Performance Improvement of Multilevel Load Power System by Using Two-Stages Fuzzy Controller

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Abstract

This paper presents a new approach to improve the performance of power system by enhancing the voltage profile and reducing the real power losses based on two stages fuzzy controller which is used to select the appropriate size and location of capacitor banks required to minimize the power losses and maintain the voltage profile in permissible limits.

The first stage of fuzzy controller is used to specify the optimal location of capacitors installation, while the optimal size is specified by the second stage . The proposed method is tested on a 34-bus, 74-transmission lines from Iraqi Northern power system with multilevel of loads. The load levels are represented by 50%, 75%, 100% and 125% of peak load and satisfied results are obtained to show the feasibility and flexibility of the proposed method.

Keywords : Load – flow , Fuzzy- logic , optimal ,location , optimal size .

المستخلص

البحث يقدم طريقة جديدة لتحسين أداء منظومة القدرة من خلال تعزيز مقدار الفولتية وتقليل الخسائر بالاعتماد على المسيطر المضبب ذو مرحلتين الذي يستخدم لاختيار القيم المثلى والأماكن المناسبة لتنصيب المتسعات اللازمة لتحسين الأداء. المرحلة الأولى من المسيطر المضبب تستخدم لتحديد الأماكن المثلى للتنصيب بينما يتم تحديد القيم المثلى للمتسعات باستخدام المرحلة الثانية من المسيطر المضبب. الطريقة المقترحة اختبرت على منظومة قدرة كهربائية مؤلفة من 34- قضيب توصيل عمومي و 74- خط نقل من منظومة شمال العراق بمستويات متعددة من الحمل، مستويات الأحمال التي اعتمدتها الدراسة حددت بـ 50%، 75%، 100%، 125% من القيمة القصوى للحمل وتم استحصال النتائج التي بينت فعالية ومرونة الطريقة المقترحة.

1. Introduction

Electricity networks are called to accommodate more and more generation capacity in order to supply the increasing demand. However, social, planning and environmental reasons hinder the expansion of the existing networks, but even where this is possible it raises a tremendous cost for the operator. Therefore, the efficient utilization of the existing transmission and distribution lines is not only suggested for economy, but also imposed by need. Reactor and capacitor banks have long been utilized as a remedy for a series of technical and economic problems in power systems. Large reactive power surplus or deficiency at light or heavy load operation, respectively, can be tackled with the placement of reactor and capacitors at the appropriate network locations [1]. Furthermore, several methods have been suggested for the reduction of transmission losses by the local consumption or production of reactive power from optimally located reactive power compensation banks [2]. Finally, a series of methods are attempted to optimally allocate capacitor banks, so that both losses are reduced and power quality is improved, using other inherent capabilities of those elements[3-5].

In recent years, increased efforts have been centered on developing intelligent control systems that can perform effectively in real-time. These include the development of non-analytical methods of soft computing such as evolutionary computation and fuzzy logic. These methods have proven to be effective in designing intelligent control systems and handling real-time uncertainty, respectively. This paper is an attempt , which is based on fuzzy controller to improve the performance of multilevel power system through voltages profile enhancement and reduced the real power losses by installing capacitor banks on some nodes in that power system.

2. Literature review

Fuzzy set theory applications have received increasing attention in various areas of power systems such as operation, planning and control[6].Published literature describes several approaches and techniques to the problem, standing out the analytic methods, heuristic methods, numerical programming, fuzzy logic, ant colony optimization, tabu search, neural networks, genetic algorithms and hybrid methods [7]. Mahdad and et.al describe in [8] a simple approach based on logic concept. Fuzzy logic approach is described, which achieves a logical and feasible economic cost of operation without the need of exact mathematical formulation. P.V. Prasad and et.al in [9], present a novel method to determine suitable candidate nodes in distribution systems for capacitor installation using fuzzy approach and capacitor-sizing problem for loss minimization using Genetic Algorithm method. The proposed method has been tested with several systems.

Tamer Mohamed Khalil and et.al in [10], propose a binary particle swarm optimization (PSO) for optimal placement and sizing of fixed capacitor banks in radial distribution lines with nonsinusoidal substation voltages. The objective function includes the cost of power losses and capacitor banks with constraints which include limits on voltage, total harmonic distortion (THD) and sizes of installed capacitors. Houssem Ben Aribia and Hsan Hadj

Abdallah in [11],propose an approach based on the evolutionary algorithms (AE) to solve the problem of maintaining an appropriate voltage profile, this task can be done by the minimization of the active losses in the transportation and transmission lines by implantation of reactive power sources to the load buses, in addition to the minimization of the active losses, other criteria can be considered as the compensation devices cost and the voltage deviation.

3. Overview of fuzzy control [12, 13]

A fuzzy logic controller (FLC) is an intelligent control system that smoothly interpolates between rules. A fuzzy set may be represented by a mathematical formulation known as a membership function. That is, associated with a given linguistic variable (e.g. speed) there are linguistic values or fuzzy subsets (e.g. slow, fast, etc.) expressed as membership functions which represent uncertainty, vagueness, or imprecision in values of the linguistic variable. This function assigns a numerical degree of membership, in the closed unit interval [0, 1], to a crisp (precise) number. Within this framework, a membership value of zero/one corresponds to an element that is definitely not/definitely a member of the fuzzy set. Partial membership is indicated by values between 0 and 1. Implementation of a fuzzy controller requires assigning membership functions for inputs and outputs. Inputs are usually measured variables, associated with the state of the controlled plant that are assigned membership values before being processed by an inference engine. The heart of the controller inference engine is a set of if-then rules whose antecedents and consequents are made up of linguistic variables and associated fuzzy membership functions. Fuzzy set intersection, or conjunction, operators in the antecedent are generally referred to as t-norms. They commonly employ algebraic ***min*** or ***product*** operations on fuzzy membership values. Consequents from different rules are numerically aggregated by fuzzy set union and then defuzzified to yield a single crisp output as the control for the plant.

