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ARTIFICIAL INTELLIGENCE BASED TUNING OF SVC CONTROLLER FOR CO-GENERATED POWER SYSTEM

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ABSTRACT

The gain of SVC depends upon the type of reactive power load for optimum performance. As the load and input wind power conditions are variable, the gain setting of SVC needs to be adjusted or tuned. In this paper, an ANN based approach has been used to tune the gain parameters of the SVC controller over a wide range of load characteristics. The multi-layer feed-forward ANN tool with the error back-propagation training method is employed. Loads have been taken as the function of voltage. Analytical techniques have mostly been based on impedance load reduced network models, which suffer from several disadvantages, including inadequate load representation and lack of structural integrity. The ability of ANNs to spontaneously learn from examples, reason over inexact and fuzzy data and provide adequate and quick responses to new information not previously stored in memory has generated high performance dynamical system with unprecedented robustness. ANNs models have been developed for different hybrid power system configurations for tuning the proportional-integral controller for SVC. Transient responses of different autonomous configurations show that SVC controller with its gained tuned by the ANNs provide optimum system performance for a variety of loads.

Keywords: Artificial Neural Network (ANN), Static Var Compensator (SVC), Autonomous Hybrid Power System (AHPS)

1. INTRODUCTION

Applications of ANN to power systems are a growing area of interest. Considerable efforts have been placed on the applications of ANNs to power systems. Several interesting applications of ANNs to power system problems [1]-[5], indicate that ANNs have great potential in power system on-line and off-line applications. The feature of an ANN is its capability to solve a complicated problem very efficiently because the knowledge about the problem is distributed in the neurons and the connection weights of links between neurons, and information are processed in parallel.

Back-propagation is an iterative, gradient search, supervised algorithm which can be viewed as multiplayer non-linear method that can re-code its input space in the hidden layers and thereby solve hard learning problems. The network is trained using ANN technique until a good agreement between predicted gain settings and actual gains is reached.

During last three decades, the assessment of potential of the sustainable eco-friendly alternative sources and refinement in technology has taken place to a stage so that economical and reliable power can be produced. Different renewable sources are available at different geographical locations close to loads, therefore, the latest trend is to have distributed or dispersed power system. Examples of such systems are wind-diesel, wind-diesel-micro-hydro-system with or without multiplicity of generation to meet the load demand. These systems are known as hybrid power systems. To have automatic reactive load voltage control SVC device have been considered. The multi-layer feed-forward ANN toolbox of MATLAB 6.5 with the error back-propagation training method is employed.

2. TRAINING OF ANN PARAMETERS

The input to the ANN is the value of exponent of reactive power load-voltage characteristic (n_q) and the output is the desired proportional gain (K_P) and integral gain (K_I) parameters of the SVC. Normalized values of n_q are fed as the input to the ANN the normalized values of outputs are converted into the actual value. The process of determining the weights is called the training of the learning process. Prior to conducting the training process, a set of input-output patterns is first prepared. The set is developed by computing the desired PI controller gains based on typical loading conditions. The exponent of load voltage characteristics ranges between 0.0 and 4.0, which covers all typical loads in power systems [6]. Table 1 shows the optimum gain settings of SVCs for different reactive power loadings of different hybrid power systems considered, which has been developed using MATLAB 6.5. The network is trained until a good agreement between predicted gain settings and actual gains is reached.

Once the network is adequately trained, the network is again tested to ensure that it can adequately predict the correct gain settings for the load models that are not included in the training set. Network has been tested for two different values of n_q i.e. 1.5 and 3.5. Corresponding to these two values SVC gain parameters K_P and K_I are obtained and corresponding to these values of gains transient responses have been presented for different autonomous hybrid power systems.

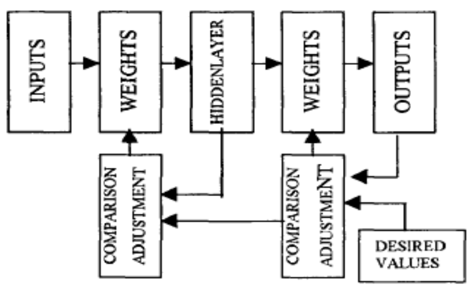


Figure 1: Multi-layer Feed-forward Neural Network

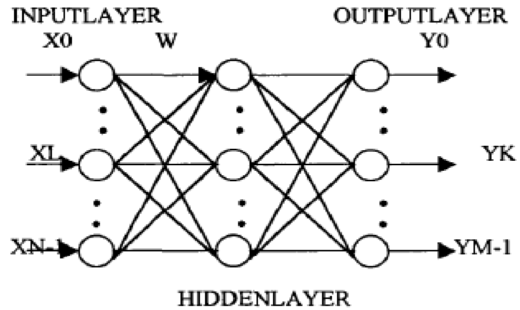


Figure 2: Basic Block Diagram of BP algorithm

The training process of ANN model has been performed using the ANN toolbox of MATLAB 6.5. The multi-layer feed-forward network used in this paper was trained using the back-propagation (BP) paradigm developed as shown in figure 1&2. Finally various ANN tuned transient responses are shown for step disturbances in reactive power load and/or input wind power.

