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Neuro - Fuzzy System Based Augmentation for Transient Stability

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Abstract— Computational Intelligence combines neural network, fuzzy systems and evolutional computing. Neurofuzzy integrated system utilizes features of both Neural and Fuzzy networks together for better results by which generalization of the unseen data from seen data by forming the fuzzy rules and training. In this project training of the system with training data which usually is 70% of the whole available data, rest 30% data is used for testing. The algorithm used in work is hybrid algorithm. A characteristic inherent to Electric power system is that they operate under the influence of disturbance. With the growing stress on today's power system, the potential impact of faults and other disturbances on their security is increasing. Here an Adaptive Network based fuzzy system is used. The data with power speed and fault clearing time is used in order to train network with rule based structure.

Keywords: ANN, Fixed Control Logic (FLC), Hybrid Algorithm.

I. INTRODUCTION

Neurofuzzy integrated system utilizes features of both Neural and Fuzzy networks together for better results by which generalization of the unseen data from seen data by forming the fuzzy rules and training. In this project training of the system with training data which usually is 70% of the whole available data, rest 30% data is used for testing. The algorithm used in project is hybrid algorithm. A characteristic inherent to Electric power system is that they operate under the influence of disturbance. With the growing stress on today's power system, the potential impact of faults and other disturbances on their security is increasing. The power system can be considered to go through changes in configuration in three stages, from pre fault, faulted to a post- fault system. The analysis required to know whether, the power system will survive the transients and move into stable operation or lead to loss of synchronous operation is subject of primary concern and is referred to as transient stability assessment. There are various methods for the improvement of transient stability assessment and subsequent enhancement. Methods of improvement stability try to achieve – Reduction in disturbing influence by minimizing the fault severity and duration. Increase of the restoring synchronizing forces.

II. ANN & FUZZY LOGIC

During the late 1980s, the number of researchers and engineers interested in neural networks (NNs) and fuzzy logic (FL) increased, dramatically introducing the NN and FL technologies into several application fields. Both technologies are widely used and are considered fundamental engineering technologies. Within several years, NN+FS fusing technology was already being used in commercial products and industrial systems. The practicality of technology, introduced at the beginning of this paper, is supported by the number of real-world applications based on this technology. Since its introduction, the fusion technology has widely expanded into application fields requiring such tasks as control, operations research, retrieval, clustering, and speech recognition.

A. Neural Networks:

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

B. Biological Neurons:

Dendrites carry electrical signals in into the neuron body. The neuron body integrates and thresholds the incoming signals. The axon is a single long nerve fiber that carries the signal from the neuron body to other neurons. A synapse is the connection between dendrites of two neurons (fig.1).

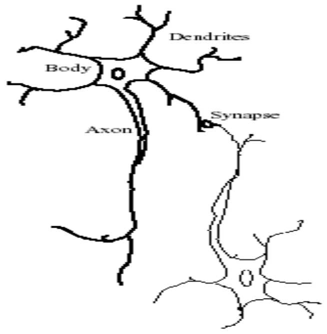

Figure. 1 Representation of a Neuron

C. Neuron:

Biological neuron has a complicated structure, which receives trains of pulses on hundreds of excitatory and inhibitory inputs. Those incoming pulses are summed and averaged with different weights during the time period of latent summation. If the summed value is higher than a threshold then the neuron generates a pulse, which is sent to neighboring neurons. If the value of the summed weighted inputs is higher, the neuron generates pulses more frequently. An above simplified description of the neuron action leads to a very complex neuron model, which is not practical. McCulloch and Pitts in 1943 show that even with a very simple neuron model it is possible to build logic and memory circuits. The McCulloch-Pitts neuron model assumes that incoming and outgoing signals may have only binary values 0 and 1. If incoming signals summed through positive *or* negative weights have a value larger than threshold T, then the neuron output is set to 1. Otherwise it is set to 0. Example of McCulloch-Pitts neurons realizing *OR, AND, NOT* and *MEMORY* operations are shown in Fig. 2.

