Ann Based Mrac Controller For Transient Stability Enhancement Of Smib

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ABSTRACT: In this paper, an artificial neural network ANN is presented to enhance the transient stability of a single machine infinite bus based on model reference adaptive controller MRAC. Critical clearing time CCT is a main factor in analysis of transient stability that indicates of maximum permissible time period of fault in power system. Increment value of CCT has important issue to improve system stability. The simulation results using MATLAB / SIMULINK package show that the proposed ANN-MRAC can dramatically improve the dynamic system behavior and force the system to track the reference model and reduce the error between them. The comparison between conventional Range-Kutta method and the ANN-MRAC is demonstrated that the proposed controller scheme is increasing of CCT and damping of electromechanical power oscillations.

Keywords: Transient Stability; Model Reference Adaptive Control; single Machine to Infinite Bus; Neural Network.

1. INTRODUCTION:

Present the increasing demand of electricity has significantly increment and power systems reconstruction make system work closer to their stability limits. Transient stability involves the response to large disturbance and is associated with appreciable change of rotor speeds, power angle and power transformer. System response to such a disturbance is usually considered within one second [1, 2]. Recently sophistication and complexities of the control of nonlinear systems has been an important research area due to the difficulties in modeling and nonlinearities. Adaptive control is one of the widely approach of control schemes to deal with nonlinear system. MRAC is point out to certain class of adaptive systems. In this class, the controller is designed to achieve system output converges to reference model output having the same reference input. Recently, an ANN has broad opportunities for identification, estimation, and control due to their ability to process the higher mathematical rate like nonlinear functions. The ANN application in power system stability has been taken a wide research area which has fast and parallel data processing, highly accurate solution. Many reports were published on TSA, in references [3- 5] were used an artificial intelligent techniques including FACTs devices to assess of transient stability for SMIB. In this work, the ANN-MRAC was used to improve transient stability of SMIB through increasing of CCT of system.

2. MODELING OF SMIB:

Figure (1) shows that a SMIB system used to demonstrate the fundamental concepts and the principles of transient stability when subject into disturbance.

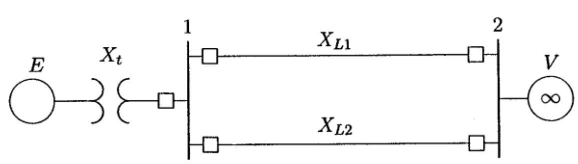


Figure 1: *Single line diagram of SMIB* the

$$\frac{2H}{w_0}\frac{\partial^2\delta}{\partial t^2} = P_a = P_m - P_e - D\frac{d\delta}{dt}$$

$$= P_m - P_{max}\sin\delta - D\frac{d\delta}{dt} \quad (1)$$

Where:
P_m: Mechanical power input, in pu.
P_e is the generator's electrical power output
P_{max}: Maximum electrical power input, in pu.
H: Inertia constant, in MW.S/MVA.
δ: Rotor angle, in electrical rad.
t: Time, in sec.
D: Coefficient of damping power.
Equation (1) may be written in terms of the two first-order equations:

$$\frac{d\,\Delta w_r}{dt} = \frac{1}{2H}\left(P_m - P_{max}\sin\delta - D\frac{d\delta}{dt}\right) \quad (2)$$

$$\frac{d\delta}{dt} = w_0\,\Delta w_r \quad (3)$$

Any of the numerical integration may be used to solve equations 2 and 3. In this paper we used fourth-order Runge-Kutta (R-K) method [1, 2]. The general formula giving the values of Δw_r ,δ and t for the (n+1) first step of integration are as follows:

$$(\Delta w_r)_{n+1} = (\Delta w_r)_n + \frac{K_1+K_2+K_3+K_4}{6} \quad (4)$$

$$\delta_{n+1} = \delta_n + \frac{L_1+L_2+L_3+L_4}{6} \quad (5)$$

$$t_{n+1} = t_n + \Delta t \quad (6)$$

Where:

$$K_1 = f[(\Delta w_r)_n\,, t_n]\,\Delta t \quad (7)$$
$$K_2 = f[(\Delta w_r)_n + \frac{K_1}{2}\,, t_n + \frac{\Delta t}{2}]\,\Delta t \quad (8)$$

$K_3 = f[(\Delta w_r)_n + \frac{K_2}{2}, t_n + \frac{\Delta t}{2}]\,\Delta t$ (9)

$K_4 = f[(\Delta w_r)_n + K_3, t_n + \Delta t]\,\Delta t$ (10)

$L_1 = f[\delta_n, t_n]\,\Delta t$ (11)

$L_2 = f[\delta_n + \frac{L_1}{2}, t_n + \frac{\Delta t}{2}]\,\Delta t$ (12)

$L_3 = f[\delta_n + \frac{L_2}{2}, t_n + \frac{\Delta t}{2}]\,\Delta t$ (13)

$L_4 = f[\delta_n + L_3, t_n + \Delta t]\,\Delta t$ (14)

K_1, L_1: The slop of the beginning of time stepΔt.
K_2, L_2: The first approximation to slop at mid stepΔt.
K_2, L_2: The second approximation to slop at mid stepΔt.
K_2, L_2: The slop at the end of stepΔt.

$\Delta w = \frac{1}{6}(K_1 + 2K_2 + 2K_3 + K_4)$ (15)

$\Delta \delta = \frac{1}{6}(l_1 + 2l_2 + 2l_3 + l_4)$ (16)

Thus Δw and $\Delta\delta$ is the incremental value of w and δ given by the weight average of estimation based on slopes at the beginning, mid-point, and end of the time step. This method is equivalent to considering up to fourth derivative terms in the Taylor series expression, it has an error on the order of$(\Delta t)^5$. Refereeing to equations (1 – 6), a SIMULINK model is constructed as shown in figure (2) [1]. By solving the non-linear swing equation (1), the transient stability of a power system could be determined.

