RESEARCH ARTICLE

Performance Analysis of High Voltage Intelligent Supervisory Systems Using Neural Networks

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ABSTRACT: This work is to design a neural network based High voltage intelligent model reference adaptive controller. In this scheme, the intelligent supervisory loop is incorporated into the conventional model reference adaptive controller framework by utilizing an online growing multilayer back propagation neural network structure in parallel with it. The Conventional Model Reference Adaptive Controller (MRAC) schemes the controllers were designed to realize plant output converges with reference model which is linear. But this scheme is more efficient for controlling linear plant with unknown parameters. However, using MRAC for controlling the nonlinear system in a real time application is a challenging one. The control input parameter values are given by the sum of the output of conventional MRAC and the output of Neural Networks (NN). The NN is used because to compensate the non-linearity of the plant. The parallel neural controller is designed to precisely track the system output to the desired commend trajectory. The proposed work can improve the system behavior and also force the system to follow the reference model. The effectiveness of the proposed work is demonstrated by MATLAB simulation. The results of the proposed work have been demonstrated by simulations and compared with the existing methods for improved results. This MRAC scheme doesn't need any initial parameters and works even in uncertain environmental conditions. It easily adopted for all real time environmental conditions without any pollution and fuel consumptions.

KEYWORDS: Model Reference Adaptive Controller, Artificial Neural Network (ANN), Backlash and Dead zone

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1. INTRODUCTION

In Adaptive literature, an important research work is very difficult in modeling, nonlinearities and uncertainties. Model Reference Adaptive Control (MRAC) is one of the major schemes used in adaptive systems. Model Reference Adaptive Control is one of the methods with considerable attention, and also many new approaches are applied to practical applications [1,2]. In this the controller is designed to realize plant output converges to reference model and output based on assumption the plant can be liberalized. This scheme is effective for controlling the linear plants with unknown parameters. However, it may not confirm for control the nonlinear plants with unknown structures. Artificial Neural network (ANN) has become a very popular tool in many control applications due to their higher computation rate and able to handle nonlinear system performance. The relevant research work with ANN as a part of control scheme is illustrated next. An Adaptive control system of uncertain conditions with neural network was discussed in [3].Various types of neural network algorithms were efficiently utilized in identification of nonlinear systems [4,5]. A variety of algorithms were utilized to adjust the weight of the NN. In a typical multilayered NN, the weights in the layers can be adjusted as to minimize the output error between the NN's output and the observed output. The back propagation algorithm for efficiently updating the weight is useful in many applications such identification of non linear systems. Off-line iterative algorithm can be employed in such care of identification or modeling. In these conditions applying any learning rules to the system, the derivatives of the system output values should respect to input parameter values [6]. Kawalo et al [7] have deeply explained the simple structure of Neural based feed forward controller which is equivalently an inverse of the controlled system after the NN completes learning of the weights which are adjusted

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to minimize the feedback error. Narendra et al [8] has shown in general indirect approach to nonlinear discrete time neuro – control scheme which consists of identification and adaptive control by using Chen [9], and Liu et al [10] that the NN – based adaptive control algorithm can cooperate well with identification of the nonlinear functions to realize a nonlinear adaptive control when the non linear adaptive control when the nonlinear control scheme is feedback linearizable. Kamalasudan [11] presented a fighter aircraft pitch controller evolved from a dynamic growing NN in parallel with MRAC Controllers. The neural networks for nonlinear approximation techniques were involved in adaptive controllers have been discussed in many industrial applications [12,13]. In particular, the adaptive tracking control architecture proposed in [14] evaluated nonlinear dynamic systems for uncertainty is either unknown or impossible. The use of NN for identification is deeply explained. Sanner and Slotine [15] have discussed a direct adaptive neural network controller for a class of non linear system. In this work, a proposed MRAC controller is designed with multilayer back propagation NN in parallel with MRAC. Baris Baykant Alagoz et al [16] have presented a model reference adaptive control scheme based on reference-shaping approach. Toreduce noise sensitivity of this system, a dead zone rule has been applied to the adaptation process involved.Ahmed et al [17] has demonstrated the use of NN for identification and control of nonlinear systemswith direct adaptive NN controller. Hossein Kaydani et al [18] have presented a newmethod of permeability prediction by combining competitive algorithms with Levenberg–Marquardt (LM) neural network algorithm.

