

MODELING AND DESIGN OF NANO SCALE CMOS CONTROLLER USING ADAPTIVE NEURO-FUZZY FOR SPEED CONTROL OF DC SHUNT MOTOR

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Abstract : The main aim of this work is to control the speed of the DC shunt motor by using a nano scale Complimentary Metallic oxide Field Effect Transistor (CMOS) inverter with Adaptive Neuro-Fuzzy based method for optimal parameter selection. The speed of the DC shunt motor can be varied by varying armature voltage with field current constant and varying the field current with armature voltage constant. It is found that the speed is said to increase with increase in armature voltage for which the graph is a linear in case of armature controlled method. Whereas for the field control method the speed is said to increase with decrease in field current with armature voltage to be constant. The stated condition is cross verified by plotting the graphs for conventional and proposed nano scale CMOS inverter with ANFIS optimization scheme. A novel technique for modeling and devising a nano scale CMOS circuit using adaptive neuro-fuzzy network for controlling and tuning the switching characteristics of the circuit so that it is symmetric with equal values of rise time and fall time with equal output for propagation delay during low to high and high to low outputs. This control over the CMOS switching characteristics using ANFIS controller offers an effective speed control for DC shunt motors. The designed scheme for 45nm process technology is simulated using MATLAB. The results for nano scale CMOS inverter with ANFIS optimization scheme proved to be accurate with an accuracy of 97.5% to 100% which is compared with experimentation results obtained in laboratory using conventional speed control techniques like field and armature control methods.

Keywords: DC shunt motor, Nano scale, CMOS technology, Adaptive neuro-fuzzy system, Armature control and Field control

1. Introduction

The DC shunt motor is a constant speed motor. Actually the motor is a rotating machine which converts electrical energy to mechanical energy. It works on the principle that current carrying armature conductors placed in magnetic field experiences a force. The CMOS controller design using digital integrated circuit design is considered to be the fundamental procedure [1]. Any other complex circuits need to be developed using CMOS, then this method becomes fundamental procedure [1, 2]. Direct laboratory design done manually for such nano scale controllers is a hilarious task. The main reason is that the sub-90nm area which has short channel effect has a profound effect. The performance behaviours of a circuit in this regime depend on the transistor channel length and width through complex high orders of equations. Therefore, for correct design and simulation of nano scale digital integrated circuits, accurate models need to be constructed [2]. The construction of accurate performance model for CMOS controller is valid in the sub-90nm domain and therefore it is important that the problem is solved [3]. In addition, the design of a controller circuit for DC shunt motor with optimized performance is considered to be a class of nonlinear optimization problem.



Table 1. Readings for Armature and Field Control Method

S. No	Armature control Test		Field control Test	
	Armature voltage	Speed (RPM)	Field current	Speed (RPM)
	Field current = 0.8A		Armature voltage = 230V	
1.	0	0	0.2	1700
2.	40	200	0.4	1600
3.	60	400	0.6	1500
4.	80	600	0.8	1400
5.	100	800	1	1200
6.	140	900	1.2	1000
7.	180	1100	1.4	800
8.	220	1300	1.6	600

