Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
15th March 2011. Vol. 25 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

TO MINIMIZE CURRENT DISTRIBUTION ERROR (CDE) IN PARALLEL OF NON IDENTIC DC-DC CONVERTERS USING ADAPTIVE NEURO FUZZY INFERENCE SYSTEM

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ABSTRACT

A control system for non identical dc-dc converters using Adaptive Neuro Fuzzy Inference System (ANFIS) is presented. The converters are connected in parallel and have a non identical inductance value, $L_1 \neq L_2 \neq L_3$, with 10% tolerance. The objective of control system is to balance the output current of each converter. One of converters is used as reference. The current error, which is subtraction of output current between the reference and other converters, is used as the ANFIS input. Therefore, it requires 2 ANFIS systems when 3 converters are in parallel. Each ANFIS has 5 membership functions. Simulations show that a system with 48 volt and various load resistances (from 10Ω to 0.75Ω) performs Current Distribution Error under 0.1%.

Key words: *Parallel Dc-Dc Converter, Control Methods, ANFIS*

1. INTRODUCTION

Paralleling of standard dc-dc converters has been widely adopted in distributed power systems for both front- end and load converters. One basic objective of parallel-connected converters is to share the load current among the constituent converters. To do this, some form of control has to be used to equalize the currents in the individual converters. A variety of approaches, with varying complexity and current-sharing performance, have been proposed in the past two decades [1]. In general, methods for paralleling dc/dc converters are described in terms of connection styles, control configurations and feedback functions. Although some forms of classifications and comparisons have been given for paralleling schemes most fall short of a systematic identification of all possible structures and control configurations. [2], [3], and [4].

In order to facilitate design and choice of appropriate paralleling configurations, a systematic classification of the paralleling schemes that permits a clear exposure of the structures, behaviors and limitations of all possible schemes, is needed. In this paper, we investigate the classification problem and utilize basic circuit theory to identify the basic structures and control methods of parallel dc-dc converters. The main purpose of this paper shows that the ANFIS control that used in parallel dc-dc converter with different inductance and the performance of control system to minimize the differences of the current distribution from each dc-dc converter module.

2. PARALLEL OF DC-DC CONVERTER CONTROL USING ANFIS

This paper presents ANFIS as controllers, where the current distribution of each dc-dc converter is used as input controllers. Parallel of non identic dc-dc converters has inductance values which are not equal, where L_1 is 100 mH, L_2 is 110 mH and L_3 is 120 mH. They use Buck dc-dc converters. The data is obtained from output current of each dc-dc converters which are arranged in parallel. They are I_{L1}-I_{L2} and I_{L1} -I_{L3} and the reference current is I_{L1}. The method of Current Mode Control is used in the circuit [5,6]. For further details see Figure 1.

$God_1(s)$, $God_2(s)$ and $God_3(s)$ are dc-dc converters module, $G(s)$ is transfer function of

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Journal of Theoretical and Applied Information Technology
15th March 2011. Vol. 25 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

compensation circuit, Q(s) is output impedance of transfer function, k_1,k_2, and k_3 are PWM Amplifier of dc-dc converter. The Matlab Simulink is used as a tool to analyze parallel dc-dc converters system. Parallel of non-identic dc-dc converters is the development of existing models. Therefore, this research discusses the concept, simulation and analysis of the parallel of non-identic dc-dc converter.

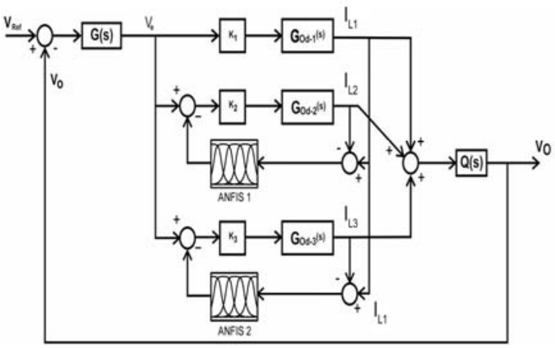

Figure 1. Parallel of non identic dc-dc converters Using ANFIS

3. ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS)

Fuzzy systems are generally used in cases when it is impossible or too difficult to define crisp rules that would describe the considered process or system, which is being controlled by a fuzzy control system. Thus, one of the advantages of fuzzy systems is that they allow to describe fuzzy rules, which fit the description of real-world processes to a greater extent.