Coman and Boldisor [19] have proposed to illustrate how the MRAC theory related to SISO systems. Ge Song and Gang Tao [20] have developed a partial-state feedback MRAC scheme for outputtracking. The importance of model reference adaptive controller has performing the model matching for uncertain systems with a given reference model. The network weighting functions has to adjust by multilayer back propagation algorithm which carried out in real time applications. The proposed method output results have more effective when compared with the existing conventional MRAC methods.

Problem description

Consider Single Input Single Output (SISO), Linear Time-Invariant (LTI) system the transfer function of the system is given by,

$$G\ (s)=\frac{y_P(s)}{u_p(s)}=K_P\frac{Z_p(s)}{R_P(s)} \tag{1}$$

Where $u_p(s)$ - plant input and $y_P(s)$ is the Laplace Transform of the plant output

The transfer function of the Reference Model is given by

$$G_m(s)=\frac{y_m(s)}{r(s)}=K_m\frac{Z_m(s)}{R_m(s)} \tag{2}$$

where r model system input and y_m is model system output.
The output error is given as

$$e=y_p-y_m \tag{3}$$

The main objective of this work is to design the control input and find output error, e goes to zero asymptotically the arbitrary initial condition.

Model Reference Adaptive Controller

Consider the Relative Degree (n) of Adaptive Controller is one. The input and output equation of filters have been given by,

$$\dot{\omega}_1=F\omega_1+gu_p \tag{4}$$

$$\dot{\omega}_2=F\omega_2+gy_p$$

Where F is a $(n-1)*(n-1)$ stable matrix and the roots include the zeros of the reference model. In the adaptive control scheme, the control u is structured as

$$u=\theta^T\omega \tag{5}$$

where $\theta\ =[\theta_1,\theta_2,\theta_3,C_0]^T$ is a vector of adjustable parameters.

The tracking error of this system is given by

$$e=G_m(s)p^*\tilde{\theta}^T\omega$$

Where

$$P^*=\frac{k_P}{k_m} \quad \text{and} \quad \tilde{\theta}=\theta(t)-\theta^*$$

P^* represented parameter error

The transfer function the parameter error and the tracking error should be Strictly Positive Real.

For n=2 control schemes, the control u is structured as

$$u = \theta^T \omega + \dot{\theta}^T \Phi = \theta^T \omega - \theta^T \Gamma \phi e_1 \operatorname{sgn}(K_p / K_m) \quad (6)$$

where $\theta = [\theta_1, \theta_2, \theta_3, C_0]^T$ is a vector of adjustable parameters.

The dynamic of tracking error is

$$e = G_m(s)(s + p_0) p^* \tilde{\theta}^T \phi \quad (7)$$

Where

$$P^* = \frac{k_P}{k_m} \text{ and } \tilde{\theta} = \theta(t) - \theta^*$$

P^* represents the parameter error. $G_m(s)(s + p_0)$ has proper and strictly positive real.

Adaptation rule for the controller gain θ is given by

$$\dot{\theta} = \Gamma \phi e_1 \operatorname{sgn}(K_p / K_m) \quad (8)$$

where

$e_1 = y_p = y_m$ and Γ is a positive gain

e_1 is tracking error

Proposed MRAC with NN

The proposed MRAC with neural network is shown in Fig.1.

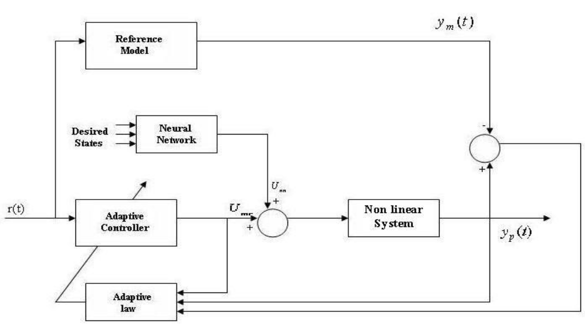

Fig. 1 Block diagram of the proposed Model RAC

The State Space and output equation of the Single Input Single output Linear Time-Invariant system is given by

