Clonal Selection Algorithm to Reduce Parallel Resonance Effect in Electrical Networks

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Abstract— Parallel resonance is significant problem in the electric networks. During parallel resonance, system impedance increase extremely. Therefore system voltage may be increase extremely. Due to the parallel resonance occurs between system impedance and capacitors of reactive power compensation, total capacitor power should be less than the parallel resonance power. In this study, parallel resonance point and power of transformer of the electric network, which was measured harmonic distortion, were determined by using search mechanism of CSA. Thus parallel resonance power of low voltage electric network can be calculated and maximum capacitor of compensation system can be determined. Coefficient of cloning in CSA was increased to obtain high affinity valuable results. But, in this case, the elapsed time increased. Increasing value of the elapsed time is undesirable case. To decrease value of the elapsed time, some changes in CSA were made to obtain high affinity value at short computational time.

Keywords— AIS, CSA, elapsed time, parallel resonance, parallel resonance point, parallel resonance power.

I. INTRODUCTION

The artificial immune system (AIS) has been used in different applications. These applications are usually optimization and classification.

AIS have been used to solve optimization problems in electrical engineering. Optimization problems are voltage stability, power flow, power quality, etc.

The main duty of electric utility resolve electrical energy requirement of the customer. While this service, the cost should not be higher value for the customer. Therefore electric dispatch problem should be solved with minimization. Minimization process was made by using the AIS. [1]

Voltage stability is major problem in electrical network. Voltage stability is maintained by making reactive power compensation. Inductive load is the majority of loads in electrical network. Thus capacitor is used to make reactive power compensation. Capacitor placement problem in electric networks is solved by using the AIS. Thus reactive power compensation is made effectively. [4]

Optimal power flow (OPF) problem was solved using a Modified Artificial Immune System. The computational time was reduced by using hypermutation. Hypermutation provides decreasing the number of generations and clones, and also speeding up the convergence process. [6]

Clonal selection algorithm is hybridized with other algorithms. Mind Evolutionary computation is hybridized with Clonal selection algorithm to search for the optimal parameters (values of inductor and capacitor) of a passive filter in the diode full bridge rectifier. According to simulation result, values of calculated inductance and capacitance for designed passive filter may be optimal values. [3]

Optimization of electromagnetic design was made by using clonal selection algorithm. Some features of algorithm were discussed to ensure diversity in antibody population. [5]

Artificial immune system is hybridized with genetic algorithm to solve constrained problem of engineering. The AIS is embedded in GA. Thus diversity in population is provided. [9]

Multi-objective programming problems are solved hybrid artificial intelligent which occur clonal selection based on artificial immune system and neural network. A neural network is used to be sensitive initial population of antibodies for the AIS. Thus feasibility of initial population of antibodies is guaranteed. [10]

II. PARALLEL RESONANCE

During parallel resonance, due to system impedance increases extremely, parallel resonance event is seriously problem in the electric plant. Therefore system voltage may increases extremely and also harmonic distortion increases. Parallel resonance occurs between system inductance and capacitance. In the electrical networks, capacitors usually are used for compensation of reactive power. Capacitors of compensation power are less than resonance power due to the parallel resonance event. Thus capacitors of electrical plant that will be connected to electric network should be chosen carefully. Because if over compensation is made in electrical plant, the risk of resonance increases.

$$Q_r = \frac{S}{n^2 \% u_k \sin \varphi_k} \quad (1)$$

Parallel resonance power is calculated with Equation (1).

S = Transformer power (kVA)
N = Harmonic degree
u_k = relative short-circuit voltage of transformer
$\sin\varphi_k$ = sine angle of transformer's relative short-circuit voltage

Parallel resonance frequency is calculated with Equation (2).

$$f_r = \frac{1}{2\pi\sqrt{LC}} Hz \quad (2)$$

L = Inductance of system
C = Capacitance of capacitors

In this study, single line diagram of an electrical network which is shown in in Figure 1 is used. Demand point of customer is A point. Measurement of harmonic distortion was made from A point. In Fig. 2 harmonic distortion rate is shown.

