# Loss Minimization in Power System Utilizing Multiagent Immune Evolutionary Programming (MAIEP) Technique

Aziz Bin Mat Ramly
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
e-mail: areziz7@yahoo.com

*Abstract*— **Electrical power system are designed and operated to meet the continuous variation of power demand. The optimal reactive power planning (RPP) is one of a vital approach to reduce total system loss and hence minimize the loss in operation of the system. Thus, this paper presents the enhancement of loss minimization in power system through optimal RPP using an optimization technique, termed as Multiagent Immune Evolutionary Programming (MAIEP) technique. The concept of MAIEP is developed base on combination of Multiagent System (MAS), Artificial Immune System (AIS) and Evolutionary Programming (EP). In realizing the effectiveness of the purposed technique, validation is conducted on the IEEE 30-Bus Reliability Test System (RTS). The program also was developed by using MATLAB software. From the result, it show that the performance of MAIEP technique in minimize the total power losses compare to the result that without using any technique.**

***Keywords; Reactive Power Planning (RPP), Multiagent Immune Evolutionary Programming (MAIEP)***

## I. INTRODUCTION

Basic elements of a modern power system consist of 4 major parts: generation, transmission, distribution and load [1]. The electrical energy is produced at generating station and distributed to the load via transmission lines. A good and the properly design power system is crucial to ensure that power can be delivered to the consumer in secure manner and without interruption.

This research describes a study to loss minimization in power system. MAIEP technique has been identified as a one technique that can optimize the RPP for loss minimization in power system. Various literatures have reported work on RPP, which dealt with optimization techniques [2]. There are numerous optimization techniques that can be used to optimize the total loss minimization. But, this research is about to see the performance of MAIEP technique to minimize the total power loss through the RPP [3].

RPP has been identifying as a one methods that can be used to minimize the total power loss. RPP embraced the reactive power dispatch (RPD), transformer tap charger setting (TTCS) and compensating capacitor placement. In total loss minimization, RPP determined the optimized reactive power to be injected to the generator buses and also altered the transmission system properties to minimize the total loss in the system.

Thus, this research presents the application of MAIEP based optimization technique for implementing RPP in power system. The proposed technique was tested on the IEEE 30-bus reliability test system (RTS) [4]. Comparative studies were performed on MAIEP technique and without technique to see the main objective function that loss minimization in power system utilizing MAIEP technique.

## II. BACKGROUND STUDY

### A. *Reactive Power Planning ( RPP )*

In optimal power flow (OPF), RPP is a sub problem of solution in power system which has been usually used in operating and planning to optimize the system. This technique focus on determine the optimal values of the control parameter which is transformer tap setting and the injection of reactive power at generator and bus. It's the most suitable values of the control parameters to fulfill the optimal solution. The optimal reactive flow problem it can be started in the following way [5]:

Maximize or minimize

$$f(\mathbf{x},\mathbf{u}) \qquad (1)$$

subject to

$$g(\mathbf{x},\mathbf{u}) = 0 \qquad (2)$$

$$h_{min} \leq h(\mathbf{x},\mathbf{u}) \leq h_{max} \qquad (3)$$

where;

**u** is the vector of control variables(these include generator active/reactive power/voltage levels and transformer tap setting).

**x** is the vector of dependent variables (load node voltages, generator reactive power).

$f(\mathbf{x},\mathbf{u})$ is the objective function .

$g(\mathbf{x},\mathbf{u})$ is nodal power constrains.

$h_{min} \leq h(\mathbf{x},\mathbf{u}) \leq h_{max}$ are the inequality constraints of the independent and dependent variable.

### B. *Multiagent Immune Evolutionary Programmning (MAIEP)*

Multiagent Immune Evolutionary programming (MAIEP) technique is a combination of EP, AIS and MAS techniques to optimize and achieve the desired objective function. All of the step and function that include in these three techniques was implement as a one in MAIEP.