$$X(t) = AX(t) + BU(t) \quad (9)$$

$$Y(t) = CX(t) + DU(t)$$

system output y_p converges to the reference system model output y_m,

The control input U is given by,

$$U = U_{mr} + U_{nn}$$

U_{mr} is output of adaptive controller and given by

$$U_{mr} = \theta^T \omega$$

$$\theta = [\theta_1, \theta_2, \theta_3, C_0]^T \quad (10)$$

$$\omega = [\omega_1, \omega_2, y_p, r]^T$$

The system stability performance and the adaptability have been achieved by an adaptive control method. The controller design concept was explained with state equation of second order system is given by

$$\dot{x}_1 = x_2 \quad (11)$$

$$\dot{x}_2 = ax_1 + bx_2 + cU$$

and let the output,

$$y_p = x_1$$

U_d can be established and track desired signals say $\dot{x}_{2d}$

controller equation can be written as

$$U_d = c^{-1}(\dot{x}_{2d} - ax_1 + bx_{2d})$$

which is the same as,

$$U_d = D(y_p, x_{2d}, \dot{x}_{2d})$$

where D is the functional relation between states.

The system response equals to desired value if the controller U_d can effectively inverse the system dynamics.

System dynamics and error equation has to be written as,

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$e = (x_d - x) = 0$

The control law of neural network now becomes

$$U_d = D^{-1}(y_p, x_{2d}, \dot{x}_{2d})$$

Where y_p is the plant output.

The input to the neural network is given by

$$X = [y_p, x_{2d}, \dot{x}_{2d}]$$

Multilayer Back propagation NN Controller

The Model Reference Controller is modeled using system output and control law. The Nonlinearity in the output can be linearized through Multilayer Neural Networks. The neural network inputs are desired system states, its derivatives, and the plant performance. The multilayer back propagation neural networks have been useful because of its inherent nonlinear mapping capabilities. This method can deal effectively for real-time computer control based applications. The Neural Network of proposed work has shown in the Figure 2.

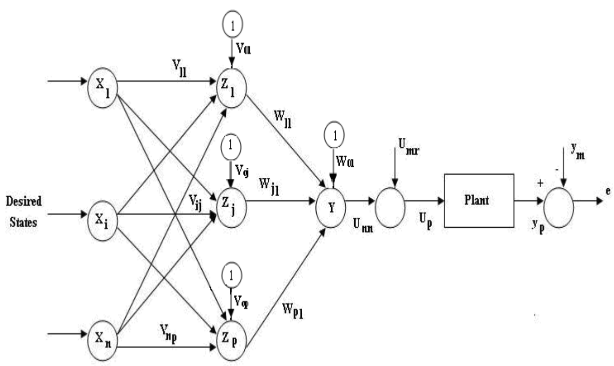

Fig. 2 Structure of Neural Network for Multilayer Back propagation

Let x_i -input to the i^{th} node in input layer,

z_j -input to the j^{th} node in hidden layer,

y -input to one node in output layer.

V_{ij} -weighting function between the input layer and hidden layer

W_{j1}- weighting function between the hidden layer and the output layer.

input $X_i = \{y_p, x_{2d}, \dot{x}_{2d}\}$

The relations between the inputs and output of NN is expressed as,

$$Z_{-inj} = V_{oj} + \sum_{i=1}^{n} x_i V_{ij} \qquad (13)$$

$$Y_{-ink} = W_{01} + \sum_{j=1}^{P} z_j W_{j1}$$

Sigmoid function for the activation function $F(x)$ as follow

$$F(x) = \frac{2a}{1+\exp(-\mu x)} - a \qquad (14)$$

where $\mu > 0$, a is a specified constant such that $a \leq 0$,

F(x) satisfies $-a < F(x) < a$

The aim of training is to minimize the sum of energy functions,

$$E(k) = \frac{1}{2}[y_m - y_p]^2 \qquad (15)$$

The weight are updated by using

$\Delta W_{j1} = -\eta \frac{\partial E}{\partial W_{j1}}$, j1 node of weighting function

