An Intelligent Technique For Optimizing The Operation Of A Static Synchronous Compensator In Northern Iraqi Network

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Abstract

The static Synchronous Compensator (STATCOM) is a solid-state shunt device that generates or absorbs reactive power and is one member of a family devices known as Flexible AC Transmission System (FACTS) devices. It is superior to the static VAR Compensator (SVC) in many ways.

In this work it is suggested to use the (STATCOM) in the existing H.V. Iraqi North Region National Grid (INRNG) for the first time. The best location of the (STATCOM) is obtained using load flow study which is also used to determine the optimal value of the reactive power needed at different load conditions. The paper discusses a method of optimizing the operation of the (STATCOM) using intelligent techniques. The method uses the Artificial Neural Network (ANN). The obtained results using load flow program are considered as the input data to train the (ANN). Then any value within the training data limit can be used to get the optimal value of the (STATCOM) output. The data of the (INRNG) for the year 2001 is used to verify the validity of the proposed method.

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[illegible] (STATCOM) [illegible] (FACTS) [illegible] (SVC) [illegible] (INRNG) [illegible]

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1. Introduction

The Iraqi North Region National Grid (INRNG) consists of 400KV and 132KV buses. The grid has three main groups of generating stations, namely Baiji, Mulla Abdula and Mosul dam. Mosul city represents an important part of the load. Mosul ring consists of seven 132 KV buses as shown in Fig 1. The lines connecting the buses are mainly of two circuits. There are three single circuit lines. This part of (INRNG) suffers from problems such as loading on these three lines can exceed the accepted loading percent during peak load periods. This causes outage due to over load.

The loading of the three lines can be reduced by supplying the reactive power locally either by a (SVC) or a (STATCOM). The latter is increasingly being used in different places in the world. It is used to improve power system stability and voltage regulation besides supplying reactive power for compensation [1,2,3]. The (STATCOM) is one of the most important Flexible AC Transmission Systems (FACTS). These are based on the use of self-commutated semiconductors. Ekstrom [4] compares a conventional (SVC) with a (STATCOM) and shows the superiority of the (STATCOM). The (STATCOM) is a solid-state synchronous voltage generator, which consists of a multi- pulse, voltage-source inverter connected in shunt with the transmission line. It can counteract both voltage depression and voltage rises. Although its output characteristics are similar to those of a rotating synchronous condenser, the (STATCOM) responds more rapidly, does not increase short-circuit current in the system, and can provide symmetrical leading or lagging reactive currents. The smooth continuous control of the (STATCOM) minimizes the possibility of large voltage fluctuations, which may occur with passive devices [5]. The basic six-pulse voltage source converters is shown in Fig 2. While it's steady-state V-I and V-Q characteristic is shown in Fig 3a and b respectively.

2. Allocation of the STATCOM:

The reactive compensation problem can be separated into three sub problems; planning, expansion and control. The control sub problem involves the operation for the most economic savings. The solution techniques for the problem can be classified into four categories: analytical, numerical programming, heuristics, and artificial intelligence- based [6].

Among these, the heuristics method is used in this paper for STATCOM allocation because it is simple to implement, easy to understand and intuitive as compared to analytical and numerical programming methods. Heuristics are rules of thumb that are developed through intuition, experience and judgment which could lead to a solution that is near the optimum with confidence.

In this paper we suggest the use of (STATCOM) somewhere in the Mosul ring for the first time in Iraq. The best location of the (STATCOM) can be obtained using load flow study which can also be used to determine the optimal value of the reactive power needed at different load conditions.

The three single lines in Mosul ring is the most week point in the ring. In bus 35 there is a generating station, therefore the (STATCOM) can be placed in

either bus 36 or bus 37. A comparison of total losses with and without compensation at bus 36 and bus 37 is illustrated in Fig. 4-a. Also the loadings at the two lines 35-36 and 36-37 with and without compensation at bus 36 and bus 37 are shown in Fig.4-b&c. The results show that placing the STATCOM at bus 37 is more convenient than bus 36.