4. Design of proposed fuzzy controller

The proposed fuzzy controller which is used to specify the optimal sizes and locations of capacitor banks placement consist of two stages which are:-

4.1. First stage fuzzy controller

Fuzzy controller in this stage used to specify the optimal locations which are the capacitor banks installed on it. Node voltages and power loss indices are the inputs to this fuzzy controller to determine the suitability of a node in the capacitor placement problem. The suitability of a node is chosen from the capacitor suitability index at each node. The higher values of capacitor suitability index are chosen as best locations for capacitor placement. To determine the power loss indices, the power loss reduction is calculated by compensating the self-reactive power at each node at a time by conducting the vector based load flow method. These loss reductions are then linearly normalized into a (0, 1) range with the largest loss reduction having a value of '1' and the smallest loss reduction having a value of '0' for calculation of power loss indices (PLI). Fuzzy variables power losses indices (PLI), voltage in p.u. and capacitor suitability index (CSI) are described by fuzzy terms ***low, medium-low, medium, medium-high and high***. The fuzzy variables described above are represented by membership functions as shown in Figures (1 and 2). To determine the location of capacitor the voltage and power loss index at each node shall be calculated and represented in fuzzy membership function. By using these voltages and PLI, rules are framed and are summarized in the fuzzy decision matrix as given in Table (1).

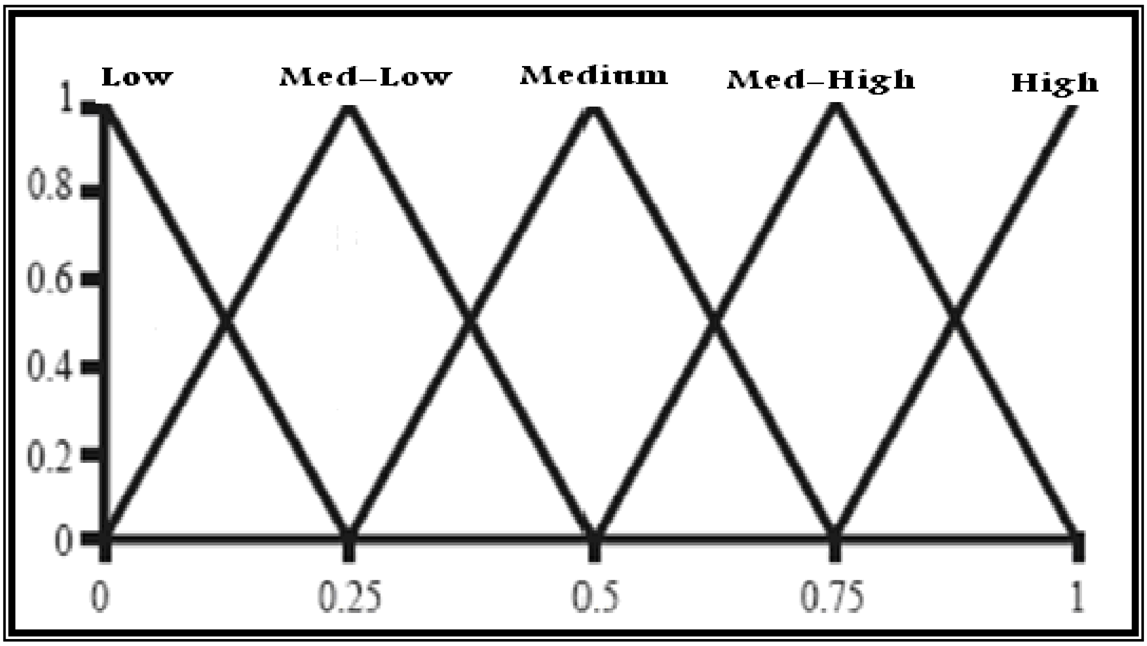

Figure (1). Power losses index and capacitor placement suitability membership functions (1^{st} FLC).