$\Delta W_{01} = -\eta \frac{\partial E}{\partial W_{01}}$,01 node of weighting function calculation

$\Delta V_{ij} = -\eta \frac{\partial E}{\partial V_{ij}}$, ij node of weighting function

$\Delta V_{0j} = -\eta \frac{\partial E}{\partial V_{0j}}$, 0j node of weighting function calculation

where η is the learning role,

$$\frac{\partial F(y_{-ink})}{\partial (y_{-ink})} = \frac{\mu}{2a}[(a - f(y_{-ink)})(a + f(y_{\_ink)})]$$

$$\frac{\partial F(z_{-inj})}{\partial (Z_{-inj})} = \frac{\mu}{2a}(a - f(z_{-inj}))(a + F(z_{-inj}))$$

$W_{j1}(new) = W_{j1}(old) + \Delta W_{j1}$,j1 node of new weighting function (15)

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$W_{01}(new) = W_{01}(old) + \Delta W_{01}$, 01 node of new weighting function (16)

$V_{ij}(new) = V_{ij}(old) + \Delta V_{ij}$, ij node of new weighting function (17)

$V_{0j}(new) = V_{0j}(old) + \Delta V_{0j}$, 0j node of new weighting function (18)

From the new weighting functions, the modified neural network was developed and trained for to minimize the sum of error energy functions. This modified back propagation neural network method can be implemented in the MATLAB – Simulink for system stability and linearization.

RESULTS AND DISCUSSION

The MATLAB-Simulink model of the proposed intelligent MRAC NN Controller is shown inFigure 4.The Initial Values of the plant are chosen as some nominal value. The proposed intelligent MRAC NN Controller scheme results have shown the effectiveness of system performance and also its performance accuracy with the Conventional MRAC technique.

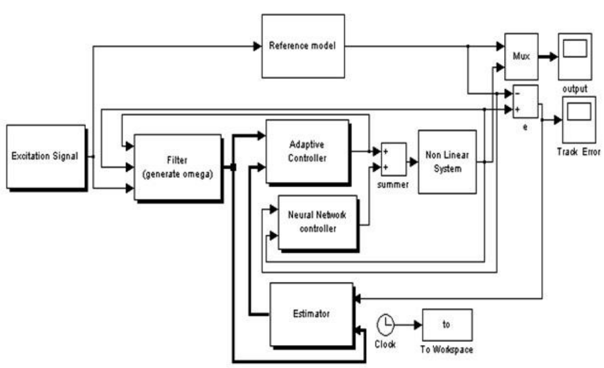

Fig. 4 Proposed Simulink Model of intelligent MRAC NN Controller system

Case study:

Consider Control of the plant - system with backlash as input part with the nonlinearity of backlash which is followed by linear system as shown in figure 5,

In this plant the nonlinearity of backlash system with linear system is followed has given. Assume that the linear part of the controlled stable system and the reference model has been given by,

$$G(S) = \frac{1}{S^2 + 5S + 6}$$

$$G_M(S) = \frac{1}{S^2 + S + 3}$$

,

with input r(t)= 25sin4.9t+30cos4.9t

It is noticed that the proposed method was very sensitive to large dead-time system delay. The results for both conventional and proposed MRAC have been shown in Figure 6 & 7.

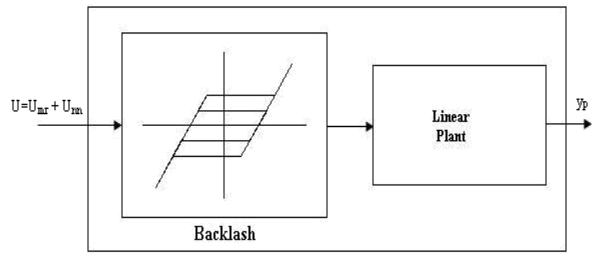

Fig.5 Non linear System Model

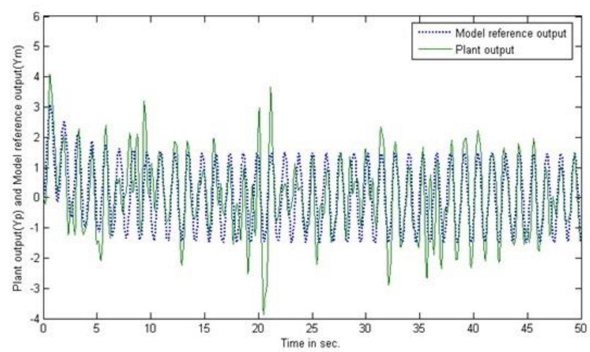

Fig. 6 Plant output $y_p(t)$ and reference output $y_m(t)$ of the conventional MRAC

