IMPROVING RADIAL POWER DISTRIBUTION SYSTEM USING NEURAL NETWORK APPROACH [+]

Entidhar Mhawes Zghair [*]

Abstract :

The objective of this research is to find of the optimal location and sizes of capacitors which can be added to reduce the power losses and keep the system voltage (within its limited value).

In this research, artificial neural network (ANN) a feed forward employing back-propagation for training algorithm. This Approach was used to find the optimal values of these capacitors that can be added in different location.

A sensitive analysis with different load level is also employed to select the optimal locations and values of these capacitors that can be distributed in this system . Neural network and sensitivity factor are used to select the best location and size of capacitors added to the redial distribution feeder with different load level(heavy, medium, light load levels respectively). This sensitivity factor method with six candidate locations is selected for placing capacitors in the system. The results were monitored the proposed algorithm that has been implemented in technical Visual Basic V.6 software.

Keywords :Neural network, back-propagation, redial distributed system, Reactive Power.

تحسين منظومة توزيع القدرة الإشعاعية باستخدام الشبكات العصبية

انتظار مهوس زغير

المستخلص:

أن الهدف من هذا البحث هو أيجاد أفضل المواقع والأحجام المختلفة للمتسعات والتي يمكن أن تضاف للحد من خسائر القدرة وتحسين عامل القدرة بالإضافة إلى تقليل الهبوط بالجهد (جعله ضمن القيمة المحددة له) .

في هذا البحث تم استخدام الشبكة العصبية طريقة الانتشار العكسي Back propagation استعملت كتدريب الخوارزميةِ وعامل الحساسية لاختيار أفضل المواقع للمتسعات المضافة ولمستويات أحمال مختلفة .

حيث أنّ تحليل عامل الحسّاسية أستخدم لاختيار المواقعِ المثاليةِ وقِيَمِ هذه المتسعات إلى النظامِ الموزع. وتستخدم الشبكة العصبية وعامل الحساسية لاختيار أفضل موقع وحجم المتسعات المضافة التوزيعِ بالأحمال المختلفة (الثقيلة والمتوسطة، ومستويات الحمل الخفيفة على التوالي) حيث تم استخدام ستة مواقع المختارة لوضع المتسعات في النظام .وتم هذا التصميم عن طريق تشغيل برامجيات ذات تقنية عالية باستخدام برنامج الفيجوال بيسك V. 6.

[+]Received on 30/1/2013 , Accepted on 16/7/2013 .

[*]Lecturer /Technical Instructors Training Institute .

Introduction :

In the operation of a distribution system, reactive power control is very essential to reduce system losses by means of control device such as shunt capacitors. Inattention to the system configuration can lead to increase in reactive power which results to a decrease in power factor and high current flows of the system resulting to significant line loss. In the past, many techniques have been employed including artificial intelligence methods. In this study, an artificial neural network is applied to control the reactive power of the distribution system without human intervention. A feed-forward ANN employing back propagation is trained to provide a proper control action required by the system. The training data is obtained from actual operation of radial distribution system prototype, initially without the controller which is subjected to different load conditions (normal or abnormal conditions).

This study aims to develop a real-time reactive power controller through an artificial neural network on a radial distribution system configuration. A neural network, once established (trained), is more efficient and accurate in circumstances where complex decision is required.

Artificial Neural Network:

Artificial neurons are similar to their biological counterparts. It has input connections which are summed together to determine the strength of their output, which is the result of the sum being fed into an activation function.

Though many activation functions exist, the most common is the sigmoid activation function, which produces a number between 0 (for low input values) and 1 (for high input values). The resultant of this function is then passed as the input to other neurons through more connections, each of which are weighted. These weights determine the behavior of the network.[1] [2].

Typical artificial neural network consists of three layers: input layer, hidden layer and output layer. Figure 1 shows an ANN with hidden layer.