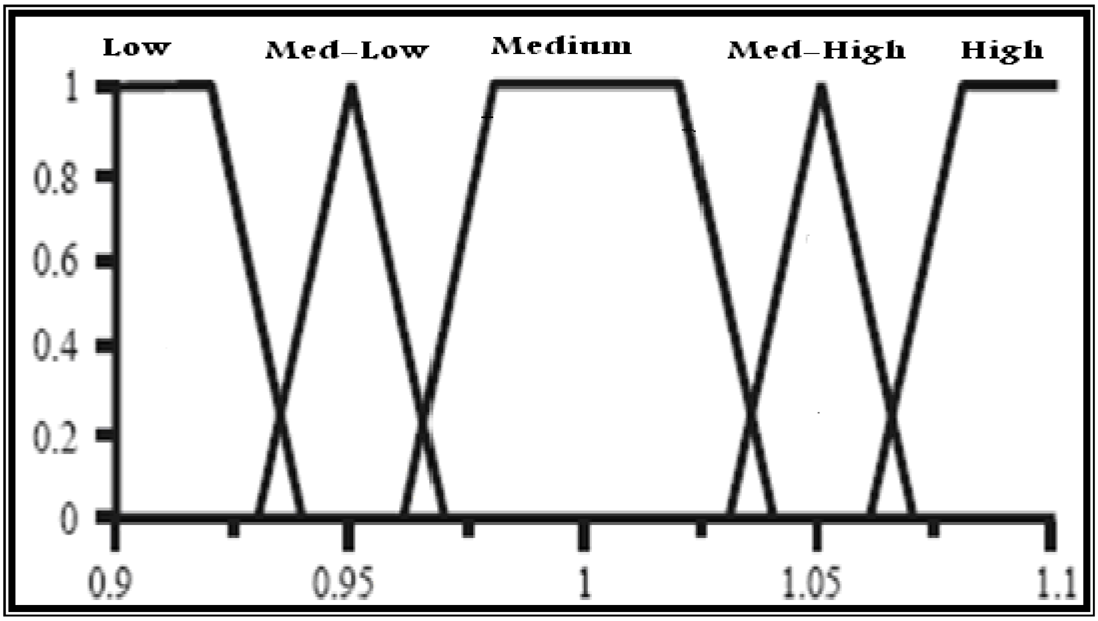

Figure (2). Voltage magnitude membership functions (1st FLC).

Table (1). Decision matrix for determining suitable capacitor location.

DND		**Voltage Magnitude**				
		Low	**Low-Normal**	**Normal**	**High-Normal**	**High**
Power Losses Index	Low	Med.- Low	Med.- Low	Low	Low	Low
	Med.- Low	Med.	Med.- Low.	Med.- Low	Low	Low
	Med.	Med.- High	Med.	Med.- Low	Low	Low
	Med.- High	Med.- High	Med.- High	Med.	Med.- Low	Low
	High	High	Med.- High	Med.	Med.- Low	Med.- Low

4.2. Second stage fuzzy controller

Fuzzy controller in this stage is used to specify the optimal sizes which are installed in pre-specified location from first stage fuzzy controller. The inputs to the second stage fuzzy controller are the voltage and load indices, and the output is the size of capacitor in (MVA). The rules in this fuzzy controller are summarized in fuzzy rule table in Table (2), the fuzzy variables; voltage, load, and capacitor size are described by the fuzzy terms; ***Down Very Very Small (DVVS)***, ***Very Very Small (VVS)***, ***Very Small (VS)***, ***Small (S)***, ***Medium (M), Large (L) and Acceptable (A)***. These fuzzy variables described by linguistic terms are represented by membership functions, the membership function are graphically shown in Figures (3, 4 and 5). The construction of these functions can be based on intuition, rank ordering or probabilistic methods [13]. The membership functions for describing the voltage have been established based on the ICE standards of acceptable operating voltage ranges for power systems ($1 \pm 5\% \, of \; per-unit \; value$ [14]). The membership functions for the load and capacitor size are established to provide a ranking. The minimum membership value for the two inputs propagates through the consequent and truncates the membership functions for the consequent of the rule.

Table (2). Decision matrix for determining capacitor size.

AND		LOAD		
		S	M	L
VOLTAGE	VS	VVS	Vs	S
	S	VS	DVVS	S
	M	VVS	VVS	VVS
	L	DVVS	S	VS
	A	None	None	None

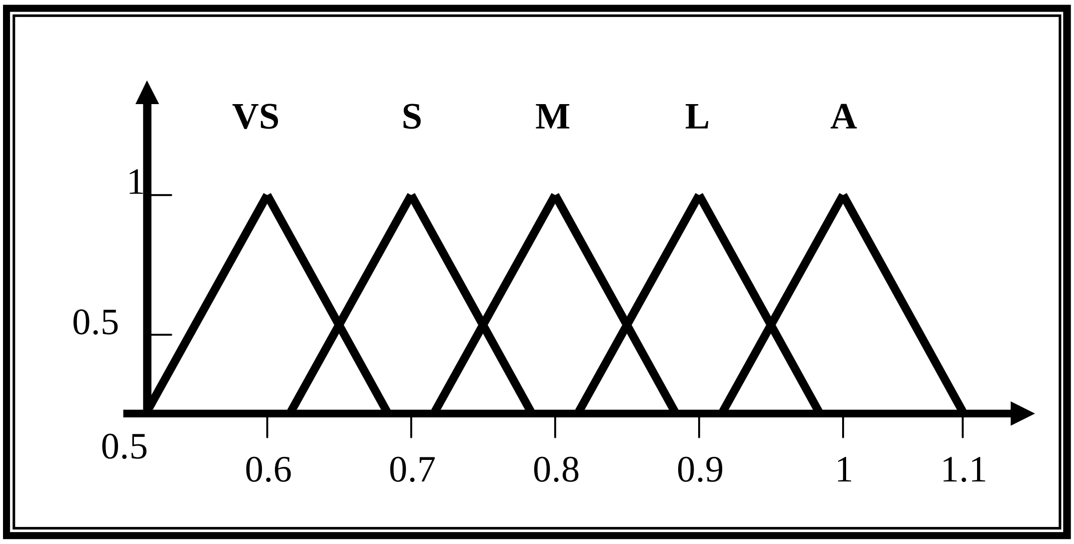

Figure (3). Voltage membership function (2nd controller).

