COMPARISON OF EVOLUTIONARY PROGRAMMING AND MULTIAGENT IMMUNE EVOLUTIONARY PROGRAMMING TECHNIQUE IN MAXIMUM LOADABILTY IMPROVEMENT

Mohd Reza Bin Sulaiman
Supervisor: Mrs Norziana Bt. Aminudin
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia, 40450 Shah Alam

Abstract - This paper presents the enhancement of system loadability through optimal reactive power dispatch technique using a newly developed optimization technique, termed as Multiagent Immune Evolutionary Programming (MAIEP). The concept of MAIEP is developed based on the combination of Multiagent System (MAS), Artificial Immune System (AIS) and Evolutionary Programming (EP). In realizing the effectiveness of the proposed technique, validation is conducted on the IEEE-30-Bus Reliability Test System. The program was developed by using MATLAB software. The main propose of this project is improving loadability system by using (EP) and (MAIEP). From the result, it shows that MAIEP has faster computation time compared to EP technique in maximum loadability improvement in the system.

Keywords: *Multiagent Immune Evolutionary Programming (MAIEP), Evolutionary Programming (EP), Artificial Immune System (AIS), load margin, Reactive Power Dispatch (RPD), Maximum Loading Point (MLP).*

I. INTRODUCTION

One of the major problems that may associate with a stressed system is the voltage instability or collapse. Voltage instability can affect the performance of a power system. According to [1], the main cause of voltage instability is insufficient reactive power supply. Reactive power can be dispatched effectively to maintain acceptable voltage levels and maintaining viable voltage levels are very important to avoid voltage collapse. Load margin analysis has been profoundly identified as one of the fundamental measurement in VC or voltage stability studies. In load margin assessment, the VC condition is predicted to occur when the load is increased exceeding the maximum loading point (MLP) and subsequently the system starts to lose its equilibriums [2]. Reactive power dispatch (RPD) in an electrical power system means an injection of reactive power into the system by the generator for improving voltage stability condition when the system in heavily loaded condition. Appropriate control of system voltage profile can enhance system security and may reduce system losses.

This paper proposed the implementation of reactive power dispatch utilizing the new technique for loading margin improvement in power system named as MAIEP. In this approach, if maximum loading point (MLP) at critical bus increased it is considered the improvement on load margin in the system. The operation method to determine the MLP is employed by gradually increases the increment of reactive power (Q_{load}). The results were obtained by comparing between pre-optimization and post optimization technique. To realize the effectiveness of the proposed both of technique (EP and MAIEP), 30-bus IEEE systems are used as the test specimen.

II. BACKGROUND STUDY

A. Reactive Power Dispatch

In optimal power flow (OPF), the problem involving RPD considers the allocation of reactive power generation to minimize the real power transmission losses and keep all the voltages within the limit [3]. This technique focus on determine the optimal values of the control parameter which is 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 power flow problem, it can be stated in the following way [4]:

Maximize or minimize

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

subject to

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

$$\mathbf{h}_{min} \leq \mathbf{h(x,u)} \leq \mathbf{h}_{max}$$

Where;
u – is the vector of control (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(**x**,**u**) is the objective function
g(**x**,**u**) is nodal power constraints

h_{min} h(**x**,**u**) h_{max} are the inequality constraint of dependent and independent variables

B. Load margin

Load margin assessment is a fundamental measure of proximity to voltage collapse [5].The load margin values for several selected load buses, critical bus of a system can be identified [2]. Figure 1 below show the loading margin in graphical from where λ_0 represents the load at the base case and λ_{max} represents the MLP value.

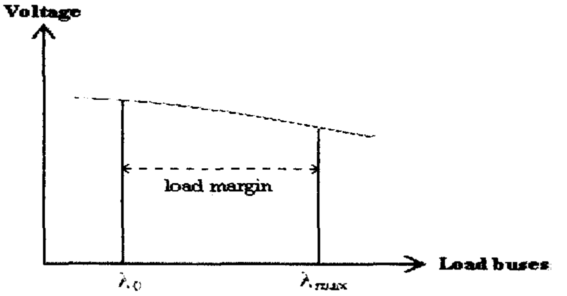

Fig.1. Voltage profile with respect to load buses [2]

Critical bus is identified from the load margin values for selected load buses. The lowest load margin in the system is considered ad a critical bus. Fig. 2 shows that the voltage profile and load margin before and after the implementation of optimization process.

