Coherency Identification of Generating Units based on Neural Network

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Abstract— In the modern era of power system security is very important. As complexity of power system increases, large data storage is required and its analysis makes it further complex. Algorithmic approaches are done by various existing methods such as Modal Analysis, empirical Based Simplifications, Coherency based techniques etc. In the proposed work Artificial Neural Network based techniques are developed for coherency identification and dynamic aggregation. Based on the transient stability analysis software the rotor angle oscillations of the different generating units in the system under study are estimated. The coherency index techniques are applied for clustering the coherent units.

Index Terms—Coherency, Coherency Index, Dynamic aggregation, Neural Network, SoftComputing.

I. INTRODUCTION

THE operation and control of present day power system becomes quiet complex owing to large size, interconnection to neighboring power system and introduction of new devices. To provide reliable and good quality power to the customers, the power system has to be maintained in a stable operating condition even in the events of disturbances. As power system is being increasingly interconnected a detailed stability study is not efficient. Simple equivalents that model the transient behavior of distant generators in response to system changes are desirable. A good solution to this dimension problem is to use a technique to reduce the size of the external systems. A full scale assessment is too time consuming and impractical for optimal control, hence it is reasonable to use an equivalent representation for the external areas. [2]

II. COHERENCY IDENTIFICATION TECHNIQUES

A coherent group of generating units for a given perturbation a group of generators oscillating with the same angular speed, and terminal voltage in a constant complex ratio. Thus, the generating units belongs to the same coherent group can be attached to a common bus, if it is necessary through an ideal complex ratio transformer. [3] The dynamic equivalent of a coherent group of generating units is a single generating unit that exhibits the same speed, voltage and total mechanical and electric power as the group during any perturbation where those units remain coherent.[3] Coherency based dynamic aggregation has the following procedure

 i. Coherent group identification
 ii. Generator and related governor aggregation,
 iii. Network reduction

Two generator buses are defined as coherent if their angular difference is closely invariable within a predefined tolerance over a certain period. It is necessary to consider the coherency of both internal and terminal generator buses, because the first one forms the basis for the network reduction. The coherent groups of generators can be defined by a specific fault occurring inside an area but it is essential to describe the fault type. The procedure for identifying coherency for a single fault will be described.

A. Assumption

The coherent groups of generators are completely independent from the size of the disturbance. For that reason, coherency could be determined by taking into consideration a linearised system model. The amount of detail in the generating unit is independent of the coherent groups. Thus, a classical synchronous machine model will be supposed and the excitation and turbine governor system will be ignored. To reproduce the fault effect on the power system, the mechanical output will be pulsed to attain the same accelerating power, like if a fault would have existed.

B. Coherency Index

Coherency means that the rotor angles of some generators swing together for remote disturbances [6]. Coherency index that uses the swing curves of each generator is proposed to identify coherency between two generators. , If the relative rotor angle between generator i and j has constant value at all simulation time, then generator i and generator j are coherent and can therefore be represented by a single equivalent generator. In order to find coherent generators, the following coherency index is calculated [3]

$$C_{ij} = \sum_{t=0}^{t=n-1} \{ (\delta_i(t) - \delta_{i.avg}) - (\delta_j(t) - \delta_{j.avg}) \}^2$$

Where

$$\delta_{i.avg} = \frac{\sum_{t=0}^{t=n-1} \delta_i(t)}{n}, i = 1,2,3......k$$

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$\delta_{i.avg}$: Average rotor angle at generator i

$\delta_i(t)$: the rotor angle of generator at time t.

   k   : the number of generators in the external subsystem

   n   : the number of sampling

   c   : coherency index matrix

In above coherency index Cij, the dc offset is eliminated by the average rotor angle in order to remove the effect of the initial values. To accumulate the errors, the difference is squared before summation. Coherent groups of generators are determined by comparing the coherency Indices with a specified tolerance.

C. Algorithm for Coherent Group Identificationt

      C.1 Collection of data for transient stability study

A load flow study of pre- transient network, to determine the mechanical power of the generators and to calculate the values of Ei $\angle\delta_{io}$. For all the generators, the equivalent impedance of the loads is obtained from the load bus data.

      C.2 System data Requirement

The inertia constants H and the direct axis transient reactance Xd'. For all the generators. The transmission line impedance for initial line network conditions and the subsequent switching.

      C.3 Coherency Grouping

Run load flow. Obtain the steady state pre transient values for all the voltages, power and angles. Obtain the numerical solution of the swing equation for the individual generators during fault with initial conditions obtained in the load flow analysis. The values of δ_i for all i^{th} generator is calculated with respect to time. Select any one machine as reference and find the deviation with respect to each other. Group the machines which are swinging together. The flow chart of the coherency grouping is shown in fig.1

III. NEURAL NETWORK BASED COHERENCY IDENTIFICATION

Artificial Neural Networks (ANN) is scientific tool for the accurate prediction scientific targets, which reduces the overall complexity and internal relationship between the inputs and the targets. ANN have received special attention from the researchers because of its simplicity, learning and generalization ability, and it has been applied in the field of engineering, such as in load forecasting, harmonic detection, power system stabilities. This paper presents a neural network-based algorithm for coherency identification which can be further is used for stability studies.

