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Speed Control of Separately Exited DC Motor Using Artificial Neural Network

A.L. Hashmia SH. Dakheel
University of Technology
Electromechanical Eng. Dep.

Abstract

This paper proposes implementing intelligence techniques to improve efficiency speed control of separately excited DC motor (SEDM). This technique is Artificial Neural Network (ANN) which is one of the most important modern techniques that using in control applications.

In this study, the intelligent model is developed to speed control of SEDM which operated at three stages:-the first, NARMA-L2 controller used to control the speed under different external loads conditions. The second, the controller is performance at different reference speed and the last, the intelligent controller deals with various parameters of SEDM.

Simulation results indicates to the advantages, effectiveness, good performance of the artificial neural network controller which is illustrated through the comparison obtain by the system when using conventional controller (Proportional-Integral (PI)). So the results show ANN techniques provide accurate control and ideal performance at real time.

Keyword: - Separately dc motor (SEDM), Artificial Neural Network (ANN), PI -NARMA-L2.

السيطرة على سرعة محرك تيار مستمر ذو إثارة منفصلة باستخدام الشبكة الاصطناعية العصبية

الخلاصة

يقدم هذا المقال بناء تقنيات ذكية لتطوير كفاءة السيطرة على سرعة محرك تيار مستمر ذو إثارة منفصلة (SEDM). هذه التقنية هي الشبكة العصبية الاصطناعية التي هي واحدة من أهم التقنيات الحديثة المستخدمة في مجال تطبيقات السيطرة.

في هذه الدراسة ,النموذج الذكي طور للسيطرة على سرعة SEDM الذي يعمل عند ثلاثة مراحل:-الأولى مسيطر (NARMA-L2)يستخدم في السيطرة على السرعة تحت ظروف أحمال خارجية مختلفة والثانية, المسيطر يعمل عند سرع مرجعية مختلفة والأخيرة المسيطر الذكي يتعامل مع مواصفات متنوعة ل(SEDM).

نتائج المحاكاة تشير إلى المزايا والفاعلية والعمل الجيد لمسيطر الشبكة العصبية الاصطناعية والتي توضح من خلال المقارنة التي يتم الحصول عليها من المنظومة عندما يتم استخدام المسيطر التقليدي مسيطر(النسبة-التكاملية (PI)).وكذلك تبين النتائج إن تقنيات ANN تجهز سيطرة دقيقة وأداء مثالي عند الزمن الحقيقي.

1. Introduction:-

The direct current DC motors have been widely utilized in many industrial applications [1,2] such as electric vehicles, steel rolling mills, electric crank, and robotic manipulators due to precise, wide ,simple and continuous control characteristics.

Direct current motor drives have been widely used where accurate speed control is required. The proportional Integral (PI) controller is one of the conventional controllers and it has been widely used for speed control of dc motor drives .The major features of the PI controller are its ability to maintain a zero steady-state error to a step change in reference[3].

The last decade has seen an increasing interest in computational intelligence (CI) applications in control of various dynamic systems, including electric motor drives. Most frequently used CI methods, Artificial Neural Networks (ANN) and Fuzzy logic (FL), are widely utilized in area of modeling, identification, diagnostics and control [4].

With the emerging development in artificial intelligence applications, Neural Network has been used in identification and control of linear and non-linear system. The main advantage of ANN based techniques over conventional techniques is the non-algorithmic parallel-distributed architecture for information processing that allows it to learn any complex input-output mapping[5] .So, ANN are rapidly gaining popularity among power system researches. ANN are extremely useful in the area of learning control. Consequently, the traditional adaptive control designed has taken a new turn with advent of ANN.

ANNs are capable of learning by training data under various operating conditions [6].

In this study, the ANN application has been proposed for the speed control of separately exited dc motor SEDM by using NARMA-L2 controller. Also this study discusses difference in speed control of SEDM by using conventional (PI) controller and NARMA-L2 controller.

2. Mathmetical Model of Separately Exited DC Motor:-

A DC motor considered a single input single output system having torque-speed characteristics compatible with most mechanical loads. This makes the DC motor controllable over a wide range of speeds by proper adjustment of its terminal voltage. Therefore DC motors are used in high performance drives applications[7].

The dynamics of the SEDM. As shown in fig. (1) are described by the following electrical and mechanical differential equations:-

$$L_a \frac{di_a}{dt} = -i_a R_a - kw + v_a \ldots\ldots\ldots\ldots(1)$$

$$J\frac{dw}{dt} = ki_a R_a - BwT_L \ldots\ldots\ldots\ldots(2)$$

Where v_a is the motor input voltage; i_a is the armature current; w is the rotor speed; T_L is the load torque; R_a is the armature resistance; L_a is the armature inductance; J is the motor rotation inertia; B is the damping constant and K is the torque or EMF constant[5].

The parameters of the SEDM are:1800 rpm, 220 volts, L_a= 0.0025H, R_a=0.5Ω,TL=21.4N.m, J=0.0013kg/m^2, B=0.001 N.m, the speed at full-load=1500rpm.

3-Simulation of SEDM model:-

The transfer function block diagram of SEDM can be developed by MATLAB Simulink as shown in fig (2).

And the speed response without controller at no load and full load is shown in fig.(3) when T_L=21N.m.

