AN IMMUNE BASED MULTI-OBJECTIVE APPROACH TO ENHANCE THE PERFORMANCE OF ELECTRICAL DISTRIBUTION SYSTEM

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ABSTRACT

An immune based approach to enhance the performance of electrical distribution system through capacitor placement is proposed in this paper. Major challenges that occur in distribution system are voltage drop and real power losses. The placement and sizing calculations of capacitor gives more insight to solve problems, which occur while maintaining voltage profiles at each bus by reducing voltage drops in each branch. The performance of the electrical distribution system can be improved with the above proposed technique. This technique have two sub methods, one for finding capacitor location through heuristic and second one for finding capacitor size through genetic algorithm and the proposed methods are tested on IEEE 69 bus system to reduce the real power losses with better voltage profile at each load buds and the results are validated.

Keywords*—Heuristic method, Genetic algorithm, Loss sensitivity factor, Voltage drop, Real power loss, Capacitor placement and size.*

I. INTRODUCTION

Around 33% of the generated power is wasted as heat during distribution of power. The presence of reactive elements further increases real and reactive power losses since they draw more current than resistive elements. Hence in order to improve efficiency of the distribution system, capacitor banks are to be placed at suitable locations.

The placement of capacitor banks also improves the voltage profile of the system. Thus the capacitor bank placement is vital for power flow control, improving system stability, power factor correction, voltage profile management and the reduction in energy losses. Capacitor placement is used to minimize active and reactive power losses in electrical distribution system and also attain quality power supply. If proper selection and placement of capacitor is not done then it behaves in abnormal way and voltage drops may increase beyond limits and effects the system with more power losses with poor voltage profile at each load bus. Considering the above problems, many researchers are working for the best solution using various methods. Among them some of the techniques are taken as main choices like Particle swarm optimization, Genetic Algorithm, Ant colony algorithm, Fuzzy evolutionary programming, simulated annealing etc.

A new approach of using immune based optimization to solve capacitor placement problem [1].In this paper they considered two methods one is simulated annealing[SA] and other is mixed integer programming, SA is used to find computation time and system cost whereas mixed integer programming decomposed into two problems, master and slave. The master is used to determine capacitor location and slave is used to find type and size of the capacitors. It is applied for a IEEE-69 test bus system.

Mixed integer programming [2] is used for determining placement of capacitor and its size, but the assumptions made in this are not permissible. Applying loss sensitivity factor and genetic algorithm for calculating location and size of capacitor [3] had shown an improvement in voltage regulation. These methods are applied for an IEEE-34 bus, 15 bus, and 69 bus test systems. DG placement in distribution network for power loss minimization using genetic algorithm [4].Genetic algorithm is applied for a

IEEE-33 bus system where the GA arecomparedwith the results of harmony search algorithm using Matlab.Large number of capacitor banks may reduce reactive power demand from conventional generators, but it can affect generators and transmission line performance. In this power DG's are used with capacities ranging from 1 kW to 1000MW.To overcome drawbacks like system power less, voltage fluctuation etc.

Reconfiguration of system helped in reducing power loss by 31.05% .Forthcoming methods have shown better result than this by determining optimum capacitor placement in electrical distribution system using loss sensitivity factor [5].In this paper the results are compared with index vector method which showed a better result.

The capacitor placement in electrical distribution system is assessed by using simulated annealing method [6], where it showed 13% of thepower produced in the system wastes as ohmic losses. Here analytical method is used to find capacitor allocation and size. Analytical method is mostly preferred by the researchers as it needs few numerical data from the distribution system and it is easily applied in practice. But it is practically good for determining cost and computation time of the electrical distribution system.

In past lot of work has been carried out on the area of reactive power compensation. Recently to obtain optimum values of capacitors researchers are picking up genetic algorithm and simulated annealing [7] for better results.

But genetic algorithm requires high CPU time whereas genetic operations like (selection, crossover and mutation) requires very less time. In an early researcher's work fuzzy technique is used for calculating capacitor allocation and size of it [8].It is applied for a radial distribution system, which is popular among all electrical distribution systems based on low cost and simple design. This technique has a disadvantage that it lags with mathematical description.

