Design Feed Forward Neural Networks To Solve Control Problem In Electric Power System

Luma. N. M. Tawfiq & Manar. I. Ismail

Abstract— The main aim of this paper is to use artificial neural networks to solve control problem in electric power system, since the neural networks are universal and effective means for the different control problems. The use of such method of the artificial intelligence allows solving the reactive power and voltage control problem with higher level of its reliability and quality. The solving of the reactive power and voltage control problem is to increase the electric network effectiveness. It allows to reduce the electric power losses, substation loading and to improve the electric power quality. In this paper, the main principles of such control is considered on the basis of the neural networks.

Index Terms— Artificial neural networks, control problem, power factor, reactive power.

1 Introduction

Nowadays, the necessity to automate the tasks of complexes power systems operation and control has o be achieved with utmost accuracy and speed [1]. The needs for faster and automotives, which can be used online and in real time application is raised. The artificial neural networks (ANN) are an ideal choice, given the ability to cover the non-linearity and its fast response time. Neural network considered to be the most promising area in artificial intelligence as it is based on human experiences and on link of the input and output sets, training concepts and a pattern recognition function. The ANN adopts various learning mechanisms and self-organization. They have been successfully applied to problems in the fields of pattern recognition, image processing, data compression, forecasting, and optimization [2]. The ANN can be trained to generate the control parameters for minimizing the active power losses and determining reactive power to be injected in the system. The ANN allows not only solving multi complex mass problems in the electrical system, but also to adapt with continuous variation of conditions in real time [3]. There are many different neural network types that can be widely used in applied different cases [4]. On the other hand real power systems have thousands of variables at the system level. If all the measured variables are used as inputs to ANN, it results in large size of the network and hence larger training time. To make the ANN approach applicable for large scale power system problems, some dimensionality reduction is mandatory [5]. The problem of minimizing electric power losses in electrical networks is a major aspect of power systems research. There are many control methods used to improve the performance of the electrical system, in order to obtain the optimal mode of operation which satisfies the voltage quality and the reliability of the electrical system. The power losses are affected by means of the automatic voltage control for power transformers and control of the injected reactive power. On load tap changers and shunt capacitors where used to minimize the power losses and maintain voltage profile in the permissible values at the consumers terminals. As the loads of consumers of electrical power system are variable with time, obtaining the optimal operation mode could be realized by controlling the means of regulating devices.

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2 Artificial Neural Network

Artificial neural network is a simplified mathematical model of the human brain. It can be implemented by both electric elements and computer software. It is a parallel distributed processor with large numbers of connections, it is an information processing system that has certain performance characters in common with biological neural networks [6].

The arriving signals, called inputs, multiplied by the connection weights (adjusted) are first summed (combined) and then passed through a transfer function to produce the output for that neuron. The activation (transfer) function acts on the weighted sum of the neuron's inputs and the most commonly used transfer function is the sigmoid function (tansig.) [7], [8].

There are two main connection formulas (types): feedback (recurrent) and feed forward connections. Feedback is one type of connection where the output of one layer routes back to the input of a previous layer, or to the same layer. Feed forward neural network (FFNN) does not have a connection back from the output to the input neurons [9].

There are many different training algorithms, but the most often used training algorithm is the Delta rule or back propagation (BP) rule. ANN is trained to map a set of input data by iterative adjustment of the weights. Information from inputs is fed forward through the network to optimize the weights between neurons [10]. Optimization of the weights is made by backward propagation of the error during training phase. The ANN reads the input and output values in the training data set and changes the value of the weighted links to reduce the difference between the predicted and target (observed) values [11]. The error in prediction is minimized across many training cycles (iteration or epoch) until network reaches specified level of accuracy. A complete round of forward backward passes and weight adjustments using all input output pairs in the data set is called an epoch or iteration [12]. In order to perform a supervised training we need a way of evaluating the ANN output error between the actual and the expected outputs. A popular measure is the mean squared error (MSE) or root mean squared error (RMSE) [13].