3. TRANSIENT RESPONSE OF HYBRID POWER SYSTEM

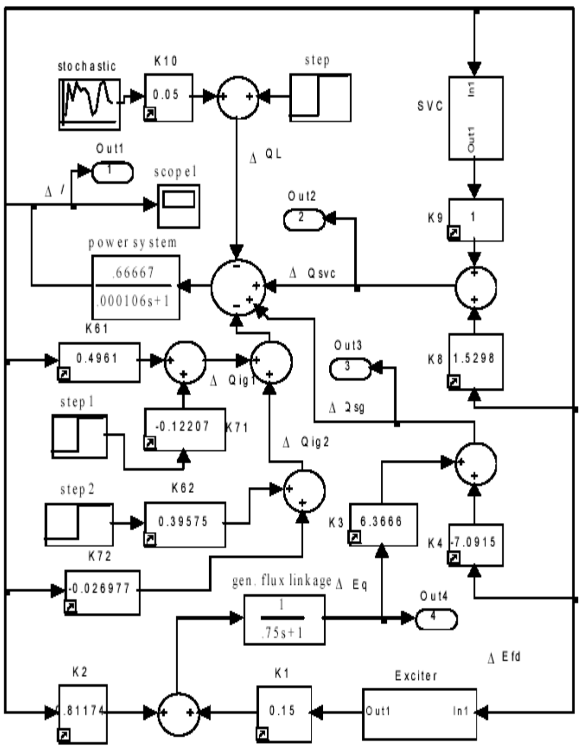
Transient responses of different hybrid power systems, e.g. multi-wind-diesel, wind-diesel micro-hydro system using IEEE type-I excitation system for system with SVC have been presented. Simulation block diagram of multi-wind diesel AHP system for step and

TABLE I: OPTIMUM GAIN SETTINGS OF SVCS FOR DIFFERENT VALUES OF EXPONENT OF (QL–V) CHARACTERISTIC

S.N.	System type	n_q	0.5	1.5	2.0	3.5	4.0
1.	Multi wind- diesel	K_P	306	342	357	417	436
		K_I	8300	9400	10000	11800	12600
2.	Wind-diesel-micro-hydro	KP	398	480	528	670	716
		KI	8100	9250	9800	11600	12200

stochastic disturbances are shown in figure 3. The dynamic responses are shown for deterministic disturbance in reactive power load. To study the effect of multiplicity of generation an example of multi-wind diesel AHP system is presented. In wind-diesel system another type of non-conventional energy sources (micro-hydro) has been added to study its effect.

Figure 3: Simulation block diagram of multi-wind



diesel Hybrid Power Systems For step + stochastic disturbances

MULTI-WIND-DIESEL HYBRID POWER SYSTEMS

Transient responses of the multi-wind-diesel hybrid power system with SVC for 1% step increase in reactive power load and input wind power is shown in figure 4&5. Table 2 gives the maximum deviations of different parameters of multi-wind-diesel for 1% step increase in reactive power load and input wind powers for n_q =1.25and 3.25. It is observed that maximum deviations of all parameters are more for larger values of n_q.

A lot of difficulty is observed in following the general guidelines suggested in [6], in which 'purlin' is considered in the last layer. In the present case program works well when 'purlin' is considered first instead of last. Prior to the training process, a training data set consisting of full range of exponent n_q (0.5 to 4 in the present case) and desired gains of SVC are compiled.

Table 2: The maximum deviations of different parameters of multi-wind-diesel for 1% step increase in reactive power load and input wind powers

	1	2
n_q	3.25	1.25
ΔV	-0.002089	-0.001708
ΔQ_{SG}	0.014810	0.012114
ΔQ_{SVC}	0.021546	0.021098
ΔQ_{IG1}	0.003232	0.003185
ΔQ_{IG2}	0.000883	0.000873