The load data of the (INRNG) of the year 2001 is taken as the reference data. The range of the load data taken varies from 60 % to 150 % of the reference data. The load flow program is used to obtain the optimal value of the MVAR needed by the grid.

The paper describes a method of optimizing the operation of (STATCOM) using intelligent techniques. The method uses the (ANN). The obtained results using load flow program are considered as the input data to train the (ANN). Then any value within the training data limit can be used to get the optimal value of the (STATCOM) output.

3. Artificial Neural Network

3.1- Basic Theory

The theory of the Artificial Neural Network (ANN) is well known [7,8]. Neural Networks are composed of simple elements (neurons) operating in parallel. These elements are inspired by logical nerve system. As in nature, the network function is determined largely by the connections between elements. An (ANN) can be trained to perform a particular function by adjusting the values of the connection (weights) between elements.

Commonly Neural Networks are adjusted or trained, so that a particular input leads to a specific target output. Therefore, the network is adjusted, based on a comparison of the output and the targets until the network output matches the target. Typically many such input/output pairs are used, in this supervised learning, to train a network. A two-layer network having R^1 inputs, S^1 neurons in the first layer, and S^2 neurons in the second layer is shown in Fig 5.

Neural Networks have been trained to perform complex functions in various fields of applications including pattern recognition, identification, classification speech, vision and control systems. Today Neural Network can be trained to solve problems that are difficult for conventional computers on human beings. The choice of the type of network and its type of implementation is based on the nature of the application, the nature of the data and performance consideration. The Neural Network implementation is achieved through three stages:-

1- **Initialization (creating) of Neural Network.**
2- **Training of the initialized network.**
3- **Simulating (testing) of the trained network.**

Once the network weights and biases have been initialized, the network is ready for training. The training process requires a set of examples of proper network behavior, network input p and target outputs t. During training the weights and biases of he network are iteratively adjusted to minimize the network performance function. The default performance function for feed forward networks is mean square error, the average squared error between the network outputs a and the target t.

There are several different training algorithms for feed forward networks. All of these algorithms use the gradient of the performance function to determine how to adjust the weights to minimize performance. The gradient is determined using a technique called back propagation, which involves performing computations back wards through the network.

Since the early to mid 1980s much of the effort in power systems analysis has turned away from the methodology of formal mathematical modeling which came from the fields of operations research, control theory and numerical analysis to the less rigorous techniques of artificial intelligence (AI). Today the main (AI) techniques found in power systems applications are those utilizing the logic and knowledge representations of expert systems, fuzzy systems, (ANN) and more recently evolutionary computing [8].

3.2- Application of ANN to STATCOM

The main factors affecting the output of the (STATCOM) in our case is the loading. So different load data have been considered. These have been obtained from (INRNG) for the year of 2001. The data points as appeared in Table 1 involve the grid active and reactive loads (PL,QL) , Mosul ring active and reactive loads (PM,QM), and the four active and reactive loads (P4,Q4) connected to buses 35,36,37 and 38 of Fig. 1. Also to take the constraints into consideration (generating station constraints), the generated active power in Mosul ring is added to input data (Mansoor station PG). A two-layer back propagation Neural Network was used. The hidden layer has 30 neurons and the output layer has one neuron (QS) corresponding to the MVAR output of the (STATCOM).

4-Results

A load flow program based on the method of fast decoupled load flow [10] is developed. The Matlab software version 6.5 (release 13, June 2002) is used to run the program. The superiority of the Matlab in dealing with complex matrices has been very useful. The accuracy of the program results have been checked with other load flow documents. The results were accurate.

The load data of the (INRNG) of the year 2001 is taken as the reference data. The best location of the (STATCOM) may be obtained using the load flow study. The best location of (STATCOM) may be near bus (37) as indicated in Fig.1. Also the load flow program is used to obtain the optimal value of the MVAR needed by the grid. The range of the load data taken varies from 60 %

to 150 % of the reference data. These data are shown in Table 1.