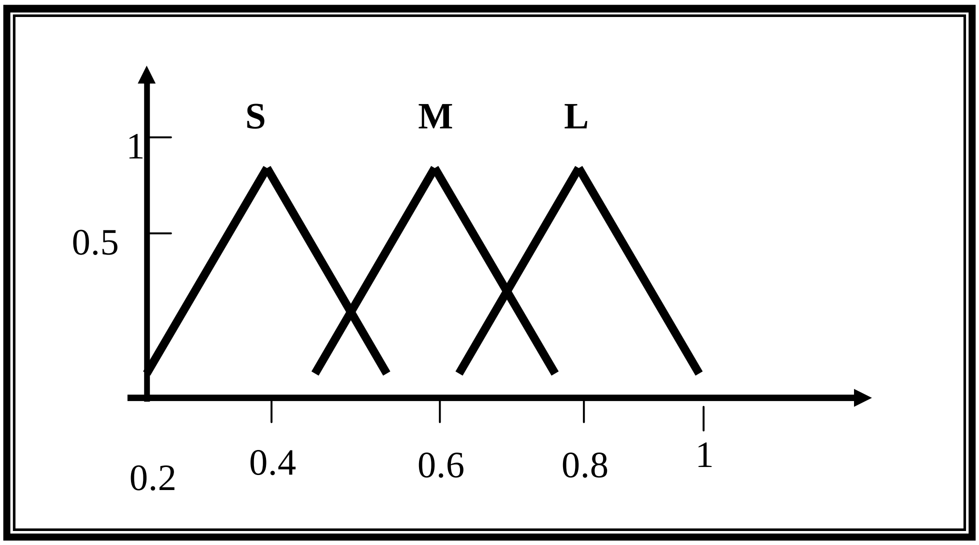

Figure (4). Load membership function (2nd controller).

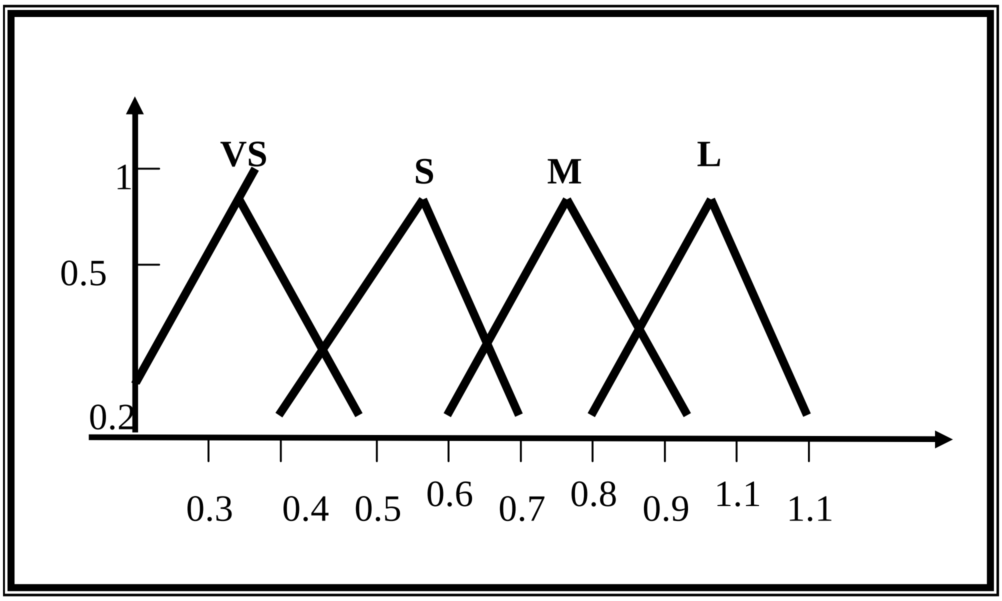

Figure (5). Capacitor size membership function (2nd controller).

5. Fuzzy inferencing and de-fuzzification

After the fuzzy controller receives inputs from the load flow program, several rules may fire with some degree of membership. The MAX-MIN METHOD involves truncating the consequent membership function of each fired rule at the minimum membership value of all the antecedents. A final aggregated membership function is achieved by taking the union of all the truncated consequent membership functions of the fired rules. For the capacitor location problem, resulting capacitor placement suitability membership function, μ_S, of node i for k fired rules is given by:- [9]

$$\mu_S(i) = \max_k[\min[\mu_P(i), \mu_V(i)]] \tag{1}$$

Where μ_P and μ_V are the membership functions of the power losses index and voltage magnitude respectively.

For the capacitor size problem, resulting capacitor size membership function, μ_C, of node i for k fired rules is given by:-

$$\mu_C(i) = \max_k[\min[\mu_V(i), \mu_L(i)]] \tag{2}$$

Where μ_V and μ_L are the membership functions of the voltage magnitude and load level respectively.

Once the suitability and capacitor size membership functions of a node is calculated, it must be defuzzified in order to determine the node suitability and size ranking. The centroid method of defuzzification is used; this finds the center of the area of the membership function. Thus, the capacitor suitability and capacitor size indices are determined by:-

$$S \ or \ C = \frac{\int \mu_{S,C}(z).dz}{\int \mu_{S,C}(z)dz} \tag{3}$$

Where

S, C is the Suitability of optimal location and optimal capacitor size respectively.

$\mu_{S,C}(z)$ is the membership function.

Z is the height of the membership function.