First is EP where an optimization technique that based on the natural generation [6]. In EP it involves the random number of generation at the initialization process. The generated random numbers is representing the parameters responsible for the optimization of the fitness value. The basic EP method is involves 3 steps:

*1) Initialization*

Initialization process in EP is conducted by generating a series of random number using a uniform distribution number. The initial population of μ individuals element consists of $(\mathbf{x}_i, \mu_i)$, $\forall i \in \{1,2,\ldots,\mu\}$ where its generate randomly based on its limits. $\mathbf{x}_i$ represent the control variable/s and $\mu_i$ is strategic parameter/s for each $\mathbf{x}_i$. The fitness value is measured for each individual based on its objective function, $f(\mathbf{x}_i)$.

*2) Mutation*

Mutation is performed on the random number, **xi**, to produce offspring. Each parent (**xi**, **μi**), $i$=1,...,μ, creates a single offspring (**x'i**, **μ'i**), $j$=1,..., $n$, where **x'i** and **μ'i** are given by:

$$\mathbf{x'i}(j) = \mathbf{xi}(j) + \boldsymbol{\mu}\mathbf{'i}\ (j)\ \mathrm{Nj}\ (0,1) \tag{4}$$

$$\boldsymbol{\mu}\mathbf{'i}(j) = \boldsymbol{\mu}\mathbf{i}(j) \exp(\tau'\mathrm{N}(0,1) + \tau\mathrm{N}(0,1)) \tag{5}$$

and

$$\tau = ((2(n)\ ^{1}/_{2})\ ^{1}/_{2})^{-1} \tag{6}$$

$$\tau' = ((2n)^{1}/_{2})^{-1} \tag{7}$$

$xi\ (j)$, $x'i(j)$, $\eta i\ (j)$ and $\eta' i(j)$ are the $j$-th component of the vectors x$i$, x'$i$, η$i$ and η'$i$ respectively. N (0,1) denotes as the normally distributed one-dimensional random number with mean of zero and standard deviation of 1. N$j$ (0,1) denotes that the random number is generated in a new for each value of $j$. the value of fitness is measured for each offspring.

*3) Combination and Selection*

At this stage, the union of parents and offspring are ranked in descending order as started by its fitness to determine the maximum value of load. Then the highest individuals of $\mu$, are chosen to be parents for the generation at the selection process. In this project, the difference between the maximum and minimum value of fitness is considered as the stopping criterion.

Then, for AIS is a computational systems inspired by the principles and processes of the vertebrate immune system [7]. In general, the basic algorithm of AIS consists of initialization, cloning, mutation and selection. At cloning stage, the best individual of the population is reproduced to make sure that the only best result will be processed.

Lastly is MAS where is a system composed of multiple interacting intelligent agents. An agent in MAS represents a candidate solution to the optimization problem is arranged in a lattice like environment with other agents. An agent and it neighbors are the competed, corporate and use their own knowledge in order to transfer the information can only be shared by all agents in the lattice after the process of diffusion.

For the process of the MAIEP there are several characteristic that must be considered. At the beginning, the characteristic of the agent is in condition below:

*1) Global Environment*

All agents in MAIEP are arranged in the form of lattice like an environment, L. the value of L is from $L_{size}$ x $L_{size}$ where $L_{size}$ is an integer. From figure 1, the circle is represent as an agent in MAIEP and coordinate in lattice represents the data carries. In additional, certain fitness value and a set of control variables of the optimization problem contains in each agent which is generated during initialization procedure in the EP.

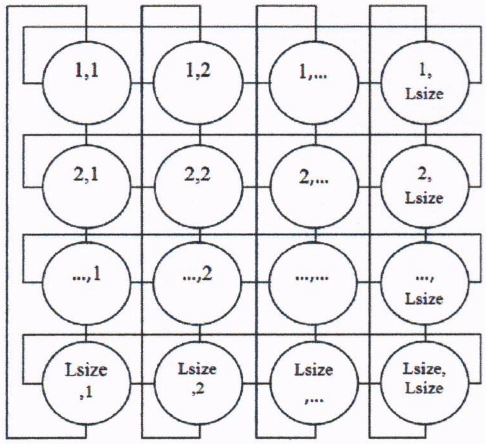


Figure 1: Agent lattice.