4-PI Controller:-

The proportion integral (PI) speed controller is initially designed using the symmetrical optimum criterion[8].This controller is used to reduce or eliminate the steady-state error between the measured motor speed (w) and the reference speed (w_{ref}) to be tracked. The transfer function of PI controller is given by [9]:-

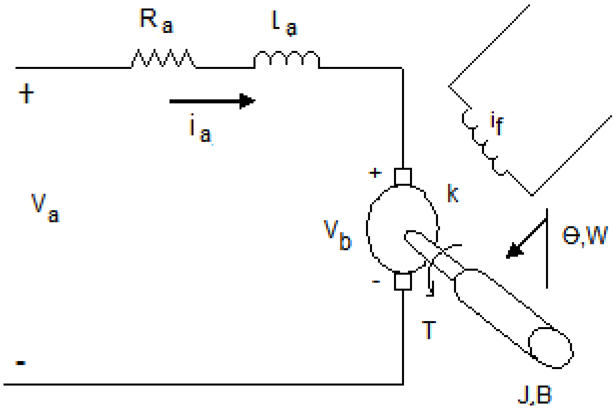
$G_C(s)=K_p+K_1/s$……………………(3)

Where K_p and K_1 are the proportional and integral gains (K_P=10, K_1=0.1).

Figure (4) shows the block diagram of SEDM with PI controller at different load and different reference speed, and the speed response of SEDM with PI controller can be shown in figure (5),(6) at different load and different reference speed respectively.

In the feedback control system, the dynamics of the DC motor can be described by transfer function. The signal will be sent to the plant and the output signal will be obtained, this new output signal (speed)will be sent back to find the new error signal and computes until the error signal becomes so small [10].

In this paper the mean square error reach under 10^{-5} which can be shown in figure (7).



Fig(1) electrical model of SEDM

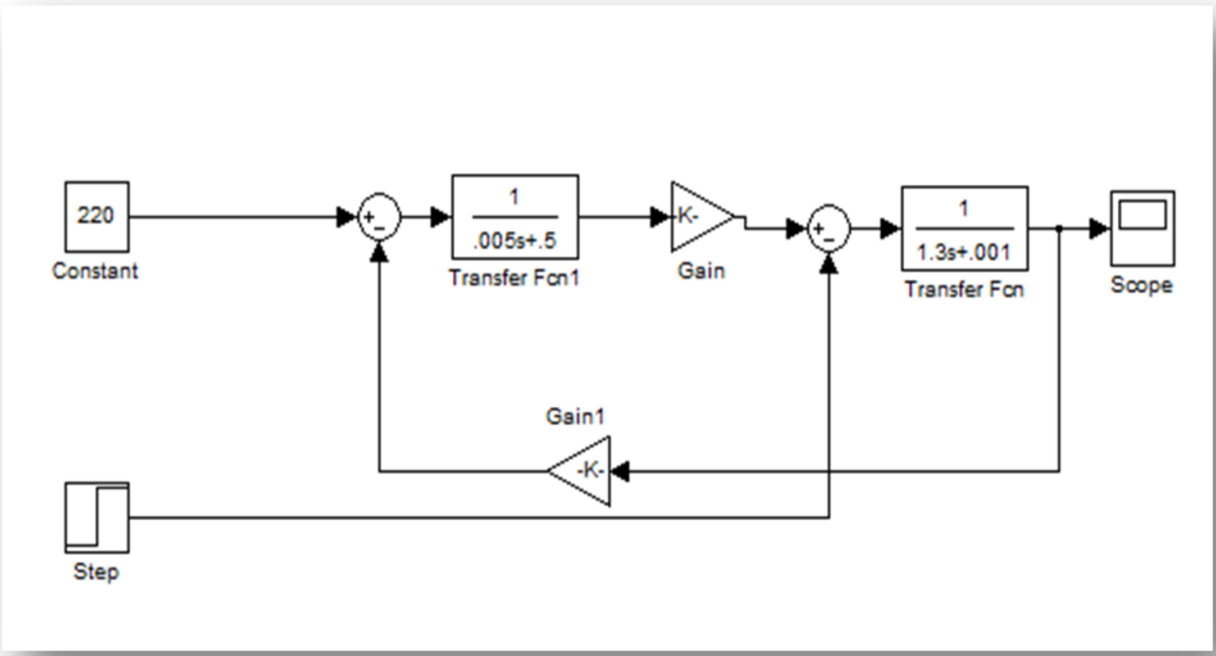


Fig. (2) The transfer function block diagram of separately excited D.C. Motor without control