6. Proposed solution method

From studies and experiments with several methods reported in literature, a two- stage fuzzy controller is proposed to solve the problem of voltage collapse and increase in real power losses which effect the performance of power system. First stage fuzzy controller is used to specify the suitability indices of buses, since the buses of highest suitability indices (SI) represent the optimal locations to capacitor placement, the second stage of this fuzzy controller works only with the buses previously selected. The proposed method consists of the following steps:-

1- Perform Load-Flow program to calculate bus voltages and power losses considering the original configuration which means without any capacitor installed.
2- Bus voltage (BV) is defined for each bus dividing the voltages calculated in step one by the substation voltage.
3- Calculate the power losses reduction by injecting the same amount of reactive power at every node of power system.
4- The losses reduction calculated by step three are linearly normalized into a "0" and "1" range with the largest losses reduction having a value of "1" and the smallest one having a value of "0", the values between "0" and "1" are the power losses indices (PLI).
5- Values which are calculated from steps two and four (BV and PLI) are the input values of 1^{st} stage fuzzy controller to find the optimal locations of capacitor installation which represents the output of this controller.
6- After specifying the optimal locations of capacitor installation in steps (1-5), the variables of BV and the amount of load in each load level are processes as input variables to the 2^{nd} stage fuzzy controller to find the optimal sizes of capacitor value in MVA installed in each pre-specified optimal locations. The optimal value of capacitors represents the output of 2^{nd} stage fuzzy controller.
7- After finding of optimal sizes and optimal locations by two stages fuzzy controller, the load flow program is then performed again to know the impact of proposed solution method on the real power losses reduction and if the voltage profile within permissible limits ($1 \pm 5\% \, of \;\; per - unit \;\; value$) or not.

7. Application

The proposed method is applied to 34-bus, 74- transmission line power system whose single line diagram can be shown in figure (6). This power system is derived from a portion of a transmission power system from Al-Mousel in the north of Iraq found in [15]. This power system consists of bus-1 as slack bus, buses 30,31,32,33 and 34 as voltage-controlled buses and buses from 2 to 29 as load buses. The power system under test is subjected to four levels of loads namely Level-1 (50% PL), Level-2 (75%PL), Level -3 (Peak Load) and Level-4 (125%PL). The system parameters and initial buses data are shown in Tables (3-5). [15].

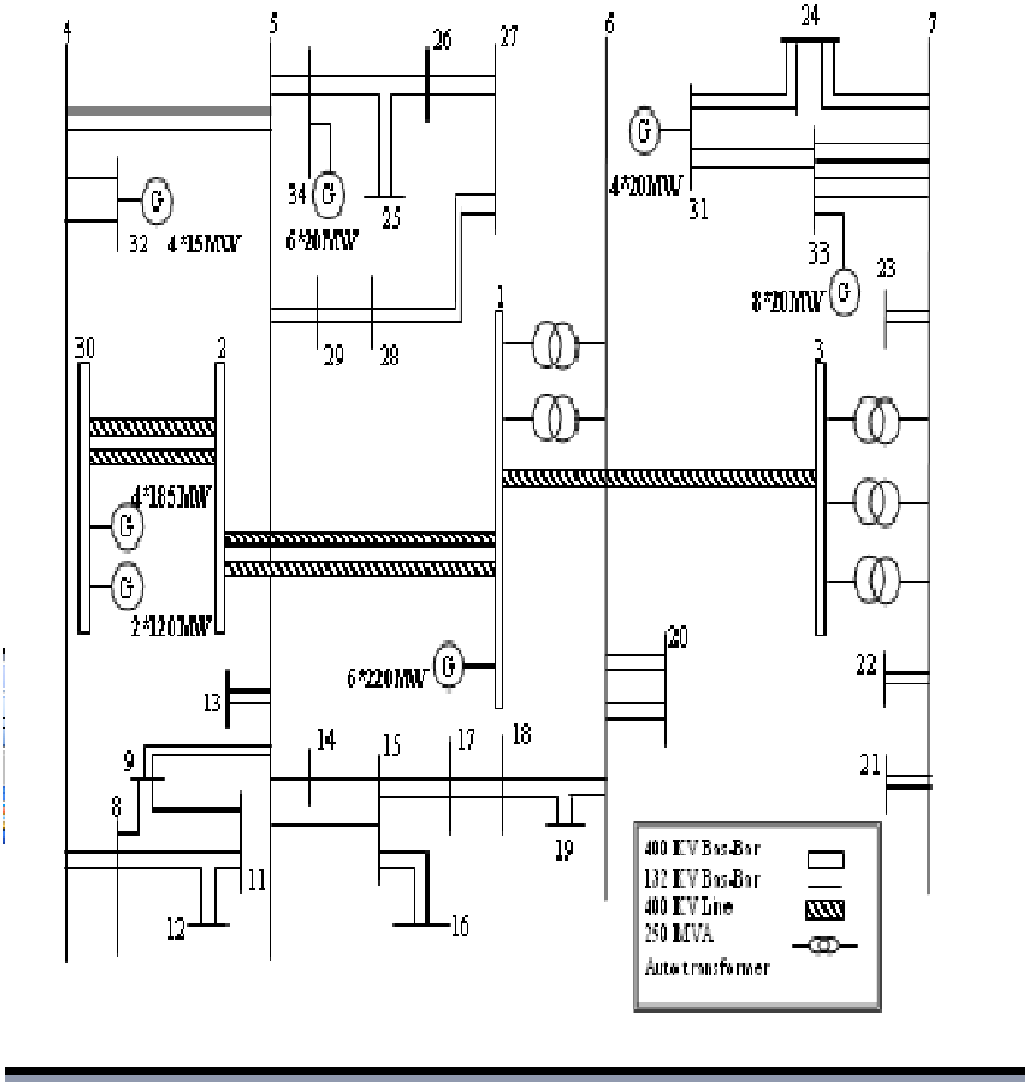

Figure (6). Single line diagram of power system under study .[15]

Table (3). Network data .[15]