*2) Local Environment*

Since each agent can only sense its local environment in MAS, the definition of the local environment is very important in the proposed the method [8]. Suppose that the agent $\alpha_{ij}$, $i, j$ = 1,2,...,$L_{size}$ then the neighbors of $\alpha_{i,j}$, $N_{i,j}$ are defined as follow:

$$N_{i,j} = \{\alpha_{i^1,j}, \alpha_{i,j^1}, \alpha_{i^2,j}, \alpha_{i,j^2}\} \tag{8}$$

$$i^1 = \begin{cases} i-1 & i \neq 1 \\ L_{size} & i = 1, \end{cases} \qquad j^1 = \begin{cases} j-1 & j \neq 1 \\ L_{size} & j = 1, \end{cases}$$

$$i^2 = \begin{cases} i+1 & i \neq L_{size} \\ 1 & i = L_{size}, \end{cases} \qquad j^1 = \begin{cases} j+1 & j \neq L_{size} \\ 1 & j = L_{size}, \end{cases}$$

In general, only four neighbors consists in each agent and before the information is diffuse to the global environment its first spread in the local environment.

*3) Agent's Behaviors*

All agents have some distinctive behavior to respond to change that occurs in the environment. In order to obtain optimal solution quickly, each agent competes and cooperates with their neighbors to diffuse the information using competition and cooperation operator [8]. The evolutionary mechanisms (EP operator) are as its knowledge in the competition, and use the self learning operator as the learning capability to solve the problem behaviors. The explanation on these three operators is briefly discussed as follow:

*a) Competition and cooperation operator*

The purposed of this operator are to compare the fitness of the selected agent with its neighbors' fitness. The best value of fitness in agent is chosen to replace the selected agent's location in the lattice. Assume that this operator is presented on agent $L_{i,j} = (l_1, l_2, \ldots, l_n)$ and $M = (m_1, m_2, \ldots, m_n)$ is the agent where have the highest value of fitness to achieved the objective function between the neighbors of $L_{i,j}$ if agent $L_{i,j}$ contented equation (9) it is a winner, and apart from that will be loser.

$$(L_{i,j}) > f(Max_{i,j}) \tag{9}$$

If $L_{i,j}$ is a winner, it can live and will be life untouched. If $L_{i,j}$ is loser, it must die and will be contribute a vacant will be occupied by $Max_{i,j}$. $l_1, l_2, \ldots, l_n$ and $m_1, m_2, \ldots, m_n$ are the set of control variables represented by agent $L_{i,j}$ and $Max_{i,j}$ respectively [9].

*b) EP operator*

Mutations are the only search operators to generate a population of solutions that compete with their parent population to survive to the next generation based on a selection scheme in MAIEP [10]. Hence, mutation is a key search operator which generates new solution to archive the reliable result.

*c) Self learning operator*

Self learning operator is opted to realize the behavior of using knowledge. In this approach, it is introduced in AIS based on clone operation. At the first stage in EP operator, the beat agent is produced after execution is clone before its go to the second stage in EP operator system.

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

## III. METHODOLOGY

The methodology of RPP for loss minimization improvement utilized MAIEP is show in Figures 2 and 3. Figure 2 shows the flow chart to determine the total power loss where consist three steps without using any technique. To determine the total power loss, must be set the increment for load bus of reactive power. The increments are starts from zero into 100Mvar by increment of 20Mvar per step. From the figure 3, the all process loss minimization using MAIEP technique is conduct by all integrates the EP, AIS and MAS technique to optimize the objective function.