3 PROBLEM FORMULATION

At technical statement of the problem to reduce the losses, firstly, the electrical power systems can be improved the voltage drop by change the transformer tap setting, secondly, add electric power capacitor, i.e., control reactive power distribution.

From the practical study, firstly, the power is moved with a certain voltage from one station to another, in the meantime gets voltage drop for many reasons, including the transmission of reactive power. A system under optimal power conditions operates with a high power factor. The power factor of a system is composed of two elements, active power and apparent power. Apparent power is the aggregate of active power and reactive power. Figure (1) illustrate the relations between apparent (S), active (P) and reactive power (q) at a certain power factor (cos φ) of the load.

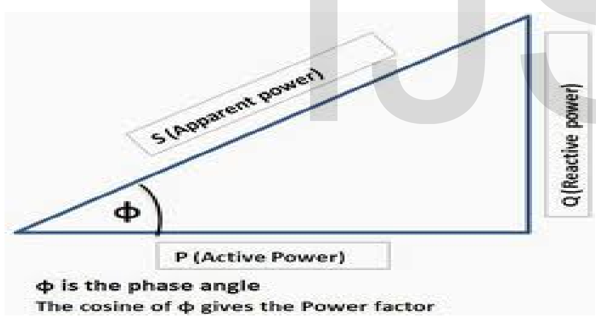


Figure 1: Relations between apparent, active and reactive power

If the voltage drop, due to VARS transmission is considered then, the voltage at the end of the line can be expressed as equation (1) [14], [15]:

$$V_{end} = V_{beg} - \text{ voltage drop} = V_{beg} - \frac{q\,X\,L}{V_{nom}}$$

$$= V_{beg} - \frac{P\tan\theta\,X_0 L}{V_{nom}} = \frac{V_{beg}V_{nom} - p\tan\theta X_0 L}{V_{nom}} \qquad (1)$$

This voltage V_{end} will be corrected when entering the transformer. The basic transformer is shown in Figure (2).

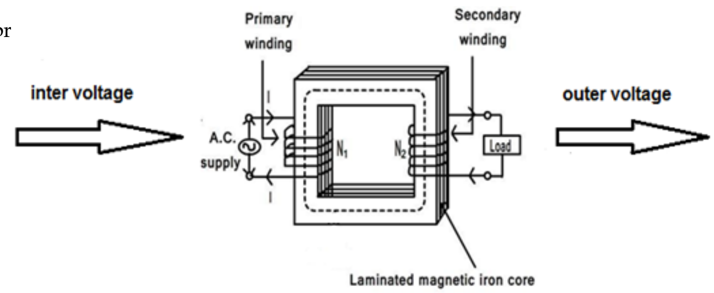


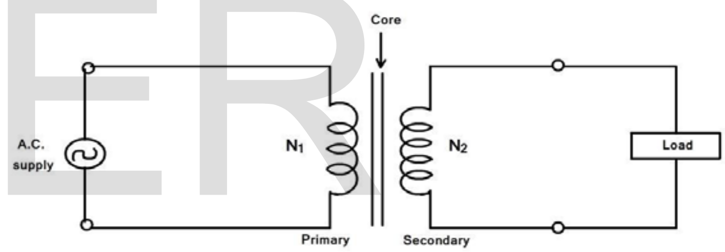
Figure 2: The basic transformer

An alternating voltage source is connected to one of the coils. This coil in which electrical energy is fed with the help of source is called primary winding. The other winding is connected to the load. The electrical energy which is transformed to this winding is drawn out to the load. This winding is called secondary winding. The primary winding has N1 number of turns while the secondary has N2 number of turns see Figure (3).

The secondary voltage depends on the number of turns in primary and secondary winding. The ratio of primary winding to secondary winding which is equal to ratio of inter voltage to outer voltage and known as voltage transformation ratio denoted as K [14]:

$$K = \frac{N_1}{N_2} = \frac{\text{inter voltage } V_{end}}{\text{outer voltage } V_{out}} \qquad (2)$$

Figure 3: The primary and secondary winding



The transformer is provided with a taps in order to adjust the voltage ratio of the transformer. These taps are provided along the winding with connections to a tap-changing device that makes the physical change in the in-service tap. The tap changing device is usually placed on the primary winding to minimize the current to be switched and can be "off-circuit " or "on-load" type.