Feeder reconfiguration with dispatch able distributed generators in distribution system by Tabu search[9].The main intention of feeder reconfiguration is to minimize the system power losses and distribution generators cost is minimized. This method is applied on 69-test bus system.

In this paper, based on mechanism of evolution immune based optimization is considered for determining capacitor location and size. This paper deals with two methods: Heuristic search is to find optimal capacitor allocation, for determining capacitor size Genetic algorithm is used. Loss sensitivity factor is used through heuristic approach for capacitor allocation based on ranking.

The paper is organized as Chapter-II that states about problem statement, Chapter-III reveals about techniques proposed and Chapter-IV mentions about results and analysis followed by conclusions.

II. PROBLEM STATEMENT

Electrical distribution system is growing in large and becoming complex, leading to more real power losses and maximum voltage drop in each branch, this results poor voltage at each load bus. Therefore to minimize this problem,suitablecapacitors are to be placed at appropriate locations in electrical distribution system. After calculating optimal size and location of the capacitor, when capacitor is placed at above location with appropriate size the voltage profile gets improved as capacitors inject reactive power at nodes to reduce losses and voltage drop. Capacitor placement iscapable to minimize the chance in voltage deviation. When some large or small disturbances occur in the system the voltage will fall,if it declines sharply then it can damage loads that are connected to electrical distribution system. So by installing suitable capacitor at proper location with suitable size, the electrical distribution system attains good quality power supply in terms of voltage.

A. Problem Formulation

Line losses:

The amount of power that can be transmitted through a material is limited by several factors, including the material itself and the temperature of the environment. This limitation is observed as a decrease in power from the source to the destination, called line loss.The purpose or intention of placing a capacitor at proper

location with proper size is to reduce voltage drop at each bus where reactive power compensation is required and minimize real power losses and improve bus voltage.
The real power loss which is expressed as $[I_k\text{^}2]*R_k$ can also be given as,
P_{loss} [j] = $[[P_{jeff}\text{^}2+Q_{jeff}\text{^}2]*R_k]/[V_j\text{^}2] \rightarrow$ (1)
Q_{loss} [j] = $[[P_{jeff}\text{^}2+Q_{jeff}\text{^}2]*X_k]/[V_j\text{^}2] \rightarrow$ (2)

Loss sensitivity factor:
It is used to determine proper capacitor allocation. Loss sensitivity factor decides the sequence in which buses are to be considered for capacitor placement. It is used to predict which bus will have the biggest loss reduction when a suitable capacitor is placed. The estimation of buses which require reactive power compensation basically helps in reduction of the search space for the optimization problem. As few number of buses are recommended for compensation with optimal installation cost. Formula for loss sensitivity factor is given by partially differentiating line loss with respect to reactive power,

$$\frac{\partial Plineloss}{\partial \mathrm{Qeff[j]}} = (2 * \mathrm{Qeff[j]}) * \frac{Rk}{[\mathrm{Vj}^2]} \rightarrow (3)$$

$$\frac{\partial Qlineloss}{\partial \mathrm{Qeff[j]}} = (2 * \mathrm{Qeff[j]}) * \frac{Xk}{[\mathrm{Vj}^2]} \rightarrow (4)$$

Where $P_{eff}[j]$ = Total effective active power supplied beyond the bus'j'
$Q_{eff}[j]$ = Total effective reactive power supplied beyond the bus 'j'

III. PROPOSED METHOD

Immune algorithm:
Immune algorithm belong to the artificial immune systems field of study concerned with computational methods inspired by the process and mechanisms of the biological immune system. A simplified description of the immune system is an organ system intended to protect the host organism from the threats posed to it from pathogens and toxic substances. Pathogens encompass a range of microorganisms such as bacteria, viruses, parasites and pollen. The traditional perspective regarding the role of the immune system, which is divided into two primary tasks, detection and elimination of pathogens. The architecture of immune system is such that a series of defensive layers protect the host.

For an immune system operation, the antigens should be eliminated by an antibody. Immune system is made up of organs, cells and tissues including a type of white blood cells called lymphocytes. These lymphocytes acts as antibody and eliminates antigens. Lymphocytes are of two types:

- B-Lymphocytes,
- T-Lymphocytes.