Another advantage of fuzzy systems is their interpretability; it means that it is possible to explain why a particular value appeared at the output of a fuzzy system. In turn, some of the main disadvantages of fuzzy systems are that expert input or instructions are needed in order to define fuzzy rules, and that the process of tuning of the fuzzy system parameters (e.g., parameters of the membership functions) often requires a relatively long time, especially if there is a high number of fuzzy rules in the system. Both these disadvantages are related to the fact that it is not possible to train fuzzy systems. A diametrically opposite situation can be observed in the field of neural networks. User can train neural networks, but it is extremely difficult to use a priori knowledge about the considered system and it is almost impossible to explain the behaviour of the neural system in a particular situation.

In order to compensate the disadvantages of one system with the advantages of another system, several researchers tried to combine fuzzy systems with neural networks. A hybrid system named ANFIS (Adaptive-Network-Based Fuzzy Inference System or Adaptive Neuro-Fuzzy Inference System) has been proposed in [7].

ANFIS is the fuzzy-logic based paradigm that grasps the learning abilities of ANN to enhance the intelligent system's performance using a priori knowledge.

Using a given input/output data set, ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a backpropagation algorithm alone, or in combination with a least squares type of method. This allows your fuzzy systems to learn from the data they are modeling.

These techniques provide a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. This learning method works similarly to that of neural networks [8]. Fig. 2 shows the basic structure of the ANFIS algorithm for a first order Sugeno-style fuzzy system. It is worth noting that the Layer-1 consists of membership functions described by the generalized bell function:

$$\mu(X) = (1+((X-c)/a)^{2b})^{-1} \qquad (1)$$

where a, b and c are adaptable parameters. Layer-2 implements the fuzzy AND operator, while Layer-3 acts to scale the firing strengths.

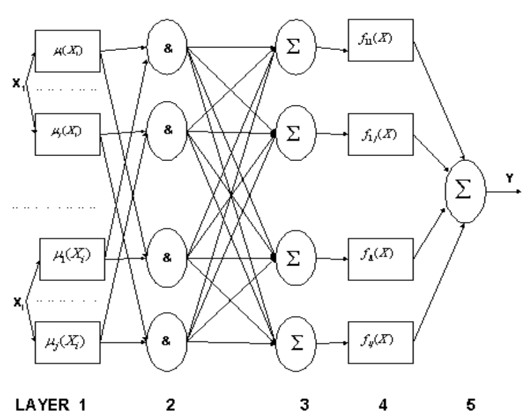

Figure 2. Structure ANFIS

Journal of Theoretical and Applied Information Technology
15th March 2011. Vol. 25 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

output of the Layer-4 is comprised of a linear combination of the inputs multiplied by the normalized firing strength w :

$$Y = w(pX + r) \qquad (2)$$

where p and r are adaptable parameters. Layer-5 is a simple summation of the outputs of Layer-4. The adjustment of modifiable parameters is a two step process. First, information is propagated forward in the network until Layer-4 where the parameters are identified by a least-squares estimator. Then the parameters in Layer-2 are modified using gradient descent. The only user specified information is the number of membership functions in the universe of discourse for each input and output as training information. ANFIS uses back propagation learning to learn the parameters related to membership functions and least mean square estimation to determine the consequent parameters. Every step in the learning procedure includes two parts.

The input patterns are propagated, and the optimal consequent parameters are estimated by an iterative least mean square procedure. The premise parameters are assumed fixed for the current cycle through the training set. The pattern is propagated again, and in this epoch, back propagation is used to modify the premise parameters while the consequent parameters remain fixed.

To use ANFIS for classification problem, the designer needs to perform the following steps: 1). Design a Sugeno FIS appropriate for the classification problem. 2). Hands optimize the FIS, given actual input classification data. 3). Set up training and testing matrices. The training and testing matrices will be composed of inputs and the desired classification corresponding to those inputs. 4). Run the ANFIS algorithm on the training data. 5). Test the results using the testing data.

ANFIS has a network-type structure similar to that of a neural network which maps inputs through input membership functions and associated parameters, and then through output membership functions and associated parameters to outputs, can be used to interpret the input -output map.

The parameters associated with the membership functions will change through the learning process. The computation of these parameters (or their adjustment) is facilitated by a gradient vector, which provides a measure of how well the fuzzy inference system is modeling the input/output data for a given set of parameters. Once the gradient vector is obtained, any of several optimization routines could be applied to adjust parameters that will reduce some error measure (usually defined by the sum of the squared differences between actual and desired response).