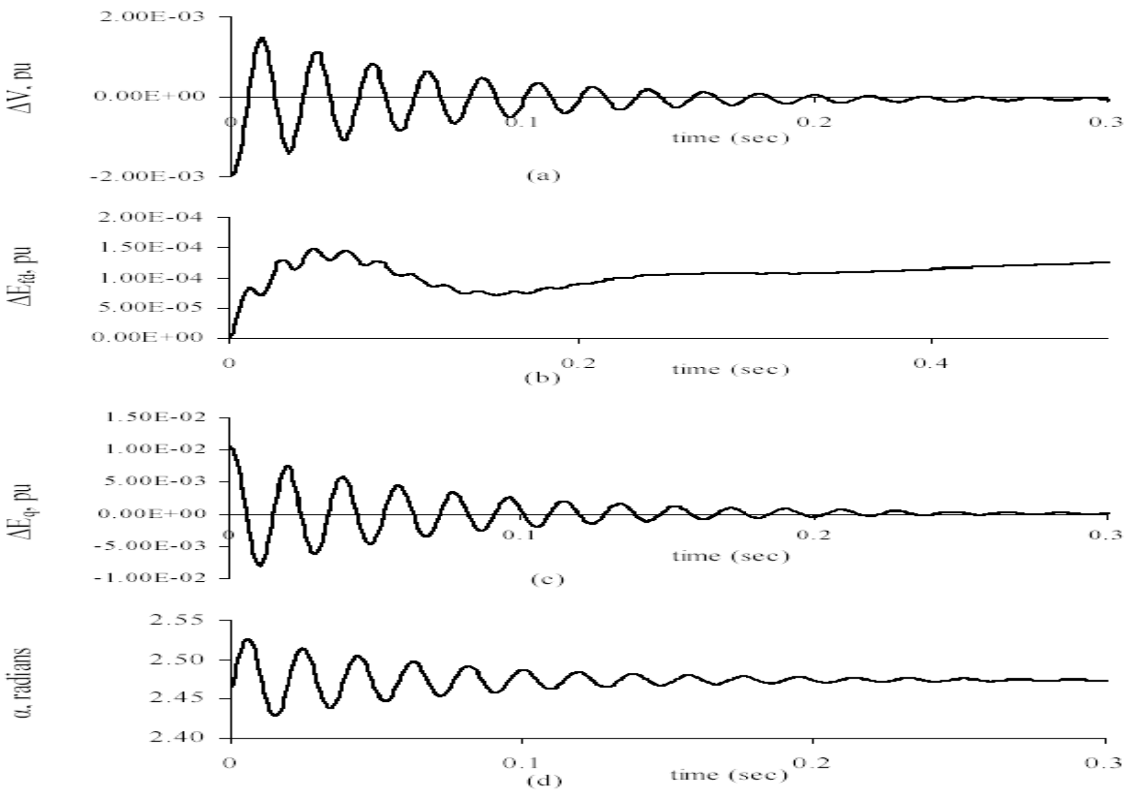


Figure 4: Transient responses of the multi-wind-diesel hybrid power system with SVC for 1% step increase in reactive power load and input wind power