B-Lymphocytes are emerged from bone marrow and T-Lymphocytes from thymus-Lymphocytes are the cells that are alerted when" bad agents" enter the system. These bad agents have antibodies on their surface which are also called as antigens.
T-Lymphocytes come into action when B-Lymphocytes detect bad agents and pass information to take action to T-Lymphocytes. The antibody which recognize antigen is called as epitope. The mechanism of immune system is shown in fig.1.

Mechanism of immune system:

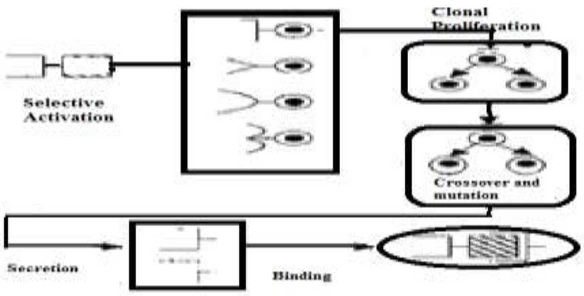

Figure: 1-Immune mechanism

Basically voltage drop is considered as major problem in electrical distribution system, because it is becoming large and complex. Initially calculate actual reactive power losses at selective activation. After the calculation of reactive power losses lymphocytes that play a vital role in immune system, in this paper loss sensitivity factor is considered as lymphocytes i.e.; Loss sensitivity factor is calculated and given ranking based on their severity in decreasing order(max to min).The clonal proliferation process detects the affected branch at which capacitor placement is needed. According to biology clonal proliferation process is described as selection and reproduction of only one type of cell. After this process it is given to genetic operations like crossover and mutation where the capacitor size is calculated using genetic algorithm. In this paper the capacitor location and size are considered as antibodies in electrical distribution system. The process secretion generates antibodies that help in reducing voltage drop at each branch and decrease real power losses by placing suitable capacitor at proper location with appropriate size. The calculations after placing capacitor shows that the antigens like real power losses are reduced and can attain good quality of power supply.

Heuristic search algorithm for capacitor allocation:

Conventional optimization methods face difficulties and often end up by preventing these methods to determine a solution to optimization problem within reasonable period of time. To avoid these cases alternative methods are proposed, which are able to determine solution which are not accurate but they provide quality approximations to exact solutions. These alternative methods are called as heuristics, which are initially and essentially based on expert's knowledge and experience and aimed to explore in a proper and convenient way.

The alternative method used in this paper is loss sensitivity factor for calculating capacitor allocation. The exact bus is predicted after capacitor placement. The following steps are to be performed to find out the potential buses for capacitor placement:

Step-1: Initially calculate line losses as given in equations 1 and 2.

Step-2: Now calculate loss sensitivity factor at each bus using equations 3and 4.

Step-3: Among all the values, select few buses based on their severity, and arrange it in a descending order and give ranking for it.

Genetic algorithm for capacitor size:

Implementing genetic algorithm based capacitor sizing. To minimize voltage drop and real power losses calculate optimum values of capacitors that are to be placed at proper location in electrical distribution system.

Algorithm for GA based capacitor sizing:

Step-1: Generate random population at candidate nodes for sizes of capacitors.

Step-2: Perform load flows to determine various node voltages, active power losses.

Step-3: Determine fitness function values.

Step-4: Select parent strings by stochastic universal sampling selection process.

Step-5: Perform crossover and mutation on the selection strings and obtain new strings for next generation.

Step-6: Repeat steps 2 to 5 until the difference between best fitness and average fitness is less than specified error or predefined iterations.

Step-7: Stop.

