Neural Network Based Approach Applied to Review Transient Stability of an Alternator Connected to Infinite Bus

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***Abstract* — This paper approaches to analyse the transient stability of an alternator connected to infinite bus. A three phase fault is considered to happen to the total system. The characteristics behaviour of the alternator relative torque angle is studied in time domain**

Simulink model, based on MATLAB, of a single machine connected to an infinite bus system is assumed to suffer severe three phase short circuit faults. The transient state behaviour of the rotor relative torque angle shows a sustained oscillations indicating an uncertainty of the system to reach the steady state. The behaviour of the system is improved by providing a damping to the system. Inclusion of negative feedback technique is utilized to provide the damping. The damped system shows an underdamped behaviour in the post fault conditions ensuring a good tendency of the system to reach to steady state quickly.

A neural network (NN) is assumed to be configured for prediction of the behaviour of the transient stability of the actual system.

The artificial neural network is configured by learning and training of the actual system by the Levenberg-Marquardt method of training (trainlm) to predict the actual system.

The NN based system predicts the actual system successfully showing its good strength and reliability.

Keywords- *Transient Stability, neural network, relative torque angle, training (trainlm).*

I. INTRODUCTION

This paper deals with the study of transient stability of a power system. A single machine is considered to be connected with infinite bus which is suffering three phase short circuit fault. The nature of variation of rotor relative torque angle in time domain has been studied for analysis. The transient state of the post fault condition has been considered. The post fault analysis shows the transient state of variation rotor torque angle which suffers sustained oscillation indicating an uncertainty of reaching to steady state of the power system.

The system is provided with a small amount of negative feedback which in turn offers a damping to the system and enables the system to attain a steady state ultimately, travelling through an underdamped transient state, within two or three cycles.

A neural network is configured to predict the behaviour of the post fault condition of an alternator suffering from the three phase short circuit fault. The neural network based configuration is trained (*trainlm*) by the process of learning the behaviour of the alternator connected to the infinite bus. Now, the system configured with the trained (*trainlm*) neural network is simulated. Without providing any damping to the system, NN based system shows a sustained oscillation in post fault condition identical to that as was observed in case of the actual system in its post fault condition. Then the system was provided with the damping to reduce the sustained oscillations appearing in the system. The NN based system successfully predicts the behaviour of the actual system ensuring its strong effectiveness and reliability.

Section 2 describes about the different types of stability of the power system and swing equation. Section 3 describes behaviour of the simulink model of the alternator connected to the infinite bus. Section 4 describes behaviour of the simulink model of an alternator connected to an infinite bus provided with damping. Section 5 describes the procedure of learning, training (*trainlm*) of a neural network **.** Section 6 describes the behaviour the neural network based model of the alternator connected to infinite bus. Section 7 describes the behaviour of the neural network based model of the alternator connected to infinite bus provided with damping. Section 8 furnishes the conclusions.

II. STABILITY OF POWER SYSTEM AND SWING EQUATION

The term ‘stability’, associated with the performance or operation of a power system, is very much significant regarding disturbance of the power system created by appearance of different types of faults. Power system stability is the strength of a power system, for a specified initial operating criteria, to re-establish a state of almost operating equilibrium after being subjected to the disturbances, i.e., the power system faults, provided with most of the system variable parameters bounded so that the entire system ensures a intact status of the system.

The parameters associated with it are voltage stability, frequency stability and the stability related to rotor relative torque angle variation.

The stability related to rotor relative torque angle variation is defined as the ability of the alternator itself, connected to an infinite bus, to keep itself in a good synchronism after being subjected to the power system faults. This phenomenon has been subdivided into two different sub-categories. One of them is associated with small signals. The other is the most vital one, defined as the transient stability.

The transient state starts just after clearing the fault occurred in the system.