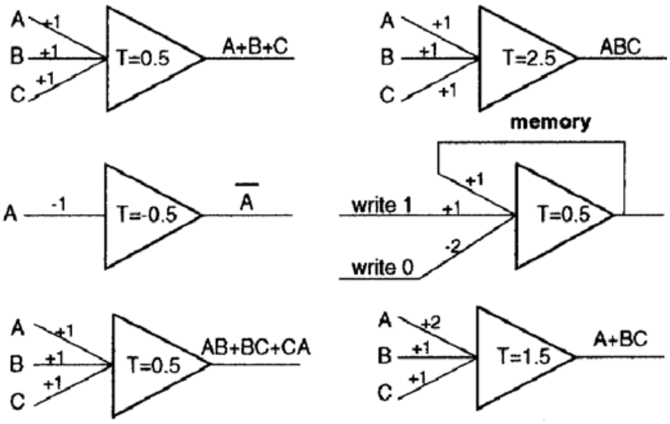

Figure. 2 Several logical operations using networks with McCulloch-Pitts neurons.

$$O = f(net) = \frac{1}{1 + \exp(-\lambda net)}$$

$$O = f(net) = \tanh(0.5\lambda net) = \frac{1}{1 + \exp(-\lambda net)} - 1$$

These continuous activation functions allow for the Typical gradient based training of multilayer networks. Activation functions are shown in Fig. 3

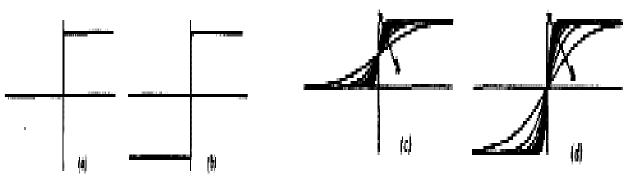

Figure.3 Typical activation functions: *(a)* hard threshold *(b)* hard threshold bipolar, (c) Continuous unipolar, *(d)* continuous bipolar

D. Fuzzy Logic:

Originally introduced by Lotfi Zadeh in the 1960s, resembles human reasoning in its use of approximate information and uncertainty to generate decisions. It was specifically designed to mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision intrinsic to many problems.

E. Design Parts and Parameters of The Fuzzy Model:

The information extracted from data has an important effect on a fuzzy model design in the above mentioned applications areas. Furthermore it has been stated that the exploitation of expert knowledge and system engineering know how in the traditional way is either very difficult or impossible on an ad hoc basis. Therefore, a new kind of approach to the fuzzy model design, when fast adaptation and tuning of the fuzzy model is needed. It is also considered that specific automatic algorithms are then necessary (Fig 4).

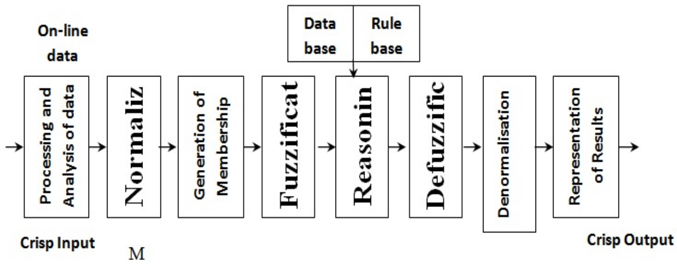

Figure: 4

III. ENHANCING TRANSIENT STABILITY

A characteristic inherent to electric power system is that they operate under the influence of disturbances. With the growing stress on today's power systems, the potential impact of fault and other disturbances on their security is increasing. A disturbance irrespective of its origin can significantly affect the characteristics of electromechanical oscillations of the synchronous generator in the power systems. The power system can be considered to go through changes in configuration in three stages, from pre fault, faulted to a post fault system. The pre fault is in a stable steady state. The fault occurs and the system is then in faulted condition until it is cleared. The analysis required to know whether following a disturbance, the power system will survive the transient and move into a stable operating condition or load to loss of synchronous operation is the subject of primary concern and is referred to as transient stability assessment. Based on this, the power system operators can the necessary preventive control actions. There are various methods for the improvement of the transient stability assessment and subsequent enhancement. Being one of the discrete supplementary control methods used to perform transient control, fast valving aims to reduce turbine mechanical input power quickly when a unit is being accelerated due to fault in transmission network, and therefore to assist in preventing loss of synchronism, and to ensure the stability of the turbine generator with respect to the rest of the power system.

The most widely used scheme until now has been the use of fixed control logic (FLC), which has a fixed stroke characteristics curve. It is however that its non availability may cause instability in the first or second swing that leads to large oscillations of the system. Transient stability is the stability of the power system to maintain synchronism when subjected to a severe transient disturbance such as fault on transmission facilities, loss of generation or loss of large load.