Neural network training can be made more efficient if certain preprocessing steps are performed on the network inputs and targets. Several preprocessing routines can be used. Post processing routines are used to get the original data. The input patterns are preprocessed to get the normalized data. Different train functions are examined and best results are obtained using the Matlab train function Levenberg_Maruardt (trainlm)[11]. The (trainlm) algorithm was designed to approach second order training speed without having to compute the Hessian matrix. This algorithm appears to be the faster method for training moderate size feed forward neural networks up to several hundred weights.

The flow chart of the program used is shown in Fig. 6. The training performance is shown in Fig 7. It is found that the losses in the network at 100% load have been reduced from7.2 MW to 6.68 MW, i.e. 7.2% improvements. However this figure will be higher at higher loads. At the same time the voltage at bus 37 has been raised from 0.966 to 0.988 p.u.. Fig. 8 shows the (ANN) used as block diagram, showing the numbers of inputs and outputs, the numbers of layers and numbers of neurons in each layer etc…. The input is a vector of seven variables. The output is vector of one variable. The first layer has 30 neurons. The second layer has one neuron.

When the same train data is used as test data, the results were 100 % accurate. A simulating data of 80 % and 125 % of reference load, which is not part of Table 1, are used and the results are shown in Table 2. The error is found to be less than 1 MVAR. This error has a negligible effect on the operation of the system.

5- Conclusions

The use of STATCOM for the first time in Iraq may be a promising solution for many problems found in the ring system around Mosul city of (INRNG). As a First step heuristics method is used to allocate the STATCOM within the ring. An intelligent technique (ANN) is then implemented which is trained to simulate a practical data of (INRNG) to obtain the optimized MVAR needed by the STATCOM. The results obtained show that the implemented technique has less than 1 MVAR error.

6- References

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Table (1): Train data for ANN.

No.	load %	PL MW	QL MVAR	PM MW	QM MVAR	P4 MW	Q4 MVAR	PG MW	QS MVAR
1	60	641.4	385.2	189.6	100.2	113.4	64.2	40	27.5
2	60	641.4	385.2	189.6	100.2	113.4	64.2	100	19.5
3	65	694.8	417.3	205.4	108.5	122.8	69.5	40	39.5
4	65	694.8	417.3	205.4	108.5	122.8	69.5	100	30.5
5	70	748.3	449.4	221.2	116.9	132.2	74.9	0	38
6	70	748.3	449.4	221.2	116.9	132.2	74.9	40	45
7	70	748.3	449.4	221.2	116.9	132.2	74.9	100	42
8	75	801.7	481.5	237	125.2	141.7	80.2	100	50
9	75	801.7	481.5	237	125.2	141.7	80.2	40	49.5
10	90	962.1	577.8	284.4	150.3	170.1	96.3	100	65
11	90	962.1	577.8	284.4	150.3	170.1	96.3	40	66
12	90	962.1	577.8	284.4	150.3	170.1	96.3	0	64
13	100	1069	642	316	167	189	107	100	75
14	100	1069	642	316	167	189	107	40	92
15	100	1069	642	316	167	189	107	0	75
16	110	1175.9	706.2	347.6	183.7	207.9	117.7	0	89
17	110	1175.9	706.2	347.6	183.7	207.9	117.7	40	118
18	110	1175.9	706.2	347.6	183.7	207.9	117.7	100	86
19	120	1282.8	770.4	379.2	200.4	226.8	128.4	100	97
20	120	1282.8	770.4	379.2	200.4	226.8	128.4	40	143.5
21	120	1282.8	770.4	379.2	200.4	226.8	128.4	0	103
22	130	1389.7	834.6	410.8	217.1	254.7	139.1	100	108
23	130	1389.7	834.6	410.8	217.1	254.7	139.1	40	171
24	130	1389.7	834.6	410.8	217.1	254.7	139.1	0	117
25	135	1443.1	866.7	426.6	225.4	255.1	144.4	100	114
26	135	1443.1	866.7	426.6	225.4	255.1	144.4	40	184.5
27	135	1443.1	866.7	426.6	225.4	255.1	144.4	0	124
28	140	1496.6	898	442.4	233.8	264.6	149.8	100	133.5
29	140	1496.6	898	442.4	233.8	264.6	149.8	40	198.5
30	140	1496.6	898	442.4	233.8	264.6	149.8	0	132
31	145	1550.1	930.9	458.2	242.1	274	155.1	0	139
32	145	1550.1	930.9	458.2	242.1	274	155.1	40	213
33	145	1550.1	930.9	458.2	242.1	274	155.1	100	146
34	150	1603.5	963	474	250.5	283.5	160.5	100	161.5
35	150	1603.5	963	474	250.5	283.5	160.5	40	227.5
36	150	1603.5	963	474	250.5	283.5	160.5	0	147