The tap changer is provided with an equivalent range of ± 10 % of reference voltage (V_R) of primary winding in 16 or 32 steps,16 step tap changer provides 1.25% voltage change in each step called "magnitude of the additional voltage per tap step D". Thus D=0.0125V_r , when the primary voltage is low, the tap changer reduces correspondingly the number of primary turns in other word moves up to the next tap to maintain the voltage ratio. Similarly, when the primary voltage is high, the tap changer increases correspondingly the number of primary turns in other word moves to the previous tap to maintain the voltage ratio.

To know the number of taps to move we have to know the rated tap setting (K_r) and the difference between V_{end} and V_r.

$$M = \left[\frac{(V_R - V_{end})}{D}\right]$$

Since, M must be integer, then

$$M = \text{round}\left[\frac{(V_R - V_{end})}{D}\right] \quad (3)$$

So that the actual tap n expressed as:

$$n = M + K_r \quad (4)$$

One primary dilemma with reactive power is that a sufficient quantity of it is needed to provide the loads, but having too much reactive power flowing around in the network causes undesirable voltage drops as previously shown. The normal answer to this dilemma is to provide reactive power sources exactly at the location where the reactive power is consumed. Thus reducing the amount of the reactive power generated and transmitted from the main generators.

Among the benefits that reduce the current transferred and saving in the active power, we can calculate the current passing in the line and losses in active power (respectively) by [16]:

$$I = S / V \quad (5)$$

and

$$\Delta P = I^2 R \quad (6)$$

Where, ΔP is saved power and R is the resistance of the line.

4 Illustration of the Design Feed Forward Neural Network

In this section, we describe how can control the reactive power and voltage using ANN, i.e., design FFNN for regulation reactive power and voltage level according to a daily substation loading. In this section the FFNN is employed to regulate the reactive power of capacitor bank and voltage depending on substation loading. The first suggested network consist of two subnet. The first subnet includes three layers: the input layer, the output layer and one hidden layer. The neurons in the input layer receive the initial information - value of substation demand reactive power (q) and active power (p), that is, have two input nodes. The neurons in the output layer give out the resultant value of power factor (pf), apparent power (S) and the voltage at the end of the line (V_{end}), that is, have three output nodes. There are nine hidden neurons with tansigmoid transfer function (tansig.) illustrated in Figure (4). Firstly, we implement the training where the data given from the generator, that is, input p and q which send with determinant voltage to the other direction of the line and occur through transforming decreasing in the voltage at the end we get V_{end}, then the tap improve this V_{end} which represent S generated in the station. Then send S and V_{end} (output of first subnet) as the input of the second subnet, that is, the second subnet consist three layers: the input layer, the output layer and one hidden layer. The neurons in the input layer receive the initial information from the first subnet (S and V_{end}), that is, have two input nodes. The neurons in the output layer give out the resultant value of current (I) and saved power (ΔP), that is, have two output nodes. There are nine hidden neurons with tansig. transfer function illustrated in Figure (4) and the results give in Table (1), and illustrated in Figure (6). Now, if the value of pf near to 1, i.e., pf ϵ [0.97, 1],
then this mean that, most exploitage to the S, but if the value of pf is less than or equal to the 0.95, this mean that is priming q from two source: generator and static var capacitor (S.V.C), to decrease the current pass in the line, then decrease S and ΔP with stability voltage relatively. In this case we suggest FFNN consist two subnet, the first subnet consist three layers: the input layer have three input nodes P, q, and installed reactive power (Q_k), the output layer have three output nodes pf, S and V_{end} and one hidden layer. There are eleven hidden neurons with tansig. transfer function. The second subnet consist also three layers: the neurons in the input layer receive the initial information from the first subnet (S and V_{end}), that is, have two input nodes. The neurons in the output layer give out the resultant value of current (I) and saved power (ΔP: is the quantity of power which we saving), that is, have two output nodes. There are nine hidden neurons with tansig. transfer function illustrated in Figure (5). After the suggest FFNN has been trained and checked up, it can be applied to control the reactive power with voltage and the results gave in Table (2) and Figure (7).