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The problem arises when there is a sudden change in the electrical power output due to a severe and sudden disturbance. The severity is measured by drop of this power to a very low or to zero value and a consequential sudden acceleration of the machines govern by the swing equation:

$$\frac{2H}{\omega}\frac{d^2\delta}{dt^2} = P_m - P_e = P_a$$

Where,

δ = rotor angle, in electrical radian

P_m = electrical driving power input, in pu,

P_e = electrical power output, in pu,

H= inertia constant, in MW-s/MVA,

ω= nominal speed, in electrical radian/sec

A dynamic brake is a resistor with a very high power dissipation capacity for short time periods. It can be viewed as a fast load injection to absorb the excess transient energy cost by a disturbance. The brake is shunted between the terminals of the disturbed generator and urged to dissipate the excess energy gained by the generator during the transient period.

From equation, it is apparent that the decrease in mechanical driving power has the same impact on the rotor angle swings as that of increase in the electrical power output. Fast valving has a function of reducing the mechanical power input to the turbine so the generated power, while the resistance break can absorb the momentary excess power, acting as an artificial load. This gives the motivation to apply coordinated fast valving and braking resistors control scheme for a very effective control and damping of rotor angle swings.

A WSCC 3-machine, 9-bus system has been chosen to verify the application of FNN for transient stability enhancement. A three phase fault has been simulated at various buses (Fig.5). The three important input variables chosen for FNN are the value of FCT (fault clearing time) and the accelerating power and rotor speed. Then a 3 phase fault has been simulated at various buses with different values of FCT (fault clearing time), to achieve the required training set.

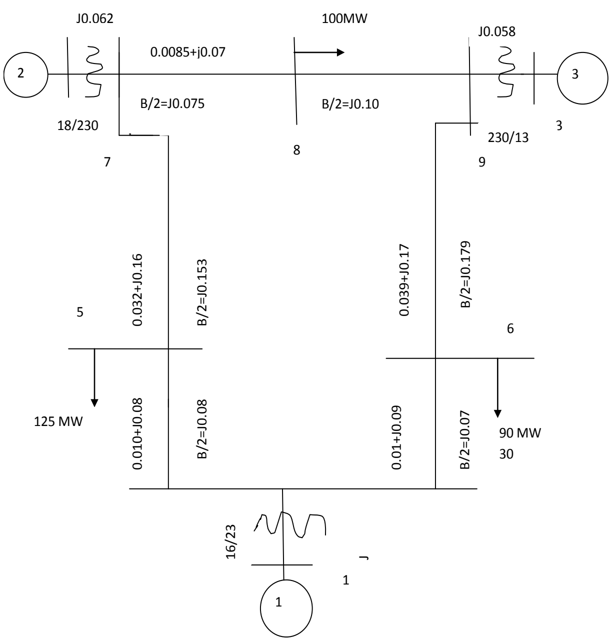

Figure.5 WSCC 3-machine, 9-bus system

A typical 3-generator 9- bus system has been considered for the present study. The system comprises a small hydro unit and two steam units. The line diagram is given in figure1. Only severe faults are considered presently. A symmetrical three phase fault on the high tension site of a line transformer is cleared by opening of the corresponding line.

A. *Factors Influencing Transient Stability:*

a. How heavily the generator is loaded.
b. The generator output during the fault.
c. Fault locations and type of fault.
d. The fault clearing time (FCT).
e. The post-fault transmission system reactance.
f. The generator reactance. A lower reactance increases peak power and reduces initial rotor angle.
g. The generator inertia. The higher the inertia, the Slower the rate of change in angle. This also reduces the kinetic gained during the fault.
h. The generator internal voltage magnitude (E). This Depends on the field excitation.
i. The infinite bus voltage magnitude Eb.

B. *Transient Energy Function Method:*

The transient energy function method can be considered as a generalization of the conventional equal –area criterion for the first swing stability analysis of machine –infinite bus system. Consider the power system shown. Assume the fault occurs on one of the transmission line. Operating the circuit breakers B3, B4 clears the fault by disconnecting the faulted transmission line (fig.6).

