be employed. Three triangular membership functions are used in this work for reasons of simplicity and also to reduce complexity in calculations. Hence the Fuzzy representation of quantized values of above errors and change in errors are the Fuzzy sets and the degree to which they belong to each Fuzzy set.

4. Rule base

The collection of rules is called a rule base. The rules are in '*If Then'* format and formally the *If a side* is called the *conditions* and the *Then side* is called the *conclusion.* The computer is able to execute the rules and compute a control signal depending on the measured inputs *error* (e) and *change in error* (Δe). In a rule based controller, the control strategy is stored in a more or less natural language. A rule based controller is easy to understand and easy to maintain for a non- specialist end user, and an equivalent controller could be implemented using conventional techniques.

According to these criteria, rule bases for FLC developed are shown in Table 6.1. Since every input variable error (e) and change of error (Δe) belongs to almost two Fuzzy sets, a maximum of four rules are considered at any sample to process any combination of input variables. The inferred degree of membership for the rest of the rule is zero. The inference result of each rule consists of two parts, the weighting factor Wi of the individual rule and the degree of change in control action Ci according to the rule.weighting factor Wi of the individual rule and the degree of change in control action Ci according to the rule.

Table 1Rule Base Developed for FLC

e/Δe	**NL**	**Z**	**PS**
NS	PS	NS	PB
PS	NB	PB	PS
Z	NL	Z	NS

The weighting factor wi is obtained by means of Mamdani's min Fuzzy implication of µVe(Ve)and µVce (Vce). ci is retrieved from the control rule table. The inferred output of each rule using Mamdani's min Fuzzy implication is written as zi= min {memberships of error and change in error}. ci = wizi, where wi denotes the Fuzzy representation of the change in control action inferred by the ith rule. Since the inferred output is a linguistic result, a defuzzification operation is performed to obtain a crisp result.

5. Defuzzification

Defuzzification is when all the actions that have been activated are combined and converted into a single non-Fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the nonlinearities existing to the systems. To achieve the result, the control curve of the system is developed representing the I/O relation of the systems and based on the information; the output degree of the membership function is defined with the aim to minimise the effect of the non-linearity.

This logical sum is the Fuzzy representation of the change in control action. A crisp value for the change in control action is calculated in this work using the centre of gravity method. The product of centroid mi of ci (obtained from control rules) and the weighting factor wi gives the contribution of ith inference result to the crisp value of the change in control action. The resultant change of control action can, therefore, be represented by

$$\delta d_k = \frac{\sum_{i=1}^{4} w_i m_i}{\sum_{i=1}^{4} w_i}$$

The performance of the Fuzzy Controller also relies very much on the size of rule table. A rule set of moderate size is used in the proposed Fuzzy controller. As the number of rules increases, the overall performance improves in general. However, a larger rule table may lead to the longer processing time of the Fuzzy controller. For a given rule set, nevertheless, the performance can be improved by the tuning parameters: gain factor η, the normalisation factor of errors ßve and the normalisation factor of change in errors ßvce which have to be adjusted to fit the operating conditions of the converters.

6. Simulation Results

Closed loop EZSIBIMD with fuzzy controller simulation circuit is shown in Figure 5. The FLC is used due to non-linearity in induction motor and IGBTS. The motor speed is shown in Figure 6. and its value is 440 RPM. The Torque response is shown in Figure 7. and its value is 0.6 N-m.