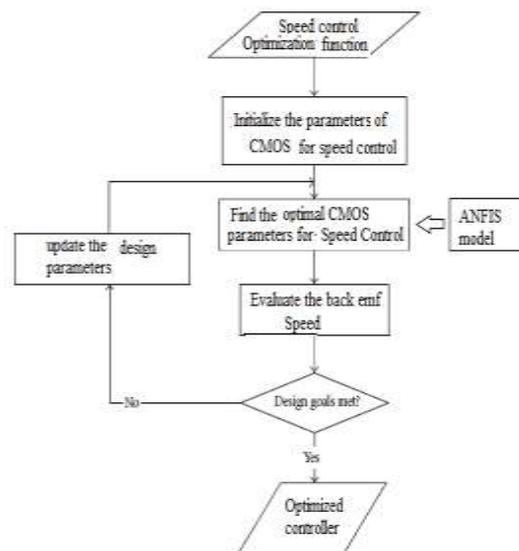


Fig. 1. Schematic for Nano Speed controllers with ANFIS using CMOS technology

In this figure, a circle represents a fixed node and a square represents an adaptive node. The essential parts of a fuzzy inference system consist of five layers. All the nodes are adaptive nodes in layer 1 and the outputs of this layer are the fuzzy membership grade of the inputs. In layer 2, all the nodes are fixed nodes. This layer used AND operator which is a fuzzy operator to fuzzify the inputs. In layer 3, all nodes are fixed nodes which play a normalization role. This normalization layer uses the current values of all fuzzy variables for calculating the value of the mass firing of all rules. In layer 4, all the nodes are adaptive and the output of each node is the product of the normalized strength. In layer 5, only one node labeled ‘ Σ ’ which performs the summation of all incoming signals. The ANFIS refines fuzzy IF-THEN rules that are used to describe the behavior of the system. The learning algorithm of ANFIS is a combination of gradient descent and least squares methods [4].

2. Design Procedure for Nano scale controllers with ANFIS for speed control of DC shunt motors using CMOS technology

The design parameters are denoted by the vector ‘ Y_d ’ with a wide channel ‘ W_n ’ with NMOS transistor and ‘ W_p ’ with PMOS transistor. The capacitance on the load side is taken to ‘ C_l ’ and the input signal denoted by ‘ X_{input} ’ with rise and fall times put together given as ‘ T_{input} ’. An optimal design for the controller circuit for controlling the speed of the DC shunt motor using ANFIS with inputs mentioned in Table 1 with certain forced constraints is proposed here. The complete problem can be considered to be divided into two sub-problems [5]. These design parameters for CMOS technology are optimized using ANFIS and finally with the optimized parameters the speed of the DC shunt motor is controlled by achieving comparable speeds [2, 3]. The design methodology for nano speed controllers with ANFIS for parameter optimization in CMOS technology is illustrated in Figure 1. The optimization objectives are to be finalized at the start of the design procedure. Initially these design parameters are chosen at random and finally optimized by the ANFIS algorithm. These parameters used for design has an impact on the performance of CMOS inverter which includes the rise time (T_R), fall times (T_F) and the propagation delay (T_D) which are calculated using the ANFIS model for the reference value taken as the input. The objective function is minimized to obtain optimal speeds during speed control of DC shunt motor. The ANFIS algorithm facilitates to infer the optimal set of design parameters for the CMOS technology so that the speed of the DC shunt motor is efficiently controlled and these values of speeds obtained are comparable with the conventional field and armature control test conducted in the laboratory.

3. Formulation of ANFIS model

Multilayer perceptron (MLP) is used to control the speed of the DC shunt motors by field and armature control methods using nano technology. The fuzzy logic is used to update the weights adaptively for the ANN structure [1,5] so that the optimal parameter values are obtained for modelling the nano scale

CMOS inverter. The MLP consists of nodes classified into three layers namely, the input, hidden and output layers respectively. The layers in this network are interconnected by connection strengths that are associated with a set of coefficient values (random numbers from 0 to 1) called weights which determines the effect of the information that transits through them. In an MLP, each node will receive inputs from the adjacent nodes and are processed using the sigmoidal activation function to obtain the output from the nodes in the neighbouring layer. The sigmoid function is used as the activation function in the hidden and output layer nodes. This MLP is trained by using supervised learning rule which uses an iterated Back Propagation Algorithm (BPA). Training the ANFIS starts with manoeuvring the raw data set obtained, so that it can be used by the standard CMOS technology for implementing the speed controllers in DC shunt motors. The entire data set is segregated as training and testing data. At the beginning the MLP parameters are assumed in a random fashion. The optimal set of weights is obtained during training of the data set until the objective function is optimized.