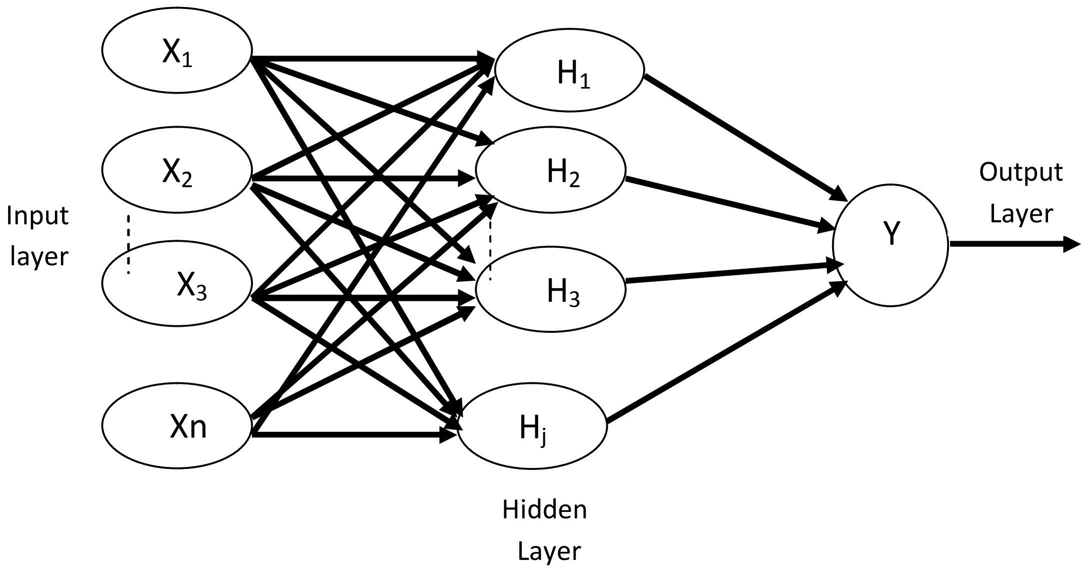


Figure (1) Artificial Neural Network Diagram

Capacitors in distribution system:

Shunt power capacitors connected to a power system are the most economical source to meet the reactive power requirement of inductive loads and transmission lines operating at a lagging power factor. Capacitors are usually installed on distribution systems in a three-phase configuration rather than single phase, a single unit, or as a bank series or shunt. These banks provide power factor correction on transmission and distribution networks and control the required voltage level.

The use of a shunt capacitor bank reduces electrical power transmission costs, reduces system losses, increases the effective capacity of generating units and system components, and helps to provide better use of electrical network.

The shunt capacitor modifies the characteristic of an inductive load by drawing a leading current which counteracts some or all of the lagging components of the inductive load current at the point of installation. By using a shunt capacitor to the distribution feeder, the magnitude of the source current can be reduced; the power factor is improved, and the voltage drop between the sending end and the load end is reduced [2].

Capacitor Size and Control Setting:

Suppose that there are N_c possible locations to place capacitors in the system **let U_s** be the standard size of one bank and let U^0 be a N_c dimensional vector, $U^0 = [U_1^0, \quad U_2^0, kU_{Nc}^0]^T$ with U_k^0 representing the size of capacitor at location k. Note that in practice U_1^0 is a multiple of the standard size of one bank, in mathematics, U^0 / U_S is a non-negative integer.

Let $U^j = [U_1^j, \quad U_2^j, kU_{Nc}^j]^T$ with U_k^j representing the control setting at location k during j^{th} level. Fixed Capacitors are connected to the system permanently and will be treated as a constant reactive power source at all load levels. For instance, let the capacitor at location k be of fixed type then:

$$U_k^1 = U_k^2 = \cdots = U_k^{Nt}$$

U_k^j = Discrete variable $j \in N_t, k \in N_C$

Where U^0: is the sizing vector whose components are multiples of the standards sized of one bank.

U^j: is the control setting vector at load level j.

The voltage magnitude of each node at each load level must lie in a permissible range as expressed below [3]

$$V_i^{min} \le |V^j{}_i| \le V_i^{\max} \qquad i=1,2,\ldots\ldots n \quad \text{and} \quad j=1,2,\ldots\ldots N_t$$

Where N_t: is the No. of load level.

N_c: is the No. of Capacitor location.

V_i : voltage at node i,

The load constraints to be considered are the active and reactive power balance constraints described by a set of power flow equations at different load levels. [3]

Distribution System Power Flow (Fast Decoupled Method) :

Consider a main feeder with a lateral branching out from the main feeder as shown in Fig (2). We refer to node (k) as a branching node indicating that there is a lateral.

$|V_o|$ Represents the substation bus voltage magnitude. [4]

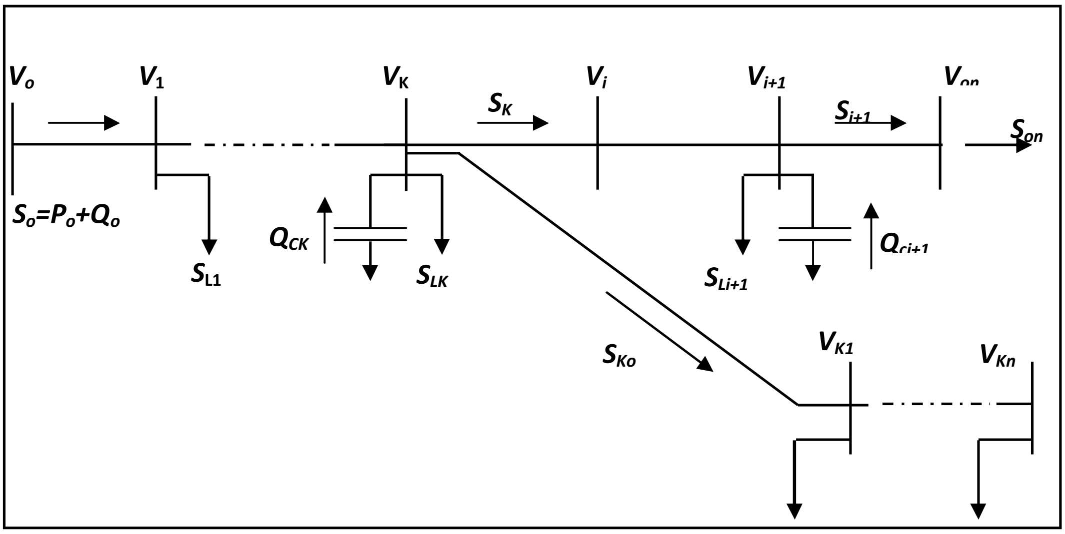


Figure (2) Single Line Diagram of a Main Distribution Feeder with One Lateral

The distribution lines are modeled as series impedance $Z_i = R_i + jX_i$.. Load demand at bus (i) is modeled as a constant power sink, $S_{Li} = P_{Li} + jQ_{Li}$.