ANFIS uses either back propagation or a combination of least squares estimation and back propagation for membership function parameter estimation. The next section describes application of ANFIS for DC-DC Converter parallel [8,9]

4. THE RESULT OF GBELL MEMBERSHIP FUNCTION IN ADAPTIVE NEURO FUZZY INFERENCE SYSTEM

Membership function is a curve that shows the mapping of data input points to the value of membership or so-called degree of membership, with the interval is between 0 and 1. In general, parameter a and c are the membership functions as shown in the following equation:

$$f(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \qquad (3)$$

In general, parameter b is positive. Parameter c is located in the middle of the curve, while parameter a is the inflection point that determines the width of the curve shape.

Membership Function used in this research is 5 gbellmf. The design of input V_e (V_{error}) and ΔV_e *(delta Error)* can be seen in figure 3, 4and 5. The results of ANFIS design e.i:

```
[System]
Name='anfis5m'
Type='sugeno'
Version=2.0
NumInputs=2
NumOutputs=1
NumRules=25
AndMethod='prod'
OrMethod='probor'
ImpMethod='prod'
AggMethod='sum'
DefuzzMethod='wtsum'
[Input1]
Name='Error'
Range=[-64 64]
NumMFs=5
MF1='NB':'gbellmf',[27.9634920634921 2.5 -55.9]
```

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MF2='NM':'gbellmf',[22.5195767195767 2.5 -29.8]
MF3='Z':'gbellmf',[26.5498941798942 2.5 -4.37]
MF4='PM':'gbellmf',[24.8084656084656 2.5 24.8]
MF5='PB':'gbellmf',[29.5793650793651 2.5 56.5]
[Input2]
Name='Derror'
Range=[-64 64]
NumMFs=5
MF1='NB':'gbellmf',[35 2.5 -60.9365079365079]
MF2='NM':'gbellmf',[21.5650793650794 2.5 -30.2]
MF3='Z':'gbellmf',[26.0001375661376 2.5 0.434]
MF4='PM':'gbellmf',[21.4492063492064 2.5 31.1]
MF5='PB':'gbellmf',[30.3 2.5 59.9365079365079]
[Output1]
Name='Keluaran'
Range=[0 1]
NumMFs=5
MF1='NB':'constant',[0]
MF2='NM':'constant',[0.5]
MF3='Z':'constant',[1]
MF4='PM':'constant',[0]
MF5='PB':'constant',[1]

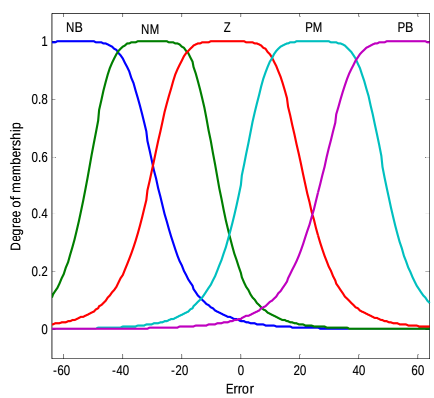

Figure 3. Design of 5 gbellmf for *Error Input*

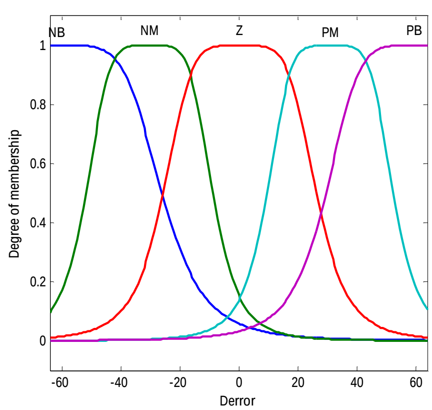

Figure 4. Design of 5 gbellmf for *Delta Error*

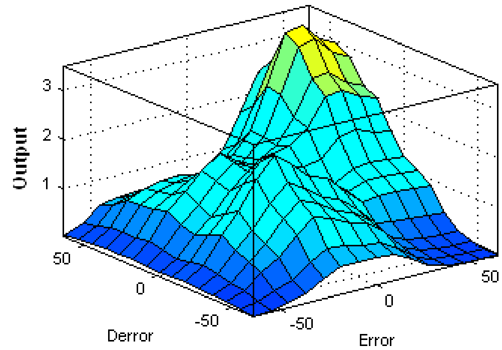

Figure 5. 3D design of ANFIS Rules view

5. RESULTS AND DISCUSSION

Table 1 shows the parameters of parallel dc-dc converters. Parallel of non-identic dc-dc converter is arranged from general components. The Current Mode Control is a method of current substraction from each converter. In this research Simulink of Matlab is used for the analysis and simulation.