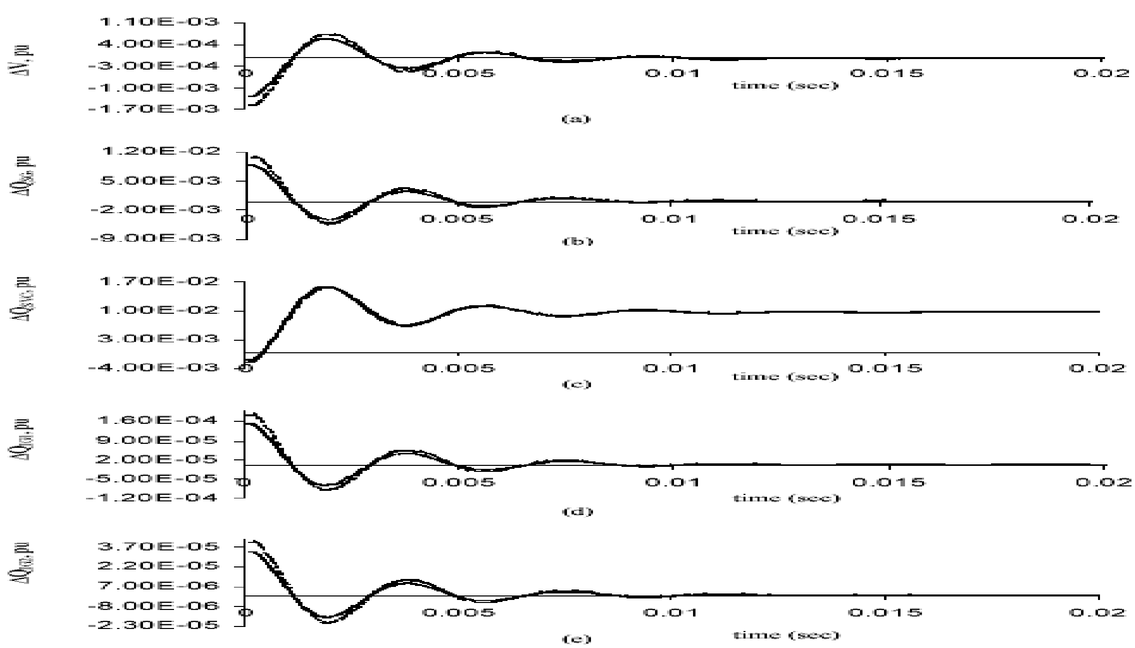


Figure 5: Transient responses of the multi-wind-diesel autonomous hybrid power system for 1% step increase in reactive power load ---- for nq = 3.25, ___ for nq = 1.25

3.2. WIND-DIESEL MICRO-HYDRO HYBRID POWER SYSTEMS

The dynamic performance for 1% step increase in reactive power load for n_q = 3.25 and n_q = 1.25 is shown in Figure 6&7. The maximum deviations of different parameters of wind-diesel-micro-hydro system for 1% step increase in reactive power load are presented in Table 3. It is observed that maximum deviations of all parameters are more for larger values of n_q.

Table 3: The Maximum Deviations of Different Parameters of Wind-Diesel-Micro-Hydro System For 1% Step Increase in Reactive Power Load

	1	2
n_q	3.25	1.25
ΔV	-0.001531	-0.001249
ΔQ_{SG}	0.010850	0.008858
ΔQ_{SVC}	0.016679	0.014426
ΔQ_{IG1}	0.000187	0.000153
ΔQ_{IG2}	0.000045	0.00032

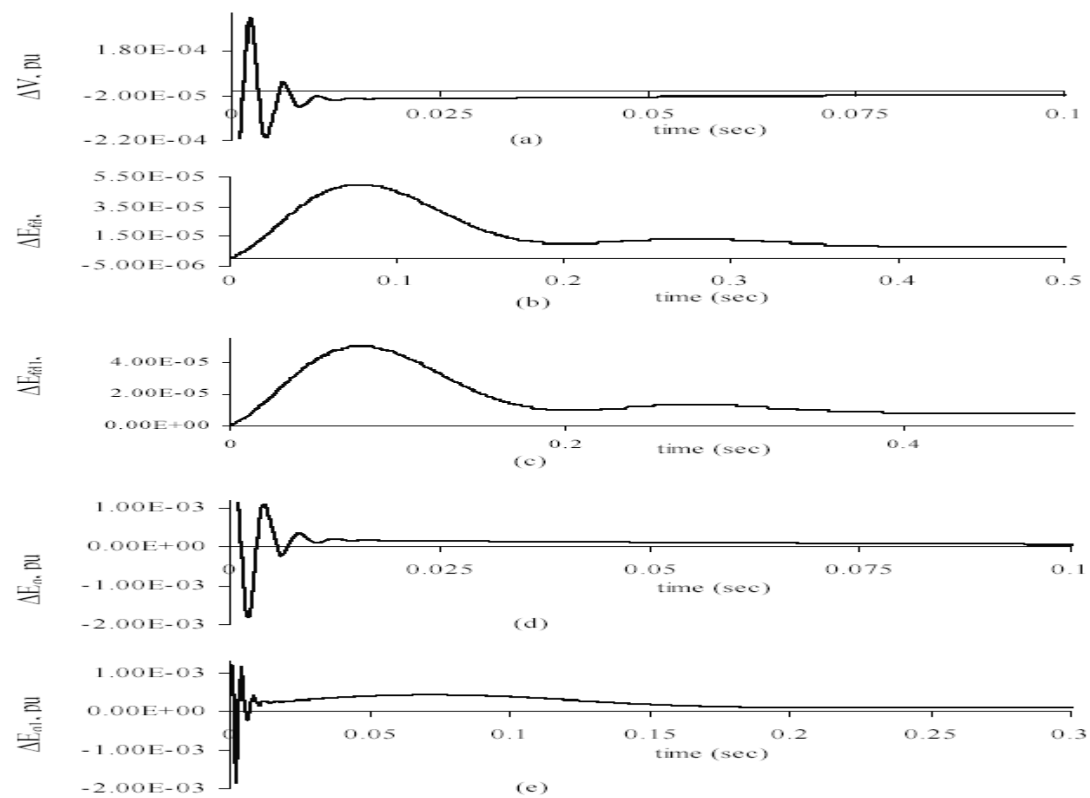


Figure 6: Transient responses of the wind-diesel-micro-hydro hybrid power system with SVC for 1% step increase in reactive power load and input wind power

