ANN BASED CONTROL PATTERNS ESTIMATOR FOR UPFC USED IN POWER FLOW PROBLEM

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ABSTRACT

The continuous growth in the demand for electric power necessitates the flexibility of operation in power system. Of different power electronics-based Flexible AC Transmission System (FACTS) devices, which enhance the power transmission capabilities, Unified Power Flow Controller (UPFC) provides an emerging and promising solution for the power flow problems in the system, as it simultaneously and/or selectively controls the transmission parameters. In this context, the paper proposes the power flow control in a simple system by injecting the series compensating voltage, which is an important function of UPFC. For this purpose, ANN controller based UPFC is used. Control patterns are generated for obtaining the adjustable series voltage from the second converter that, in turn, controls the power flow in the system. With the proposed model, by varying control coefficient the series injected voltage can be adjusted. MATLAB Simulation is used to test the proposed model. The control horizon is identified and presented for various values of existing active and reactive powers.

Key words: *FACTS, UPFC, ANN, Power Flow Control.*

1. INTRODUCTION

The UPFC is conceptually a Synchronous Voltage Source (SVS) [1, 2] which generates the adjustable voltage on the ac side. The voltage source exchanges both active power and reactive power with the transmission system. The UPFC consists of two-voltage source converters, one in series and one in shunt in a transmission line. Both using switching elements and operated from a common dc storage element as shown in Fig.1.1. This configuration facilitates free flow of real power between ac terminals of two converters in either direction while enabling each converter to independently generate or absorb reactive power at its own ac terminals. The series converter referred as converter 2 shown in Fig. 1.2 injects a voltage with controllable magnitude v_i and phase angle ρ in series with the line via an insertion transformer, there by providing main function of UPFC. Electric power flow through an alternating current transmission line depends on the line parameters and complex voltages at the sending end and receiving end of the line. The adjustable voltage at one end of the line would allow us to control the power flow through the line [3]. A voltage magnitude and phase angle at a particular point in a transmission system can also be adjusted by using more advanced device like UPFC. This paper presents the use of two-converter model of UPFC with ANN controller for power flow problem.

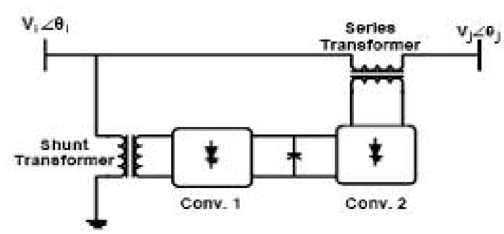

Fig. 1.1 Two-converter model of UPFC

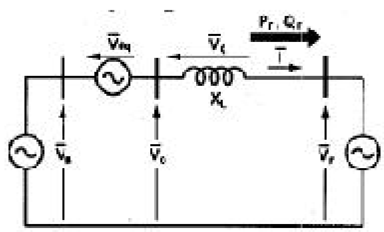

Fig.1.2. Conceptual representation of UPFC with two-machine system

Basically, the UPFC control system can be divided functionally into two units concerning internal and external controls [1]. The internal control unit operates the two inverters so as to produce the commanded series injected voltage, and simultaneously draws the desired shunt real and reactive currents from the shunt inverter by controlling a proper output voltage at its AC terminals. On the other hand, the external control unit is responsible for generating the proper voltage commands for the internal control unit so as to regulate the controlled system variables, real and reactive power flows; to meet the desired values. However, the process in the external control unit is normally a tedious task; it takes a long time to solve a set of non-linear equations so as to get the input reference voltages requested by the internal control unit of the UPFC.

Over the last two decades, ANN has gained a lot of appreciation from many engineering fields. The electric power industry is no exception. With the advent of powerful and cheap computers, digital control is being used in a growing number of power system applications. Many new effective algorithms have been developed and implemented in real time. Artificial Neural Network controller (ANNC) is a new control approach with a great potential for real-time applications.

In order to realize a real time control of the power flow in steady state, an ANN based control algorithm is proposed in this paper to solve the above mentioned problem. Instead of using the iteration method, a trained Neural Network can be used as an estimator to predict the internal control variable (K) in the UPFC system.

2. POWER FLOW CONTROL

Consider transmission line that is connected between two buses of a power system as shown in figure 2. Some other lines also may be connected parallel in with the above line. Assuming that receiving end voltage Vr of the line maintained constant. When the line is represented by a two-port network with generalized ABCD constants, The active power Pr and reactive power Qr at the receiving end of the line can be written as [4]

Pr $=VsVr/B \cos(\beta_s - \delta_s + \delta_r) - AVr^2/B \cos(\beta - \alpha)$ ---(1)

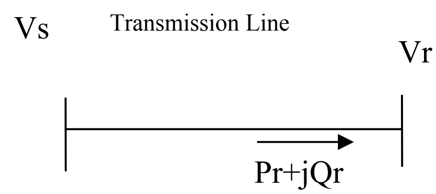

Fig. 2. Representation of a two bus system

Qr$= VsVr/B \sin(\beta_s - \delta_s + \delta_r) - AVr^2/B \sin(\beta - \alpha)$--(2)

Here **Vs**$= Vse^{j\delta s}$, **Vr**$= Vre^{j\delta r}$

A$=Ae^{j\alpha}$ and **B**$=Be^{j\beta}$

$(\delta=0)$

Without any UPFC the active and reactive power flows through the line are fixed and are defined by the (1) and (2) respectively. However UPFC can control the power flow through the line, which is described in the next section.