Power of TRA is 1250kVA and power of TRB is 100MVA. However, assuming that the power of TRA with TRB, and also R_1, X_1, R_2, X_2, R_3, X_3 values are unknown. Thus parallel resonance point and power of parallel resonance are determined using the AIS. The results of the AIS simulation were compared with the actual values.

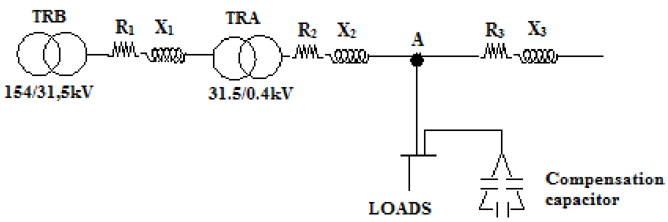

Figure 1. Electric network and electric plant

In the Figure 2 is seen that seventh harmonic is dominant in three phases (R, S, and T). So the parallel resonance frequency can be accepted as 350 Hz. Total harmonic distortion rate of current is approximately % 19.8. Total harmonic distortion rate of voltage is approximately % 2.8. Current value of 7^{th} harmonic is %19.5 and voltage value is %2.5.

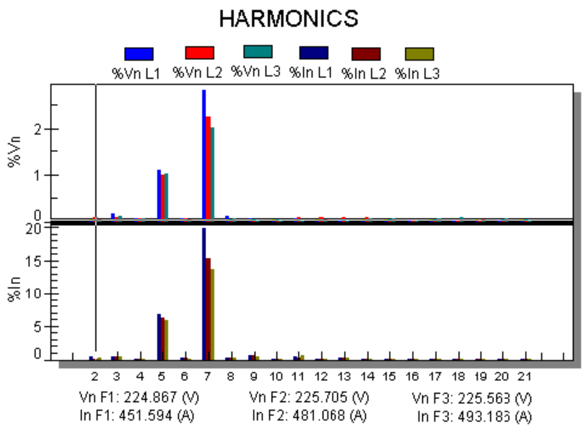

Figure 2. Harmonic graph of electrical network

III. ARTIFICAL IMMUNE SYSTEM

Immune system provides to protect against antigen in organisms. Some terms are used in immune system.

Immune cells, these cells are used to identify harmful substances by immune systems. These cells are B cells and T cells.

Antigen-Ag, these which are identified by immune system are harmful substances.

Antibody-Abs, Antibodies which are molecule is used to identify antigens in immune system. [8]

Antibody is used to identify antigen in immune system. Identification sensitivity of antibody is defined to be affinity. If affinity of antibody against to antigen is high level, antigen is recognized. And then the number of antibody is increased to improve affinity and to stimulation body of organism.

Artificial immune system was consisted of the result of immune system's simulation by using computer. Using terms in artificial immune system like using terms in natural immune system. AIS consist of negative selection and clonal selection algorithms.

A. Negative selection algorithm

Negative selection algorithm usually is used to identify virus. Virus is called as antigen, and antibody is used to identify antigen. In negative selection algorithm, primarily a memory population is formed. Memory population consists of antibodies. These antibodies mature to detect unknown antigens. During maturation period, sensitivity of antibodies improves against antigen. In Figure 3 and Figure 4 are shown working principle of negative selection algorithm. In Figure 3 memory population is called as detector set. In Fig.4 is shown formation algorithm a set of detector. [8]