3.1 Collection of data set and Scaling of data

In order to generate training and test data, CMOS inverters are constructed to control the speed of the DC shunt motors corresponding to the design parameters related to the parameters and input signal as illustrated in Table 2. This stream of Berkeley Predictive Technology model is used to construct the ANFIS based structure using nano technology. It is noticed from Table 2 that the input parameters for CMOS technology vary over a wide range. Consequently the output performance parameters will also vary over a wide range. Therefore, a systematic preprocessing of training data, referred to as data scaling is required for efficient construction of the ANN model. In this work, we have used linear scaling of the data between 0 and 1, described by the following formula: The data recorded in Table 2 is scaled using the formula given in Equation 2.

$$Z_{\text{normalized}} = Z_i / Z_{\text{max}} \tag{2}$$

This normalized data is stored in MATLAB workspace is utilized for building the ANFIS structure using

S. No	Type of the parameter	Reference values		Scaled values	
		Minimum value	Maximum value	Minimum value	Maximum value
1.	Channel width for N-MOS (W_n) in nm	47	1000	0.047	1
2.	Channel width for P-MOS in nm (W_p)	47	1000	0.047	1
3.	Load Capacitance (C_L) in Farads	0.1	4	0.025	1
4.	Time for the input signal	500000 ns	10 ns	0.05 ns	0.1 ns

the Graphical User Interface (GUI). The ANFIS editor is opened in MATLAB tool box and the normalized training data set is given to the ANFIS structure. To generate the ANFIS structure for the given data by sub clustering techniques are used.

3.2. ANN training and Optimization of the weights using fuzzy logic

A typical 3-layered feed forward MLP architecture is used to model the CMOS inverter using ANN. Depending on the minimum value of the Mean Squared Error (MSE) for training, the weight parameters and the bias values are adjusted. The MSE is set to 10^{-5} .

Table 2. Range of Inverter circuit design parameters with CMOS technology using speed control

In this neuro fuzzy system, the fuzzy model is built by following steps like Fuzzification, Knowledge Base, Decision Making and Defuzzification. In the fuzzification stage the linguistic variables like low, medium and high corresponding to speed nature, armature voltage and field current values are assigned. Then a suitable membership function is to be chosen so that each and every support value is assigned to the appropriate Universe of Discourse value. The process of fuzzification is dependent on the knowledge base which forms two parts, the data base and the rule base. The data base in gathered from the conventional speed control method carried out in the laboratory and the standard parameter values for CMOS technology which is recorded in Table 1 and 2 respectively. Then the rule base includes the formation of ‘IF THEN’ rules using the linguistic variables. Then the Decision Making Logic which uses ‘MIN-MAX criteria to infer single truth value. The last step is defuzzification, where the crisp values are converted to real values by using area of centroid method. The fuzzy logic is used to tune the weights for which an appropriate number of inputs, outputs, and activation function of the ANN so that the tuned set of weights are obtained and weight values are required.

4. Results and Discussion

For a CMOS inverter to effectively control the speed of the DC shunt motor, the symmetric static switching characteristics is essentially needed. Conventional design procedure involves manual adjustment of the channel length for PMOS and NMOS in equal ratio. Therefore, an automatic optimization strategy is needed so that the symmetry is achieved without sacrificing the speed characteristics during armature and field control of DC shunt motor. Thus the justification of the optimization problem lies not only in optimizing the single design objective but also in attaining design solution within a desired design specification space. The accuracy obtained by the proposed nano CMOS technology is indicated in Table 3. The result for field control and armature control methods are indicated in Figure 2 and 3 respectively using nano scale CMOS inverter with ANFIS optimization. The parameters for the ANFIS structure are given below. The ANFIS network information includes the Number of nodes: 20, Number of linear parameters: 8, Number of nonlinear parameters: 8, Total number of parameters: 16, Number of training data pairs: 10, Number of checking data pairs: 0, Number of fuzzy rules: 4.