Many attempts had been for developing a dynamic equivalent of power system. Neural network based methods are also developed with various type of ANN. A method with self organizing map, which is an unsupervised ANN, is discussed in [13].The clustering of generating unit is done with an unsupervised method in [13].The clustering of generating unit requires coherency identification.

Signal processing approaches are also developed. Hilbert Huang transform application on coherency identification is a notable contribution in this field [16].

Since the coherency index and hence the accuracy requirement can be set in advance for off-line studies, the online recorded or simulated rotor oscillation can be used as the input of a supervised neural network as well. The

proposed work uses a supervised neural network for coherency identification.

ANN with supervised learning methodology is used in identifying the coherent group. A multi layer network with Back propagation algorithm is proposed for the same. Training pairs are to be initially collected by running the transient stability software. The target vectors in this case are the coherent groups. The multi layer Back Propagation network are found well suited for this purpose as its found to be converging with minimum time and good accuracy.
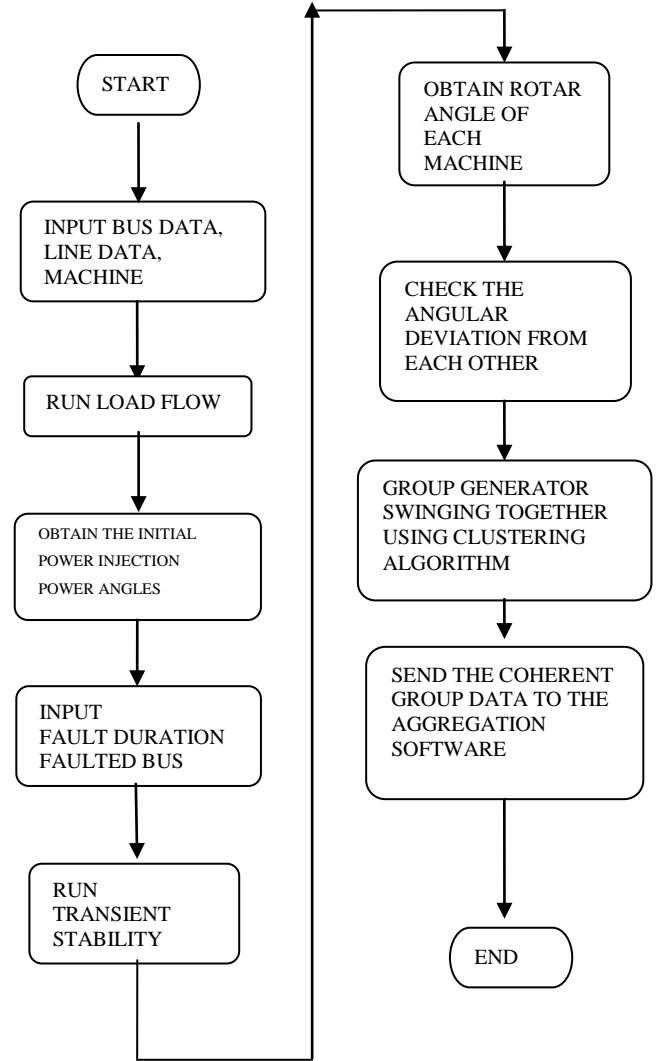

Fig 1 Flowchart for the Coherency Identification program

IV. COHERENCY USING ANN FROM ROTOR DYNAMICS DATA

In this section two reference system considered for Coherency identification.

A. 3 Generator 9 Bus System

Coherency identification program was run for a 3-generator 9-bus system .The fig 2 shows the single line diagram of this system. [11] .Transient stability program is to be run for getting the rotor angle response of the system. The initial conditions are to be obtained by a load flow program. The Newton-Raphson method is used to analyze the load flow for the system. These initial conditions are fed to transient stability program. The rotor angle of the 3 generators are obtained from the simulation .The coherency index is calculated for each machine. And change in rotor

angle with respect to time is plotted. From the coherency index value the machines arranged in the order of their coherency index. Now those machines having similar coherency index is grouped, to form coherency group. The plot of rotor angle deviation of each machine for a fault at bus no.4 is shown in fig 3
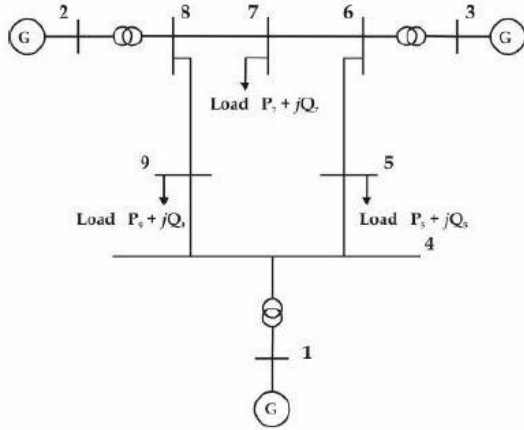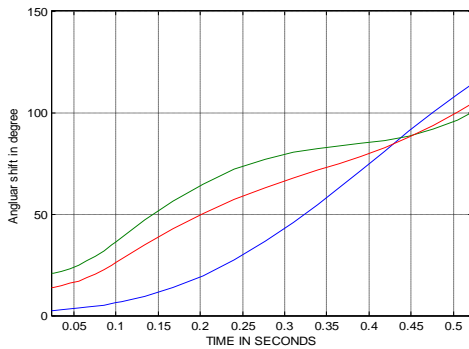

Fig 2. 3 Generator 9 Bus System.