Transient stability study focuses on the point to analyse whether the fault-affected system may retain the condition of synchronism, just after clearing the major disturbances such as different unsymmetrical faults like L-G, L-L and L-L-G faults, loss of generating units, sudden major load changes or abnormal switching transmission line done on the transmission lines. The objective is to determine whether or not the rotors of an alternator is coming back to a constant speed operation.

The swing equation of an alternator is the relation between the shaft power and the electromagnetic power being produced at the terminals of the turbo-alternator. This can be described mathematically as follows:

$$P_a = P_s - \frac{EV}{X}\sin\partial = M\frac{d^2\partial}{dt^2} \qquad (1)$$

or,

$$P_a = P_s - P_e = M\frac{d^2\partial}{dt^2} \qquad (2)$$

where, P_a is the accelerating power $= M\frac{d^2\partial}{dt^2}$

P_s = shaft power and

$\frac{EV}{X}\sin\partial$ = electromagnetic power.

III. STATE SPACE MODEL OF AN ALTERNATOR CONNECTED TO INFINITE BUS

The simulink diagram of the single machine system connected to infinite bus based on state space model has been considered here.

This model is simulated based on *MATLAB simulink toolbox-7.2.*

The variation of rotor relative torque angle is observed via 'scope-1' in time domain. The workspace ' priya212' is used to store different data for further work. A switch is used to change the state

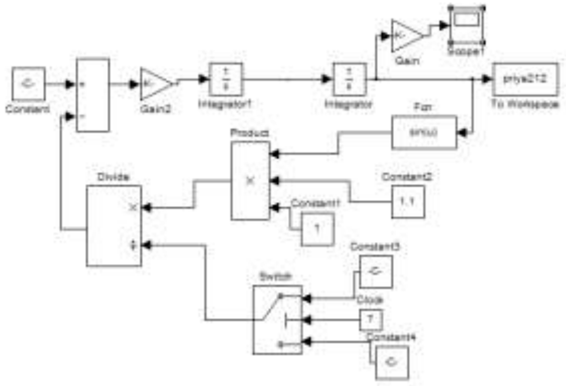

Fig. 1: State space configuration of the alternator connected to infinite bus.

from sustained fault condition to post fault condition. The clock provided as shown in the simulation diagram is used to vary the fault clearing time. This will show the time of existence of the fault occurring in the system. The values of reactance are provided to the system within the blocks 'constant3' and 'constant4'.

The system is assumed to be disturbed severely by a three phase fault. The fault clearing time for this simulation process has been considered to be 7 milliseconds. It is chosen arbitrarily for getting a feasible solution from this simulink model.

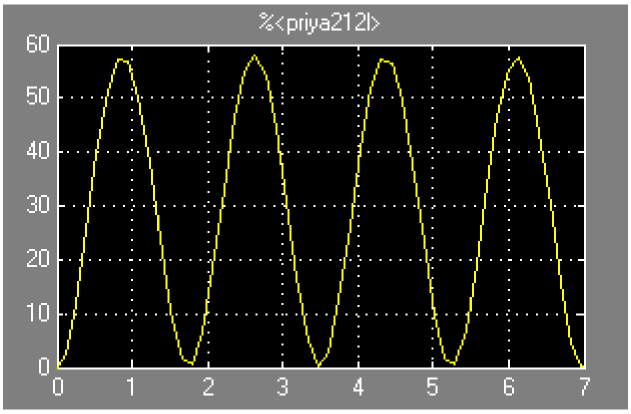

Fig.2: Transient response of rotor torque relative angle in time domain for the single machine connected to infinite bus at post fault condition

The behaviour of the system just after clearing the fault has been shown in Fig. 2. The transient part of the response at post fault has been considered. This is mare a state of sustained oscillation. It is difficult and quite uncertain for an alternator to attain a steady state, even it may never attain steady state stability.

IV. STATE SPACE MODEL OF AN ALTERNATOR CONNECTED TO INFINITE BUS PROVIDED WITH DAMPING

A damping has been provided with the previous system as shown in fig. 1. The technique of providing negative feedback is used in this case.