In general, the active and reactive power flowing at the receiving end of branch i+1, P_{i+1}, Q_{i+1} and the voltage magnitude at the sending end $|V_{i+1}|$ can be expressed by the following recursive set of equations [5]

$$P_{i+1} = P_i - R_{i+1}\frac{P_i^2 + Q_i^2}{|V_i|^2} - P_{Li+1} \qquad \text{(1.a)}$$

$$Q_{i+1} = Q_i - X_{i+1}\frac{P_i^2 + Q_i^2}{|V_i|^2} - Q_{Li+1} + Q_{ci+1} \qquad \text{(1.b)}$$

$$|V_{i+1}|^2 = |V_i|^2 - 2(R_{i+1}.P_i + X_{i+1}.Q_i) + (R^2_{i+1} + X^2_{i+1})\frac{P_i^2 + Q_i^2}{|V_i|^2} \qquad \text{(1.c)}$$

And at the end of main feeder $P_n = 0$ and $Q_n = 0$

$$P_{loss\,(i+1)} = R_{i+1} * \frac{Pi^2 + Qi^2}{|Vi|^2} \qquad (2)$$

$$Q_{loss\,(i+1)} = Q_{i+1} * \frac{Pi^2 + Qi^2}{|Vi|^2} \qquad (3)$$

$$\text{Total} \quad P_{loss\,(i+1)} = \sum_{i=1}^{n} R_{i+1} * \frac{Pi^2 + Qi^2}{|Vi|^2} \qquad (4)$$

$$\text{Total} \quad Q_{loss\,(i+1)} = \sum_{i=1}^{n} R_{i+1} * \frac{Pi^2 + Qi^2}{|Vi|^2} \qquad (5)$$

Energy loss = Total power losses * time
Where:
P_i, Q_i : active and reactive powers flowing into the sending end of branch i+1.
n : is the total number of branch in the system.
i : is the number of branches in specified feeder.
$|V_i|$: Bus voltage magnitude at node i.

Equations (1.a), (1.b) and (1.c), are called the branch flow equations. In general, for a distribution system consisting of a main feeder (with n segments, and n nodes) with j laterals, (with n1, n2….nj branches on laterals 1, 2,…….j respectively)[5]

Programming:

The simulations of Improving Radial Power Distribution System are performed on an personal computer using Visual Basic V.6 programming. The Programming is divided into three parts: Load flow solution, sensitivity factor analysis, and ANN implementation of Improving Radial Power Distribution System.

1- Power Flow Solution

Power flow study includes the calculation of bus voltage and line power flow of a network. A single phase representation is adequate. Associated with each bus, there are four quantities to be determined or specified: real and reactive powers, voltage magnitude, and phase angle. After applying load flow equations using the "fast-decoupled" method, the total power loss of the feeder is determined, $P_{T\ loss}$ by summing up the losses of all sections in the feeder, The total power loss is given by:

$$p_{T\ Loss} = \sum_{i=0}^{n-1} P_{Loss}(i, i+1)$$

Where n = the total no. of buses in the feeder.

The purpose of placing compensating capacitors along the distribution feeder is to reduce the total power loss and bring the bus voltage within its specified limits. [5], [6]

2- Sensitivity Factor Analysis

A sensitivity analysis is employed to select the candidate locations for placing capacitors in the distribution system. The evaluation of these candidate locations basically helps in reducing the search space during optimization procedures. The sensitivity analysis is a systematic procedure to select locations, which reduce system real power losses to the most when we place capacitors at those locations [5],[3].

The sensitivity factor associated with a node is defined as:

$$\delta = \frac{\partial P_{LOSS}}{\partial Q_{ci}} \quad \text{watt/var}$$

where δ is the sensitivity factor which is estimated at each node every time a configuration change occurs in the feeder such as the addition of a capacitor bank. The nodes are ranked in the order of the values of sensitivity factors for these nodes.

The bus which has the greatest sensitivity factor is tentatively added to it. The power losses and bus voltages are then calculated. If a power loss is reduced and voltage limits of the nodes are satisfied, the addition is accepted; otherwise, this addition is discarded, and a similar tentative addition to the node with next greatest sensitivity factor is taken. Once the addition is accepted, the sensitivity factors of the nodes are re-evaluated. A new priority list is then established. Similar procedures for addition are repeated. The final results obtained from this sensitivity factor method are taken to be the initial weight for the subsequent ANN.

3- Reactive Power Control Using ANN

Artificial neural networks possess several properties that make it particularly attractive for applications to modeling and control of complex non-linear systems. ANNs represent the promising new generation of information processing networks. ANNs can supplement the enormous processing power of the digital computer with the ability to make sensible decisions and to learn by ordinary experience. ANNs have widely been used in electric power engineering [7].