Now, we can compute the current reduction (ΔI:is the quantity of current which we saving current (I) with or without Q_k), which equal to the difference between I computed without Q_k and I computed with Q_k, i.e.,($I_{without\ Qk} - I_{with\ Qk}$).

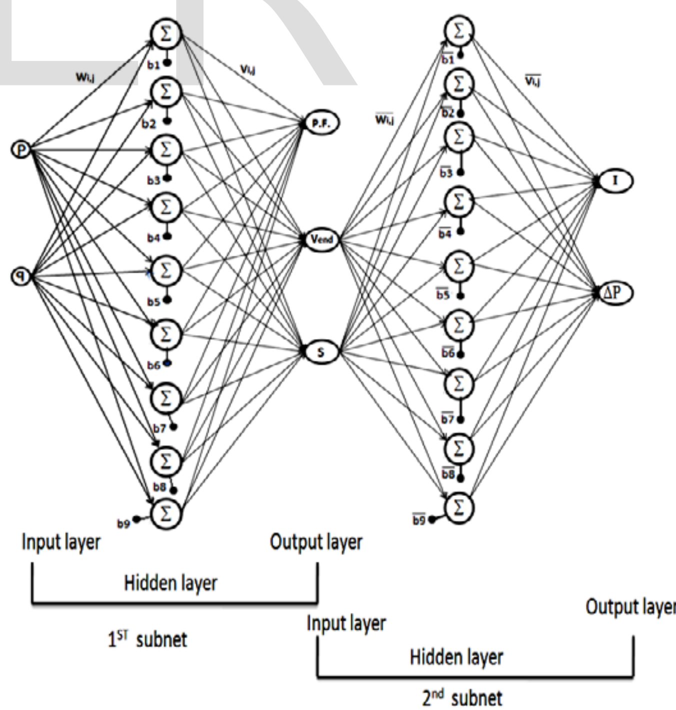


Figure 4: The structure of the first suggested network

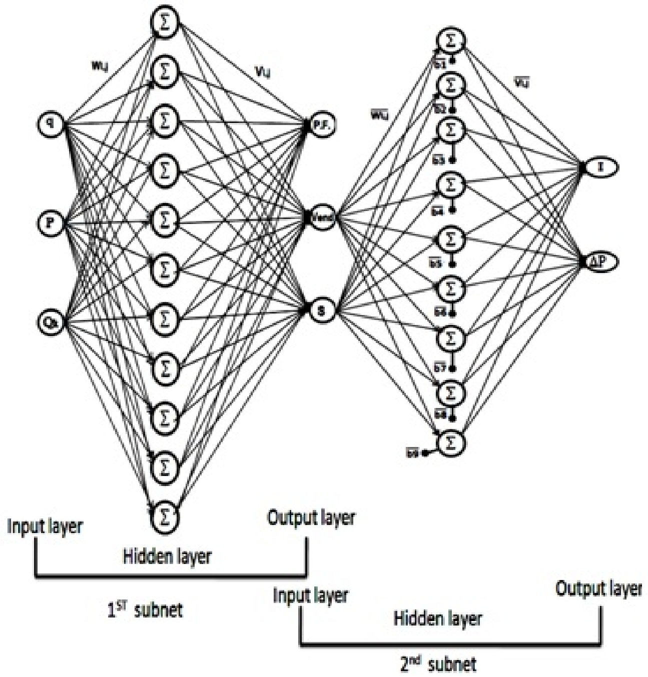


Figure 5: The structure of the second suggested network

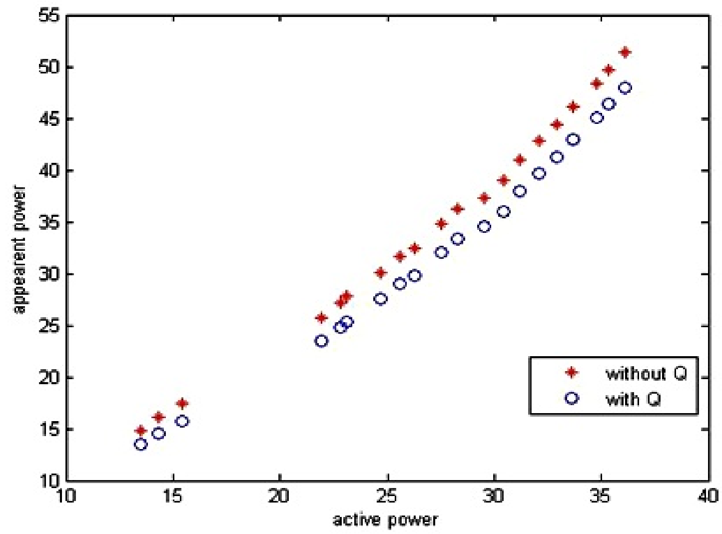


Figure 6: The relation between active & apparent power with &without Q_k

Table 1: The results of the 1^{st} subnet for PF, S and V_{end}

		Without Q_K					With Q_K					
Time	P	q	pf	S	V_{end}	n	Q_K	q	pf	S	V_{end}	n
00:00	-	-	-	-	-	-	-	-	-	-	-	-
01:00	-	-	-	-	-	-	-	-	-	-	-	-
02:00	30.4	24.8589	0.77	38.9610	134.3198	8	5	19.8589	0.83	35.9774	134.4566	8
03:00	27.5	21.3423	0.79	34.8101	134.4160	8	5	16.3423	0.86	31.9894	134.5528	7
04:00	31.2	26.6811	0.76	41.0526	134.2699	8	5	21.6811	0.82	37.9936	134.4067	8
05:00	21.9	13.5724	0.85	25.7647	134.6286	7	5	8.5724	0.93	23.5180	134.7654	7
06:00	33.7	31.5509	0.73	46.1644	134.1367	8	5	26.5509	0.79	42.9027	134.2735	8