FLOWCHART:

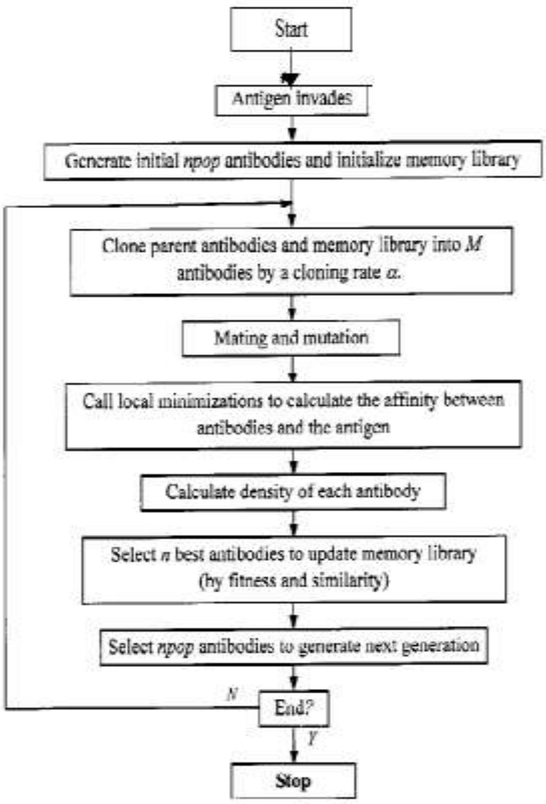

Figure: 2-Flowchart for immune algorithm

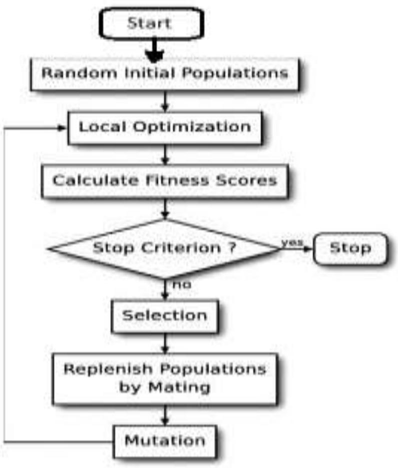

Figure:3-Flowchart for heuristic method

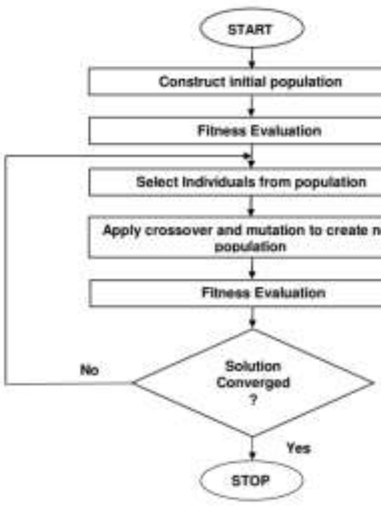

Figure: 4-Flowchart for calculating capacitor size using genetic algorithm

IV.RESULTS

In this chapter Loss sensitivity factor and Genetic algorithm for capacitor allocation and size are discussed. The loss sensitivity factor and Heuristic approach are used to determine the candidate buses for capacitor placement and genetic algorithm is used to find the sizes of shunt capacitors to be installed at candidate buses.fig:2-describes the immune algorithm by using flowchart, and fig:3-represents flowchart that shows step by step procedure of calculating capacitor allocation using heuristic method and fig:4-describes genetic algorithm for calculating capacitor size. Base configuration of IEEE-69 bus system is shown in Fig: 5 and table.1 shows the data of testing system. For calculations of IEEE-69 bus system the following are considered, that is Base kV= 12.66, Base MVA= 0.1.Fig-6 shows optimal configuration of 69 bus system after capacitor placement.