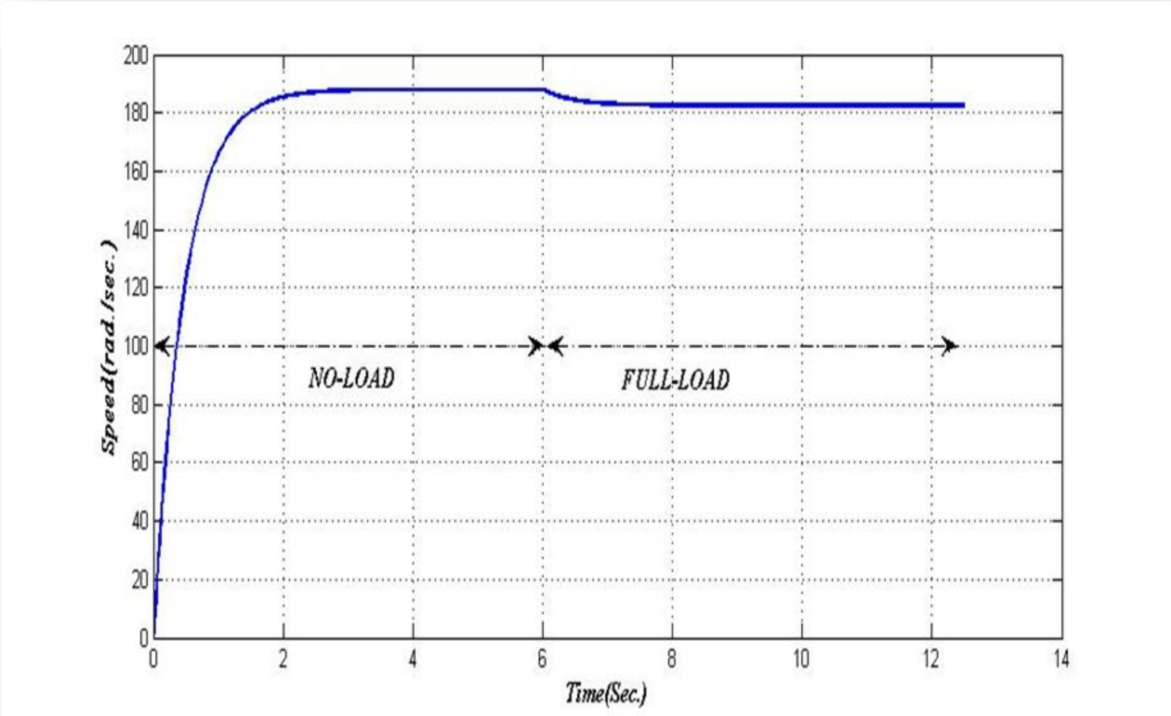


Fig.(3) The speed response (w) of the separately excited D.C. motor without control.

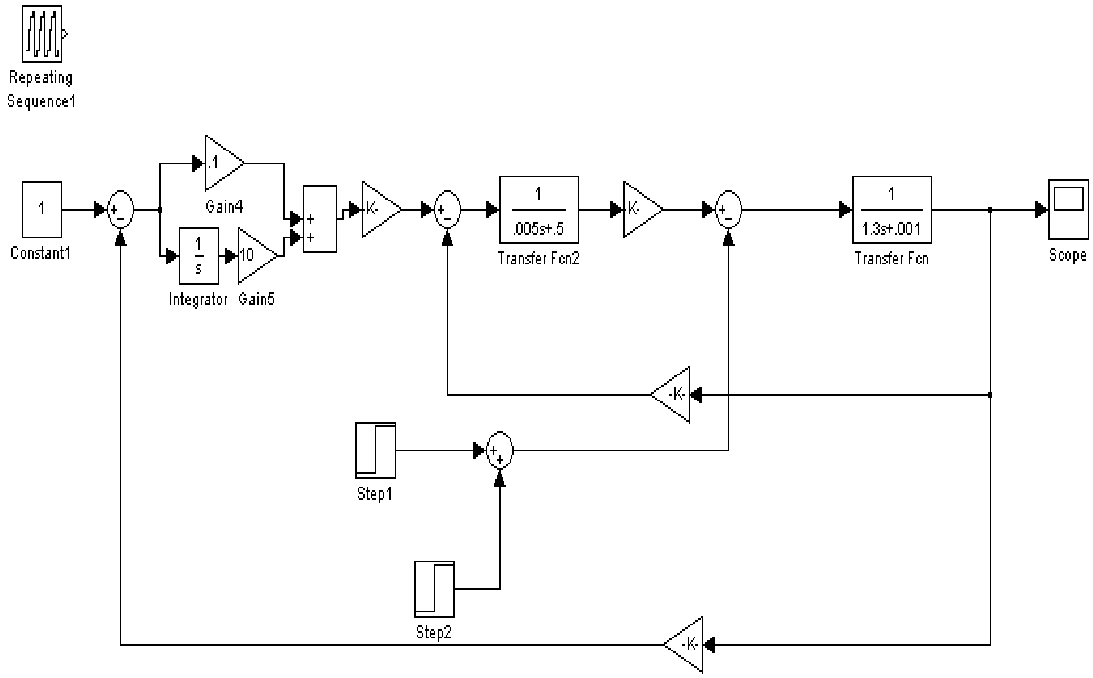


Figure (4) the block diagram of SEDM with PI controller

5-Training the NARMA-L2:-

Training is the process of the modifying the connection weights in some orderly fashion using a suitable learning method. The network uses a learning model, in which input is presented to the network along desired output. The weights after training contain meaningful information whereas before training they are random and no meaning

Training set is a group of matched input and output patterns used for training the network, usually by suitable adaptation of the synaptic weights.

It is important that all the information, the network needs to learn is supplied to the network as a data set. When each pattern is read, the network uses the input data to produce an output, which is then compared to the training pattern, if there is difference, the connection weights are altered in such a direction that the error is still greater than the maximum desired tolerance, the ANN runs again through all the input patterns repeatedly until all the errors are within the required tolerance. The trained network can then be used to make decisions, identify patterns, or define associations in new input data sets not used to train it [11], figure (8) shows neural training data.

6- Neural Network control:-

Nowadays, we have seen extensive researches developments effort to use the intelligent system in many industrial applications, because of its strong features like:- learning ability, massive-parallelism, fast adaptation, inherent approximation capability, and high degree tolerance[12].