Bus-No	From Bus	To Bus	R (P.U)	X (P.U)	B (P.U)	Length (Km)
1	2	30	0.00143	0.01202	0.3643	63
2	2	30	0.00143	0.01202	0.3643	63
3	2	1	0.004	0.03605	1.068	183
4	2	1	0.004	0.03605	1.068	183
5	1	3	0.00182	0.01654	0.49	84
6	1	6	0	0.036	0	0
7	1	6	0	0.036	0	0
8	2	5	0	0.036	0	0
9	2	5	0	0.036	0	0
10	2	5	0	0.036	0	0
11	3	7	0	0.036	0	0
12	3	7	0	0.036	0	0
13	3	7	0	0.036	0	0
14	4	5	0.0367	0.1465	0.0342	66
15	4	5	0.0367	0.1465	0.0342	66
16	4	32	0.00556	0.0222	0.00518	10
17	4	32	0.00556	0.0222	0.00518	10
18	4	8	0.00725	0.04058	0.01917	26
19	4	8	0.00725	0.04058	0.01917	26
20	5	9	0.0322	0.1288	0.03	58
21	5	9	0.0322	0.1288	0.03	58
22	5	13	0.007	0.0279	0.0065	12.6
23	5	13	0.007	0.0279	0.0065	12.6
24	5	14	0.0247	0.0538	0.0113	23
25	5	15	0.0573	0.1158	0.0238	49
26	5	34	0.0025	0.014	0.0066	9
27	5	34	0.0025	0.014	0.0066	9
28	5	29	0.0016	0.0094	0.0044	6
29	5	29	0.0016	0.0094	0.0044	6
30	6	18	0.0493	0.13615	0.0298	59.5
31	6	19	0.0343	0.09807	0.0216	43
32	6	20	0.0084	0.0229	0.005	10
33	6	20	0.0084	0.0229	0.005	10
34	6	20	0.0084	0.0229	0.005	10
35	6	20	0.0084	0.0229	0.005	10
36	7	21	0.00446	0.0249	0.01179	16
37	7	21	0.00446	0.0249	0.01179	16
38	7	22	0.0118	0.032	0.007	14
39	7	22	0.0118	0.032	0.007	14

Table (3).Continued.[15]

Bus-No	From Bus	To Bus	R (P.U)	X (P.U)	B (P.U)	Length (Km)
40	7	23	0.0448	0.01215	0.0265	53
41	7	23	0.0448	0.01215	0.0265	53
42	7	24	0.0081	0.0453	0.0214	29
43	7	24	0.0081	0.0453	0.0214	29
44	7	33	0.0169	0.0459	0.01	20
45	7	33	0.0169	0.0459	0.01	20
46	7	33	0.0169	0.0459	0.01	20
47	7	33	0.0169	0.0459	0.01	20
48	8	9	0.0183	0.0732	0.0171	33
49	8	10	0.01337	0.0659	0.0258	38
50	8	11	0.0389	0.01555	0.0362	70
51	8	12	0.0184	0.0859	0.0304	47
52	9	11	0.0205	0.08217	0.0192	37
53	10	12	0.01056	0.0422	0.0098	29
54	14	15	0.0326	0.062	0.0125	26
55	15	16	0.03636	0.0985	0.0215	43
56	15	16	0.03636	0.0985	0.0215	43
57	15	17	0.2114	0.0573	0.0125	25
58	15	17	0.2114	0.0573	0.0125	25
59	17	18	0.03213	0.0871	0.019	37
60	17	18	0.03213	0.0871	0.019	37
61	18	19	0.0169	0.0458	0.01	23.5
62	24	31	0.0515	0.0977	0.0197	41
63	24	31	0.0515	0.0977	0.0197	41
64	31	33	0.01457	0.06411	0.01873	32
65	31	33	0.01457	0.06411	0.01873	32
66	34	25	0.02479	0.0687	0.015	31
67	34	26	0.03128	0.085	0.0185	37
68	25	26	0.0087	0.0251	0.00554	11
69	26	27	0.02114	0.0574	0.0125	25
70	26	27	0.02114	0.0574	0.0125	25
71	27	28	0.00715	0.042	0.202	55
72	27	28	0.00715	0.042	0.202	55
73	29	28	0.00379	0.0212	0.01003	13.6
74	29	28	0.00379	0.0212	0.01003	13.6

Table (4). Load data .[15]

Bus-No	P (Mw)	Q (Mvar)	Bus-No	P (Mw)	Q (Mvar)
1	0	0	18	37	21
2	595	173	19	35	28
3	0	0	20	172	115
4	0	0	21	89	48
5	0	0	22	63	32
6	0	0	23	32	29
7	0	0	24	104	69.4
8	18	12	25	135	53
9	38	30	26	189	57
10	20	13	27	92	52
11	43	34	28	87	37
12	18	13	29	158.2	56
13	34	24	30	0	0
14	28	22	31	0	0
15	24	20	32	0	0
16	18	10	33	93	61
17	42	26	34	51	27

Table (5). Generators data .[15]

Base Value (100 MVA)					
Bus-No.	PGi max	QGi min	QGi max	VGi min	VGi max
1	13.2	-2	4	0.95	1.1
30	9.8	-1.5	3.5	0.95	1.1
31	0.8	51-0.	0.25	0.95	1.1
32	0.6	-0.1	0.2	0.95	1.1
33	1.6	-0.2	0.8	0.95	1.1
34	1.4	-0.05	0.5	0.95	1.1

