Reduction Power losses on distribution feeders in Electrical Distribution Systems

تقليل الخسارة في الطاقة على خطوط التوزيع في نظم الطاقة الكهربائية

M.sc A .S.ALLW   B.sc M.S.ALMURIEB   B.sc Z.A.ALAMIDY

Islamic university college

Reduction Power losses on distribution feeders in Electrical Distribution Systems

تقليل الخسارة في الطاقة على خطوط التوزيع في نظم الطاقة الكهربائية

M.sc A .S.ALLW B.sc M.S.ALMURIEB B.sc Z.A.ALAMIDY

Islamic university college

Abstract:-

This paper presents a study the power losses and its impacts on distribution of electric power networks, Capacitors are widely used in distribution system for reactive power compensation to achieve power and energy loss reduction, voltage regulation, and system capacity release. The extent of these benefits will depend upon how the capacitors are placed on the system, the number and location, the type (fixed or switched), the size, and the control scheme of the capacitors. Therefore, the capacitor placement problem in distribution feeders consists of determining the place (number and location), type, size, and control scheme of capacitors to be installed such that the benefits mention above is weighted against the fixed and running costs of the capacitors and their accessories. The installation of shunt capacitors on radial distribution systems is essential for many reasons. These reasons arc power flow control, improving system stability, voltage profile management. and losses minimization

By taking the twenty two nodes, and apply the MATLAB program on this network. The result improved performance of the electrical network known, control adding shunt capacitor in the exact locations as needed to improve the voltage profile and reduces power losses

Kay Word: power losses, Shunt capacitor, MATLAB Program

1-Introduction

There use several methods to know the sizes and locations of capacitors to get the best correction. The general capacitor placement problem consist of determining the location, type, and size of capacitors to be installed in the nodes of radial distribution system such that the economic benefits due to peak power and energy loss reduction be weighed against the cost of installment of such capacitors while keeping the voltage profile of the system within defend limits [6].

Shunt capacitors are installed at appropriate location a large distribution system to reduce power losses and improve voltage profile [1, 9].

Analytical method The early methods were used, When power computing resource, is unavailable these methods are expensive. The capacitor saving function is defined as fallows [3]

Cost saving = $KE \times \Delta E + KP \times \Delta P - Kc \times Qc$ (1)

For the most simplified version of the problem, the analytical method established the "two – thirds" .According to the rule, the cost function can be maximized by choosing the value of capacitor to be equal to two – thirds of the value of the peak .The capacitor is installed at a location at two thirds distance of the total feeder length, downstream from the source [5].

Numerical programming method when computer memory becomes cheaper, the numerical method become preferred to solve the optimization problem. Numerical programming methods are iterative techniques used to maximize on objective function of allocation variables. With this method objective function and decision variables are present for optimal capacitor allocation the object function is saving function and the locations, size number of capacitors and bus voltage are taken as the decision variable. All decision variables must satisfy the operation at conditions. The numerical method considers discrete size of the capacitor and the place of the node. [10],[12]. With this method, the capacitor allocation problem formal can be written as follows

Max S = $K_L \times \Delta L - Kc \times c$ (2)

Heurist method is rules of thumb that are developed from experience, judgment and knowledge. The heuristic are approximate method is easy to understand approximate method is easy to understand and also simple to implement compound with the analytic and numerical methods but this method is not guaranteed to result in optimal result this method is approximate because it does not need perfect data. This method is not guaranteed to minimize the cost function [12], [19] the problem formulation is a follows

$$P = \sum_{j=1}^{n} I_j^2 \times R_j \quad (3)$$

$$P = \sum_{j=1}^{n} I_{dj}^2 \times R_j + \sum_{j=1}^{n} I_q^{\,2} \times R \quad (4)$$

$$P_j = \sum_{j=1}^{n} I_{dj}^2 \times R_j + \sum_{j=1}^{n} (I_{qj} - I_{qk})^2 \times R_j \quad (5)$$