07:00	36.1	36.7273	0.70	51.4286	133.9950	8	5	31.7273	0.75	47.9856	134.1318	8
08:00	34.8	33.5421	0.72	48.3333	134.0822	8	5	28.5421	0.77	45.0077	134.2190	8
09:00	28.3	22.7046	0.78	36.2821	134.3787	8	5	17.7046	0.85	33.3818	134.5155	7
10:00	15.4	8.3120	0.88	17.5000	134.7726	7	5	3.3120	0.98	15.7521	134.9094	7
11:00	25.6	18.5341	0.81	31.6049	134.4928	7	5	13.5341	0.88	28.9574	134.6297	7
12:00	14.3	7.3261	0.89	16.0674	134.7995	7	5	2.3261	0.98	14.4880	134.9363	7
13:00	13.5	6.1508	0.91	14.8352	134.8317	7	5	1.1508	0.99	13.5490	134.9685	7
14:00	35.3	35.0117	0.71	49.7183	134.0420	8	5	30.0117	0.76	46.3335	134.1788	8
15:00	32.9	29.9037	0.74	44.4595	134.1817	8	5	24.9037	0.80	41.2626	134.3185	8
16:00	24.7	17.2407	0.82	30.1220	134.5282	7	5	12.2407	0.89	27.5667	134.6650	7
17:00	32.1	28.3095	0.75	42.8000	134.2253	8	5	23.3095	0.81	39.6704	134.3622	8
18:00	-	-	-	-	-	-	-	-	-	-	-	-
19:00	26.3	19.0409	0.81	32.4691	134.4790	7	5	14.0409	0.88	29.8134	134.6158	
20:00	-	-	-	-	-	-	-	-	-	-	-	-
21:00	22.8	14.7273	0.84	27.1429	134.5970	7	5	9.7273	0.91	24.7883	134.7338	7
22:00	29.5	22.8945	0.79	37.3418	134.3735	8	5	17.8945	0.85	34.5031	134.5103	7
23:00	23.1	15.5233	0.83	27.8313	134.5752	7	5	10.5233	0.91	25.3840	134.7120	7