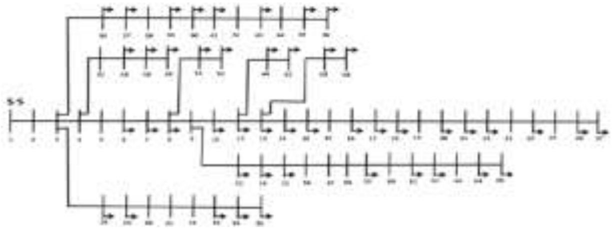

Figure.5- Base configuration of 69-bus system

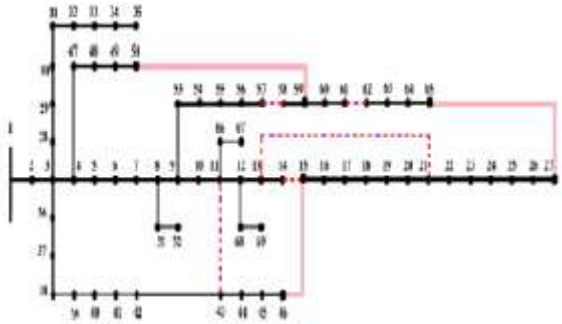

Figure: 6-Optimal configuration of 69-bus system

Table 1: Network data for 69-bus system

Line no.	Bus (From)	Bus (To)	R (ohms)	X (ohms)	P_{load} (kW)	Q_{load} (kVAR)
1	1	2	0.0005	0.0012	0	0
2	2	3	0.0005	0.0012	0	0
3	3	4	0.0015	0.0036	0	0
4	4	5	0.0251	0.0294	0	0
5	5	6	0.3660	0.1864	2.6	2.2
6	6	7	0.3811	0.1941	40.4	30
7	7	8	0.0922	0.0470	75	54
8	8	9	0.0493	0.0251	30	22
9	9	10	0.8190	0.2707	28	19
10	10	11	0.1872	0.0619	145	104
11	11	12	0.7114	0.2351	145	104
12	12	13	1.0300	0.3400	8	5.5
13	13	14	1.0440	0.3450	8	5.5
14	14	15	1.0580	0.3496	0	0
15	15	16	0.1966	0.0650	45.5	30.0
16	16	17	0.3744	0.1238	60	35
17	17	18	0.0047	0.0016	60	35
18	18	19	0.3276	0.1083	0	0
19	19	20	0.2106	0.0690	1	0.6
20	20	21	0.3416	0.1129	114	81
21	21	22	0.0140	0.0046	5.0	3.5
22	22	23	0.1591	0.0526	0	0
23	23	24	0.3463	0.1145	28	20
24	24	25	0.7488	0.2475	0	0
25	25	26	0.3089	0.1021	14	10
26	26	27	0.1732	0.0572	14	10
27	3	28	0.0044	0.0108	26	18.6
28	28	29	0.0640	0.1565	26	18.6
29	29	30	0.3978	0.1315	0	0
30	30	31	0.0702	0.0232	0	0
31	31	32	0.3510	0.1160	0	0
32	32	33	0.8390	0.2816	14	10
33	33	34	1.7080	0.5646	19.5	14
34	34	35	1.4740	0.4873	6	4

35	3	36	0.0044	0.0108	26	18.55
36	36	37	0.0640	0.1565	26	18.55
37	37	38	0.1053	0.1230	0	0
38	38	39	0.0304	0.0355	24	17
39	39	40	0.0018	0.0021	24	17
40	40	41	0.7283	0.8509	1.2	1.0
41	41	42	0.3100	0.3623	0	0
42	42	43	0.0410	0.0478	6.0	4.3
43	43	44	0.0092	0.0116	0	0
44	44	45	0.1089	0.1373	39.22	26.30
45	45	46	0.0009	0.0012	39.22	26.30
46	4	47	0.0034	0.0084	0	0
47	47	48	0.0851	0.2083	79	56.40
48	48	49	0.2898	0.7091	384.7	274.5
49	49	50	0.0822	0.2011	384.7	274.5
50	8	51	0.0928	0.0473	40.50	28.30
51	51	52	0.3319	0.1114	3.60	2.70
52	9	53	0.1740	0.0886	4.35	3.50
53	53	54	0.2030	0.1034	26.40	19.00
54	54	55	0.2842	0.1447	24.00	17.20
55	55	56	0.2813	0.1433	0	0
56	56	57	1.5900	0.5337	0	0
57	57	58	0.7837	0.2630	0	0
58	58	59	0.3042	0.1006	100.0	72.0
59	59	60	0.3861	0.1172	0	0
60	60	61	0.5075	0.2585	1244.0	888.0
61	61	62	0.0974	0.0496	32.0	23.0
62	62	63	0.1450	0.0738	0	0
63	63	64	0.7105	0.3619	227.0	162.0
64	64	65	1.0410	0.5302	59.0	42.0
65	11	66	0.2012	0.0611	18.0	13.0
66	66	67	0.0047	0.0014	18.0	13.0
67	12	68	0.7394	0.2444	28.0	20.0
68	68	69	0.0047	0.0016	28.0	20.0

Table:2-Represents real power loss calculations before and after capacitor placement.