Fig 3. Rotor Angle Variation of machines for fault at bus no.4
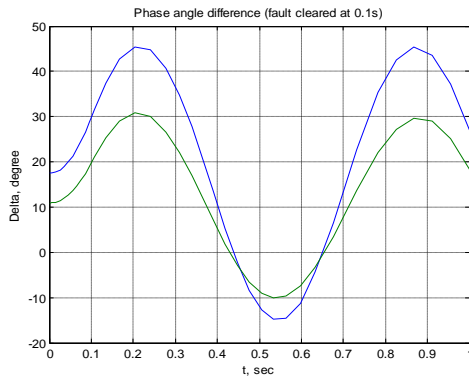

Fig 4 Delta plot for Machine2,3 w.r.t 1

B. 9 Generator 28 Bus System

The coherency identification program has been run for 9-generator 28-Bus system. The rotor angle variation for a fault at bus no. 4 for duration of 0.1s is obtained as in fig.5 The rotor angle variation and the coherency index calculation shows that machine numbers 3,4,5,6,7 and 8 are coherent, for this particular fault. The coherency indexes of these machines are found to be close to each other. The machine no2 and 9 are of separate group.
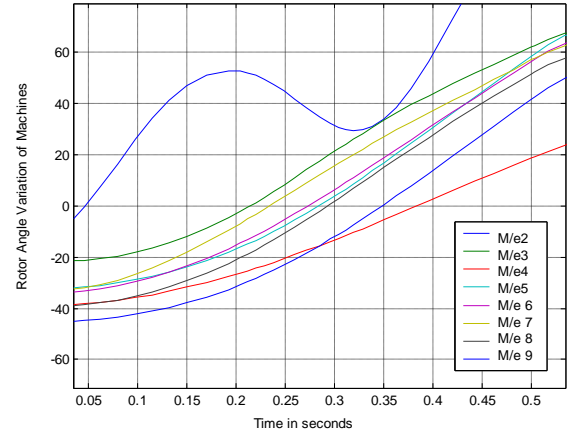

Fig 5. Rotor Angle Variation of the 9 machines for fault at bus no.4

C. ANN based approach for Coherency Grouping

In coherency based dynamic aggregation the coherent groups are formed based on the rotor oscillation for a given fault. The rotor angles are taken for each machine with respect to a reference. The coherent groups are based on properties of these points in the swing curve ($\Delta\delta$) of different machines. This can be more reliably can be identified by defining an ANN feed forward network and hence we can avoid rigorous calculations. An input vector can be defined with the set of measured rotor angles. Hence get the coherent groups. The training pattern for a particular system can be developed from a typical set of rotor swing curves, which are obviously coherent .The coherency of this pattern can be made confirmed using any of the known method. This pattern is used for the training of the Neural Network.

The training pattern can be developed by taking a group of points from the swing curves for a predefined duration of time. For example the swing curves of Machine No.3 and Machine No.8 are taken for developing pattern, from the above 9 Generator28 Bus system. The curves are obviously swing together which is tested with the coherency identification program. Now select a part of the curve take sample points from both the curves for the same duration and at the same instants. For every point check the coherency. The target value is assigned zero or one based on their property of coherency, i.e., the points, which satisfies the coherency criterion is assigned zero and others one.

A Feed Forward Neural Network with two layers is formed with the help of MATLAB neural network toolbox Here a set of 20 points within a given time interval from all the machine swing curves are taken as input data.The training has been done with the pattern developed as in explained. The coherency grouping is done with a specified percentage of outputs of the ANN being in the coherency "Zero" group. For a 9 generator 28-bus system the coherent groups with ANN is found to be as in table 1.

Group No	Generators Coming Under The coherent Group
1	1, 3, 5, 6,7,9
2	2
3	4

Table 1 The Coherent Groups Using ANN for 9-Generator 28-bus system.

V. CONCLUSION AND FUTURE SCOPE

Dynamic security assessment plays a critical role in the competitive market today. Coherency identification and Dynamic Aggregation is very important as far as the studies on Power system stability studies are concerned. The coherency identification techniques, which are used in this paper, are based on the swing of rotor obtained through stability software. The aggregated system reduced the total time taken by the transient stability program with reasonable accuracy. The ANN methodology used reduces the total time in checking different part of the swing curve for the interested study period.

The power system oscillation for a given perturbation is always correlated with the eigen value of the system. Hence the eigen value of the system will give good idea regarding the rotor oscillations. The characteristic plot of eigen vectors can be used for coherency identification. These can be incorporated with the rotor angle based coherency detection may further improve this process

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