In the past, several techniques have been employed using sensitivity relationships and gradient search approaches to overcome power system problem. In these approaches, the bus voltage violations are alleviated one by one. In case of many violations, the method may run into an infinite Number of iteration. To avoid these difficulties, ANN has been proposed to control the actions. The method can handle complex problem and does not require computational effort in determining the required adjustments to control variables [1].

The study suggests the application of ANN technique in real-time and implement it to real power system. The above studies are supported by the following simulation studies on reactive power control using ANN:

- Voltage and Reactive Power Control Simulations Using Neural Networks [8].
- Regulation of reactive power and voltage by artificial neural network [9].
- ANN-based reactive power compensation [10].

Similarly, a voltage control study based on artificial neural network presented as new method of control successfully and correctly identify data. The proposed method conforms to the method presently employed in the substation [11].

Theoretical Test Systems:

The test system is an 11.1 KV system with 38 buses and 8 laterals. The schematic diagram of the test system is shown in Figure (3) the system data with power demand information are tabulated in AL-Dura No.5 feeder Load at different season.

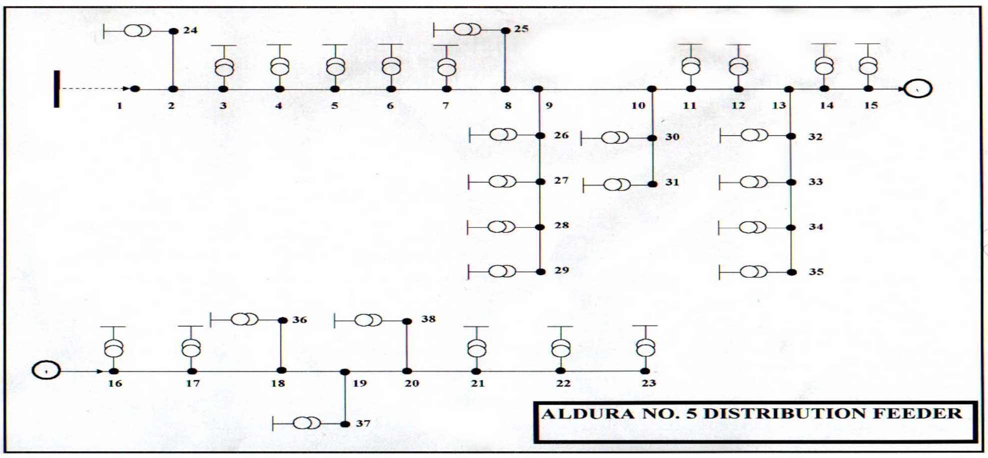


Figure (3) ALDURA NO.5 distribution feeder

Load factor = 1, V0 =11.0Kv, load p.f =0.87 lag.

Table (1) load flow output by fast – decoupled method

Send. Bus	Rec. Bus	Power between send. & rec. bus		Voltage sends. Bus (volt)
		Real power (W)	Reactive power(VAR)	
1	2	3133473.93	2532202	1121100
2	3	3474549.75	2428432	13086.03
3	4	3424220.72	4251012	12045.33
4	5	3372822.52	3334123	12333.65
5	6	3765811.69	3103466	12302.50
6	7	4563211.91	3426212	12001.50
7	8	432221.69	3425614	123033.6
8	9	421322.18	3564214	10125.90
9	10	321435.38	2784321	12205.90
10	11	3228113.85	1188821	10101313
11	12	336817.50	19863776	10221.21
12	13	133226.90	1682365	10235.48
13	14	153312.30	1344466	10991.80
14	15	143333.55	1123464	10769.80
15	16	123396.02	76544332	10654.22
16	17	780072.30	766464.5	10444.80
17	18	675640.80	651820.6	10908.20
18	19	544294.80	455100.8	10700.60
19	20	544429.06	688473.8	10760.60
20	21	321953.80	438835.4	10629.90
21	22	233335.24	233212.7	10529.75
22	23	142334.25	122204.5	10528.85
23	-	0544294.80	438835.4	10526.46
4	24	123343.60	129653.85	10068.07
24	-	438835.4	0438835.4	10007.70
4	25	1229851.22	129212.42	10015.90
25	-	00000	00000	10004.90
12	26	233530.72	323581.12	10005.97
26	27	319585.63	2358869.3	10713.66
27	28	233703.43	2239224.2	10612.47
28	29	1322844.62	1221602.7	10711.68
29	-	342111110	34322655	10711.28
13	30	233727.87	222250.72	10891.88
30	31	122269.12	1233630.3	10992.17
31	-	0000000	0000000	10967.60
13	32	2339625.02	423881.12	10080.69
32	33	1229609.61	1258895.1	107778.1
33	34	2233705.92	2233227.26	10776.28
34	35	1233845.21	11122605.5	10775.39
35	-	0000000	0000000	10774.94
37	-	0000000	0000000	113728.41
20	38	122844.76	11225.02	10729.966
38	-	12333677	01233556	112729.55

Results:

1- SENSITIVITY FACTOR RESULTS:-

A sensitivity analysis is employed to select the candidate locations for placing capacitors in the distribution system. After employing sensitivity factor at each node of the test system (11.1 KV system with 38 buses and 8 laterals), every time a configuration change occur in the feeder such as the addition of a capacitor bank, the nodes are ranked in the order of the values of sensitivity factors for these nodes. The top-ranked node in the priority list has the greatest sensitivity factor and is the one to be first considered for capacitors addition in the optimization process.