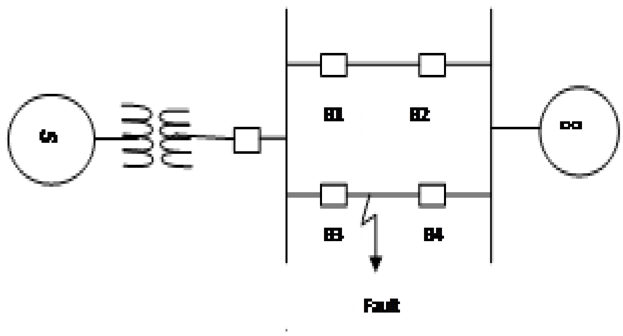

Figure.6 Single machine-infinite bus system

C. *Single Machine Infinite Bus System:*

Fig.7 illustrates the use of the equal area criterion method, first swing stability. This may be interpreted using the transient kinetic energy and potential energy concepts. The measure of the energy delivered by the turbine to the machine during the fault. The potential energy is associated with the machine torque angle. The potential energy between any two transient states is the net area between the post fault power output curve and turbine power line, determine by the torque angle at the two transient states . It gives the potential energy , with respect to the post fault, stable equilibrium point , accumulated during fault on period. The difference between the potential energy of the post fault stable equilibrium point and unstable equilibrium point. This is referred to as the Critical energy.

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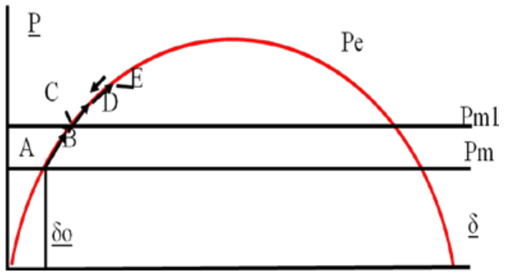

Figure.7 Equal area criteria

D. Transient Stability Enhancement:

Reduction in the disturbing influence by minimizing the fault severity and duration. Increase of the restoring synchronizing forces. Reduction of the accelerating torque through control of prime mover mechanical power. Reduction of the accelerating torque by applying artificial load.

E. Fast Valving:

Fast valving as it sometimes referred to is a technique applicable to thermal units to assist in maintaining power system transient stability. It involves rapid closing and opening of the steam valves in a prescribed manner to reduce the generator accelerating power following the recognition of a severe transmission fault (fig.8).

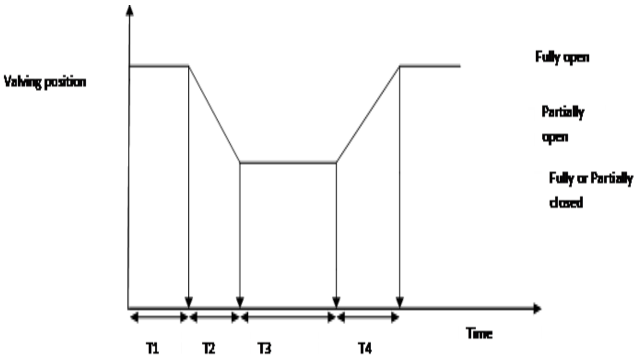

Figure.8 Typical valve closing and opening sequence

T1= delay between the time of initiation and the time when the valve begins to close.
T2= valve closing time
T3= Time during which the valve remains closed.
T4= valve opening time

IV. NEURO- FUZZY

A. Need For Neuro-Fuzzy Integration:

Neural network and fuzzy systems are dynamic parallel processing systems that estimate input output functions. They estimate a function without any mathematical model and learn from experience with sample data. Neural networks do not provide a strong scheme for knowledge representation, while fuzzy logic controllers do not possess capabilities for automated learning. Neuro-fuzzy hybridization is done broadly in two ways: a neural network equipped with the capability of handling fuzzy information [termed *fuzzy-neural network.*(FNN)] and a fuzzy system augmented by neural networks to enhance some of its characteristics like flexibility, speed, and adaptability [termed *neural-fuzzy system* (NFS)].

V. HYBRID ALGORITHM

Hybrid genetic algorithms have received significant interest in recent years and are being increasingly used to solve real-world problems. A genetic algorithm is able to incorporate other techniques within its framework to produce a hybrid that reaps the best from the combination. A genetic algorithm is a population-based search and optimization method that mimics the process of natural evolution. The two main concepts of natural evolution, which are natural selection and genetic dynamics, inspired the development of this method.

The block diagram shown from the view point of designing of neuro-fuzzy network for applying in fast valving for transient stability enhancement. The proper choice of neural network includes choosing of neuro-fuzzy network architecture. In the process started of improving the transient stability using neuro-fuzzy, first there is the need of input and output variables to be selected. Then the data is loaded and it is trained and tested with the error tolerance= 0.01 and Epoch =200. If the tolerance is more than error then rules are modified and the again the process is repeated.