From equation (1-4, 1-5)

$$\Delta P_k = P - P_j = 2\, I_{qk} \sum_{j=1}^{k} I_{qj} \times R_j - I_{qk}^{\,2} \sum_{j=1}^{k} R_j \quad (6)$$

$$\text{Cost saving} = Kp \times P + Kc_k \times Qc_k \quad (7)$$

Artificial intelligence is the basis of methods recently being applied by many researchers to the capacitor placement problem. Artificial intelligence methods that have been used for the capacitor placement problem are as follows:

1. Genetic algorithms (GA'S)
2. Simulated annealing (SA)

3. Artificial neural networks (ANN's)

4. Fuzzy set theory (FST)

Case study:

The feeder is consists of 22 buses Reference [32] the rated voltage is 11Kv the input data is shown in Tables. 1

The system is shown in Fig. 1

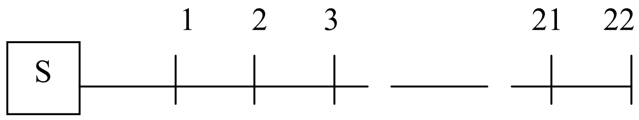

Fig. 1 Twenty Two - bus system

Problem formulation and application for reduction power losses In radial distribution feeders

In a three phase radial distribution feeder with (n) number of nodes.

$$S_j = P_j + Q_j \qquad j = 1, \ldots\ldots, n \tag{8}$$

$$P_{(j+1)} = P_j - R_{(j+1)}(P_j^2 + Q_j^2)/V_j^2 - P_{L(j+1)} \tag{9}$$

$$Q_{(j+1)} = Q_j - X_{(j+1)}(P_j^2 + Q_j^2)/V_j^2 - Q_{L(j+1)} \tag{10}$$

$$V_{(j+1)} = V_j - 2(R_{(j+1)}P_j + X_{(j+1)}Q_j) + (R_{(j+1)}{}^2 + X_{(j+1)}{}^2) \times (P_j{}^2 + Q_j{}^2)/V_j{}^2 \tag{11}$$

$$P_{loss(j+1)} = R_{j+1}(P_j^2 + Q_j^2)/V_j^2 \tag{12}$$

$$Q_{LOSS\ (j+1)} = X_{j+1}(p_j^2 + Q_j^2)/V_j^2 \tag{13}$$

$$P = \sum_{j=0}^{n-1} (P_{loss(j+1)}) \tag{14}$$

$$Q_{max} = L \times Q_c \tag{15}$$

Where: L is an integer. Then at each selected location there are L sizes to choose from. Let K_{1c} , K_{2c}, …. K_{Lc} be the corresponding capital invested per KVAR assuming that only capacitor banks are used voltage excursions, the cost function S can be selected as Kp : is cost per power losses ($ / kW / year), assume

Kp = 200$/KW/Year.

j = 1, 2, …….. k represents the selected buses. The objective function is to be minimized as $V_{min} \leq V_j \leq V_{max}$

j = 1, 2,3, ………….., n

kjc = cost of additional capacitors

Q_{cj} : KVAR compensation

Kcj :Cost of KVAR ($/KVAR

Table.1 Input date for 22-bus system

Section feeder No.		R (Ohm)	X (Ohm)	P(kW)	Q(KVAR)
0	1	0.530	0.778	21	14
1	2	0.037	0.071	18	12
2	3	0.224	0.428	23	16
3	4	0.262	0.499	173	121
4	5	0.176	0.335	36	25
5	6	0.100	0.190	222	155
6	7	0.174	0.332	213	148
7	8	0.174	0.332	222	155

8	9	0.174	0.332	101	71
9	10	0.100	0.190	20	14
10	11	0.150	0.285	223	156
11	12	0.096	0.183	126	88
12	13	0.274	0.522	60	42
13	14	0.075	0.142	103	72
14	15	0.025	0.048	251	175
15	16	0.025	0.048	33	23
16	17	0.050	0.096	33	23
17	18	0.025	0.048	197	138
18	19	0.025	0.048	38	26
19	20	0.050	0.096	33	23
20	21	0.075	0.143	30	20
21	22	0.075	0.143	302	211

This test is carried out when the power losses is(129kw) each sensitive node .Table 3,4 shows the output data before and after compensation.

