Electrical Power and Energy Systems 64 (2015) 536–541

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Artificial Neural Network for coordinated control of STATCOM, generator excitation and tap changing transformer

S. Sumathi [a,*], Bansilal [b]

[a] RNS Institute of Technology, Bangalore, India
[b] The National institute of Technology, Mysore, India

ARTICLE INFO

Article history:
Received 29 September 2013
Received in revised form 29 June 2014
Accepted 14 July 2014

Keywords:
STATCOM
Tap changing transformer
Generator excitation
Artificial Neural Network (ANN)

ABSTRACT

Control of voltage in a power system under varying load conditions can be achieved by varying the generator excitation, changing the tap position of transformers and by varying the reactive power injection or absorption at the shunt compensated buses. Proper coordination of these controllers is essential for the effective operation of the power system. This paper deals with the development of Artificial Neural Network which gives the voltage controller settings, such that the voltage deviations at the load buses are minimum.

Introduction

Voltage control is an important aspect in the day to day operation of power systems. The voltage control can be achieved by various reactive power controlling devices. Present day power systems use FACTS devices for the control of real and reactive power in the system. The shunt FACTS devices such as Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM) are the devices commonly used for the control of reactive power and hence used for the control of voltage in the system [1,2]. The coordinated control of these FACTS devices with the generator excitation system and tap changing transformers is essential for the control of voltages at the load buses. Hence the objective is to find the settings of these control devices so as to minimize the voltage deviations at the load buses. Generally non linear optimization techniques are used to find the controller settings [3].

Artificial Neural Network is one of the important artificial intelligence tools which can be used for non linear function mapping. A trained ANN can be used to model any function approximation in real time. In literature, we find many Artificial Neural Network applications for the monitoring and control of power system operation.

Artificial Neural Networks are used to detect the type and location of fault in distribution system [4]. Artificial Neural Networks find application in insulation failure detection in transformer windings [5]. ANN are also used in locating the phase of partial discharge in transmission line [6]. They are also used in evaluation of loadability limit of systems with TCSC [7]. Artificial Neural Networks find application in transient stability analysis of power system [8]. Artificial Neural Networks are developed even for protection co-ordination schemes [9].

In this paper ANNs are developed which give the controller settings for minimum voltage deviation under normal condition and under contingency condition. Prototype Artificial Neural Networks are developed for a 24 bus EHV power system. The single line diagram of the power system is shown in Fig. 1. The power system considered for analysis has 4 generators, 7 tap changing transformers at the load buses and a STATCOM connected at bus 24.

The developed ANN take the load factor as input and gives the generator excitation, tap position of the transformers and the reactive power to be supplied by the STATCOM as output. The data for training the ANN is obtained by the conventional non linear optimization technique.

Formulation of problem

For the given loading condition the non linear optimization problem is to minimize the voltage deviations at the load buses. Hence the objective function is expressed as:

* Corresponding author. Tel.: +91 98801 29596.
E-mail addresses: sumathi_saba@rediffmail.com (S. Sumathi), bansilal_nie@rediffmail.com (Bansilal).

http://dx.doi.org/10.1016/j.ijepes.2014.07.056

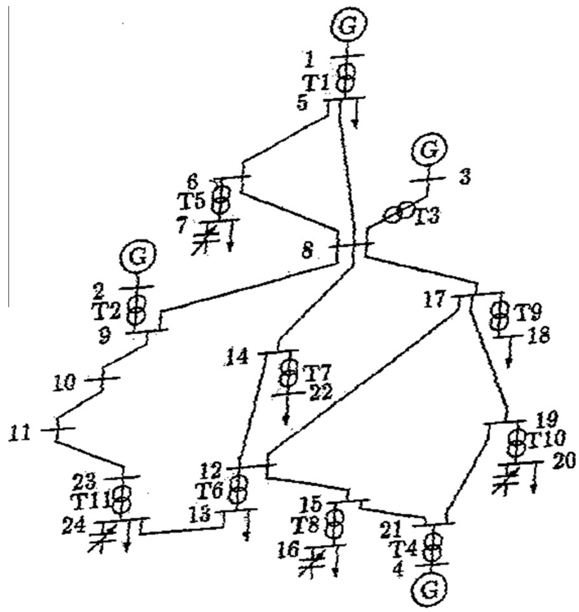

Fig. 1. Single line diagram of 24 bus system.