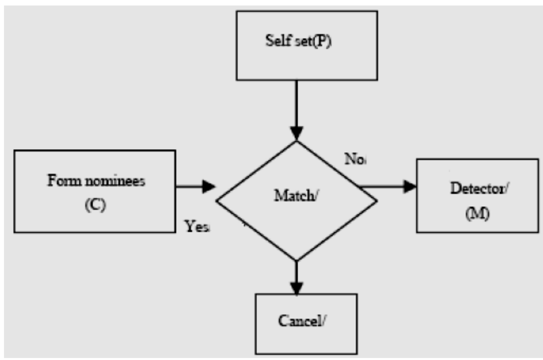

Figure 3. Identifying model with negative selection algorithm

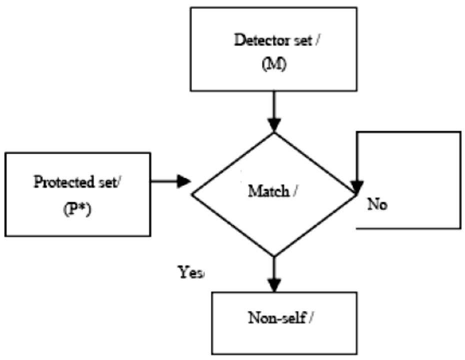

Figure 4. Formation algorithm a set of detector

1. Candidate element occurs as random. (C)
2. Element in C compare with element in P. If element in C don't recognize element in P, element in C save to detector's set. [8]

B. Clonal selection algorithm

When clonal selection algorithm (CSA) is used to solve optimization problems, the suitable results have been taken. Antigens are defined by optimum value of function. Antibodies are used to find optimum value of the function. To find the best antibody should be used operators of clonal selection algorithm.

Clonal selection operators occur from cloning and mutation. In cloning operation, antibodies are cloned by multiplying coefficient which is calculated according to affinity of antibodies. So population of cloned antibodies is occurred (C). Then according to mutation rate, mutation process is applied to population of cloned antibodies. Mutation rate is inversely proportional to affinity. Namely antibody having high affinity is mutated less according to antibody having low affinity.

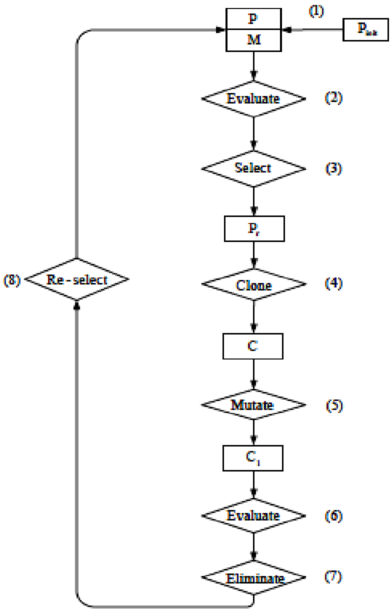

Figure 5. Flow chart of CAS

In Figure 5 is shown the block diagram of CSA optimization algorithm. [1] [8] [11]

1. Antibody population is occurred as random.
2. The fitness values of all the individuals are calculated in Population P. Affinity is determined according to the fitness value.
3. According to affinity value, the best antibodies are selected and Pn population is occurred.
4. These antibodies are cloned and C population is occurred.
5. Mutation process is applied to C population which occurs from cloned antibodies. Generate a mutated antibody pool (C1). The mutation rate of each individual is inversely proportional to its fitness.
6. The fitness values of all the individuals are calculated in Population C1.
7. Similar antibodies in C are eliminated and C1 is updated.
8. To select advanced antibodies, reselect process is applied to C1.

New generated individuals are combined with random generated individuals. Thus new antibody population is occurred. This process prevent local minimum fitting event. Thus various results may be found in this algorithm.

IV. OBJECTIVE FUNCTION AND AFFINITY VALUE

Objective function is mathematical model of the system. Affinity is determined according to value of objective function. Therefore objective function should be determined correctly. Objective function of this study was determined with Equation (3).

$$f_r = \frac{1}{2\pi\sqrt{(L_s + L_t)C_c}} Hz \quad (3)$$

In Equation (3) Ls is system impedance and Lt is transformer impedance. Cc is capacitance of compensation capacitors. And value of total capacitance is 0.004975µF at normal working conditions. The fitness value is calculated with objective function. Ls : [0, 0.0133] H, Lt : [0, 0.006] mH

In the AIS (CSA), binary code system was used. Ls is defined with 14 bit binary code, Lt is defined with 6 bit binary code. In artificial immune system, affinity is calculated according to the result of objective function. In this study affinity criteria are parallel resonance frequency and transformer inductance. Affinity of antibodies is calculated according to these criteria, and then antibodies are selected according to affinity. In Equation (4) and Equation (5) are shown calculation of affinities.