From the results obtained from this sensitivity factor method **six** candidate locations selected for placing capacitors in the system was taken to be initial for the subsequent artificial neural network application. The results of **six** locations are tabulated in table (2) according to the priority (the greatest sensitivity factor). Where table (2.a), (2.b) & (2.c) present the **six** greatest sensitivity factors at different load levels (heavy, medium, light load levels respectively). The optimum size of capacitors added to each bus to obtain minimum real power loss or larger sensitivity factor are: (At heavy load level the optimum reactive power injected is 2200 kvar, At medium load level the optimum reactive power injected is 2000 kvar, At light load level the optimum reactive power injected is 1680 kvar). Figure (4.a) represents six candidate locations; it obtains the best sensitivity factor and minimum total real power loss after injecting the optimum reactive power (2200 Kvar) in the system buses at heavy load level. Figure (4.b) represents six candidate locations; it obtains the best sensitivity factor and minimum total real power loss after injecting the optimum reactive power (2000 Kvar) in the system buses at medium load level. Figure (4.c) represents six candidate locations; it obtains the best sensitivity factor and minimum total real power loss after injecting the optimum reactive power (1680 Kvar) in the system buses at light load level.

Table (2.a) optimum six sensitivity factor in heavy load level

optimal Sensitivity factors(KW\ Kvar)	Candidate Bus No.
24.45	10
24.30	32
23.18	15
23.17	8
22.55	30
22.16	9

Table (2.b) optimum six sensitivity factor in medium load level

optimal Sensitivity factors(KW\ Kvar)	Candidate Bus No.
18.00	9
17.50	15
16.90	10
16.81	8
16.81	32
16.44	30

Table (2.c) optimum six sensitivity factor in light load level

optimal Sensitivity factors(KW\ Kvar)	Candidate Bus No.
11.22	9
10.90	30
10.81	8
10.46	10
10.41	32
10.37	15

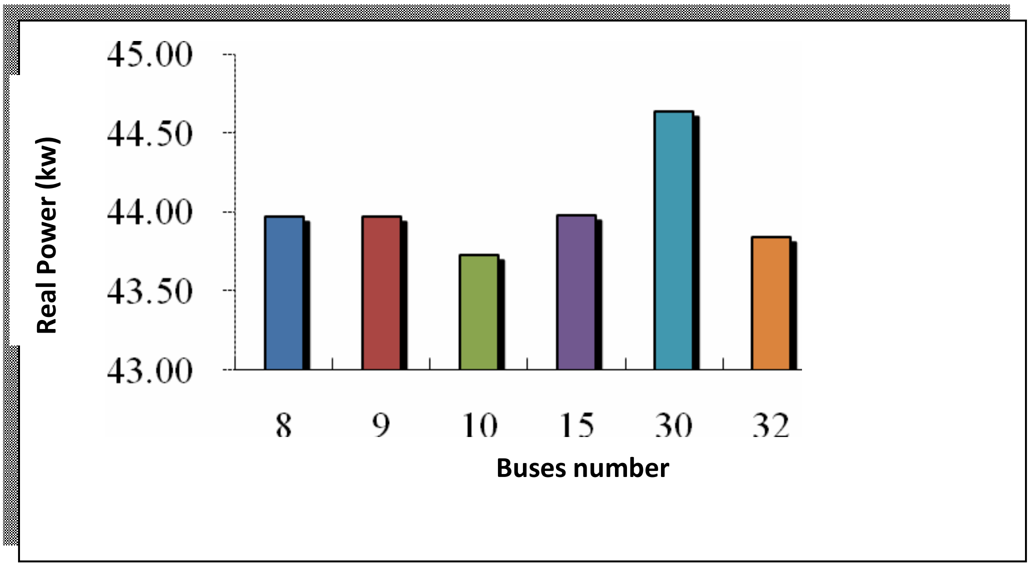


Figure (4.a) the minimum total real power loss after injected 2200 kvar in the buses (8, 9, 10, 15, 30, 32) at the heavy load level