Fig. 2 to Fig. 7 shown the power losses, the apparent power, the voltage profile, the cost, the power saving and the voltage drop on each feeder before and after compensation.

The sensitive nodes are the nodes selected at which the maximum power losses and the reactive power shown Tble2 compensation selected from Table 6 according calculated value of shunt capacitor.

Table 2 Sensitive nod and VAR compensation

sensitive nodes selected =	4	6	8	9	10	11	12	13	14	18	22
Q_c std (KVAR) =	100	150	150	50	15	150	100	50	50	150	150

Table 3 Output data before compensation of 22-bus system

Section feeder No.		S(kVA)	PF	i(Amp)	I (Amp)	id(Amp)	iq (Amp)	Id (Amp)	Iq (Amp)	Z (Ohm)	VD (Volt)	V(Volt)	V_pu	Ploss(kW)	Cost ($)
0	1	25.238859	0.8320503	2.2944417	274.63885	1.9090909	1.27272	228.51334	152.34223	0.9413735	258.53773	10741.46227	0.9764966	39.9760	7995.209
1	2	21.633308	0.8320503	1.9666643	272.34441	1.6363636	1.0909091	226.60425	151.0695	0.0800625	21.804568	10719.6577	0.9745143	2.7443447	548.8689
2	3	28.017851	0.8209052	2.5470774	270.37775	2.0909091	1.4545455	221.9545	154.40313	0.4830735	130.61232	10589.04538	0.9626405	16.375324	3275.065
3	4	211.11608	0.8194544	19.192371	267.83067	15.727273	11	219.47502	153.50565	0.5636	150.94937	10438.09601	0.9489178	18.794116	3758.823
4	5	43.829214	0.82137	3.984474	248.6383	3.2727273	2.2727273	204.22403	141.82224	0.3784191	94.089476	10344.00653	0.9403642	10.880497	2176.099
5	6	270.75635	0.8199254	24.614213	244.65382	20.181818	14.090909	200.59788	140.05708	0.2147091	52.529404	10291.47713	0.9355888	5.9855494	1197.11
6	7	259.37039	0.8212194	23.579127	220.03961	19.363636	13.454545	180.7008	125.55736	0.3748333	82.478173	10208.99895	0.9280908	8.4246329	1684.927
7	8	270.75635	0.8199254	24.614213	196.46048	20.181818	14.090909	161.08294	112.46782	0.3748333	73.639931	10135.35902	0.9213963	6.7158296	1343.166
8	9	123.4585	0.8180887	11.2235	171.84627	9.1818182	6.4545455	140.58549	98.827426	0.3748333	64.413704	10070.94532	0.9155405	5.1384185	1027.684
9	10	24.413111	0.8192319	2.2193737	160.62277	1.8181818	1.2727273	131.5873	92.111111	0.2147091	34.487172	10036.45815	0.9124053	2.5799675	515.9935
10	11	272.14886	0.8194045	24.740805	158.4034	20.272727	14.181818	129.79646	90.799316	0.3220637	51.015978	9985.442168	0.9077675	3.7637455	752.7491
11	12	153.688	0.8198428	13.971636	133.66259	11.454545	8	109.58232	76.533682	0.2066519	27.621626	9957.820542	0.9052564	1.7151061	343.0212
12	13	73.239334	0.8192319	6.6581212	119.69096	5.4545455	3.8181818	98.054652	68.638257	0.5895422	70.562869	9887.257672	0.8988416	3.9253035	785.0607
13	14	125.6702	0.8196056	11.424564	113.03284	9.3636364	6.5454545	92.642343	64.759696	0.1605895	18.151891	9869.105781	0.8971914	0.9582316	191.6463
14	15	305.98366	0.8203052	27.816696	101.60827	22.818182	15.909091	83.349798	58.112409	0.0541202	5.4990637	9863.606718	0.8966915	0.258106	51.6212
15	16	40.224371	0.8203982	3.656761	73.791575	3	2.0909091	60.538473	42.193481	0.0541202	3.9936175	9859.6131	0.8963285	0.1361299	27.22598
16	17	40.224371	0.8203982	3.656761	70.134814	3	2.0909091	57.538473	40.102572	0.1082405	7.5914255	9852.021675	0.8956383	0.2459446	49.18892
17	18	240.52651	0.8190366	21.866046	66.478053	17.909091	12.545455	54.447956	38.141208	0.0541202	3.597808	9848.423867	0.8953113	0.1104833	22.09666
18	19	46.043458	0.8253073	4.1857689	44.612007	3.4545455	2.3636364	36.818614	25.191683	0.0541202	2.4144124	9846.009454	0.8950918	0.0497558	9.951156
19	20	40.224371	0.8203982	3.656761	40.426239	3	2.0909091	33.165612	23.115427	0.1082405	4.3757552	9841.633699	0.894694	0.081714	16.34281
20	21	36.055513	0.8320503	3.2777739	36.769478	2.7272727	1.8181818	30.594055	20.396036	0.1614745	5.9373314	9835.696368	0.8941542	0.1013996	20.27992
21	22	368.40874	0.8197417	33.491704	33.491704	27.454545	19.181818	27.454545	19.181818	0.1614745	5.4080546	9830.288313	0.8936626	0.0841271	16.82541
Total														129.04477	25808.95