The artificial neural network (ANN) is best suited for solving the problems that are non-linear in nature. In ANN we can use parallel processing methods to solve some real-world problems where it is difficult to define a conventional algorithms. The ability of ANN to learn large classes of non-linear functions is well known[13].

ANNs are applied broadly because of the following special qualities:-

1-all the ANN signals are transmitted in one direction, the same as automatically control system.

2-The ability of ANN to learn the sample.

3-The ability to creating the parallel signals in analogue as well as in the discrete system.

4-The adaptive ability.

With the special qualities mentioned above, ANN can be trained to display the non-linear relationships that the conventional tools couldn't implement. It also is applied to control complicated electro-mechanics system such as DC motor and synchronous machines[14].

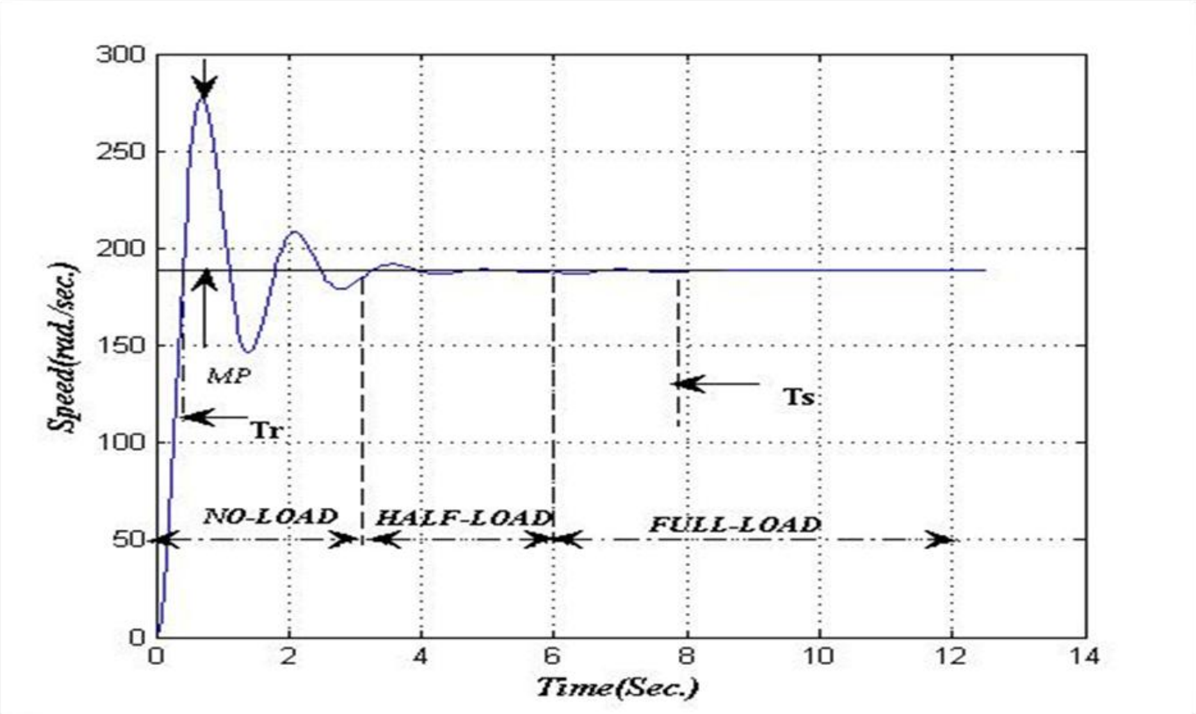
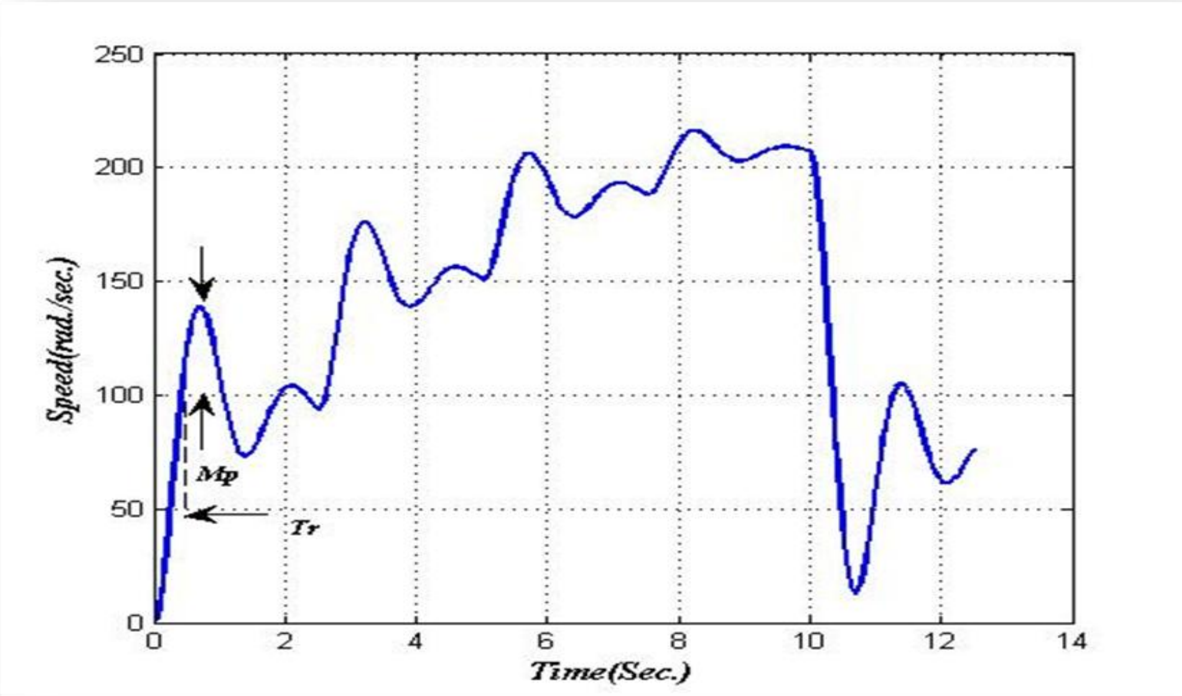