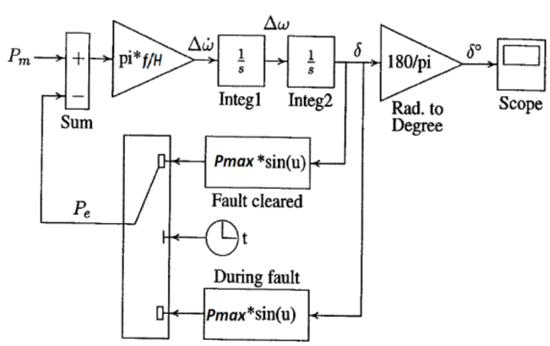
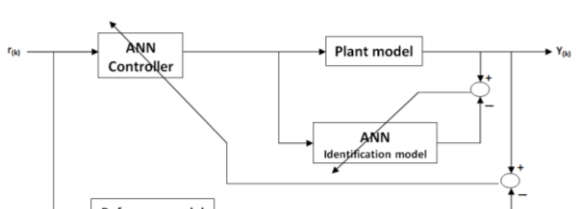


Figure 2: *Simulink model of SMIB*

3. DESIGN OF ANN-MRAC CONTROLLER:

ANN has been studied for many years with the purpose of achieving human-like performance in many scientific disciplines like speech, pattern recognition, prediction, and control. Modern developments in ANN construction like training and classification were open the road to use it in many field of the knowledge. The ANN-MRAC architecture is composed of two multilayer feed-forward neural networks: an identification model network and controller network as shown in figure (3) [6].



The feed-forward ANN identification model composed of a two-layer with four inputs, 30 neurons in the hidden layer, and one output, and the feed-forward ANN controller composed of a two-layer with five inputs, 30 neurons in the hidden layer, and one output. The ANN identification model has been trained in off-line to simulate the plant model first, and then placed in series with the ANN controller that is adaptively trained to track the reference model output. The activation function of a hidden layer was tansig to fulfill the nonlinearity of the system and puerlin function in the output layer to achieve desired range of the output. The training algorithm of networks is Levenberg-Marquardt which has a fast convergence and better performance. The weight and biases are set iteratively to fulfill a minimum mean square error between the ANN output and target output.

4. SIMULATION RESULTS

The SMIB system parameters are given in appendix A. The simulation is carried out using MATLAB /SIMULINK packages. The SIMULINK of SMIB with ANN-MRAC controller is shown in figure (4).

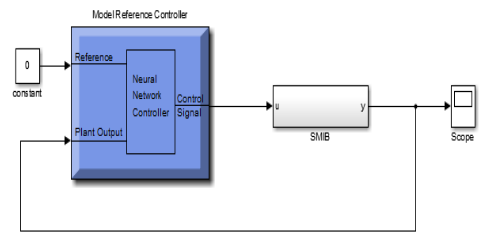
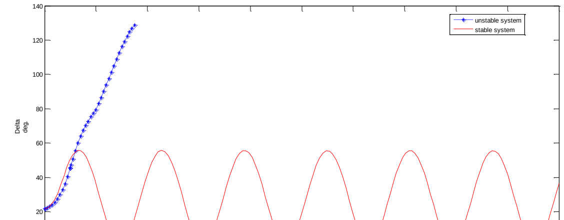


Figure 4: *System block scheme*

The disturbance is a three-phase solid fault occurs at the middle of one line. The pre-fault condition (steady state) of the system is: $\delta_0 = 21.64°$, when the fault episode on the system it was still stable for a maximum critical clearing time 0.38 sec that obtained based Range-Kutta (R-K) numerical analysis, behind this time the system is unstable, can be shown in figure (5). In order to verify the performance of the proposed controller was tested for three-phase short-circuits, we can observe that the ANN-MRAC controller damps electromechanical oscillations and increases the critical clearing time to 0.4965 sec as shown in figure (6).



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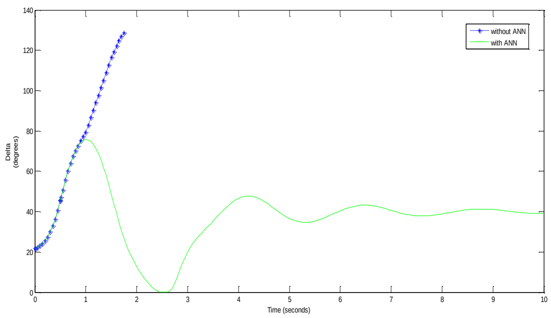

Figure 6: *Rotor angle using ANN-MRAC under 3-ph fault*

5. Conclusion

In this paper, the accuracy and effective of Artificial Neural Networks based Model Reference Adaptive Controller in enhancing the transient stability of a SMIB is verified. The simulation described here was performed with prior off-line training of the ANN, with the pre-fault condition of SMIB was used as a model reference of controller. The ANN in this work have 30 hidden neurons were used for plant and controller architecture. Comparing the CCT and rotor angle response curve of the conventional with those of ANN-MRAC controller, it could be concluded that the system increase in the critical clearing time and damping of the electromechanical power oscillations.

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Appendix

The parameters of the simulated swing equation are:

P_m =0.9 pu Mechanical power.
E =1.1 pu Generator voltage.
$V = 1\angle 0°$ pu Infinite bus voltage.
H =2.52 MJ/MVA Machine inertia constant.
X'_d =0.35 pu The transient reactance of generator along the direct axis.
X_l =0.3 pu Reactance of each transmission line.
X_t =0.2 pu Reactance of transformer.
f = 50 Hz Nominal frequency.
D = 0 Coefficient of damping power.