Table 4 Output data after compensation of 22-bus system

Section feeder No.		S(kVA)	PF	I_new (Amp)	Z (Ohm)	VD(Volt)	Vr(Volt)	V_pu	Ploss_new (Kw)	cost_new ($)
0	1	25.238859	0.8320503	226.28373	0.9413735	213.0175	10786.983	0.9806348	27.138292	5427.6585
1	2	21.633308	0.8320503	223.98929	0.0800625	17.933137	10769.049	0.9790045	1.8563344	371.26688
2	3	28.017851	0.8209052	222.02262	0.4830735	107.25324	10661.796	0.9692542	11.041866	2208.3732
3	4	174.26991	0.992713	219.47554	0.5636	123.69642	10538.1	0.9580091	12.620413	2524.0825
4	5	43.829214	0.82137	204.58235	0.3784191	77.417866	10460.682	0.9509711	7.3662933	1473.2587
5	6	222.0563	0.9997465	200.59788	0.2147091	43.070191	10417.612	0.9470556	4.0239509	804.79018
6	7	259.37039	0.8212194	184.66206	0.3748333	69.21749	10348.394	0.9407631	5.9334135	1186.6827
7	8	222.0563	0.9997465	161.08294	0.3748333	60.379248	10288.015	0.9352741	4.514902	902.98039
8	9	103.16007	0.979061	140.58549	0.3748333	52.696124	10235.319	0.9304835	3.4389849	687.79697
9	10	20.024984	0.9987523	131.5873	0.2147091	28.252992	10207.066	0.9279151	1.7315218	346.30436
10	11	223.0807	0.9996382	129.79646	0.3220637	41.802722	10165.263	0.9241148	2.5270681	505.41362
11	12	126.57014	0.9954955	109.58232	0.2066519	22.645392	10142.618	0.9220562	1.1527953	230.55906
12	13	60.530984	0.9912279	98.054652	0.5895422	57.807355	10084.81	0.9168009	2.6344319	526.88637
13	14	105.32331	0.9779411	92.642343	0.1605895	14.877391	10069.933	0.9154484	0.6436953	128.73906
14	15	305.98366	0.8203052	89.578174	0.0541202	4.847992	10065.085	0.9150077	0.2006062	40.121246
15	16	40.224371	0.8203982	61.761478	0.0541202	3.3425458	10061.742	0.9147039	0.095362	19.072401
16	17	40.224371	0.8203982	58.104717	0.1082405	6.289282	10055.453	0.9141321	0.1688079	33.761581
17	18	197.36514	0.9981499	54.447956	0.0541202	2.9467362	10052.506	0.9138642	0.0741145	14.822899
18	19	46.043458	0.8253073	38.574849	0.0541202	2.08768	10050.419	0.9136744	0.0372005	7.440095
19	20	40.224371	0.8203982	34.38908	0.1082405	3.7222903	10046.696	0.913336	0.0591304	11.826088
20	21	36.055513	0.8320503	30.732319	0.1614745	4.9624846	10041.734	0.9128849	0.0708357	14.167132
21	22	308.09901	0.9802044	27.454545	0.1614745	4.4332078	10037.301	0.9124819	0.0565314	11.306281
Total									87.386551	17477.31