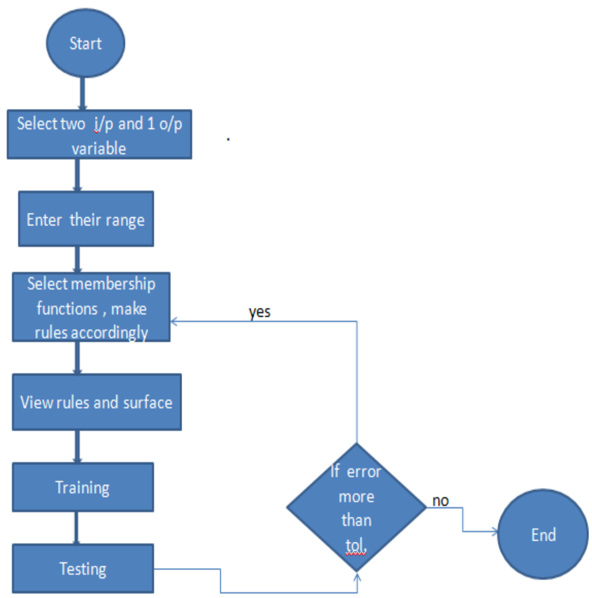

Figure: 9

VI. SIMULATION RESULTS USING ANFIS AND ITS IMPLEMENTATION TO IMPROVEMENT OF TRANSIENT STABILITY

Here we discuss the main part of an adaptive network based-fuzzy inference system in improvement of transient stability. First we use our data with input output values in order to train our network with a rule-based structure. Here we have selected our input variables accelerating power and speed. The output we have selected as the fault clearing time. Accordingly we have selected the membership functions with respect to the power, speed and fault clearing time. The rules are made based on the ranges selected. After the rules we have checked the error if the error is minimum then we have plotted the three dimensional structure. Using data for training procedure will obtain an error so in this network and with the help of following table we will generate the if-then rules and simulate using ANFIS(Table 1).

Table.1 Linguistic variables of improvement of transient stability

Variables	Range	correspondent fuzzy
Accelerating power	0-25 20-50 45-75 70-100	Very low Low Medium High
Speed	10-60 50-90 80-140 130-190	Very low Low Medium High
Fault clearing time	0-2 2-4 3-5	Low Medium High

A. *Fuzzy Inference System USING Sugeno Method*

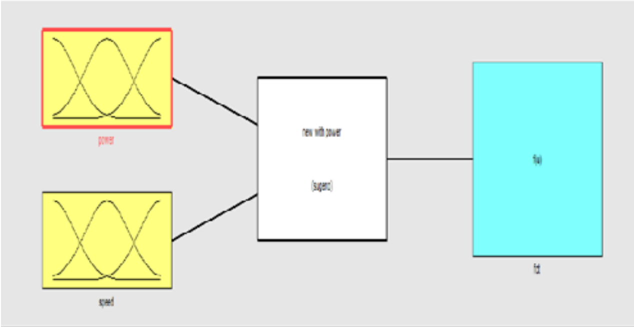

Figure.10 FIS editor showing input and output variable.