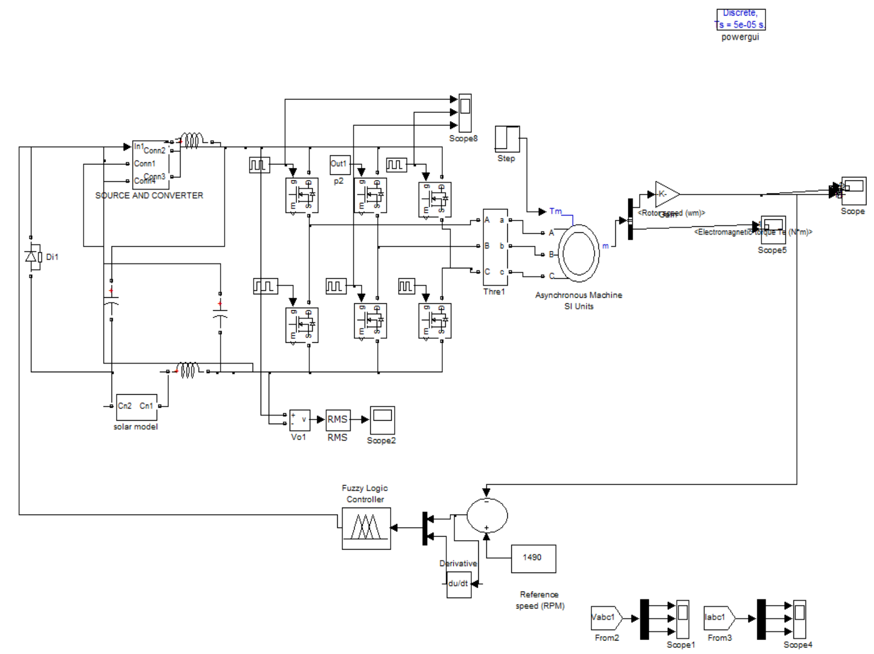

Figure .5. Closed loop EZSIBIMD with Fuzzy controller

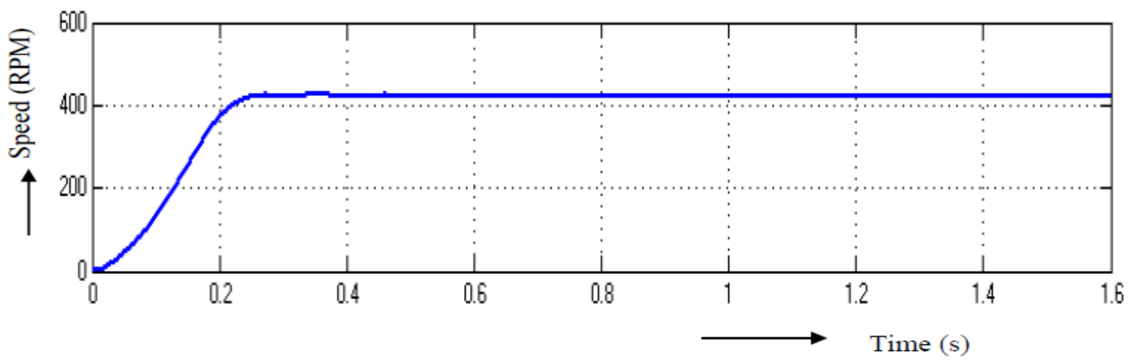

Figure 6.Motor speed

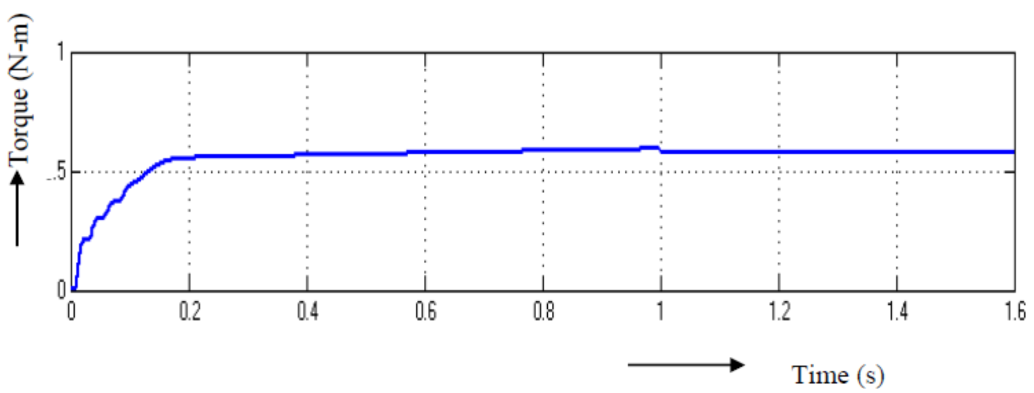

Figure 7. Torque Response

CONCLUSION

Closed loop system is established to spread out the control capability using FLC controlled EZSIBIMD systems are modeled and simulated using MATLAB.The results indicate that the time response with FLC is superior to PI, PID & HCC controlled system. The settling time with FLC is as low as 0.23 sec and the steady state error is 0.8 RPM using FLC. The proposed EZSIBIMD has advantages like high gain & low steady state error.

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