Fig. (5) The speed response with PI Controller at different load



Fig(6) different reference speed with PI controller

7-Design of Neural Network (NARMA-L2 Controller):-

The intelligent neural controller is applied for speed control of SEDM. In designing and training an ANN to emulate function, the only fixed parameters are the number of input and outputs to the ANN which are based on the input/output variables of the function[13,14].

This study uses NARMA-L2 neural controller to control the speed of SEDM, NARMA-L2 (Nonlinear Autoregressive-Moving Average) neural controller requires the least computation and it's simply a rearrangement of the neural network plant model, which is trained off-line, in batch form. The only online computation is a forward pass through the neural network controller [12].

NARMA-L2 controller, a multilayer neural network has been successfully applied in the identification and control of dynamic systems[1].

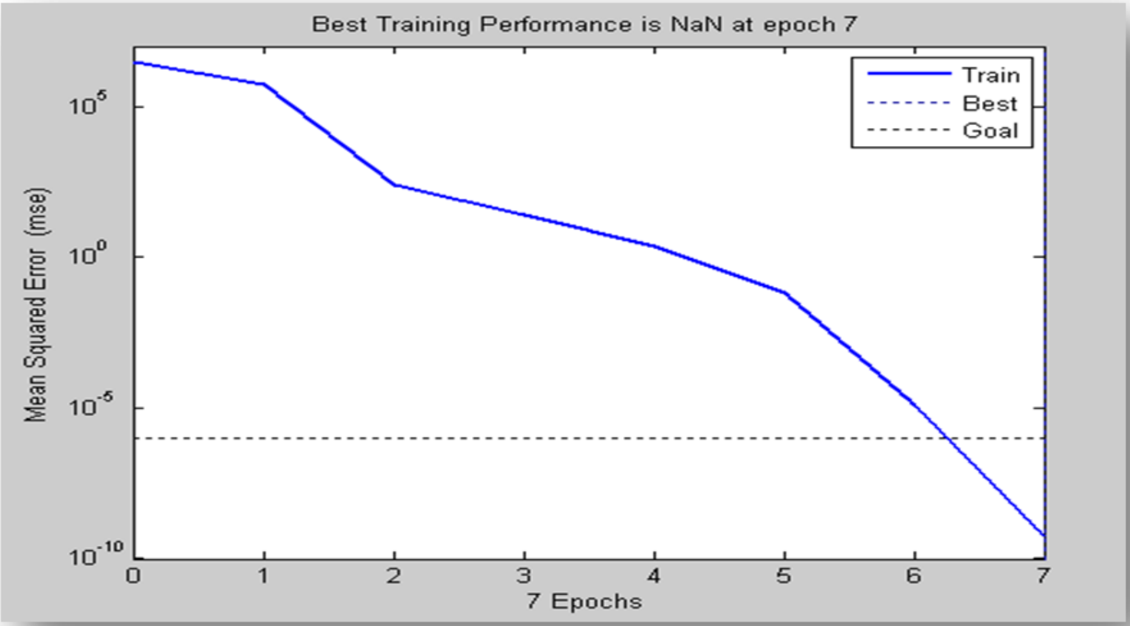
It is also widely accepted that maximum of two hidden layers are sufficient to learn any arbitrary non-linearity. However, the number of hidden neurons and the values of learning parameters, which are equally critical for satisfactory learning, are not supported by such well established selection criteria. The choice is usually based on experience, the ultimate objective is to find a combination of parameters which gives a total error of required tolerance a reasonable number of training sweeps[14]. ,fig (9) show the general structure of ANN used in this study which consist of three input represent (I_a ,V_t ,w_r) of the SEDM and one output (w) and consist of seven hidden layers. The process of training done by using large numbers of input/output data which obtained from SEDM.

8-Simulation results and discussion:-

This study proposes the simulation of SEDM to control speed using NARMA-L2 controller which is implemented and compared with conventional PI controller under different load, different reference speed and wide range of different parameters. A complete simulation model for SEDM drive is developed as shown in fig (10), the waveforms of speed control for SEDM at different load and different reference speed can be shown in figure (11) and figure (12) respectively.

This intelligent model can be applied for speed control of another DC separately motor has parameters ($R_a=2\Omega$, $L_a=3.2mH$,$TL=21.4N.m$, $J=0.11kg/m^2$, $B=0.0001\ N.m$, the speed at full-load=$1500rpm$). Comparison is made with the response of conventional PI and NARMA-L2 controller of this machine can be shown in figure (13).