Table (2): Test data for ANN

load %	PL MW	QL MVAR	PM MW	QM MVAR	P4 MW	Q4 MVAR	PG MW	Qstat Cal MVAR	Qstat ANN MVAR
80	**855.**	**513.6**	**252.8**	**133.6**	**151.2**	**85.6**	**100**	**54**	**53.02**
80	**855.**	**513.6**	**252.8**	**133.6**	**151.2**	**85.6**	**40**	**55**	**55.75**
125	**1336**	**802.5**	**395**	**208.7**	**236.2**	**133.7**	**100**	**102**	**102.28**
125	**1336**	**802.5**	**395**	**208.7**	**236.2**	**133.7**	**40**	**157**	**157.58**

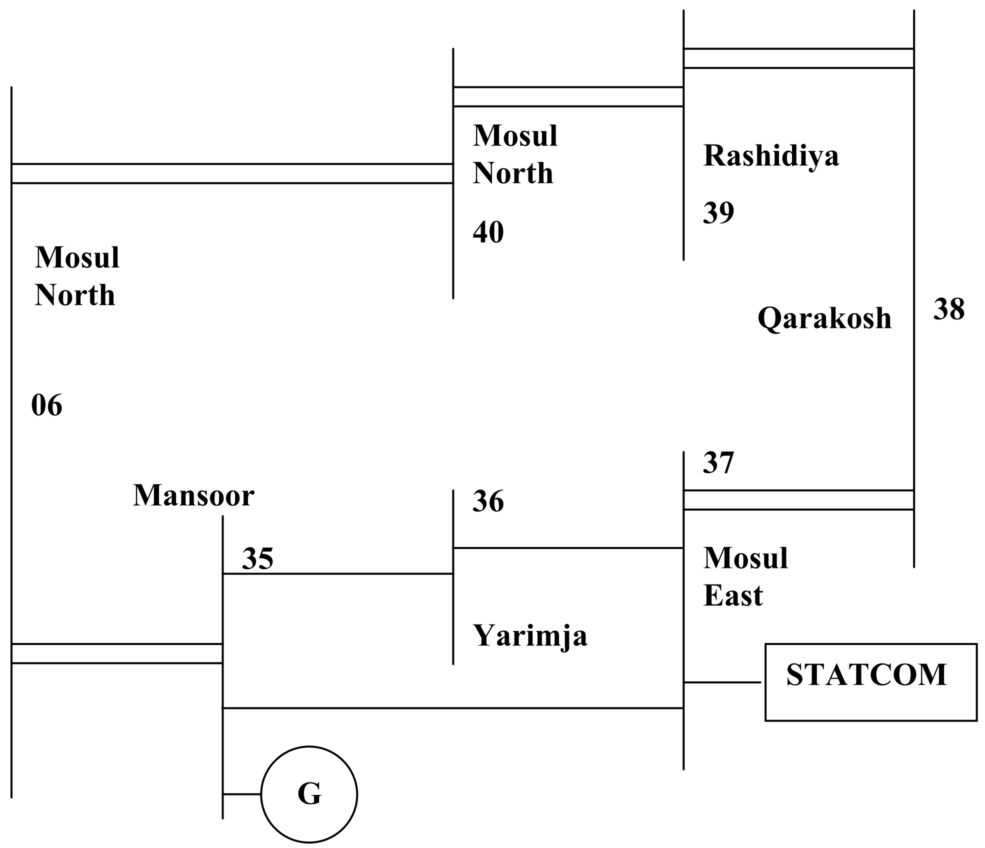

Fig. 1 Mosul ring

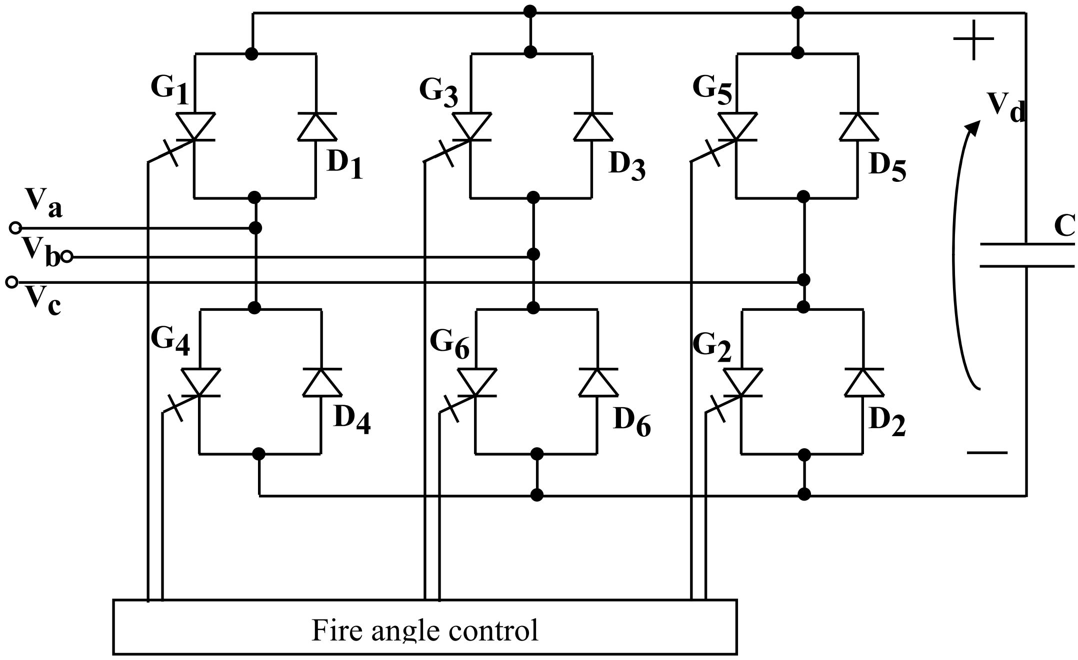

Fig. 2 Six pulse convertor

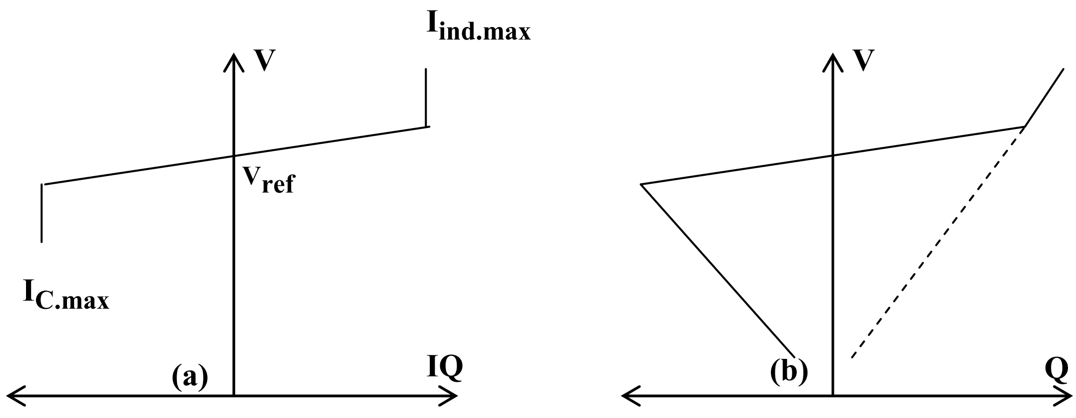

Fig. 3 Steady state capability of STATCOM

(a) V-I characteristics