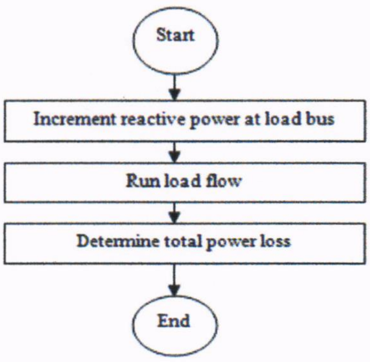


Figure 2: flowchart to determine total power loss.

From the Figure 3, the all process of loss minimization using MAIEP is conduct with the all integrates the EP, AIS and MAS technique to optimize the objective function.

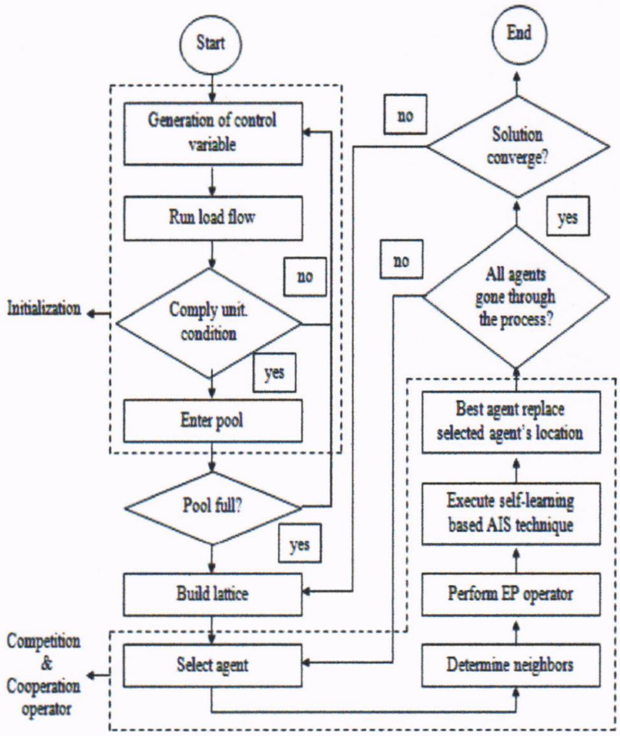


Figure 3: The all process of loss minimization using MAIEP.

## IV. RESULT AND DISCUSSION

The developed MAIEP algorithm was tested on the IEEE 30-bus RTS. In this project, the value of clone is set to 10 and the $L_{size}$ is set to 4. The program was developed by using MATLAB software.

In this project, the reactive load ($Q_{load}$) is assumed to increase at bus7 (Case 1) and bus 21 (Case2). Then, the resulted system loss and voltage profile of the system is monitoring and compared during pre optimization with post optimization stage.

In pre-optimization, it just only considered on increment of $Q_{load}$ only, same with the post-optimization but without applying any technique. Then, in post-optimization, the RPP will utilize with MAIEP technique to minimize the total loss. Results obtained during pre and post optimizations the increments of $Q_{load}$ are considered. The evaluation of the total power loss monitored at bus 7 was called as a Case 1 and bus 21 as a Case 2 by increment of $Q_{load}$, from 0Mvar until 100Mvar by step of 20Mvar.

Results obtained during pre and post-optimization for Case 1 and 2 are tabulated as follow:

TABLE I. LOSS MINIMIZATION IN PRE-OPTIMIZATION WHILE VARYING THE LOAD AT BUS7 (CASE 1)

| Load at Bus 7 (Mvar) | Total Loss (MW) | Voltage (p.u) |
|---|---|---|
| 0 | 17.599 | 1.003 |
| 20 | 17.926 | 0.981 |
| 40 | 18.415 | 0.965 |
| 60 | 19.441 | 0.945 |
| 80 | 20.298 | 0.930 |
| 100 | 21.522 | 0.915 |