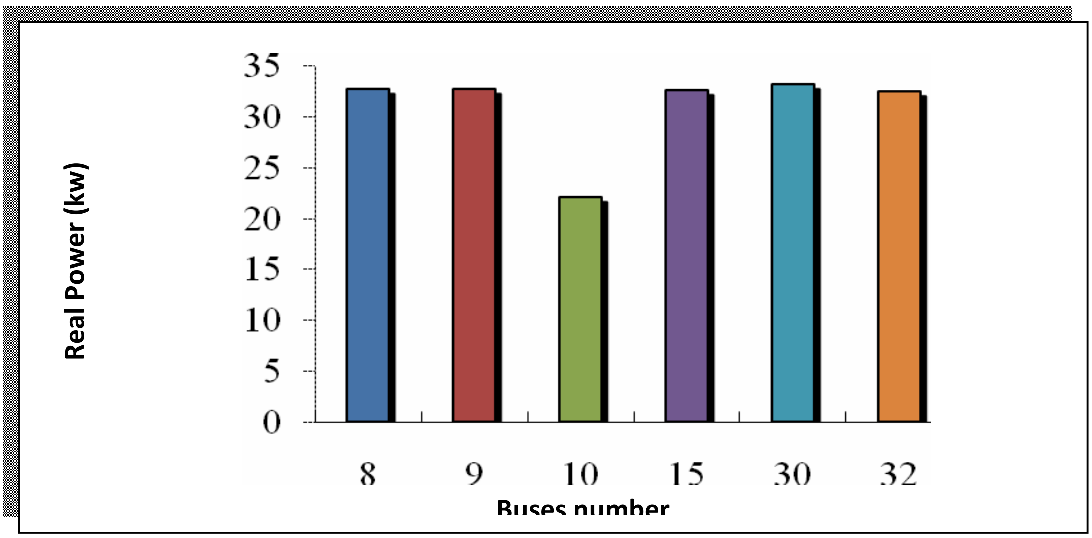


Figure (4.b) the minimum total real power loss after injected 2000 kvar in the buses(8, 9, 10, 15, 30, 32) at Medium load level

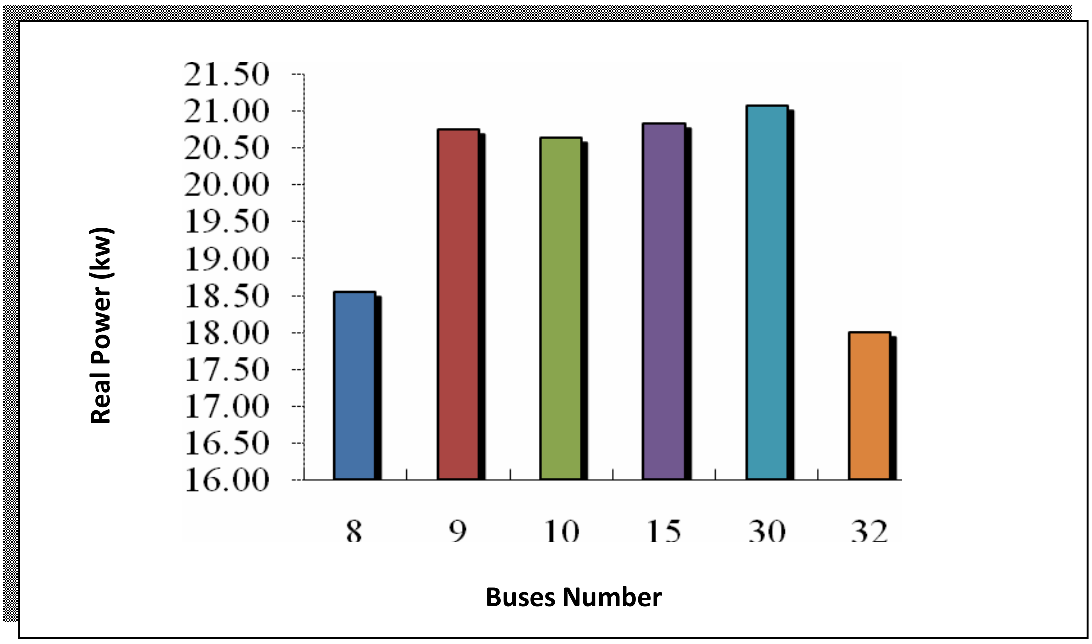


Figure (4.c) the minimum total real power loss after injected 1680 kvar in the buses(8, 9, 10, 15, 30, 32) at the Low load level

2- Fixed Capacitor Addition Results:

From the results of the sensitivity factor method, the six candidate locations that have been selected for placing capacitors in the system are taken to be the initial weight for the subsequent artificial neural network application. After running the program of implemetation of the artificial neural network for the added capacitors, the result for that option was:

The optimal locations and size to install fixed capacitors are in nodes 9, 30, 13, 19, 27 and 15 with (600kvar) (30 banks of capacitors one bank is 20kvar) being installed in node 9, (280 kvar) (14 banks of capacitors one bank is 20kvar) being installed in node 30, (740kvar) (37 banks of capacitors one bank is 20kvar) being installed in node 13, (700kvar) (35 banks of capacitors one bank is 20kvar) being installed in node 19, (260kvar) (13 banks of capacitors one bank is 20kvar) being installed in node 27, (240 kvar) (12 banks of capacitors one bank is 20kvar) being installed in node 15.

These results are summarized for each load level (heavy, medium and light loads) in tables (3.a),(3. b) and (3. c) respectivly.
In each table, the power losses and the voltage profile of the system with/without fixed capacitor addition are also included.
From the results we can see that:

- The total real power loss can be reduced significantly with proper capacitor addition.
- Voltage profile has been greatly improved when the capacitors added to the system, and no upper and lower voltage limits have occurred in the given test system even when the load levels are quite diverse. Where voltage limits on the bus are V_{min}=0.9 p.u. and V_{max}=1.1 p.u.
- Artificial neural network has been used successfully to reduce total annual cost and total power loss of the system, because ANN reaches quickly to the region of the optimal solutions and its flexibility and accuracy.