3. POWER FLOW CONTROL WITH UPFC

Consider a UPFC placed at the sending end of the line as shown in figure 3.1 .The UPFC can be represented by series injected voltage and a shunt current Ii as shown Fig.3.1. Note that Vi is fully controllable and can be expressed as

$Vi= Vi\ e^{j(\delta s+\gamma)}$

where $Vi \leq Vimax$ and $0 \leq \gamma \leq 360^o$

In this case , the sending end final voltage
Vs f= Vs + Vi------(3)

The phasor diagram of (3) is shown by the dotted circle in figure 3.2. By knowing Vsf, the active and reactive power at the Receiving end can be calculated from (1) and (2) respectively, after replacing Vs by Vsf. The Current Isf in figure can be written as [1]

Isf = CVr+DIr= CVr+D (Vsf-AVr)/B -------------(4)

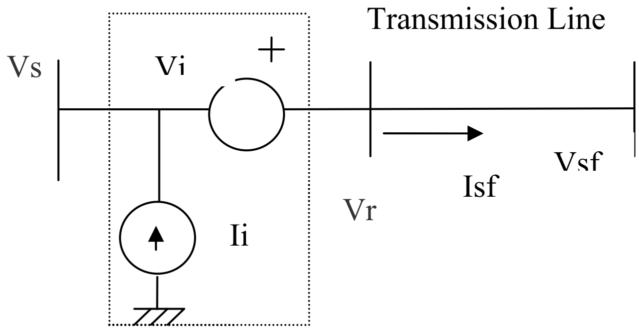

Fig .3.1Transmission line with UPFC at sending end

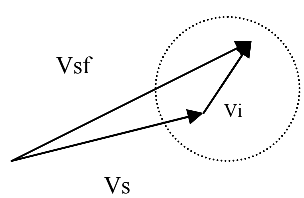

Fig. 3.2. Phasor Diagram

4. ARTIFICIAL NEURAL NETWORK CONTROLLER

The control circuit generates coefficients (Ki) that must be multiplied with output of the dual converter to get the component of voltage to be added in series to supply voltage to compensate for variation in real and reactive powers.

Intelligent controller using artificial neural network is used to obtain the coefficients. Neural network is trained for specified values with in the range. Trained neural network intelligently returns the coefficients for a given alpha, P and Q with in the range.

During training process when active power and reactive power in the data base expressed in terms of W that is, P= 389W, Q=315W, etc., as the matrix was close to singularity results were inaccurate. To avoid this P and Q are scaled to maximum 1000 and a minimum 100.

Example: P=389W,
Pscaled = (max-P)/(max-min)
= (1000-389)/1000-100)

Similarly, Q = 315var
Qscaled = (max-Q)/(max-min)
= (1000-315)/(1000-100)

They mutually correspond to a given set of real and reactive power flows (P, Q) which are practically the real and reactive power flows controlled by UPFCs. The biggest advantage of using ANN based estimators in the control scheme is that the time during the recall process of a trained estimator is almost negligible in comparison with the time taken to perform an iteration program to solve a set of non-linear equations introduced in [5] .

Theoretically, there are number of Neural Networks which can be used to achieve this control requirement. A multi-layer feed forward Neural Network has an input layer, an output layer and several hidden layers. This type of ANN is suitable for mapping a set of input patterns onto a set of output patterns and it is used in this study

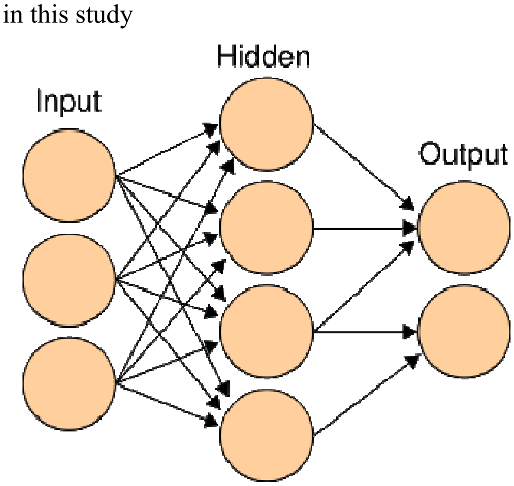

Fig.4. Simple Neural Network model

to examine the feasibility of applying the proposed ANN Based Control Algorithm (ABCA) in a practical control scheme[6]. The basic idea of ABCA is based on the fact that when the configuration of a power network maintains the same topology then the relationships between the power flow and losses patterns and the patterns of control variables in UPFCs will be conserved. Therefore, the trained ANN based estimator is able to correctly predict a set of proper control variables for the internal controllers of UPFCs to meet a certain control goal. In this paper, only the case of steady state power flow regulation subjected to the minimization of system losses and the support of voltage profile is presented .