8. Simulation results

An Iterative method of Load-Flow analysis namely Newton-Raphson method is used as a tool to determine the power losses and voltage profile of test power system before and after installing shunt capacitors used to improvement the performance of power system under study. The proposed solution method is based on designing of two-stages fuzzy controller to find the optimal sizes and locations of installed capacitors. The output of 1^{st} stage is the suitability indices of every load buses which are illustrated in Table (6), from this table we find that the optimal locations are Buss 25,26,27 in the first level and Buses 11, 25,26,27,28 in the second level and Buses 11,14,15,16,25,26,27,28 in the third level and 8,11,13,14,15,16,25,26,27,28 in the fourth level due to its highest suitability indices. The output of 2^{nd} stage of designing fuzzy controller is the optimal sizes of capacitors which are illustrated in Table (4). Also the values in Table (7) show that the minimum bus voltages during all four load levels are less than permissible limits of pre-specified minimum allowable bus voltages, then these values became within permissible values after capacitor installation as well as the reduction of real power losses with percentage reduction ratio of 28% in 1^{st} level , 35% in 2^{nd} level, 39.2% in 3^{rd} level and 51.42% in 4^{th} level after the installation process. The differences in the real power system before and after the capacitor placement in all study load level are shown in Figure(7).

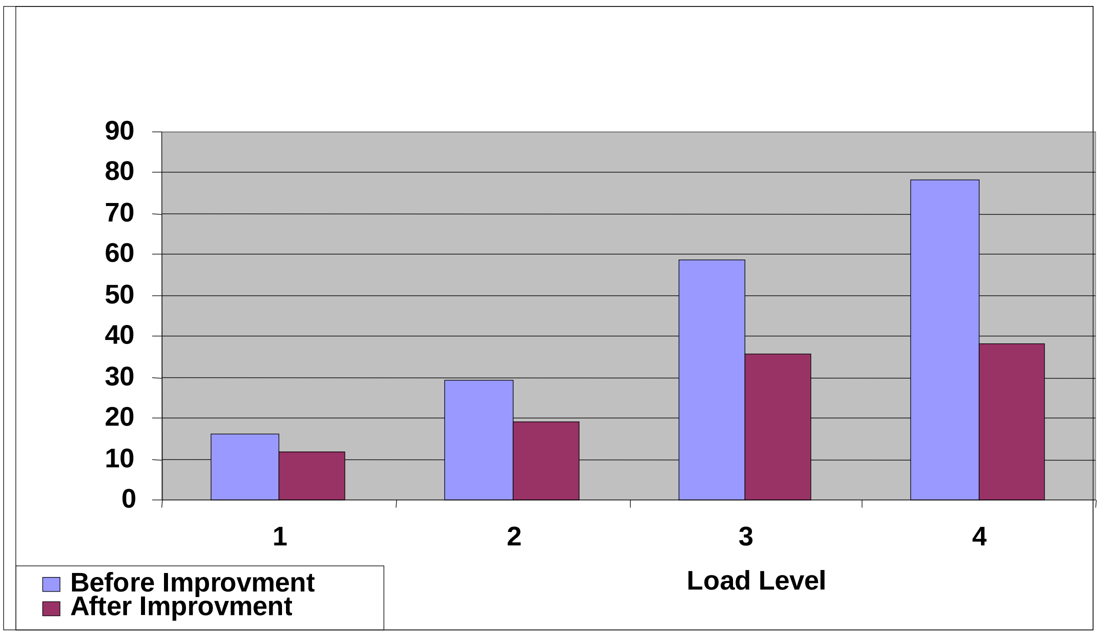

Figure (7). Impact of solution method on power losses reduction.

Table (6). Suitability indices of optimal locations.

Bus No.	Suitability Index of optimal locations			
	Level-1	Level-2	Level-3	Level-4
Bus-2	0.133	0.170	0.203	0.433
Bus-3	0.240	0.315	0.325	0.366
Bus-4	0.185	0.327	0.438	0.345
Bus-5	0.485	0.250	0.438	0.345
Bus-6	0.426	0.320	0.345	0.395
Bus-7	0.285	0.325	0.335	0.413
Bus-8	0.413	0.422	0.439	0.652
Bus-9	0.325	0.388	0.415	0.437
Bus-10	0.24	0.275	0.313	0.417
Bus-11	0.488	0.619	0.625	0.666
Bus-12	0.238	0.326	0.412	0.444
Bus-13	0.335	0.413	0.463	0.736
Bus-14	0.426	0.400	0.776	0.852
Bus-15	0.413	0.390	0.765	0.801
Bus-16	0.400	0.327	0.740	0.810
Bus-17	0.190	0.225	0.250	0.35
Bus-18	0.222	0.250	0.247	0.249
Bus-19	0.312	0.250	0.239	0.246
Bus-20	0.320	0.250	0.313	0.237
Bus-21	0.295	0.245	0.205	0.222
Bus-22	0.315	0.300	0.312	0.381
Bus-23	0.240	0.251	0.255	0.275
Bus-24	0.312	0.285	0.222	0.295
Bus-25	0.710	0.783	0.883	0.950
Bus-26	0.701	0.783	0.883	0.930
Bus-27	0.665	0.755	0.855	0.950
Bus-28	0.239	0.676	0.825	0.925
Bus-29	0.180	0.250	0.247	0.211

Table (7). Simulation results of proposed solution method.