Table (3.a) Optimal Capacitors Addition in heavy load level

Voltage Profile	Real Power Losses in (kw)	Heavy Load
V_{min}= 0.9567 V_{max}= 0.99996	52.3451	Without Capacitors Addition
V_{min}= 0.9987 V_{max}= 1.0000	35.8733	With Capacitors Placed at Node 9=600kvar Node 30=280kvar Node 13=740Kvar Node 19=700kvar Node 27=260kvar Node 15=240kvar

Table (3.b) Optimal Capacitors Addition in medium load level

Voltage Profile	Real Power Losses in (kw)	Medium Load
V_{min}=0.9555 V_{max}= 0.99998	47.4654	Without Capacitors Addition
V_{min} =0.99888 V_{max} = 1.0000	38.138	With Capacitors Placed at Node 9=600kvar Node 30=280kvar Node 13=740Kvar Node 19=700kvar Node 27=260kvar Node 15=240kvar

Table (3.c) Optimal Capacitors Addition in light load level

Voltage Profile	Real Power Losses in (kw)	Light Load
V_{min}= 0.97892 V_{max}= 0.99999	34.0566	Without Capacitors Addition
V_{min} = 0.9899 V_{max} = 1.0000	25.3421	With Capacitors Placed at Node 9=600kvar Node 30=280kvar Node 13=740Kvar Node 19=700kvar Node 27=260kvar Node 15=240kvar

3-Neural Network Design & Training Result :

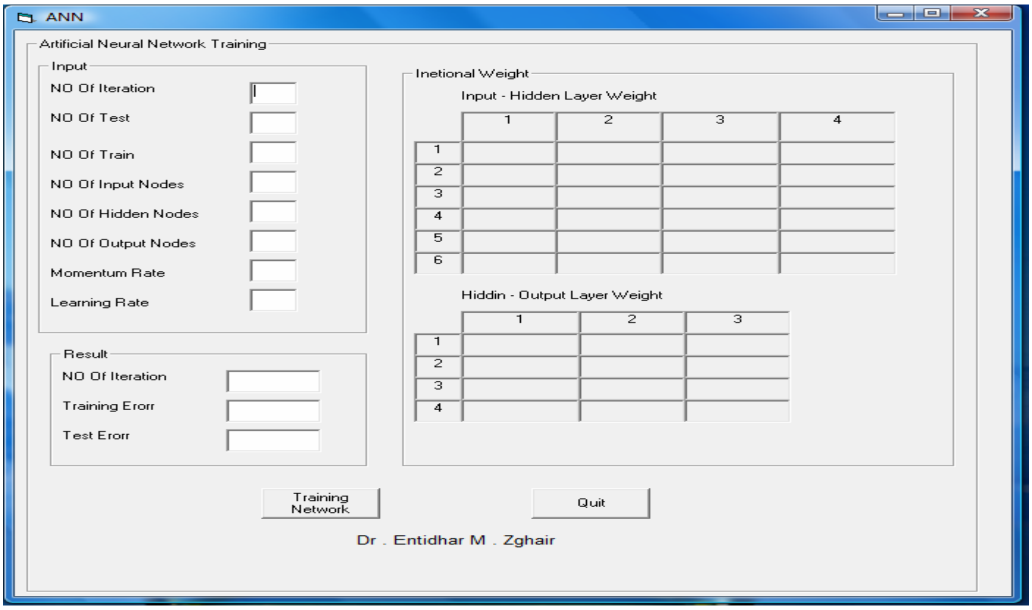
ANN network will consist of input layer, one hidden layer, and an output layer. The program is coded Visual Basic V.6 employing Graphical User Interface for a user friendly approached output. Graphical User Interface (GUI) tools will show the trained weights, training and test errors, and number of iteration after the simulation. At the same time, the weights are automatically-generated and stored in excel file. In addition, the corresponding simulated training and test output are also generated in excel file for analysis and validation of result. The data in excel format are converted into array of numbers using Visual Basic V.6 function into array of numbers.

The following components visible to user are inputs, weights, and training results. At the start of the training, all needed parameters are fed into the ANN trainer. Successive training is one by adjusting the learning rate, and momentum until it provided good results for mean-squared error (MSE).The following final parameters are fed into the ANN trainer:

No. of Training Data = 88, No. of Test Data = 11, No. of Input Nodes = 6, No. of Hidden Nodes = 4, No. of Output Nodes = 3, Learning Rate = 0.5, Momentum Rate = 0.03

Epochs = 1000

After training, the program automatically displayed the corresponding results. Figure (5) shows the final result of training. Subsequently, weights are auto-generated in excel file for further use. Using the threshold for capacitor's action: 0, for output less than 0.5 and 1, for output greater than or equal to 0.5,