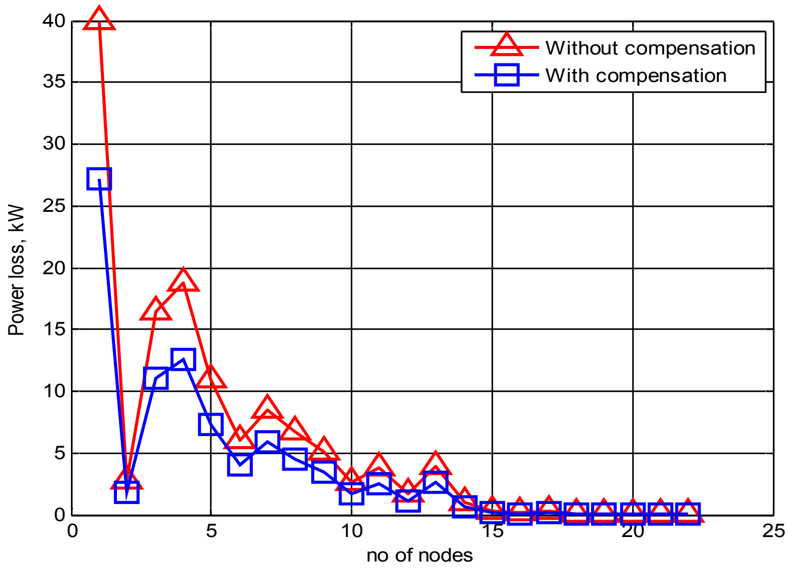

Fig 2 Power loss with and without compensation of 22-bus system

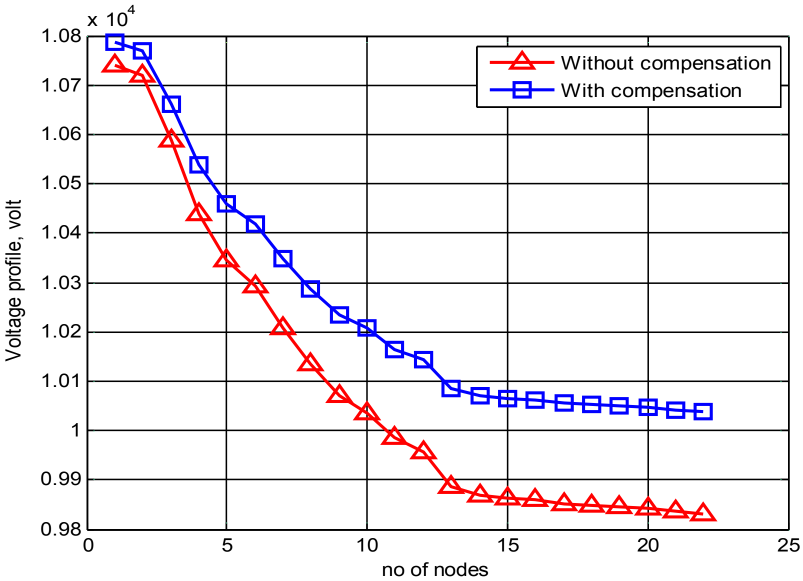

Fig 3 Voltage profile with and without compensation of 22-bus system

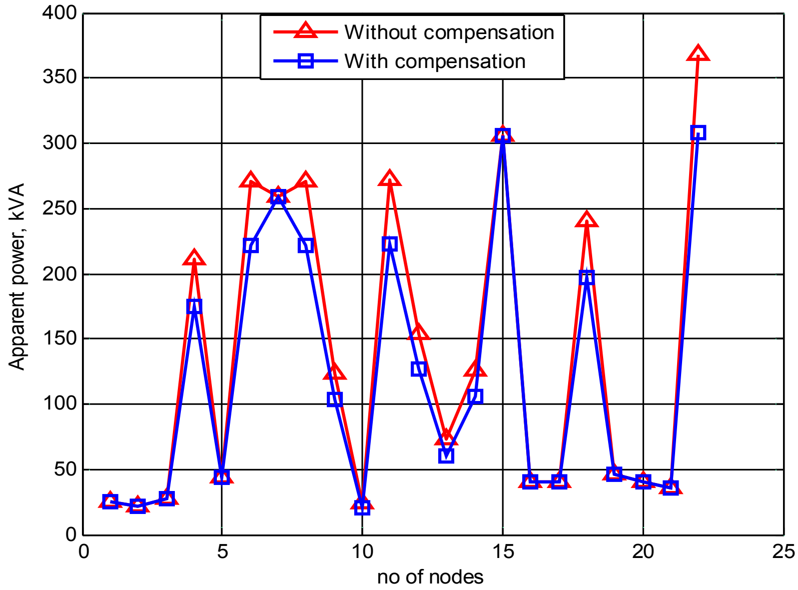

Fig 4 Apparent power, KVA with and without compensation of 22-bus system

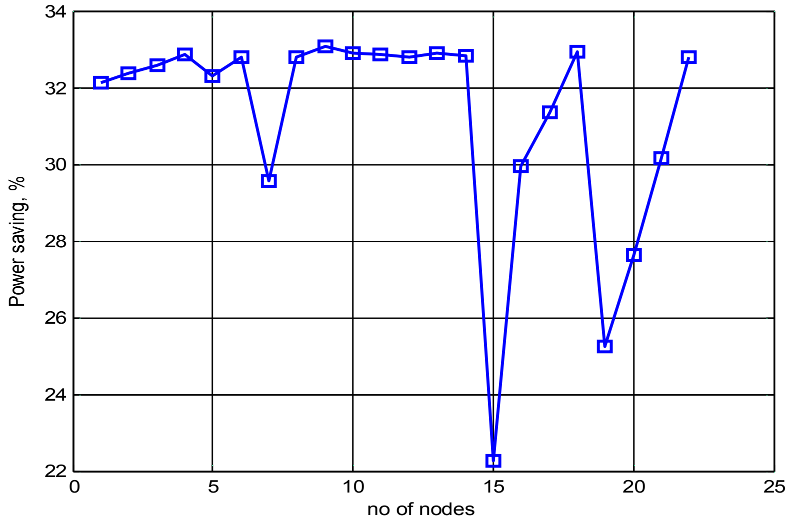

Fig 5 Power saving with and without compensation of 22-bus system

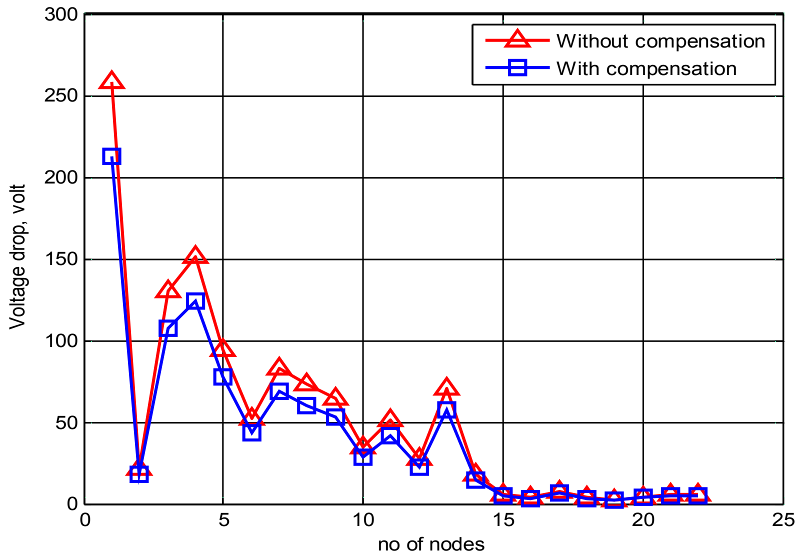

Fig 6 Cost with and without compensation of 22-bus system

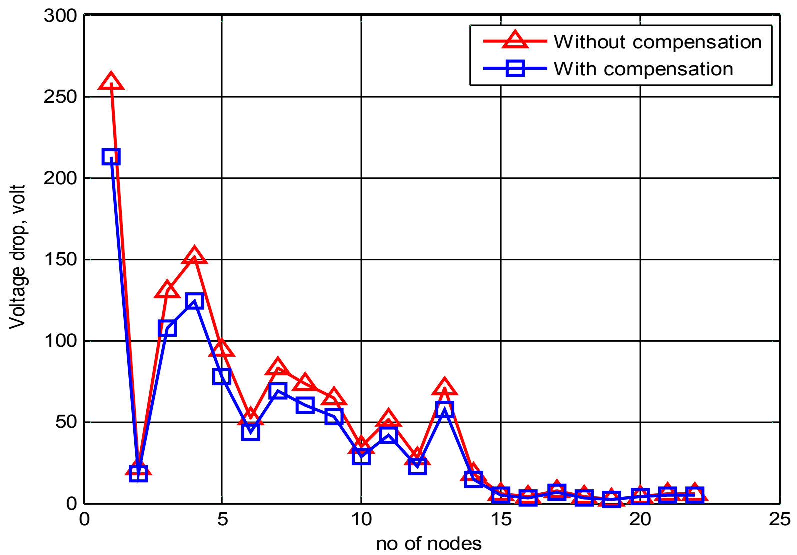

Fig 7 Voltage drop with and without compensation of 22-bus system

Table 5 The % saving in power losses, reactive power and cost losses

Test No.	PL (KW)	% Saving in PL	Q (kVAR)	% Saving in Q	Cost ($)	Saving cost ($)	% cost saving
Before compensation	129.0446	-	1728	-	25808.95	-	-
Test 1	87.38	32.282	513	70.312	18081	7728	29.943

Conclusion and discussion

The previous study shows that the location and size of shunt capacitors have very important impact on the reduce power losses problem. It is clear from the tests that the accuracy of the appropriate sizes of the capacitors will affect the values of reactive power compensation added to reduce the power losses in electric power system, the possible value added to mitigate the loss of energy or increase it according to the added value of reactive power compensation. This value must be carefully chosen because it also affects the value of the voltage in the network so that it should not exceed the allowable value in the network. In this search the total power losses 129.0446 KW, after compensation the total power losses 87.38 KW this process decreased the total apparent power and total cost 0n the network. The calculation of the economic saving shows that the reduction power losses provides us with several benefits which are as follows:

1- Economic benefits:

1-1 Decrease in investment costs in power plant.

1-2 Increase in the number of customers because of power availability which increases saving costs.

2) Reduction in reactive power drawn from the network provides us with additional capacity to the network

3) Improve the voltage profile by reducing the current passing through the network, and this leads to improve the performance of the networks.