(b) V-Q characteristics

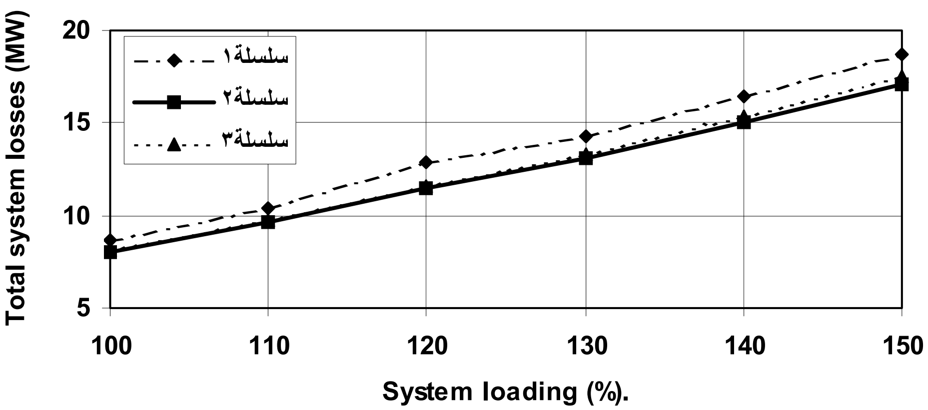

Fig.4-a Total system losses with and without compensation.

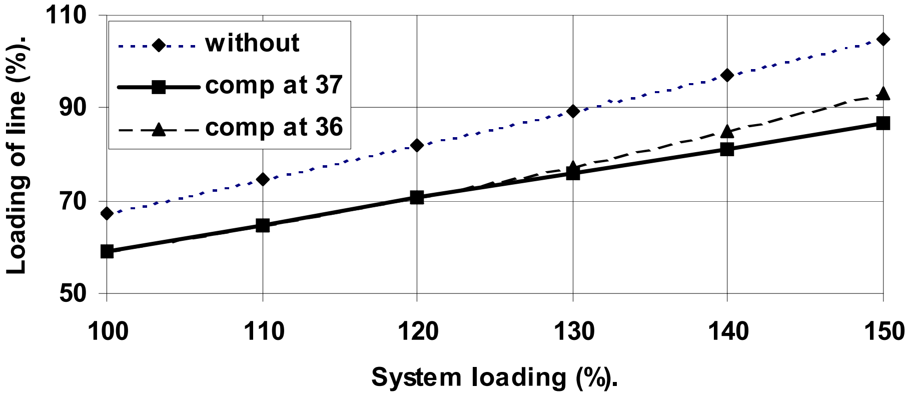

Fig.4-b Loading of line 35-36 with and without compensation.

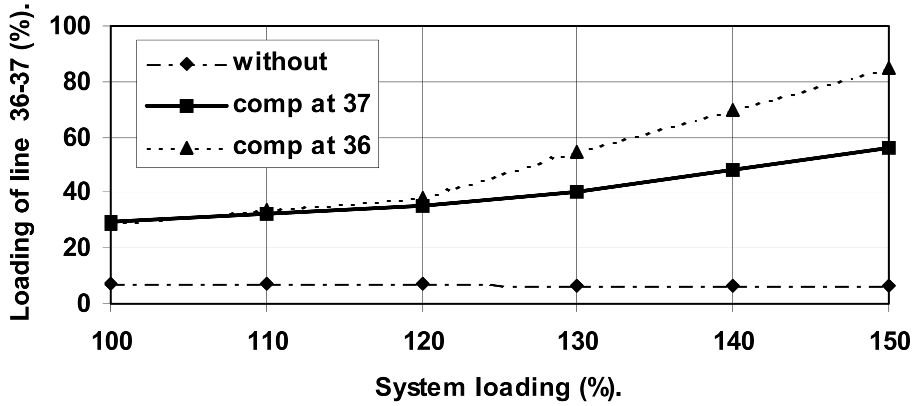

Fig.4c loading of line 36-37 with and without compensation.