$$Aff_1(i) = \begin{cases} f_r > f(i), \dfrac{|f_r - f(i)|}{f_r} \\ f_r < f(i), \dfrac{|2xf_r - f(i)|}{f_r} \end{cases} \quad i = 1,2,3,,,N \quad (4)$$

$$Aff_2(i) = \begin{cases} L_{tr} > L_{tr}(i), \dfrac{|L_{tr} - L_{tr}(i)|}{L_{tr}} \\ L_{tr} < L_{tr}(i), \dfrac{|2xL_{tr} - L_{tr}(i)|}{L_{tr}} \end{cases} \quad i = 1,2,3,,,N \quad (5)$$

Total affinity is calculated via Equation (6) for this study.

$$Aff(i) = Aff_1(i) x Aff_2(i) \quad i = 1,2,3,,,N \quad (6)$$

The best affinity value is 1; the worst affinity value is 0 in this study. Namely affinity value is between 1 and 0.

V. EXPERIMENTAL RESULTS

In this study, transformer power and parallel resonance point of the electric network which is shown in Figure1 are determined by using search mechanism of clonal selection algorithm. This electric network's harmonic distortion is measured using measurement device of harmonic distortion from A point. Because network connection of the electric plant will be made from A point. The result of measurement of harmonic distortion is shown Figure 2. According to this the result, dominant harmonic of this network is 7th harmonic. So, parallel resonance frequency can be accepted as 350Hz. As a result of measurement of harmonic distortion that there is 250kVAr capacitive power were detected in this electrical network. This capacitive power is used by electric plants and individual customer to make reactive power compensation. Therefore total capacitance value was accepted as 0.004975 farad. According to this information, the suitable capacitance can be selected to avoid threat of parallel resonance event for this electrical plant. But demand power of electrical plant should be considered.

Some changes in this algorithm were made to increase speed of algorithm operation to find the most suitable results. These changes can be made in coefficient of cloning, in number of antibody population and in number of iteration. Changing numbers of antibody population and iteration also changing of coefficient value of cloning is evaluated.

In Table I is shown simulation's results according to the input parameters of simulation. This case the correct result was found but maximum affinity value is little.

TABLE I. THE INPUT PARAMETERS AND THE RESULTS OF SIMULATION

The Input Parameters of Simulation		**Simulation Results**	
Parameter	**Value**	**Parameter**	**Value**
Population Size	10	Parallel Resonance Frequency (Hz)	334.7
Iteration Number	10	Transformer Inductance (H)	2.23E-05
Coefficient of Cloning	5	Line Inductance (H)	2.33E-05
Cc (f)	0.004975	Transformer's Power (kVA)	1250
Lt (mH)	0.038~0.019	Elapsed time (minute)	7.9
Ls (mH)	13.3 ~ 0.079		

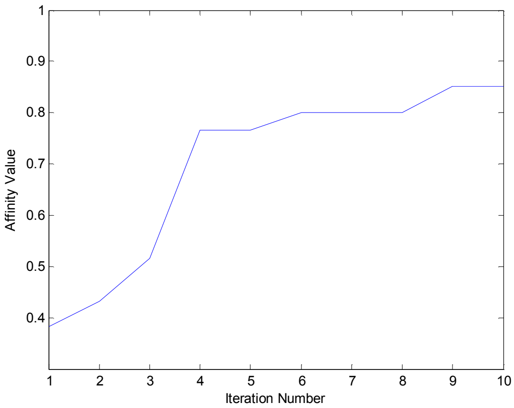

Figure 6. Change of affinity value

Affinity values of this case are shown according to iteration number in Figure 6. In this case affinity value is 0.852. But this value is little than the desired level.

In Table II, numbers of population and iteration were increased again to find the more accurate result. In this case founded results are the suitable values. But elapsed time increased.