The plant output characteristics of the system has compared with the conventional model and the model reference of MRAC. The plant output performance has shown the stable of oscillations with respect to the time period.

The plant output characteristics of the system has compared with the conventional model and the model reference of intelligent MRAC. The output graphs have shown the stable performance of intelligent Model Reference Adaptive controller Scheme.

The plant Control input characteristics of the system has compared with the conventional model and the model reference of intelligent MRAC. The plant Control input performance has shown the unstable of oscillations with respect to the time period.

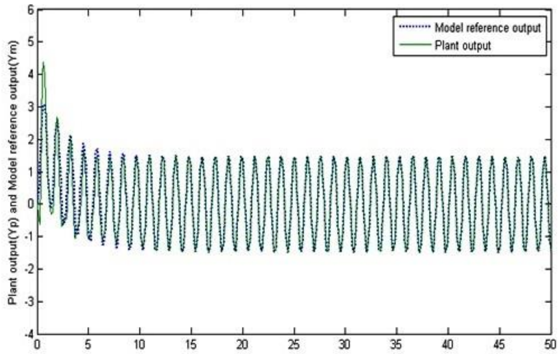

Fig. 7 Plant output $y_p(t)$ and reference output $y_m(t)$of the proposed intelligent MRAC

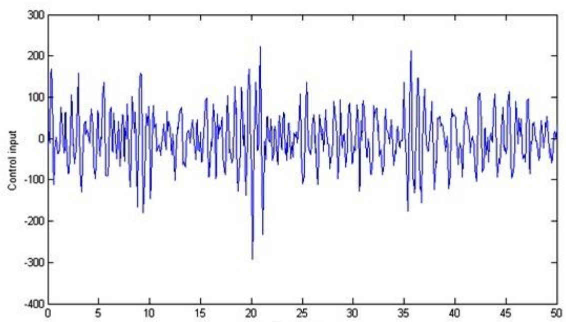

Fig. 8 Plant Control input of conventional MRAC system

The plant Control input characteristics of the system has compared with the conventional model and the model reference of intelligent MRAC. The plant Control input performance has shown the stable of oscillations with respect to the time period.

The plant tracking error characteristics of the system has compared with the conventional model and the model reference of intelligent MRAC. The plant output performance has shown the unstable of oscillations with respect to the time period. Figure 10 had shown the unstable performance of conventional Model Reference Adaptive controller Scheme.

The plant tracking error characteristics of the system has compared with the conventional model and the model reference of intelligent MRAC. The plant output performance has shown the stable of oscillations with respect to the time period. Figure 11 has shown the stable performance of proposed Model Reference Adaptive controller Scheme. The Reference model plant and the proposed MRAC plant output tracking performances were compared with different system conditions have shown in figure 12.