Bus no.	Voltage at each bus (kV)	Voltage difference	P_{loss} (kw) before capacitor placement	P_{loss}(kw) after capacitor placement
1	12.6600	0	0.06791	0.04822
2	12.6600	0	0.06791	0.04822
3	12.6600	0	0.20374	0.14468
4	12.6600	0	3.40939	2.42114
5	12.6600	0.00099	49.6421	35.24320
6	12.6590	0.001	50.5803	35.94422
7	12.6580	0.00099	11.75140	8.3632
8	12.6570	-0.0005	6.180525	4.38503
9	12.6575	0.0025	101.129848	71.76738
10	12.6550	0.0022	21.2975	15.15840
11	12.6528	0.01	74.30860	53.05617
12	12.6428	0.0008	107.077035	76.38596
13	12.6420	0.00099	108.01607	76.98817
14	12.6410	0	109.46456	78.02058
15	12.6410	0.00099	19.79933	14.04126
16	12.6400	0.002	36.41077	25.7962
17	12.6380	0	0.441109	0.3104
18	12.6380	0	30.74629	21.6363
19	12.6380	-0.00029	19.75357	13.89911
20	12.6383	0.0038	29.7675	20.98796
21	12.6345	0	1.21599	0.8568
22	12.6345	0	13.81885	9.73707
23	12.6345	0.0015	29.5250	20.72981
24	12.6330	-0.0005	63.84164	44.82382
25	12.6335	0.000399	26.0912	18.285750
26	12.6331	0.0002	14.49258	10.138349
27	12.6329	0	0.59766	0.42442
28	12.6600	0.0002	8.5745600	6.09080
29	12.6598	0	53.29624	37.85815
30	12.6598	0	9.40523	6.68085
31	12.6598	0.0008	47.02610	33.40425
32	12.6590	0.0012	111.57392	79.273719
33	12.6578	0.0032	224.781076	159.74959
34	12.6546	0.0008	193.3766	137.35024
35	12.6538	0	0.59766	0.42442
36	12.6600	0.0002	8.57466	6.090830
37	12.6598	0	14.10800	10.021320
38	12.6598	0.000099	4.02142	2.84973
39	12.6597	0	0.235078	0.166183
40	12.6597	0.0001	95.050566	67.185017
41	12.6596	0	40.45815	28.59722
42	12.6596	0	5.333658	3.767704
43	12.6596	0	1.196820	0.845436
44	12.6596	0.000399	13.87521	9.802677
45	12.6592	0	0.1122869	0.0790118
46	12.6592	0	0.4618302	0.327963
47	12.6600	0.0007	11.08339	7.8807836
48	12.6593	0.0108	30.33866	21.74444
49	12.6485	0.0031	6.732667	4.8740411
50	12.6454	-0.0005	11.6339	8.2541818
51	12.6575	0.000099	41.52533	29.4508119
52	12.6574	0.002	21.48546	15.247277
53	12.6555	0.0006	24.70104	17.4809460
54	12.6549	0.0006	34.12039	24.085700
55	12.6543	0	33.7722	23.839928
56	12.6543	0	190.89172	134.751104
57	12.6543	0	94.0892	66.417887
58	12.6543	0.003	34.49763	24.398955
59	12.6513	0	43.7854	30.9679055
60	12.6513	0.0613	23.66567	17.345052
61	12.5900	0.000299	4.41122	3.21711
62	12.5897	0	6.56702	4.7893368
63	12.5897	0.0157	25.8283	19.0416024
64	12.5740	0.006	35.59096	26.3147156
65	12.5680	0.01	21.01615	15.0054858
66	12.6428	0	0.48561	0.34603190
67	12.6428	0.0008	76.8667	54.8347419
68	12.6420	-	0.48038	0.3416247

Table: 3- Represents capacitor size and connected load using loss sensitivity factor