In this work , the performance of a DC motor with different control strategy, artificial neural network and conventional (PI) is evaluated on the basis of settling time, maximum over shoot and steady state error which can be shown in table (1).



Fig(7) mean square error

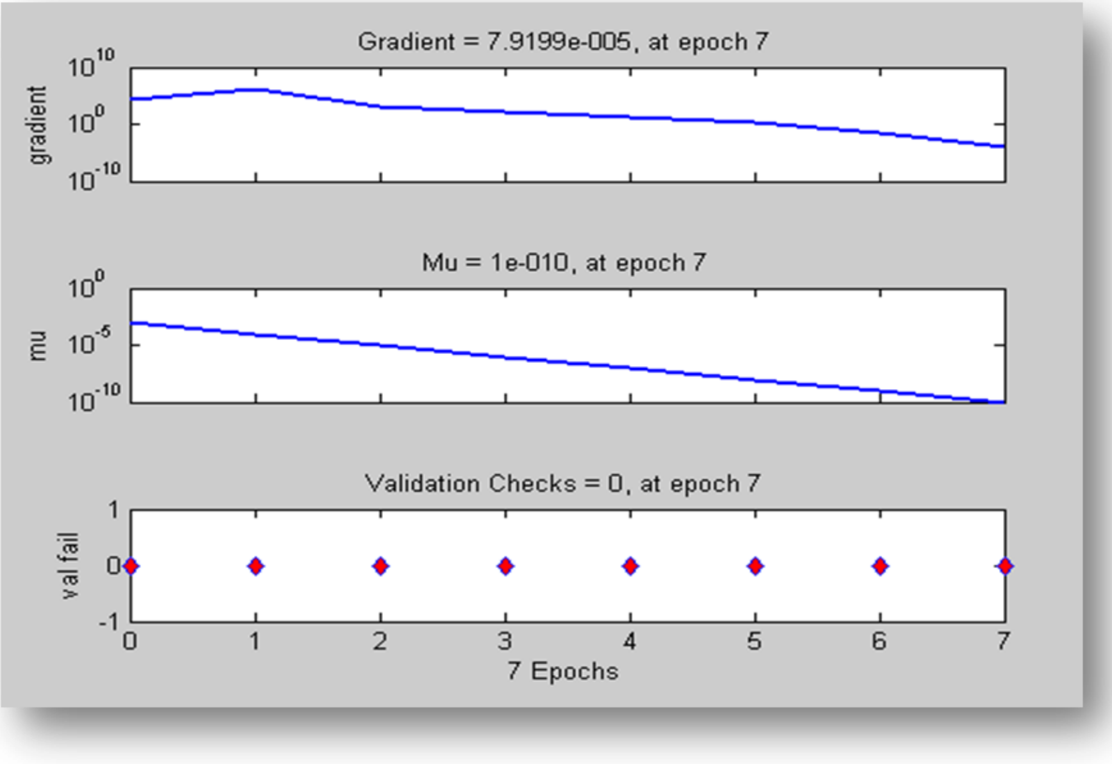


Fig (8) neural training data

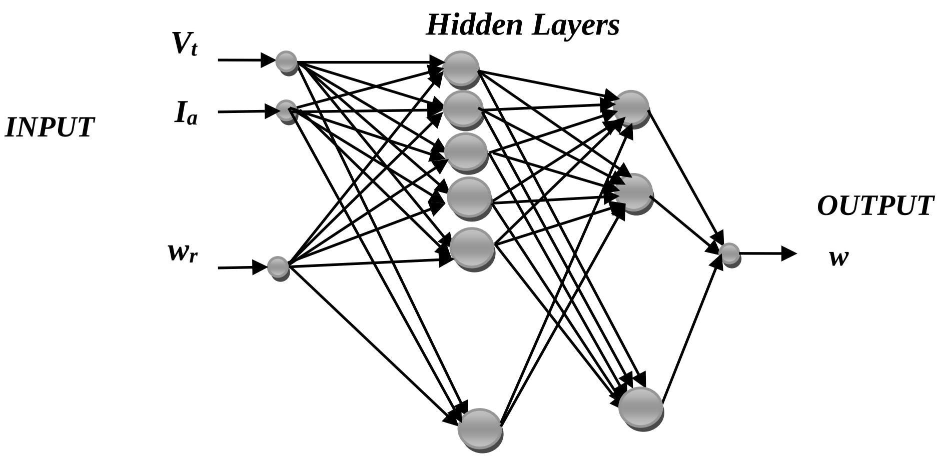


Fig. (9) A general ANN structure

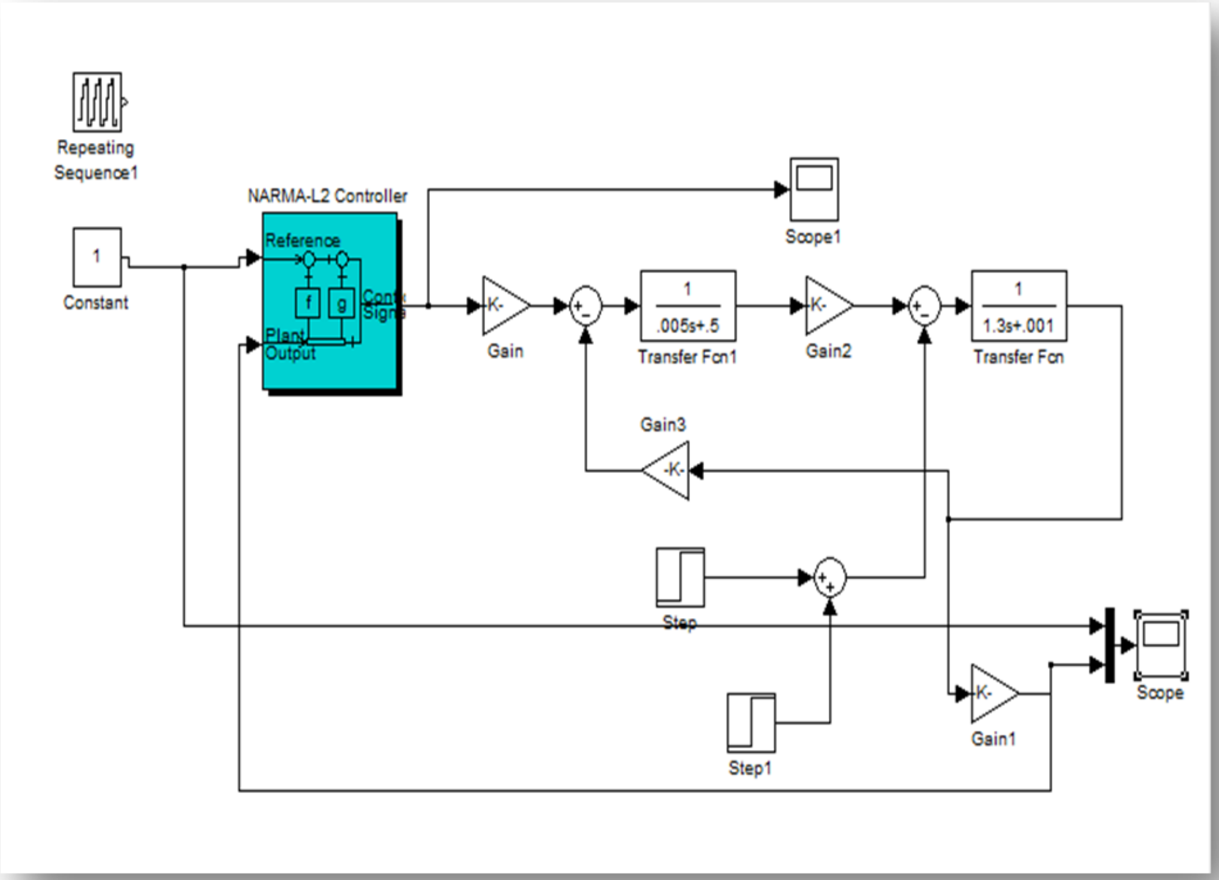


Fig. (10) Developed simulation model for SEDM drive

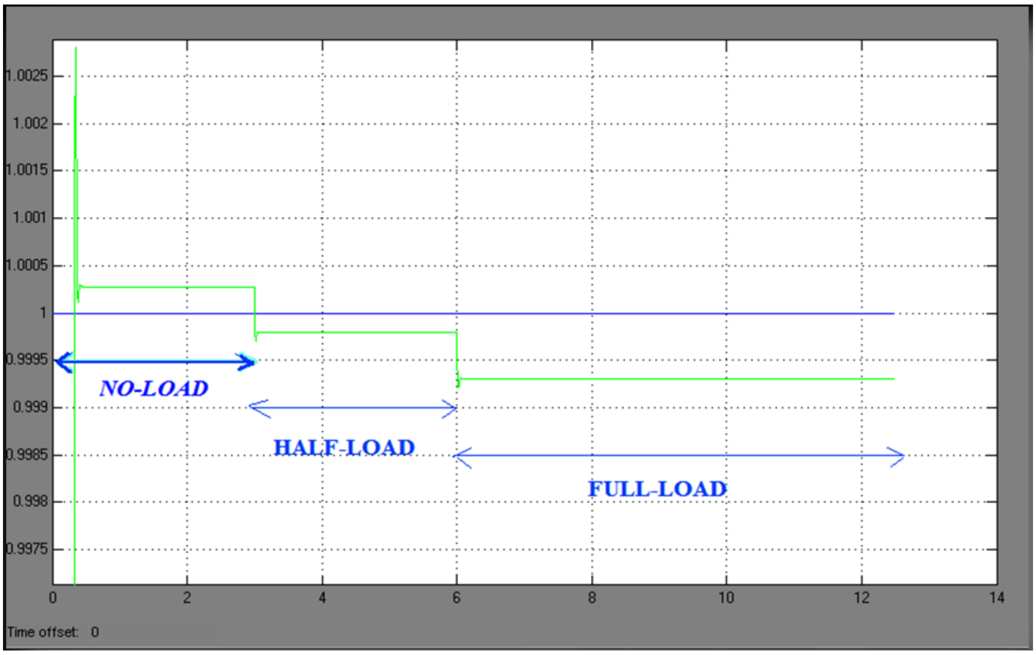


Fig. (11) Waveforms of the speed control for SEDM at different load