Table 6 Standard KVAR and COST/KVA

Kc ($)	Qc (KVAR)	No.
0.8	5	1
0.75	15	2
0.7	30	3
0.65	50	4
0.6	100	5
0.5	150	6
0.35	300	7
0.253	450	8
0.22	600	9
0.276	750	10
0.183	900	11
0.228	1050	12
0.17	1200	13
0.207	1350	14
0.201	1500	15
0.193	1650	16
0.187	1800	17
0.211	1950	18
0.176	2100	19
0.197	2250	20
0.17	2400	21
0.189	2550	22
0.187	2700	23
0.183	2850	24
0.18	3000	25
0.195	3150	26
0.174	3300	27
0.188	3450	28
0.17	3600	29
0.183	3750	30
0.182	3900	31

ملخص البحث:-

تقليل الخسارة في الطاقة على خطوط التوزيع في نظم الطاقة الكهربائية

يقدم البحث عرضاً ودراسة لأسباب الخسارة في الطاقة الكهربائية وتأثيراتها على شبكات توزيع الطاقة الكهربائية والطرق المستخدمة لإزالة تأثيرات انخفاض القدرة على الشبكة وقد تم تطبيق الطريقة الحسابية باستخدام المعادلات المعروفة لتقليل الخسارة في الطاقة وتطبيقها بالاستفادة من تقنية الماتلاب لمعرفة النقاط الحساسة والضعيفة في شبكات التوزيع الكهربائية ومعرفة سعة مكثفات التوازي اللازم إضافتها لغرض تحسين أداء الشبكة. وقد تمت دراسة نظام يحتوي على اثنان وعشرون عقدة وكانت النتيجة تحسين أداء الشبكة وتقليل القدرة الضائعة وتحسين الفولتية.

وقد حصلنا على نتائج جيدة وسريعة في العمل وكذلك المحافظة على القيم المسموح بها في الشبكة واستخدام هذه الطريقة بشكل مباشر (on-line) في شبكات التوزيع الكهربائية.

References

[1] S.F Mekhamer , M.E Elawary, S. A Soliman , M. A Moustafa and M. Mansour , " New Heuristic start egiest for reactive power compensation of Redail distribution feeders " IEEE Trans. Power Delivery, vol . 17,00 4, pp. 1128-1134, Oct. 2002.

[2] A.R Banisher and A Desbiens, " Bach stepping based A dative PID control " IEEE proceedings control Theory and Applications., Vol. 149, pp. 54-59, Jan. 2002 .

[3] H.P Huang M.L Roanm and J.C. Jeng, " Online adaptive tuning for PID controller " IEEE proceedings of " oontrol Theory and Applications , Vol. 149, pp. 60 - 67, Jan - 2002.

[4] Kevin M.Passino and Stephen Yurkovich, Fuzzy control Menlo Park, CA : Addison Wesley Longman 1998 .

[5] Kazuo Tanaka and Hua O. Wang , " Fuzzy control system design and analysis " A Linear Motriz Inequality Approach. New York: John Wiley and Sons, 2001.

[6] Hao Ying "fuzzy control and modeling Wiley, " IEEE Press 2000 . paolo Dad one " Design optimization of fuzzy logic systems " ph D. dissertation, Virginia polytechnic institute and statue university, may, 2001 .

[7] H.C Chin, Optimal shunt capacitor allocation by fuzzy dynamic programming ", pp. 133-139, Electric Power Systems Research, Vol. 35, 1995.

[8] H N. Ng M.M.A Salama, A Y. Chickani, " Capacitor Allocation by Approximate Reasoning fuzzy capacitor placement " IEEE transaction power delivery , Vol 15, No.1, January 2000 .

[9] H.S Barbuy, A.R Luiz Augusto ,P Fernades and G C Guimoraes " Voltag Collapse Risk Associated to Under-Voltage Capacitive Compensation in Electric Power System," American Journal of Applied Sciences 6 (4): 646-651, 2009 .

[10] S. F. Mekhamer, M. E. El-Hawary, M. M. Mansour, M. A. Moustafa, S. A. Soliman, "Fuzzy and Heuristic Techniques for reactive power compensation of radial distribution feeders: A comparative study", pp. 112-121, IEEE CCECE02 proceedings, Canadian conference,Vol.1., 2002.