TABLE II. LOSS MINIMIZATION IN POST-OPTIMIZATION WHILE VARYING THE LOAD AT BUS7 (CASE 1)

| Load at Bus 7 (Mvar) | Total Loss (MW) | Voltage (p.u) |
|---|---|---|
| 0 | 13.564 | 0.987 |
| 20 | 13.917 | 0.971 |
| 40 | 14.242 | 0.959 |
| 60 | 14.814 | 0.947 |
| 80 | 15.587 | 0.935 |
| 100 | 16.614 | 0.918 |

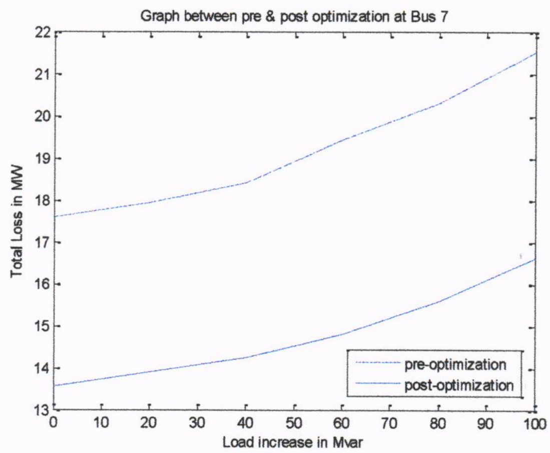


Figure 4: Comparison of loss minimization during pre and post optimization at bus7 (Case 1).

From Table I and II, it shows the total loss in pre and post-optimization when reactive power or $Q_{load}$ was increase. The total loss of the system also increases while the $Q_{load}$ is increased. But the values of voltage are opposite to the value of $Q_{load}$. If $Q_{load}$ is increase the value of voltage will decrease slightly. This case is same for both part and the difference part are the value of total loss as an objective function. Figure 4 present the comparative between pre and post-optimization at Bus 7 for Case 1 and showed that the MAIEP technique was apply in post-optimization was reduce the total loss that get in the pre-optimization. The percentages of reduction in total loss in Case 1 are about 22.36% to 23.80%.

TABLE III. LOSS MINIMIZATION IN PRE-OPTIMIZATION WHILE VARYING THE LOAD AT BUS21 (CASE 2)

| Load at Bus 21 (Mvar) | Total Loss (MW) | Voltage (p.u) |
|---|---|---|
| 0 | 17.599 | 1.032 |
| 20 | 18.067 | 1.001 |
| 40 | 18.842 | 0.969 |
| 60 | 20.151 | 0.926 |
| 80 | 22.315 | 0.884 |
| 100 | 25.321 | 0.836 |

TABLE IV. LOSS MINIMIZATION IN POST-OPTIMIZATION WHILE VARYING THE LOAD AT BUS21 (CASE 2)

| Load at Bus 21 (Mvar) | Total Loss (MW) | Voltage (p.u) |
|---|---|---|
| 0 | 12.279 | 1.011 |
| 20 | 12.607 | 0.891 |
| 40 | 13.327 | 0.946 |
| 60 | 14.595 | 0.906 |
| 80 | 16.407 | 0.864 |
| 100 | 19.820 | 0.821 |

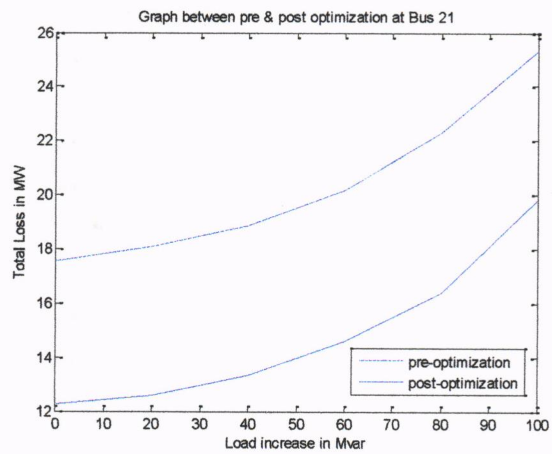


Figure 5: Comparison of loss minimization during pre and post optimization at bus21 (Case 2).