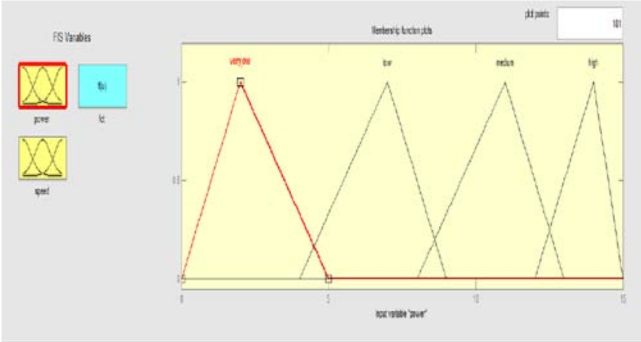

Figure.11 FIS editor showing input variable power

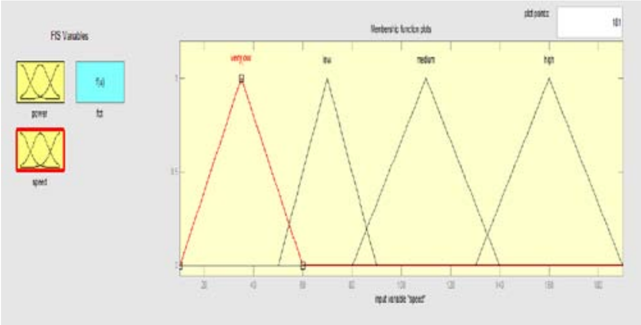

Figure.12 FIS editor showing fault clearing time

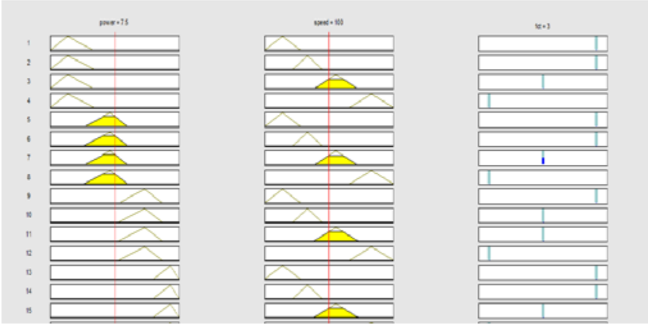

Figure.13 Rule viewer for transient stability improvement

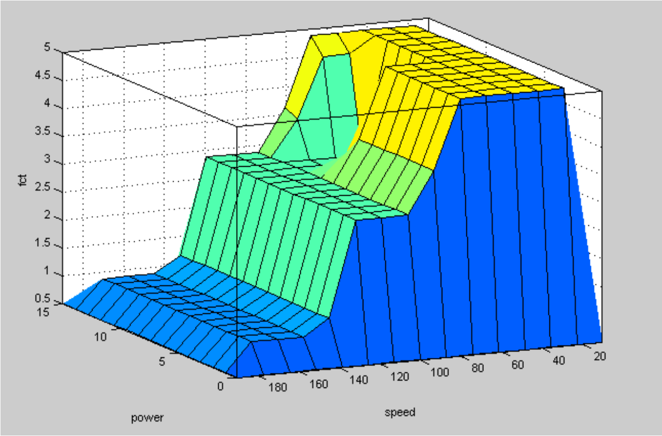

Figure.14 Surface views before training and testing of data.