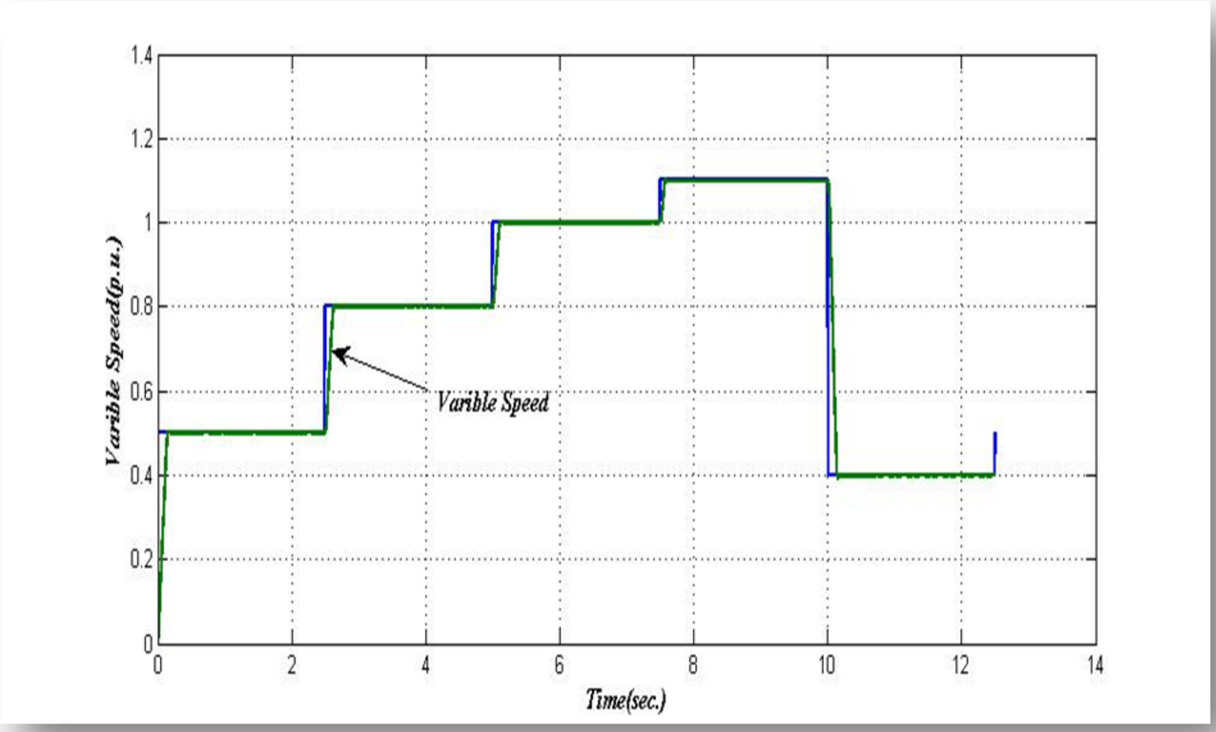


Fig (12) the waveform of model at different reference speed

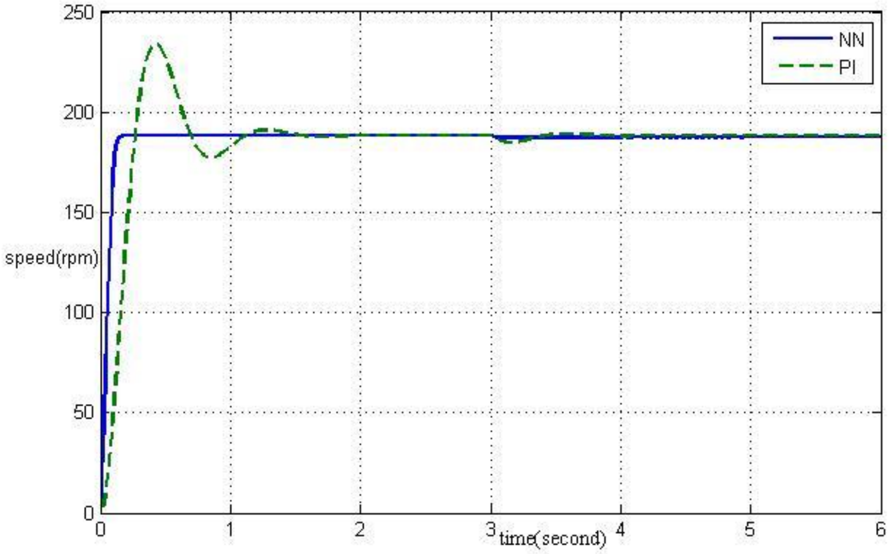


Fig. (13) Waveforms of the speed control for SEDM with PI controller and neural network controller.

Table (1)

Results	PI- CONTROLLER		NEURAL-CONTROLLER	
	No-Load	Full-Load	No-Load	Full-Load
Maximum overshot (rad/sec.)	100	2	0.00025	-0.00075
Rising time (Sec.)	6 Sec.	0 Sec.	0 Sec.	0 Sec.
Settling time (Sec.)	7.8 Sec.	7.8 Sec.	0 Sec.	0 Sec.
Steady state error (%)	0 %	0 %	0 %	0 %

9-Conclosion:-

The results shows that, NARMA-L2 controller is the better controller than PI, which is provides satisfactory performance and good response (zero steady state). This controller model shows the excellent step responses at different parameters , different external loads and many reference speed.

The results shows that the implementing NARMA-L2 controller is given simple data processing, effective solution and can be implemented easily in real time.

Finally, the DC motor has been successfully controlled using NARMA-L2 controller and that is possible to applied the artificial network for speed control in wide range of DC machine.

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