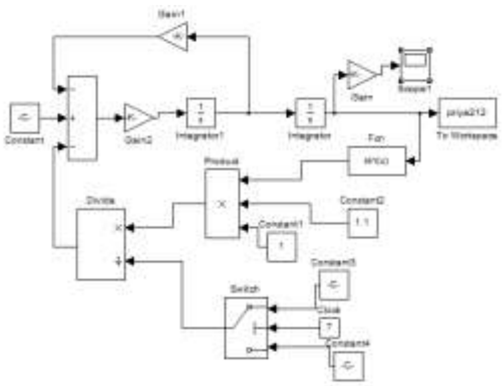

Fig. 3: The alternator, provided with damping, connected to infinite bus

The arrangement of the scheme is shown in Fig. 3. The addition of smaller amount of negative feedback has changed the behavior of the response in the post fault condition. The sustained oscillation has been changed to an underdamped oscillation and the transient state gradually undergoes to steady state.

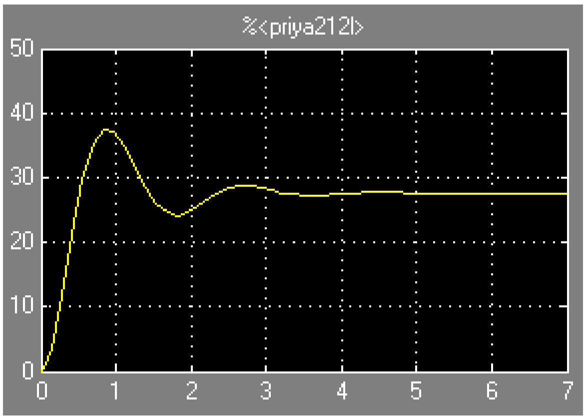

Fig. 4: Transient response of rotor relative torque angle in time domain for the single machine connected to infinite bus at post fault condition when provided with damping

Thus the machine will tend to go to the stable zone. It will take only two or three cycles of operation for reaching steady state. The amount of underdamping may be varied by changing the neural value of negative feedback. More is the amount of negative feedback, less will be the lifetime of transient state.

V. TRAINING AND CONFIGURATION OF THE NEURAL NETWORK

An artificial neural network is developed in this paper to predict the behaviour of the transient stability of the alternator connected to an infinite bus subjected to fault. The process of configuration of a neural network generally requires the procedure of learning the system which will be followed by the method of training (*trainlm*). As the neural network learns the existing system, it will execute the procedure of training (*trainlm*) of the neural network (NN) to fit it with the existing network.

The weights are assigned very randomly to achieve the updated target. During the process of training (*trainlm*) , small adjustments are carried out to reduce the difference in behaviour regarding the characteristics of the actual existing system and that of the neural network based system predicting for the actual system.

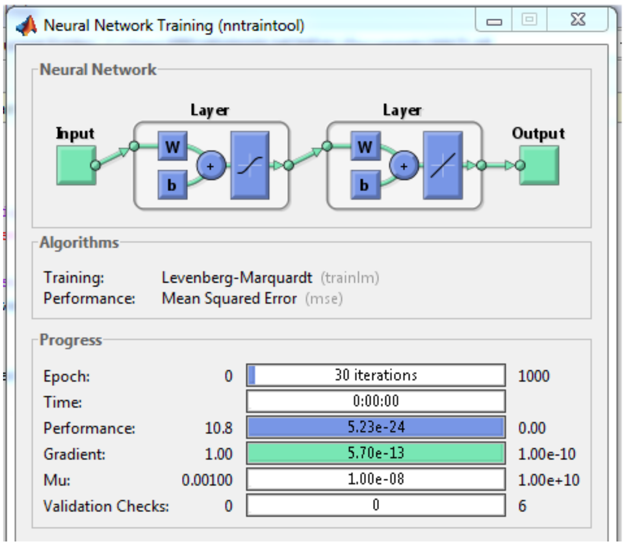

Fig 5. The report of training (*trainlm)* of the neural network as shown in Fig. 14.