In Case 2, it has a same objective function as Case 1. But, use the difference bus to compare with the result that gets in

Bus 7. For Case 2 it was use Bus 21 to show the comparative in value of total loss between pre and post-optimization. It also showed the value of total loss is increase when the value of $Q_{load}$ is increase and the value of voltage will propagates with the increment of $Q_{load}$. From the Figure 5 it's showed that the value of total loss that get in pre-optimization was reduce to the value that get in post-optimization where use the MAIEP technique. The percentages reductions of total loss in Case 2 are about 21.73% to 30.22%.

The overall result show that optimizing using RPP with loss minimization as the objective function is suitable for MAIEP technique as this technique could minimize total losses in power system.

## V. Conclusion

A study on optimal RPP for total loss minimization in power system was presented. MAIEP where developed base on combination MAS, AIS and EP was employed as the optimization approach in determining values for the control variable in optimal RPP for the objective function to minimize total system loss. This technique was implemented on the IEEE 30-bus system using software MATLAB that can monitor the result. Results showed that the MAIEP technique is reliable technique which capable to minimize the total loss in power system. Therefore, the proposed technique is possible to be implementing practically which could archive loss minimization in power system.

## Acknowledgment

The author is gratefully acknowledges her sincere gratitude to Mrs Norziana Bt. Aminudin for professional guidance and full support to complete this paper successfully as a supervisor. The author also gratefully acknowledges the co-operation and discussion with his friend.

## References

[1] P. Kundur, *Power System Stability and Control*: McGraw-Hill, 1994.

[2] K.Y. Lee, X. Bai, & Y.M. Park, Optimization method for reactive power planning by using a modified simple genetic algorithm, IEEE Transaction on Power Systems, 10 (4), 1995, 1843–1850.

[3] K.Y. Lee & F.F. Yang, optimal reactive power planning using evolutionary algorithms: A comparative study for evolutionary programming, evolutionary strategy, genetic algorithm, and linear programming, IEEE Transaction on Power Systems, 13 (1), 1998, 101–108.K. Elissa, "Title of paper if known," unpublished.

[4] Alsac O, Stott B, "Optimal load flow with steady state security," *IEEE TransPower Apparat Syst.*, 1974;PAS-93:745–51.

[5] Bjelogrlic, M.; Calvic, M.S.; Ristanovic,P.; Babic,B.S.;" Application of Newton's optimak power flow in voltage/reactive power control" *Power System,IEEE transactions* on Volume 5, Issue 4, Nov, 1990 Page(s): 1447-1454.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] Musiri, I. Rahman, T.K.A "Evolutionary Programmning Based Optimization Technique For Maiximum Loadability Estimation in Electrical Power System" Faculty of Electrical Eng.Universiti Teknologi MARA, Malaysia: this paper appears in: Power Engineering Conference, 2003. National Pubblication Date: 15-16 Dec 2003. On page(s): 205-210.

[8] B.K. Panipraghi *et al.*, "A Clonal Algorithm to Solve Economic Load Dispatch," *in Electrical Power System Research,* 77(2007) 1381-1389.

[9] Norziana Aminudin " Maximum Loadability Enhancement of Power System Using Multiagent Immune Evolutionary Programming Optimization Technique" Universiti Teknologi MARA, Shah Alam, Malaysia. Jan 2009.

[10] Zhong Weichai; Liu Jing; Xue Mingzhi, Jiao Licheng;" Global numerical optimization using multiagent genetic algorith," *Computational Intelligence and Multimedia Application,* 2003. ICCIMA 2003. Proceeding. Fifth International Conference on 27-30 Sept. 2003.

[11] Zhong Weichai; Liu Jing; Xue Mingzhi, Jiao Licheng;" Global numerical optimization using multiagent genetic algorith," *Computational Intelligence and Multimedia Application,* 2003. ICCIMA 2003. Proceeding. Fifth International Conference on 27-30 Sept. 2003.