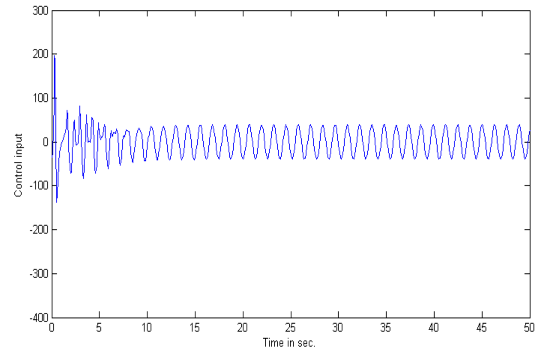

Fig. 9 Plant Control input of proposed intelligent MRAC system

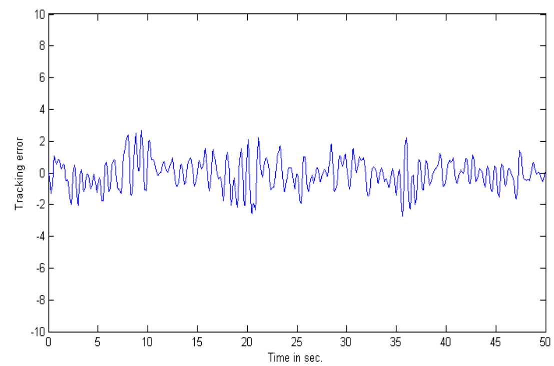

Fig. 10 Plant Tracking error e for the conventional MRAC

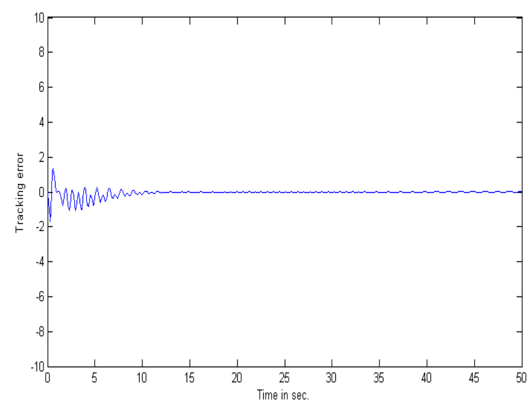

Fig.11 Plant Tracking error e for the proposed MRAC

The Adaptive Algorithm and control scheme has been developed are based on the plant model and Performances. These schemes have to be implemented on the actual plants that are most likely deviated from the plant models. Thereal plant in industries may be infinite dimensional factors, nonlinear and its measured inputs and outputs may be corrupted by added with noise and external disturbances. It was shown using conventional MRAC that adaptive scheme designed for a disturbance free plant model and may go unstable in the presence of small disturbances. The nonlinear component and the disturbance are added to the conventional MRAC has some oscillations at the peak of the signal in the output.

From the output performance results, the transient responses, in terms of tracking error and control signal, has been significantly improved from the proposed intelligent MRAC NN manipulator scheme. The proposed intelligent MRAC schemes shown better control results compared with the conventional MRAC schemes. The proposed scheme gives smaller tracking error with less control effort.On the contrary, the proposed method has much less error than conventional method in spite of nonlinearities and disturbance.

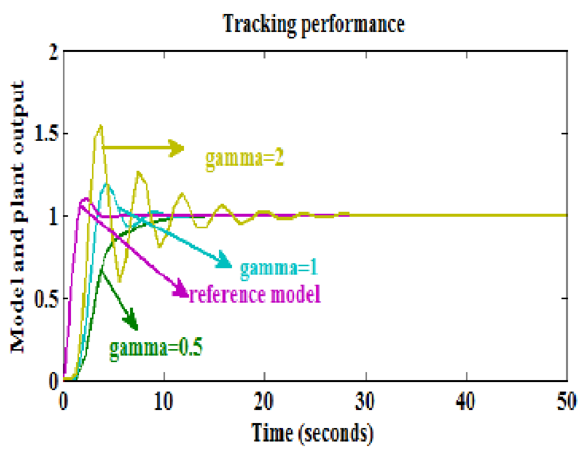

Fig.12 Simulation results of Plant Tracking for different adaptive gains in the proposed Intelligent MRAC

CONCLUSION

The conventional model reference adaptive controller output responses have been compared with the proposedHigh voltage model reference adaptive controller using neural network. The performance evaluation of intelligent MRAC has been carried out by SIMULINK. The proposed MRAC controller using Multilayer Neural Network has been shown very good tracking results when compared with the conventional MRAC. Thus the proposed high voltage intelligent MRAC controller modifies its behavior in response to the variation in the dynamics of the process and the characteristic of the disturbances. The Proposed scheme utilizes a growing dynamic neural network controller in parallel with the model reference adaptive controller. Simulations and analyses have been shown that the transient performance can be substantially improved from the proposed MRAC scheme. The proposed controller has shown very good tracking results when compared to conventional MRAC. Thus the proposed intelligent MRAC controller found to be extremely effective and efficient compared to the existing controllers.

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