Fig. 5 shows the report of training of the neural network. The method of training applied here is Levenberg-Marquardt (*trainlm*) method. The performance index is optimized calculating mean square error (MSE). The value of MSE is found to be zero after 1000 epochs.

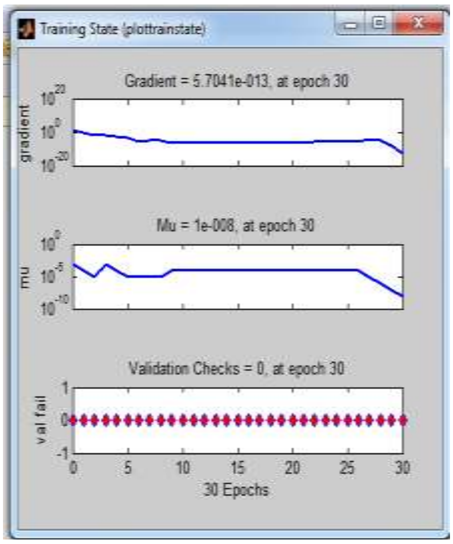

Fig. 6: Variation of different parameters during the process of training (*trainlm*)

Fig. 6 shows variation of different parameters during the process of training (*trainlm*).

Fig. 7 shows the performance characteristics of training (*trainlm*) of the neural network performed based on mean square error (MSE). The best training performance is observed to appear at epoch equals to 8.

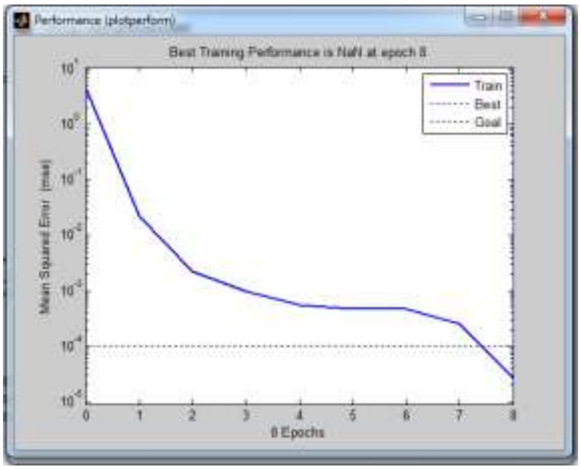

Fig. 7: The performance characteristics of training (*trainlm*) the neural network performed based on mean square error (MSE)

Fig. 8 shows the report of regression produced during the process of training (*trainlm*)

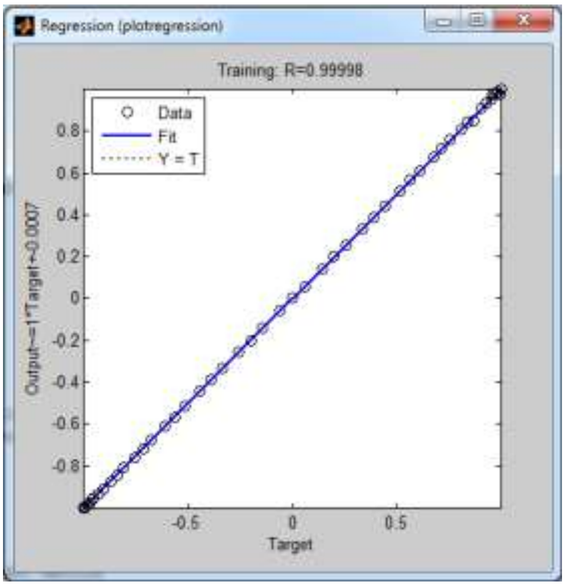

Fig. 8: The report of regression produced during the process of training (*trainlm*)

As soon as the training (*trainlm*) of the neural network is completed successfully, the neural network block is produced which is shown fig. 10.