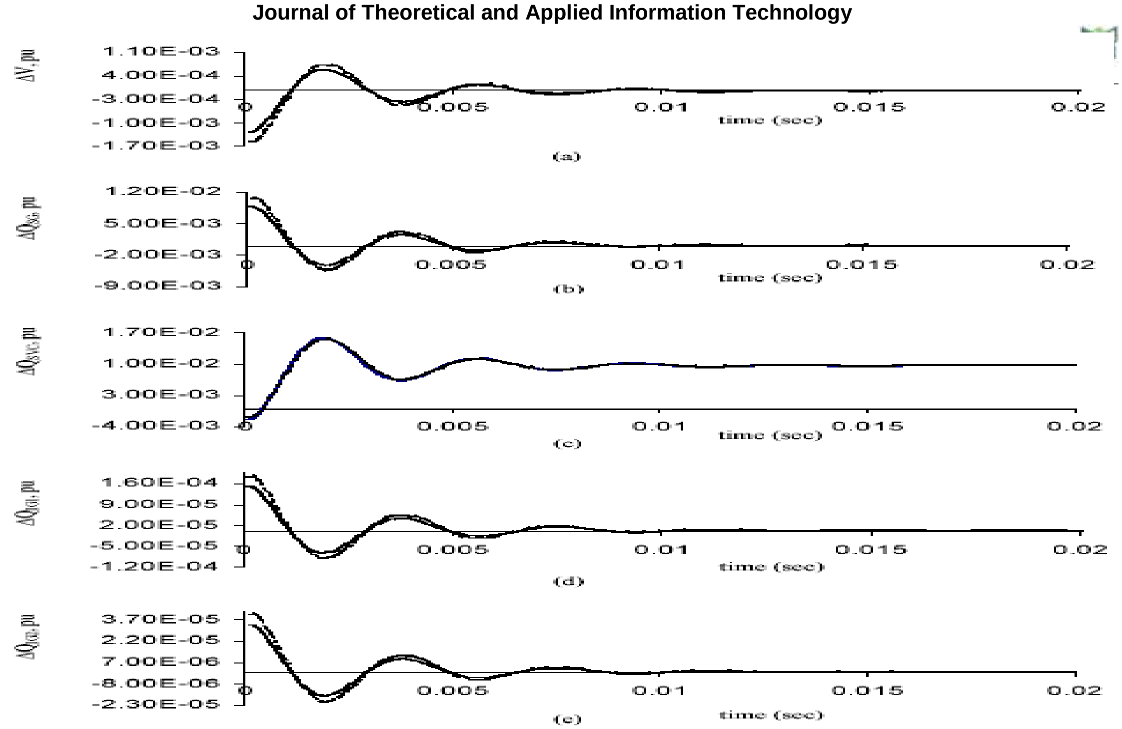


Figure 7: Transient responses of the wind-diesel-micro-hydro autonomous hybrid power system for 1% step increase in reactive power load ---- for nq = 3.25, ___ for nq = 1.25

4. CONCLUSION

ANN models have been developed for different hybrid power system configurations for tuning the proportional-integral controller for SVC. The ANN receives load voltage characteristics as its input and provides the desired gain settings K_P and K_I of SVC as the output. Transient responses of two autonomous configurations show that SVC[1] controller with its gain tuned by the ANNs can provide optimum performance of the system over a wide range of typical load models. It is also observed that maximum deviations of all parameters are more for larger values of n_q.

System Data:

For Multi-Wind-Diesel Hybrid Power Systems: The values of constants are: $K_1 = 0.15$, $K_2 = 0.811744$, $K_3 = 6.36662$, $K_4 = -7.0915$, $K_6 = 0.4961$, $K_{61} = 0.39575$, $K_7 = -0.122068$, $K_{71} = -0.026977$, $K_8 = 1.52976$, $K_9 = 1.0$, $K_V = 0.66667$, $T_V = 0.0001061$ sec., and $K_\alpha = 0.460636$.

For wind-diesel-micro-hydro Hybrid Power system: The values of constants are: $K_1 = 0.15$, $K_2 = 0.811744$, $K_3 = 6.36662$, $K_4 = -7.0915$, $K_{11} = 0.15$, $K_{21} = 0.84382$, $K_{31} = 8.27276$, $K_{41} = -8.311185$, $K_6 = 0.4961$, $K_7 = -0.12207$, $K_8 = 1.2826$, $K_9 = 1.0$, $K_V = 0.6667$, $T_V = 0.0001061$ sec., and $K_\alpha = 0.37655$

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