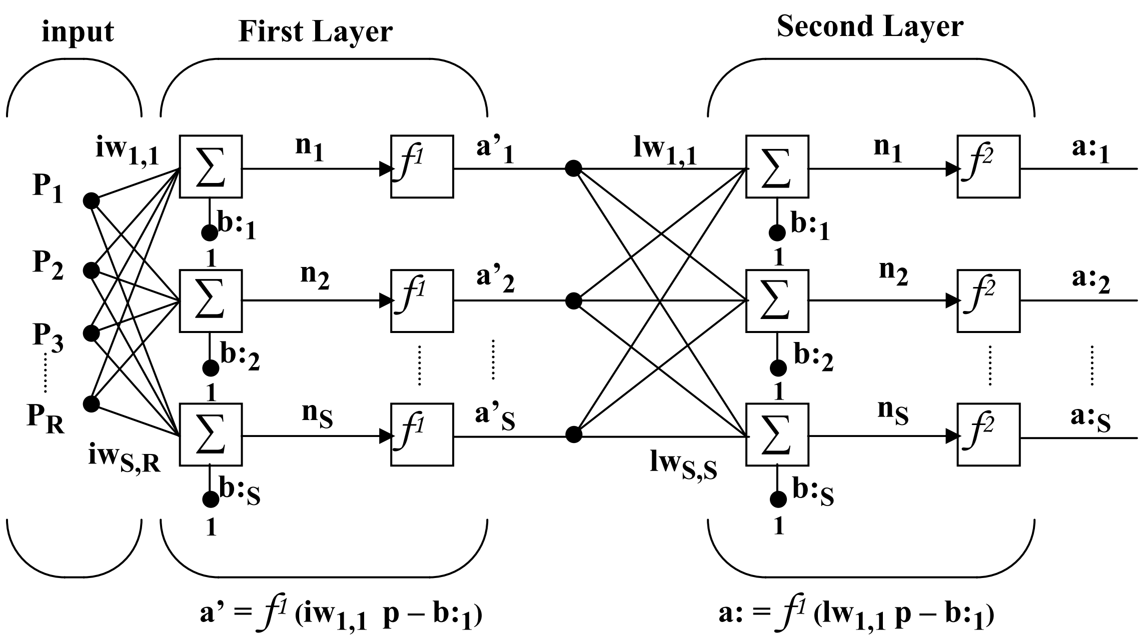

Fig. 5 The two layer Neural Network

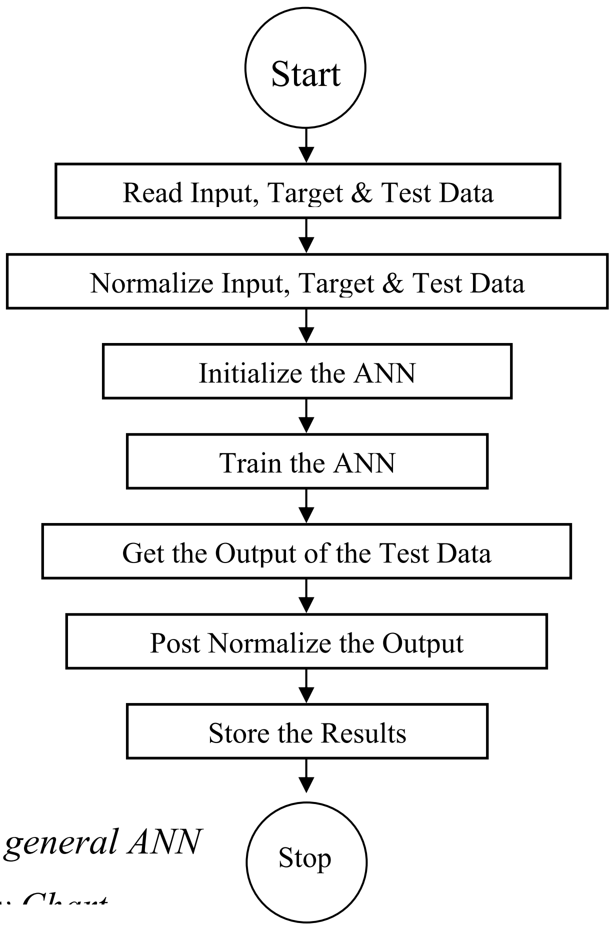

Fig. 6 The general ANN Flow Chart