Load Level	Optimal Locations	Optimal Sizes (MVar)	Minimum Voltage (P.U)		Real Power Losses (MW)	
			Before improvement	After improvement	Before improvement	After improvement
Level-1	Bus-25	15.00	0.9240	0.9606	16.3644	11.7730
	Bus-26	15.85	0.9204	0.9576		
	Bus-27	16.15	0.9255	0.9630		
Level-2	Bus-11	18.00	0.9377	0.9690	29.2004	18.9847
	Bus-25	15.00	0.9094	0.9577		
	Bus-26	15.85	0.9036	0.9537		
	Bus-27	16.15	0.9163	0.9509		
	Bus-28	16.50	0.9324	0.9659		
Level-3	Bus-11	18.00	0.9126	0.9511	58.4939	35.5592
	Bus-14	16.50	0.9078	0.9683		
	Bus-15	16.65	0.8765	0.9475		
	Bus-16	18.00	0.8592	0.9625		
	Bus-25	17.50	0.8810	0.9507		
	Bus-26	21.85	0.8723	0.9565		
	Bus-27	18.15	0.8705	0.9505		
	Bus-28	18.50	0.9012	0.9604		
Level-4	Bus-8	19.50	0.8954	0.9687	78.1732	37.9732
	Bus-11	18.00	0.8933	0.9579		
	Bus-13	15.60	0.8722	0.9543		
	Bus-14	16.50	0.8255	0.9265		
	Bus-15	16.65	0.8029	0.9586		
	Bus-16	18.00	0.8974	0.9607		
	Bus-25	17.50	0.8577	0.9573		
	Bus-26	21.85	0.8454	0.9525		
	Bus-27	18.15	0.8370	0.9607		
	Bus-28	18.50	0.8720	0.9511		

9. Conclusions

A simulation program for improving the performance of multi-level load power system by using two-stage fuzzy controller is prepared in the MATLAB-7.5 programming language to specify the optimal sizes and locations of shunt capacitors. The fuzzy logic approach is very appropriate to solve the size, location, and control problem, it is more efficient to solve this kind of problem especially when specialist's knowledge about the problem is included. This paper presents a proposed controller for managing the voltage at the different nodes of multilevel power system; it is based on the fuzzy technique using shunt capacitors. A real case study has been introduced indicating the applicability and effectiveness of fuzzy set theory to manage the voltage in power systems in addition to reduction of power losses. Fuzzy logic approach reduces the search space and consequently decreases the execution time, increasing the chances to reach the global optimal solution.

10. References

[1] Elrazaz Z. and Al-Ohaly A. A., July 1993,"Optimal Coordination of Shunt Recators to Enhance System Performance at Light Load Operation.," IEE Proceedings on Generation, Transmission and Distribution, vol. 140, pp. 293-298.

[2] H. N. Ng, Salama M. M. A., and Chikhani A. Y., January 2000,"Classification of Capacitor Allocation Techniques," IEEE Transactions on Power Delivery, vol. 15, pp. 387-392.

[3] Martins R. M., Oliveira A. de, and de Paula Silva S. F., 1998,"A New Proposal to Capacitor Bank Allocation Using Fuzzy Logic," presented at International Conference on Power Electronic Drives and Energy Systems for Industrial Growth.

[4] Masoum M. A. S., Ladjevardi M., Jafarian A., and Fuchs E. F., 2004,"Optimal Placement, Replacement and Sizing of Capacitor Banks in Distorted Distribution Networks by Genetic Algorithms," IEEE Transactions on Power Delivery, vol. 19, pp. 1794-1801.

[5] Sivanagaraju S., Giridhar M.S., Jagadeesh Babu E., and Srikanth Y., 2004, “A Novel Load Flow Technique for Radial Distribution System”, in Proc. National Power System Conference, NPSC-2, IIT Madras, India, pp. 140-144.

[6] Bansal R.C, Nov.2003,"Bibligraphy on the Fuzzy Set Theory Applications in Power Systems (1994-2001)", IEEE Trans. Power Systems, Vol. 18, No.4, pp.1291-1299.

[7] Issicaba D., Bettiol A. L., Coelho J. and Alcantara M. V. P., 2006,"A New Approach for Optimal Capacitor Placement in Distribution Systems", Proceedings of the 6th WSEAS International Conference on Power Systems, Lisbon, Portugal, September 22-24.

[8] Mahdad B., Bouktir T., and Srairi K., July-December 2005," Dynamic Compensation of the Reactive Energy using a Fuzzy Controller", Leonardo Electronic Journal of Practices and Technologies ISSN 1583-1078 Issue 7.

[9] Prasad, P.V. , Sivanagaraju, S. and Sreenivasulu, N., June, 2007,” A Fuzzy Genetic Algorithm for Optimal Capacitor Placement in Radial Distribution System”, ARPN Journal of Engineering and Applied Sciences, Vol. 2, No. 3.

[10] Tamer M. K., Hosam K.M. Y. and Abdel A., 13 - 15 June 2006,"A Binary Particle Swarm Optimization for Optimal Placement and Sizing of Capacitor Banks in Radial

Distribution Feeders with Distorted Substation Voltages", AIML 06 International Conference, Sharm El Sheikh, Egypt.

[11] Houssem B. A. and Hsan H. A., January-June 2007" Multi Objectives Reactive Dispatch Optimization of an Electrical Network", Leonardo Journal of Sciences, ISSN 1583-0233, Issue 10.

[12] Ng H. N., Salama M.M. and Chikhani A. Y., January 2000," Capacitor Allocation by Approximate Reasoning: Fuzzy Capacitor Placement", IEEE Transactions on Power Delivery, Vol. 15, No. 1.

[13] Ross T.J., 1995,"Fuzzy Logic with Engineering Applications", McGraw-Hill Inc.

[14] Dilek , Murat , 2001" Integrated Design of Electrical Distribution Systems: Phase Balancing and Phase Prediction Case Studies", Ph.D. Thesis, Virginia Polytechnic Institute and State University.

[15] AL-Suhamei , Wared S.W., 2002," Minimization of Losses In The Iraqi Northern Network of 400Kv &132Kv ", Msc Thesis, College of Engineering, University of Mosul.