TABLE II. THE INPUT PARAMETERS AND THE RESULTS OF SIMULATION

The Input Parameters of Simulation		**Simulation Results**	
Parameter	**Value**	**Parameter**	**Value**
Population Size	20	Parallel Resonance Frequency (Hz)	350.1
Iteration Number	20	Transformer Inductance (H)	2.44E-05
Coefficient of Cloning	5	Line Inductance (H)	1.60E-05
Cc (f)	0.004975	Transformer's Power (kVA)	1250
Lt (mH)	0.038~0.019	Elapsed time (minute)	35.9
Ls (mH)	13.3 ~ 0.079		

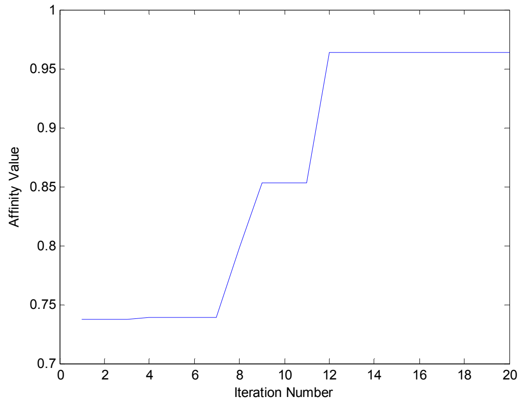

Figure 7. Change of affinity value

In Figure 7 is seen that maximum affinity value is 0.96. This result is acceptable level. But elapsed time should be decreased.

In Table III, numbers of population and iteration were increased, and coefficient of cloning is decreased to decrease elapsed time at high affinity value.

TABLE III. THE INPUT PARAMETERS AND THE RESULTS OF SIMULATION

The Input Parameters of Simulation		**Simulation Results**	
Parameter	**Value**	**Parameter**	**Value**
Population Size	100	Parallel Resonance Frequency (Hz)	353.2
Iteration Number	100	Transformer Inductance (H)	2.56E-05
Coefficient of Cloning	0.01	Line Inductance (H)	1.03E-05
Cc (f)	0.004975	Transformer's Power (kVA)	1250
Lt (mH)	0.038~0.019	Elapsed time (minute)	1.4
Ls (mH)	13.3 ~ 0.079		

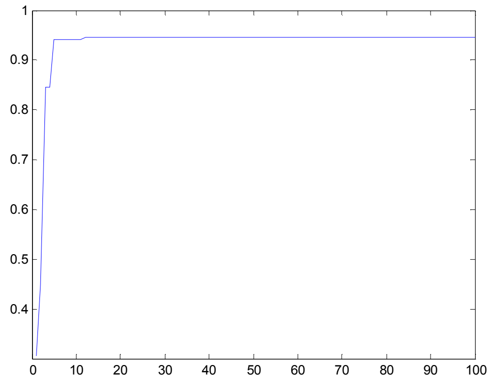

Figure 8. Change of affinity value

In this case, transformer's power and parallel resonance frequency were found correctly. Also elapsed time is little than other cases. Maximum affinity value is 0.94 in Figure 8.

TABLE IV. THE INPUT PARAMETERS AND THE RESULTS OF SIMULATION

The Input Parameters of Simulation		Simulation Results	
Parameter	**Value**	**Parameter**	**The Best Value**
Population Size	100	Parallel Resonance Frequency (Hz)	349.6
Iteration Number	100	Transformer Inductance (H)	2.56E-05
Coefficient of Cloning	0.05	Line Inductance (H)	1.60E-05
Cc (f)	0.004975	Transformer's Power (kVA)	1250
Lt (mH)	0.038~0.019	Elapsed time (minute)	6.33
Ls (mH)	13.3 ~ 0.079		

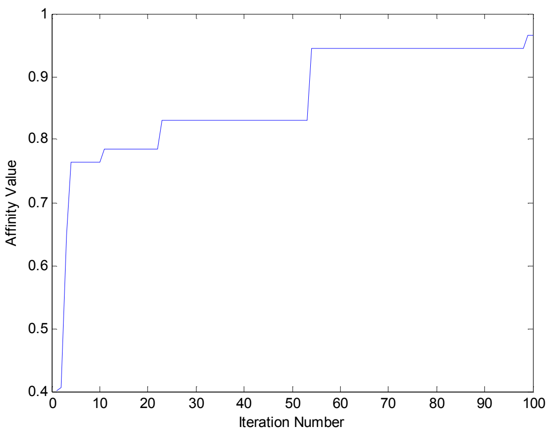

Figure 9. Change of affinity value

The results in Table IV are the suitable results. Increasing coefficient of cloning was found the more correct results. Affinity value is 0.95 in Figure 9. Although the difference between obtained affinity value in Table III and obtained affinity value in Table IV is little value, the difference between the elapsed time in Table III and the elapsed time in Table IV is high value. Namely this case elapsed time increased.