Table 1. Dc-dc Converter Parameter

Component	*1st Converter*	*2nd Converter*	*3rd Converter*
Mosfet	*Same type*	*Same type*	*Same type*
Inductor	*100 mH*	*110mH*	*120 mH*
Capasitor	*2200 uF*	*2200 uF*	*2200 uF*
Diode	*Same type*	*Same type*	*Same type*
R_L*(Load)*	*10 Ω - 0.75 Ω*		

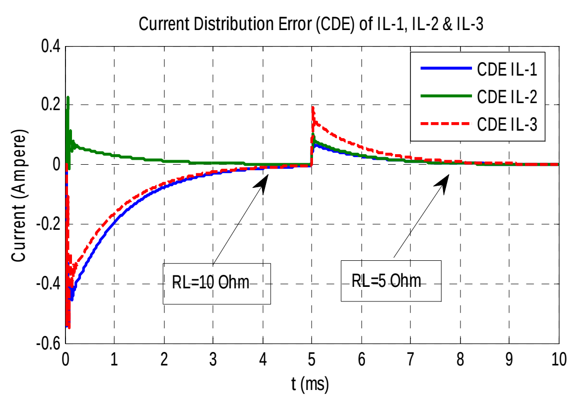

Figure 6
Current Distribution Error of I_{L1}, I_{L2} and I_{L3} with step load from 10 Ω to 5Ω.

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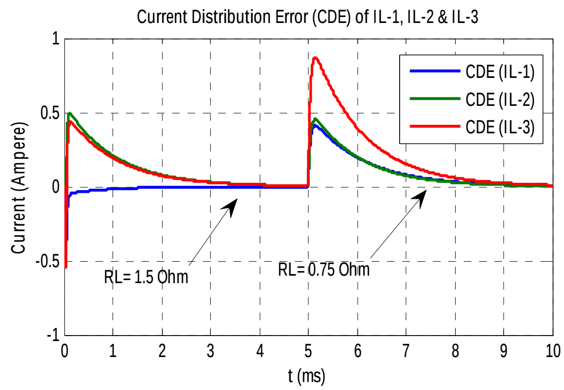

Figure 7 Current Distribution Error of I_{L1}, I_{L2} and I_{L3} with step load from 1.5 Ω to 0.75Ω.

The comparison of output current (I_{L1}, I_{L2}, I_{L3}) and the current distribution error in the change of load (R_L) from 10Ω to 0.75Ω can be seen in table 2.

Table 2.
Output currents (I_{L1}, I_{L2}, I_{L3}) and the current distribution error at R_L = 10Ω to 0.75Ω.

Output Current	R_L=10 Ω	R_L=5 Ω	R_L=2.5 Ω	R_L=1.5 Ω	R_L=0.75 Ω
I_{L1} (Amp)	1.661	3.312	6.580	10.87	21.28
I_{L2} (Amp)	1.661	3.311	6.579	10.87	21.28
I_{L3} (Amp)	1.661	3.311	6.578	10.87	21.27
(I_{L1}-I_{L2}) (Amp)	0.0002865	0.0005667	0.001123	0.0004380	0.003645
(I_{L1}-I_{L3}) (Amp)	0.0006326	0.0013180	0.002676	0.0042180	0.008903
(I_{L2}-I_{L3}) (Amp)	0.0003461	0.0007509	0.001553	0.0001622	0.005220

6. CONCLUSION

This study has produced dc-dc converters system in parallel with the inductance parameters $L_1 \neq L_2 \neq L_3$, using Adaptive Neuro Fuzzy Inference system. The results of output current are $I_{L1} \approx I_{L2} \approx I_{L3}$ and the output voltage is 48 volts, when the change of load (R_L) is from 10Ω to 0.75Ω. The current distribution error is 0.1%. Finally, the use of ANFIS in parallel of non identic dc-dc converters can optimize the current distribution and reduce current distribution error significantly.

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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

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