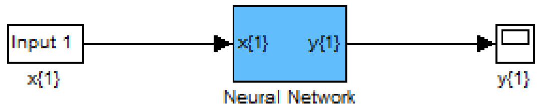

Fig. 10: The neural network block configured for the actual system.

The blue block is the neural network block. The Fig. 11 shows the different embedded layers constituting the neural network block as shown in Fig. 10.

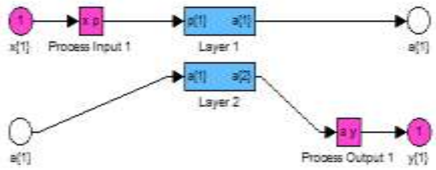

Fig. 11: Different embedded layers constituting the NN block of Fig. 10.

If the layer1 of the Fig.11 is opened, the following architecture is exposed which is shown in Fig. 12.

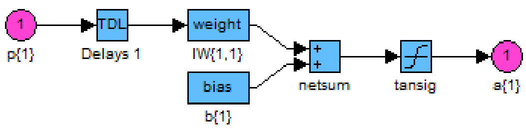

Fig. 12: The embedded parameters of layer 1 of Fig. 11.

If the weight block as shown in Fig. 12 is allowed to open, a figure looks like as follow will appear.

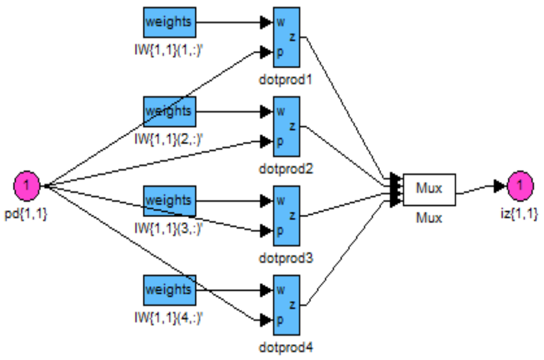

Fig. 13: The detailed configuration of the weight block of Fig. 12.

Actually 30 nodes have been considered to configure the neural network assumed in this paper. But only 4 nodes have shown for giving the idea about the pattern of configuration of the neural network.

VI. NEURAL NETWORK BASED MODEL OF THE ALTERNATOR CONNECTED TO INFINITE BUS

Fig. 14 shows the neural network based configuration of the single machine connected to the infinite bus. All other conditions are kept identical to that system shown in Fig. 1

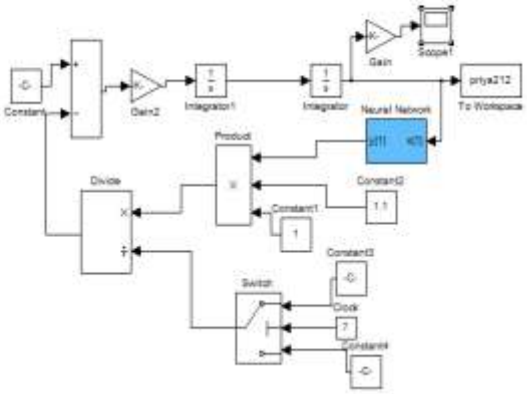

Fig. 14: The neural network based configuration of the single machine connected to the infinite bus.

Fig. 15 shows the variation of rotor relative torque angle of the neural network (NN) based machine at post fault.

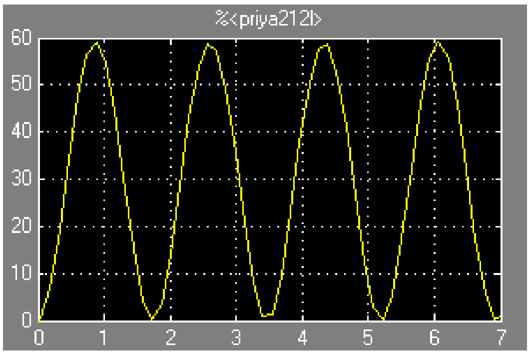

Fig. 15: The variation of rotor relative torque angle of the neural network (NN) based machine at post fault.