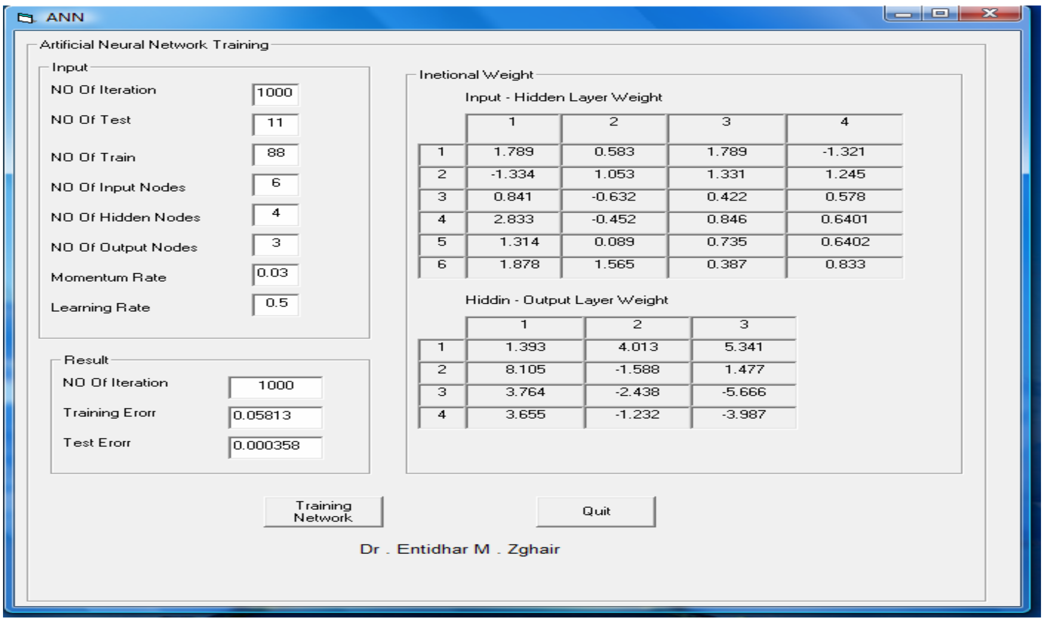


Figure (5) Training Results Improving Radial Power Distribution System

Conclusions:

Based on the presented results and findings, the researchers arrived with the following After the addition of the bank of capacitors to the distribution power system, the real power losses were tremendously minimized compared to non addition of either capacitors.

- The ANN trainer is created using Visual Basic V.6 software employing with feed-forward and back propagation algorithm.
- ANN output is satisfactorily trained as confirmed by a mean-squared error (MSE) for training equal to 0.05813and for test error of 0.000358.
- The ANN based real-time reactive power controller is successful in responding capacitor's action as exemplified by power factor within the normal range.
- The Artificial neural network has been successfully employed to calculate the size and location of capacitors' adding to the power distribution system at different load levels. The No. of Input Nodes, No. of Hidden Nodes, No. of Training Data and Learning Rate value for each string is composed of the total power loss of capacitors added for that corresponding configuration of feeders.

That will lead to reduce the power losses in systems, at the same time sensitivity factor were employed to the node aiming at reducing the total number of alternative examined for finding the optimal location to add the capacitors. Power flow formulation (Fast decoupled method) Was presented to reduce power losses and enhance voltage profile of a primary distribution system.

References:

1- Carl John O. Salaan and Noel R. Estoperez "An Artificial Neural Network Based Real-time Reactive Power Controller" Proceedings of the World Congress on Engineering and Computer Science 2011 Vol I WCECS 2011, October 19-21, 2011

2-Nissen, Steffen. Neural Network Made Simple. www.software20.org.2005.

3-J.Paatero, T.Sevon, A.Lehtolainen and P.Lund, "Distributed Power System Topology and Control Studies by Numerical Simulation", Second International Symposium on Distributed Generation: Power System and Market Aspects Stockholm, October 2002.

4-M. E. Baran and F. F. Wu, " Optimal Capacitor Placement on Radial Distribution System," IEEE Trans. On Power Delivery, Vol. 4, No. 1, pp.725-734, Jan. 1998.

5-Y.C. Huan , H.T. Yang and C.L. Huang, "Solving the Capacitor Placement Problem in a Radial Distribution System Using Tabu Search Approach", IEEE Transactions on Power Systems VOL. 11, no 4, pp. 1868. November 1996.

6-T.Basso, "Draft Standard for Interconnecting Distributed Resource with Electric Power Systems" IEEE P1547/D07, Institute of Electrical and Electronics Engineers, Inc. NewYork, 2001.

7-Jayabarathi. R.A and N.B Devarajan. ANN Based DSPIC Controller for Reactive Power Compensation. American Journal of Applied Sciences. 508-515. 2007.

8-Abdallah, J. and A. Al-Zyoud. Voltage and Reactive Power Control Simulations Using Neural Network. IJSSST. Vol. 10. No. 5.

9-Lyubchenko, V.Ya. and D.A. Pavlyuchenko. Reactive Power and Voltage Control by Genetic Algorithm and Artificial Neural Network. Transactions on Power Engineering. Vol.1. No.1. December 2009

10-Said, I. and M. Pirouti. Neural Network-Based Load Balancing and Reactive Power Control by Static VAR Compensator. International Journal of Computer and Electrical Engineering. Vol. 1. No. 1. April 2009.

11-Joorabian, M. and R. Hooshmand. Application of Artificial Neural Networks in Voltage and Reactive Power Control. 2005.