Table 3. Accuracy of the ANFIS model in CMOS parameter optimization

S. No	MSE	Output Parameter	Values obtained during Training	Values obtained during Testing
1.	0.0062	Rise Time (T_R)	1.22	1.38
2.	0.0013	Fall Time (T_F)	1.92	1.99
3.	0.0005	Propagation delay (T_D)	1.34	1.41

The Mathematical Validation for nano scale CMOS inverter based speed control of DC shunt motors with ANFIS model is done by evaluating MAE and Accuracy calculation. The Mean Absolute Error (MAE) and percentage accuracy are calculated using the Equation 3 and 4 respectively.

$$MAE = (\text{Estimated value of Speed} - \text{Actual value of Speed}) / \text{Actual Speed value} \tag{3}$$

$$\% \text{ Accuracy} = (\text{Actual Speed} / \text{Estimated speed}) * 100 \tag{4}$$

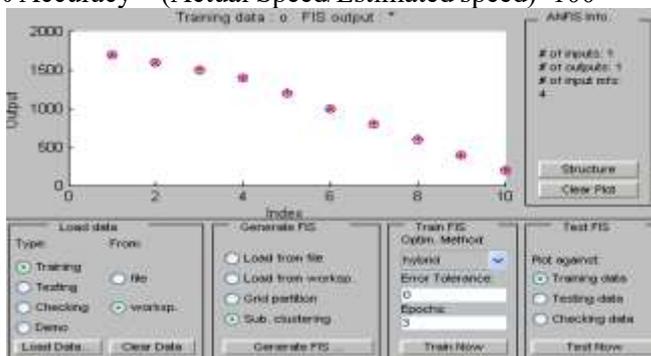


Fig. 2. ANFIS structure for field control test

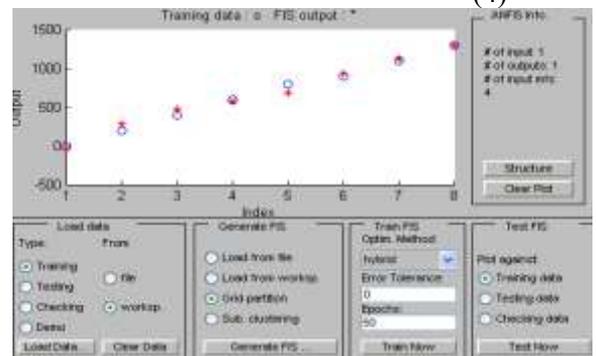


Fig.3. ANFIS structure for Armature control test using sub clustering method

From Table 4 and 5 it is inferred that the MAE values for both armature and field control lies in the range of 0 to 0.025 which means that the accuracy of speed estimation is in the range of 97.5% to 100% for field control method. Whereas for armature control method MAE is 0.0001 and the accuracy of speed estimation is 100%.

5. Conclusion

The data gathered from the experimental setup is being utilized to build the ANFIS model for controlling the speed of a DC shunt motor and it is inferred that the estimation accuracy is 97.5 to 100% for field control method and 100% for armature control method. This paper presents an approach for the design of a nano scale CMOS inverter using ANFIS scheme. A compact design was used in the nano scale range which is very complicated and difficult to handle during optimization of the design.

Table 4. MAE for Armature Voltage Control Method

S. No	Armature voltage (V)	Actual Speed (RPM)	Estimated Speed (RPM)	MAE
1.	0	0	0	0.00001
2.	40	200	200	0.00001

Table 5 MAE for Field Control Method

S. No	Field current	Actual Speed (RPM)	Estimated Speed (RPM)	MAE
1.	0.2	1700	1700	0.00001
2.	0.4	1600	1610	0.00625
3.	0.6	1500	1520	0.01333

3.	60	400	400	0.00001	4.	0.8	1400	1400	0.00001
4.	80	600	600	0.00001	5.	1	1200	1230	0.025
5.	100	800	800	0.00001	6.	1.2	1000	1000	0.00001
6.	140	900	900	0.00001	7.	1.4	800	800	0.00001
7.	180	1100	1100	0.00001	8.	1.6	600	600	0.00001
8.	220	1300	1300	0.00001					

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