VI. CONCLUSION

In this study, determinations of parallel resonance point and power transformer in electrical network which was measured harmonic distortion rate were made by using search mechanism of CSA. Thanks to determination of power transformer of this electrical network can be calculated power of parallel resonance via Equation (1). Thus the most suitable compensation power can be determined for this the electric plant, which will be connected to this the electrical network, and also parallel resonance effect is reduced in the electrical network.

Parallel resonance point occurs between low voltage coil of power transformer and low voltage power capacitor in this electrical network.

Coefficient of cloning can be increased to obtain high-affinity value, but this case elapsed time increased. When numbers of antibody population and iteration are increased and also coefficient of cloning is reduced, elapsed time reduced and high-affinity value results were obtained. The results in Table III are more efficiency results.

REFERENCES

[1] B.K. Panigrahi , S. R. Yadav, S. Agrawal and M.K. Tiwari " A clonal algorithm to solve economic load dispatch," Electric Power Systems Research, vol. 77, Issue.10, pp.1381- 1389, August 2007.

[2] X. Wang, X. Z. Gao, and S. J. Ovaska," A Hybrid Optimization Algorithm in Power Filter Design," IECON 2005 31st Annual Conference of IEEE Industrial Electronics Society, North Carolina, USA, 2005, pp. 1335 – 1340.

[3] C.Peng, R. Shibin, L. Wenhua and W. Haitao," Design of Optimization Filter Based on Novel Immune Algorithm", ICMTMA.2011Third International Conference on Measuring Technology and Mechatronics Automation, Shangshai, 2011, vol. 1, pp. 990 – 993.

[4] Huang," An Immune-Based Optimization Method to Capacitor Placement in a Radial Distribution System" IEEE Transactions On Power Delivery, vol. 15, No. 2, pp. 744 - 749, April 2000.

[5] F.Campelo, G.Guimarães, H.Igarashi and A. Ramírez" A Clonal Selection Algorithm for Optimization in Electromagnetics" IEEE Transactions On Magnetics, vol. 41, No. 5, pp. 1736 - 1739, May 2005.

[6] L.M. Honório, A.M.L. Silva, and D.A.Barbosa" A Gradient-Based Artificial Immune System Applied to Optimal Power Flow Problems" ICARIS 2007 Lecture Notes in Computer Science, Berlin, 2007, vol.4628, pp. 1-12.

[7] K.C. Tan, C.K. Goh, A.A. Mamun and E.Z. Ei" An evolutionary artificial immune system for multi-objective optimization" European Journal of Operational Researchl, vol. 187,Is.2, pp.371- 392, Jun 2008.

[8] M. Çunkaş, T. Sağ, E. Saraçoğluk " Intelligent Optimization Algorithms" unpublished.

[9] H.S. Bernardino, H.J.C. Barbosa, A.C.C. Lemonge, and L.G. Fonseca "A New Hybrid AIS-GA for Constrained Optimization Problems in Mechanical Engineering" CEC 2008 IEEE Congress on Evolutionary Computation, Hong Kong , 2008, pp. 1455 – 1462.

[10] F. Abd El-Wahed, M. Zaki, and M. El-Refaey "Artificial immune system based neural networks for solving multi-objective programming problems"Egyptian Informatics Journal, vol. 11, Is. 2, pp. 59-65, December 2010.

[11] İ.Aydin,M. Karaköse and E. Akin"The Fault Diagnosis Model Based On Artificial Immune System Using Genetic Algorithm"Dokuz Eylül University Journal of Engineering Sciences,vol.11,No.31,pp.58-72,2009.