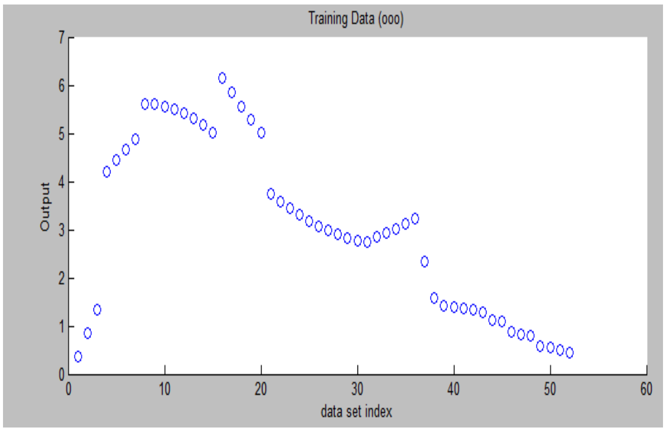

Figure.15 Training data

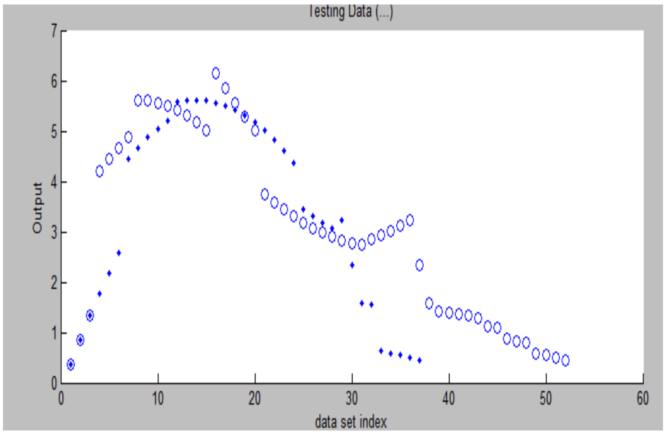

Figure.16 testing data

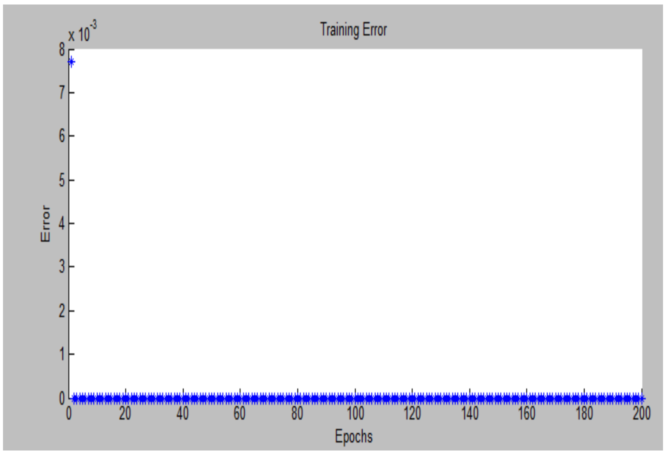

Figure.17 Training error

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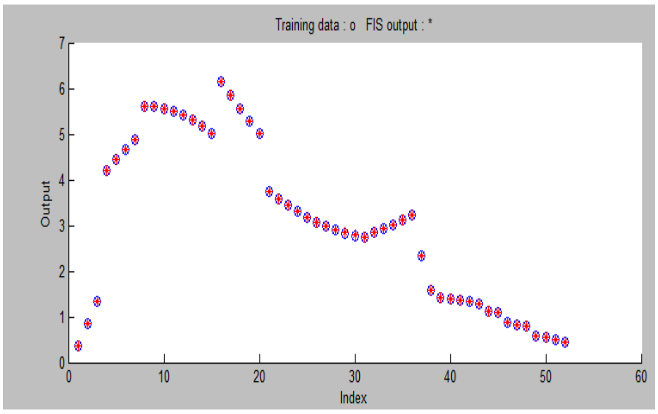

Figure.18 Testing error

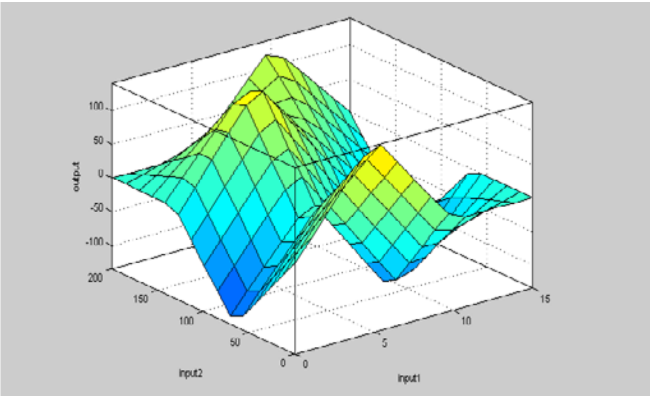

Figure.18 Surface views after training and testing of data

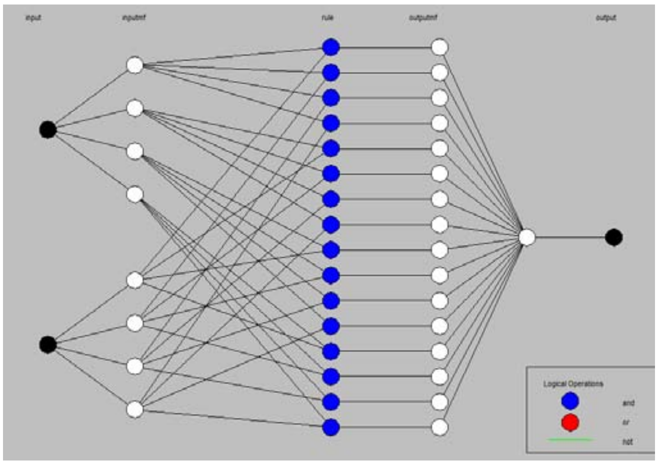

Figure.19 ANFIS Model structure

VII. CONCLUSION

The Neuro-fuzzy integrated system can be trained by numerical data and linguistic information expressed by fuzzy if-then rules. This feature makes the incorporation of prior knowledge into the design of controllers possible. Another important feature of the neuro-fuzzy integrated system is that, without any given initial structure, the system can construct itself automatically from numerical training data. This study demonstrates the improvement of transient stability using neuro-fuzzy logic.

The Application of neuro-fuzzy system to fast valving for transient stability improvement has the two inputs which include Accelerating power and rotor speed. The output are signal for fault clearing time. The Neuro-fuzzy system is stable, efficient, and reliable.

VIII. ACKNOWLEDGMENT

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