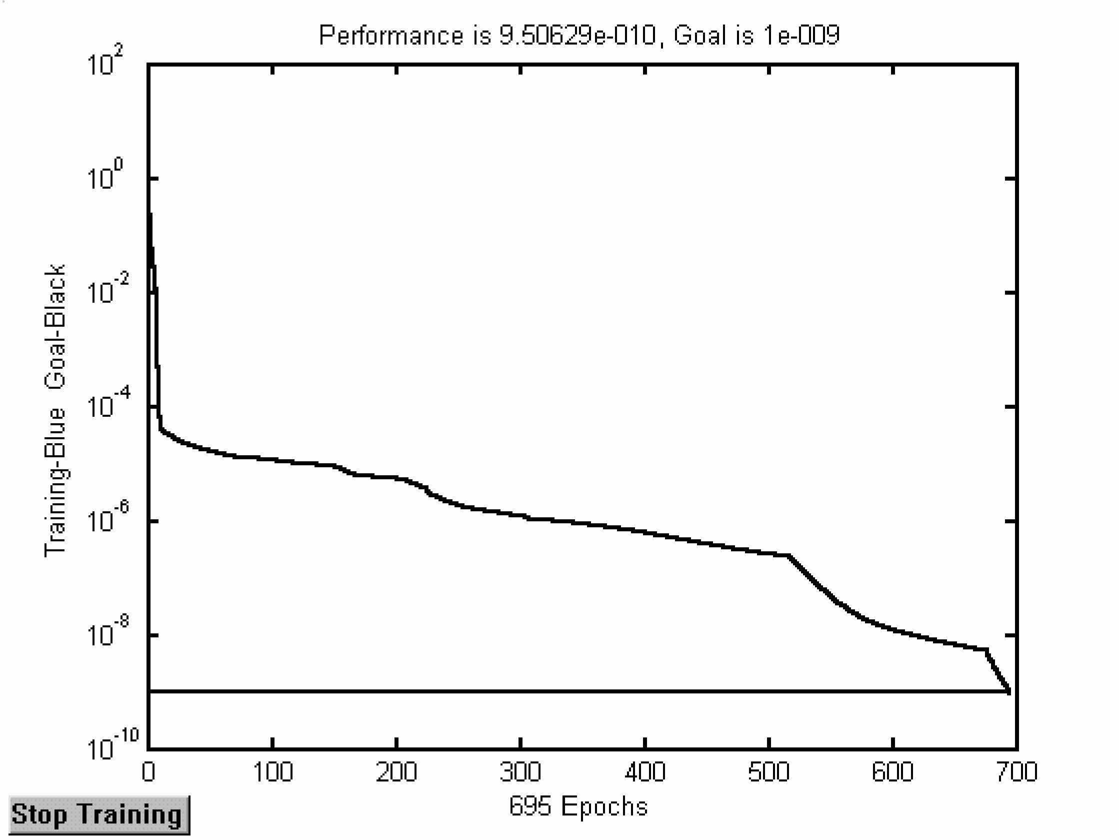

Fig.7 ANN training performance.

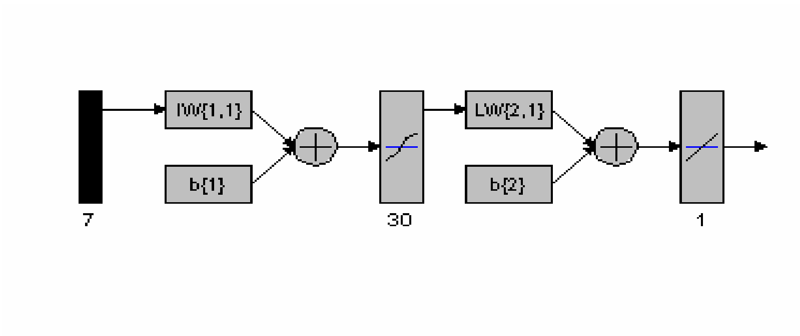

Fig.8 The Structure of the ANN.