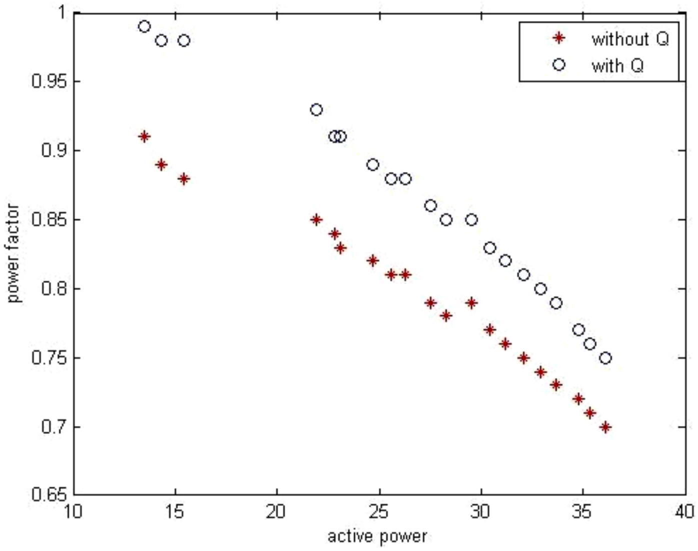


Figure 7: The relation between active power & power factor with &without Q_k

From Table (1) and (2), we see that:

- Effect of Q_k on improving pf and V_{end};
- Decrease the value of product S with the same value of p for the consumer;
- Decrease quantity of current which pass through the lines then decrease its loss;
- More stability inter transformer which increase the remaining.

Table 2: The results of the 2nd subnet for I, ΔI and ΔP

Time	P (MW)	I_1:Current without Q_K (Amp)	I_2:Current with Q_K (Amp)	Current reduction(ΔI) (Amp) = $I_1 - I_2$	Saved power (ΔP) (KW)
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	30.4	1174.7	1083.6	91.0	4.0227
03:00	27.5	1048.8	0974.9	73.8	2.6466
04:00	31.2	1238.2	1144.8	93.4	4.2350
05:00	21.9	0784.7	0715.5	69.2	2.3208
06:00	33.7	1393.8	1294.1	99.8	4.8318
07:00	36.1	1554.4	1448.8	105.6	5.4042
08:00	34.8	1459.9	1358.1	101.8	5.0311
09:00	28.3	1093.4	1017.6	75.8	2.7869
10:00	15.4	0532.4	0478.7	53.6	1.3974
11:00	25.6	0963.6	0881.9	81.6	3.2326
12:00	14.3	488.7	440.2	48.5	1.1409
13:00	13.5	451.1	411.6	39.5	0.7583
14:00	35.3	1502.2	1398.4	103.7	5.2166
15:00	32.9	1341.9	1244.1	97.7	4.6362
16:00	24.7	918.1	839.3	78.7	3.0088
17:00	32.1	1291.3	1195.7	95.6	4.4380
18:00	-	-	-	-	-
19:00	26.3	990.1	908.1	81.0	3.2553
20:00	-	-	-	-	-

5 Conclusions

The ANNs are universal and effective means for the different control problems, the use of such method of the artificial intelligence allows solving the reactive power and voltage control problem with higher level of its reliability and quality. Also, solving the reactive power and voltage control problem by using ANN assist to increase the electric network effectiveness. It allows to reduce the electric power losses, substation loading and to improve the electric power quality.

Using FFNN to control the processing of reactive power demand by calculating the apparent power, the voltages at the end of the line, the current passing in the line and pf, these calculations in the case of processing reactive power from the generator only or in the case from the generator and SVC when the pf is weak. We found that reducing reactive power transmitted in the line from the generator lead to a reduction in the current passing in the line and in the apparent power required to be generated and less voltage drop at the end of the line, thus reduce the losses in transmission. So that the consumer gets it needs with the amount of generating less within a stable system voltages.

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