The Fig. 15 shows that the neural network based machine successfully predict the behaviour of the machine at post fault condition. This shows the sustained oscillation at post fault condition.

VII. NEURAL NETWORK BASED MODEL OF THE ALTERNATOR CONNECTED TO INFINITE BUS PROVIDED WITH DAMPING

Now a little bit damping is provided with the machine. A small amount of negative feedback system is provided with the neural network based system.

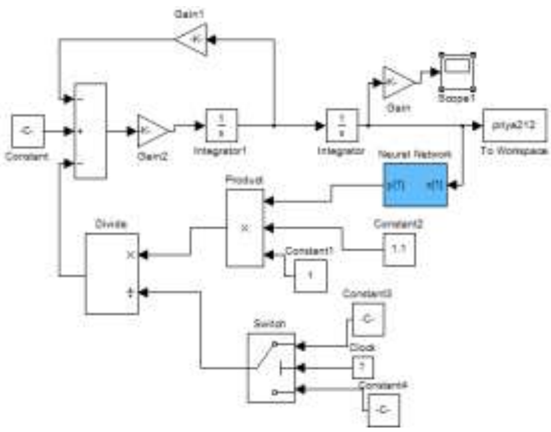

Fig. 16 : The neural network based configuration of the single machine connected to the infinite bus provided with damping

All other conditions are kept constant as were considered in the case considered in fig. 3. The response of the system of Fig. 16 is considered in Fig. 17. This is a underdamped transient state. The sustained oscillation has been provided with a damping. The neural network based machine shows a underdamped transient state.

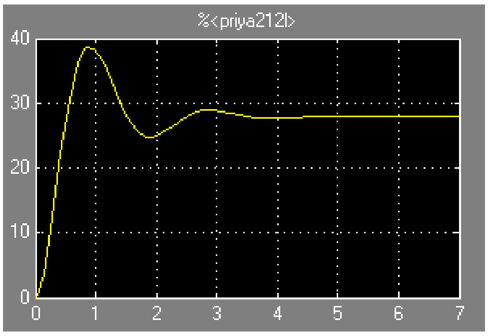

Fig. 17: Transient response of rotor torque relative angle in time domain for the neural network (NN) based machine connected to infinite bus at post fault condition when provided with damping

Ultimately, the system will attain a steady state reliably within two to three cycles. Thus the neural network based system successfully predicts the behaviour of the actual machine with even no deviation.

VIII. Conclusions

In this paper, a neural network based configuration has been developed to predict the behaviour of an alternator connected to an infinite bus subjected to severe three phase short circuit fault.

Fig. 2 shows the transient behaviour of the single machine connected to infinite bus undergone to three phase fault. This shows a mare sustained oscillation.

Fig. 4 shows the transient state under post fault condition when the total system is provided with a damping. The method inclusion of negative-feedback technique is used here. It is seen that more is the amount of negative feedback, more is the strength of damping.

Fig. 15 shows the transient state prediction of the neural network based alternator without any damping provided to it. The transient state shows a type of sustained oscillations. This prediction is comparable to the nature of the curve shown in fig.2.

Fig. 17 shows the prediction of the neural network based machine provided with damping using the method of negative feedback type of damping. This is showing an underdamped transient state of the system. The prediction as shown in Fig 17 is comparable to that observed in Fig. 4.

Thus, it is seen that the prediction shown in Fig. 15 by the NN based machine goes very close approximation to the nature of the characteristics as shown in Fig. 2.

Also, the prediction shown in Fig. 17 by the NN based machine goes very close approximation to the nature of the characteristics as shown in Fig. 4.

Thus the strength of artificial neural network based system is established.

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