S.No	Bus no.	L.S.F	Ranking	Capacitor size(kVAR)	Connected load(kVA)
1.	60	2.868356	1	554.84391	1528.42402
2.	48	2.429184	2	469.89214	472.593207
3.	63	0.739780	3	143.10023	278.878109
4.	49	0.690091	4	133.4885	472.593207
5.	11	0.30545	5	59.0850	178.440466
6.	64	0..281690	6	54.48904	72.4223722
7.	47	0.146598	7	28.35736	97.0667811
8.	20	0.114506	8	22.14960	139.846344
9.	33	0.0986693	9	19.08621	24.0052077
10.	58	0.090465	10	17.49920	123.223374
11.	10	0.08039	11	15.55033	178.440466
12.	6	0.07267	12	14.05700	50.3205723
13.	9	0.06420	13	12.41860	33.8378486
14.	67	0.0611610	14	11.83075	34.4093010
15.	16	0.05424	15	10.49198	69.4622199
16.	44	0.04506	16	8.716235	47.2218000
17.	28	0.0363236	17	7.02629	31.9681091

18.	36	0.036226	18	7.00742	31.9390435
19.	32	0.035145 0	19	6.798315	17.2046505
20.	7	0.03168	20	6.128059	92.4175308

Table 4: Test results of 69-bus system

Immune method	% Real power losses before capacitor placement	% Real power losses after capacitor placement
69-bus system	66.6859	47.366

Table: 5- Comparison of results before and after capacitor placement using different methods

Method	% of reduction in power losses after capacitor placement
Tabu search[9]	12.6252
Proposed method	19.3199

Table-2 reveals real power losses before and after placement of capacitor in 69 bus system. Table 3 shows loss sensitive factor, ranking based on severity along with capacitor size for compensation, Table 4 shows the percentage of real power losses before and after capacitor placement and Table 5 reveals the comparisons between methods applied for a 69 bus system before and after capacitor placement and reduction in percentage of real power losses. From this it is observed that the power loss regulation is reduced in proposed method compared to other methods which show an eminent performance of the system by providing best quality of power.From fig.7 commendable improvement in voltages at each bus after capacitor placement andfrom fig.8 it is observed that real power losses gets reduced considerable.

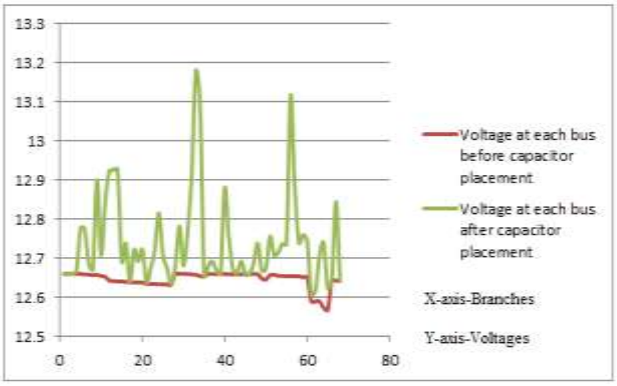

Figure: 7-Load Bus voltages before and after capacitor placement

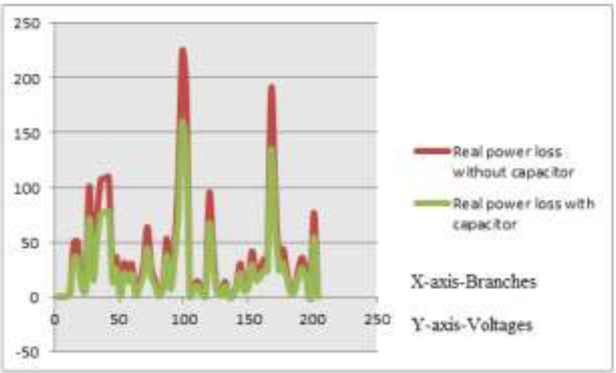

Figure:8-Real power losses before and after capacitor placement

V.CONCLUSION

In this paper a new approach of immune based optimization is introduced. For voltage drop reduction and minimization of power loss a pre-eminent approach is done using heuristic and genetic algorithm. The performances before and after proper placement of capacitor drastically improved.

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