5. ANN BASED CONTROL VARIABLES ESTIMATOR

As mentioned in the above section, the ANN based control variables estimator is used to predict a set of control variables for the internal controller of the UPFC system. For training the neural net, a set of training patterns are required. In this study case, these patterns are composed of a set of inputs given below of the external control unit in the UPFC control system.

Range of alpha=0 to 1.57
Range of Real power=375 to 425
Range of reactive power=300 to 360
Function inputs=alpha, Pr, Qr
Function output=Control Coefficient.

Fifty seven training patterns are obtained from the conventional open loop control. At each simulation step, the best voltage profile must be provided as well as the minimum system losses must be reached by properly selecting the best combination of control variables for UPFC. The training and testing processes in this study are carried out by using back propagation algorithm. The neural network learning algorithm in general view is given below. Given n training instances,

1. Initialize the network weights, set I=1 Present the i^{th} instance to the network on the input layer.
2. Obtain the activation levels of the output units using the inference algorithms. If the network per forms the predefine standard (or the stopping criterion)then exit.
3. Update the weights by learning rule of the network.
4. If i=n then reset i =1 otherwise increment i by 1. Go to step 2.

6. SIMULATION RESULTS

The proposed UPFC based on ANN controller is simulated using MATLAB software. By inputting the Pr, Qr and firing angle φ the initial sending end voltage Vsi without controller is obtained. After multiplying with a control variable K generated by the ANN controller the corrected value of sending end voltage Vsf is obtained which is shown in Table 1.This voltage will be almost equal to the referred value of sending end voltage Vs. Control variables are obtained for various ranges of active and reactive powers by keeping firing angle φ constant.
Fig. 6.(1)-(2). show a set of the performance graphs during training of ANN for given Pr, Qr and firing angle φ in the UPFC system installed in line.

TABLE 1
COMPARISON OF SENDING END VOLTAGE WITH AND WITHOUT UPFC

Pr	Vsi	Vsf	K
375	541.044	560.6323	2.01
380	543.38	560.6391	1.76
385	545.78	560.6396	1.51
390	548.19	560.6430	1.2
395	550.61	560.6581	1.01
400	553.04	560.6632	0.7641
410	557.94	560.6426	0.2683
415	560.41	560.6360	0.222
425	565.37	560.6299	-0.465

Here
Pr=receiving end real power (variable)

Qr=315,Firing angle=63deg. (made fixed)
Vs= set value=560volts
Vsf= Vs final i.e after correction
K=control coefficient obtained from MATLAB Simulation

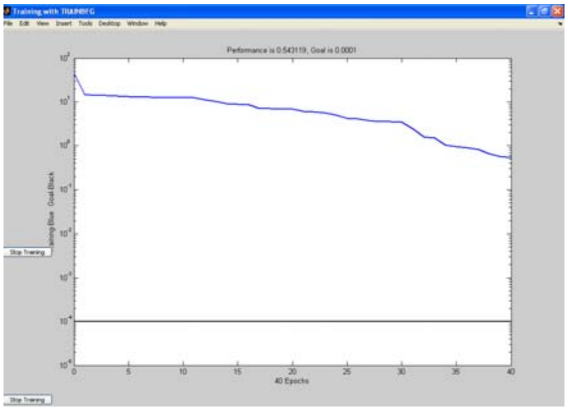

Fig 6.1 Training of Neural network before goal was met

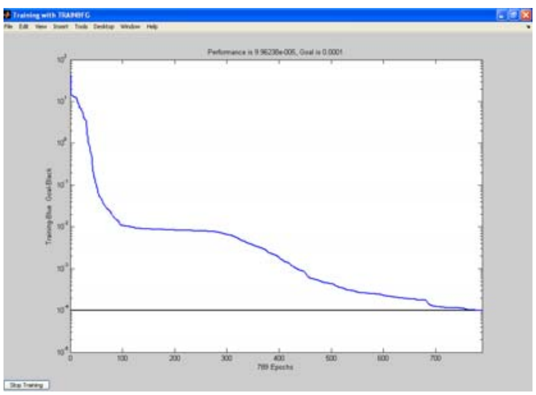

Fig 6.2. Training of Neural network after goal was met

7. CONCLUSIONS

In this paper a novel control concept using ANN based estimator in the external control unit of the UPFC system has been presented. Simulation results show that the trained ANN based estimator is able to correctly estimate the patterns of UPFC internal control variables. They are mutually mapping to a set of corresponding power flow patterns, which are based on satisfying the condition that the system voltage profile must be supported and the system losses must be minimized at the same time.

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