Minimize

$$J(X) = \sum_{i=1}^{L} [V_{i(des)} - V_{i(act)}]^2 \quad (1)$$

Where L is number of load buses; X is the vector of control variables; $V_{i(des)}$ is the desired voltage at bus i; $V_{i(act)}$ is the actual voltage at bus i.

The non linear least square optimization technique is used for the solution of this non linear optimization problem as explained in Appendix. The control variables are tap position of the transformers, excitation of the generators and the reactive power injection by the STATCOM.

Algorithm for solving non linear optimization problem

1. Read the system data and the load multiplier.
2. Initialize control variables.
3. Form network matrices.
4. Perform power flow with controller settings.
5. Compute the voltage error, and the objective function.
6. If the value of objective function is within the specified tolerance go to step 8.
7. Else solve for control variables and adjust it for suitable step size and go to step 3.
8. Print the results.

Development of Artificial Neural Network

An Artificial Neural Network (ANN) is an important artificial intelligence tool, which gives fast and acceptable solution in real time. ANNs are composed of simple elements operating in parallel. It is composed of a large number of highly interconnected processing elements that are analogous to neurons and are tied together with weighted connections that are analogous to synapses. Once trained the Artificial Neural Network is able to provide sufficiently accurate recommendations in a very short time suitable for on-line applications in energy control centers.

A Radial Basis function Neural Networks (RBNN), one of the standard ANN which has one input layer, one hidden layer and an output layer. The hidden layer uses radial symmetric activation function such as Gaussian activation function. In this paper two radial basis function neural networks are developed, corresponding to normal condition of the power system network and with line outage condition. The developed Artificial Neural Networks take the load factor as input and give the controller settings as output. The output includes the tap position of the transformers, reactive power injection by the STATCOM, and the voltages of the generator buses. The data for training the Artificial Neural Network is obtained by running the optimization program, for different load factors.

Radial basis function neural network for normal operating condition

Data for training the radial basis function neural network

The load factor is varied from 0.9 to 1.1 in steps of 0.02. For the non linear least square optimization technique the tap position of tap changing transformers are initialized to 1.00. The value of reactive power injection by the STATCOM is initialized to 0.15pu and the generator excitations are initialized to 1.00pu. The values of control variables obtained from non linear optimization technique, are used for training the RBNN. Table 1 shows part of the data used for training the radial basis function network corresponding to normal operating condition of the power system.

The developed RBNN has 11 neurons in the radial basis layer. It has 12 neurons in the output layer corresponding to 12 control variables.

Validation of the radial basis function neural network

CASE 1: load factor of 0.95. Table 2 shows the recommendations for different controller settings, provided by the non linear least square optimization technique and the predictions made by the developed radial basis function neural network for a load factor of 0.95.

It can be observed from Table 2 that the recommendations provided by the radial basis function neural network is comparable with the results obtained from conventional non linear least square optimization technique. The recommendations provided by the radial basis function neural network for the reactive power injection is 0.1720 against 0.1500 provided by the optimization technique. The error in the recommendations of the neural network is just 0.022pu (2.2MVar). It can be seen that the recommendations provided by the radial basis function neural network for generator excitations are comparable with that of optimization technique. The error is found to be maximum in the recommendation of excitation of generator 1 (V1). And this error is just 0.0029pu. In case of transformer tap settings, a small variation in the recommendations has no significant effect on the system operation, because the transformer taps are varied in steps.

Table 3 shows the voltage profile at all the load buses with the controller settings provided by optimization technique and radial

Table 1
Data for training the radial basis function neural network under normal operating condition.

Control variable	Load factor				
	0.92	0.96	1.00	1.04	1.08
T5	0.9625	0.9875	0.9750	0.9500	0.9500
T6	0.9875	0.9875	0.9875	0.9875	1.0000
T7	1.0000	1.0000	1.0000	1.0000	1.0000
T8	1.0000	1.0000	1.0000	1.0000	1.0000
T9	1.0000	1.0000	1.0000	1.0000	1.0000
T10	0.9875	0.9875	0.9875	0.9875	0.9750
T11	1.0000	1.0000	1.0000	1.0000	1.0000
$Q_{statcom}$	0.1500	0.2000	0.2500	0.3500	0.8000
V1	1.0150	1.0050	1.0100	1.0200	1.0250
V2	0.9850	0.9950	0.9900	0.9800	0.9600
V3	0.9950	1.0000	1.0000	1.0000	1.0100
V4	1.0000	1.0000	1.0000	1.0000	1.0000