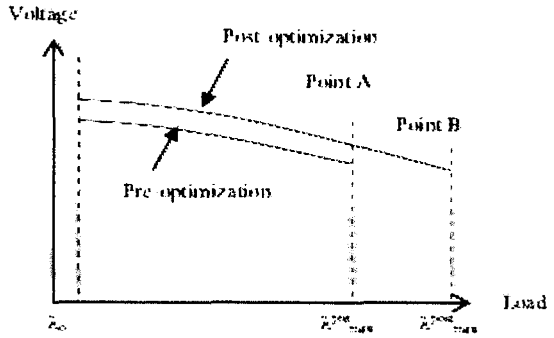

Fig.2. Voltage profile and load margin before and after the implementation of optimization technique [2]

C. Evolutionary Programming

Evolutionary Programming (EP) is an optimization technique based on the natural generation [6]. It involves random numbers represent the parameters responsible for the optimization of the fitness value. The basic EP method involves three step:

i. 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 (x_i, ηi), $\forall i \in \{1, 2, \ldots \mu\}$ where its generate randomly based on its limits. x_i represents the control variable/s and **ηi** is the strategic parameter/s for each x_i. The fitness values is measured for each individual based on its objective function, (x_i).

ii. Mutation

Mutation is performed on the random number, x_i, to produce offspring. Each parent (x_i, ηi), $i = 1,\ldots,\mu$, creates a single offspring (x'_i, η'_i), j=1,..., n, where x'_i and η'_i are given by:

$$x'_i(j)=x_i(j)+\eta'i(j)\,Nj\,(0,1) \qquad (4)$$

$$\eta'i(j)=\eta i(j)\exp(\tau'\,N(0,1)+\tau\,Nj\,(0,1)) \qquad (5)$$

AND

$$\tau=\left(\left(2(n)^{1/2}\right)^{1/2}\right)^{-1} \qquad (6)$$

$$\tau'=\left((2n)^{1/2}\right)^{-1} \qquad (7)$$

xi (j), x'i(j), η i(j) and *η'i(j)* are the *j*-th component of the vectors *xi* , *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 fir each offspring.

iii. Combination and selection

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

D. Artificial immune systems (AIS)

Artificial immune systems (AIS) are computational systems inspired by the principles and process of the vertebrate immune system [4]. 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.

E. Multiagent system (MAS)

A multi-agent system (MAS) 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 its neighbors are then compete, cooperate 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.

III. MULTIAGENT IMMUNE EVOLUTIONARY PROGRAMMING (MAIEP)

Multiagent Immune Evolutionary Programming (MAIEP) is the combination of EP, AIS and MAS techniques to optimize the desired objective function. At the beginning, the characteristic of an agent is in condition as follows:

A. Global Enviroment

All agent in MAIEP are arranged in the form of lattice-like an environment, L. The value of L is form from L_{size} x L_{size} where L_{size} is an integer. From fig.3, the circle is represent as an agent in MAIEP and coordinate in lattice represents the data carries. In addition, 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.

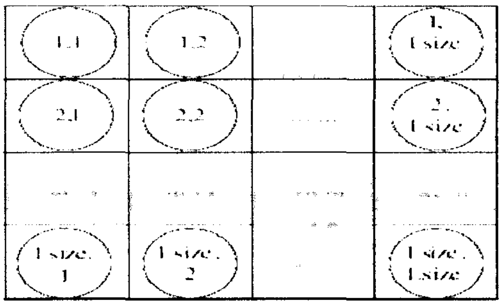

Fig.3: agent lattice

B. Local Enviroment

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 [7]. Suppose that the agent $\alpha_{i,j}, i, j = 1,2,\ldots,L_{size}$ then the neighbors of $\alpha_{i,j}$, $N_{i,j}$ are defined as follow:

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

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

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.

C. Objective of Agents

According in this project, in order to improve the loading margin each agent is assigned to identify the maximum value of MLP.

D. Agent's Behaviors

All agents have some distinctive behavior to respond to changes that occur 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 mechanism (EP operator) 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:

i. 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 (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 contribute a vacant lattice-point. The 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 [10].

ii. 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) [9]. Hence, mutation is a key search operator which generates new solutions to achieve the reliable result.

iii. 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.

IV. METHODOLOGY

The methodology of RPD for load margin improvement utilized MAIEP is show in fig.4 and fig.5. Fig.4 shows the flow chart to determine the MLP which is consist with 5th step in fig.4. To determine the MLP, V_{min} must be set at 0.85p.u as the cut-off point for voltage limit and before the system is assumed under unstable condition.

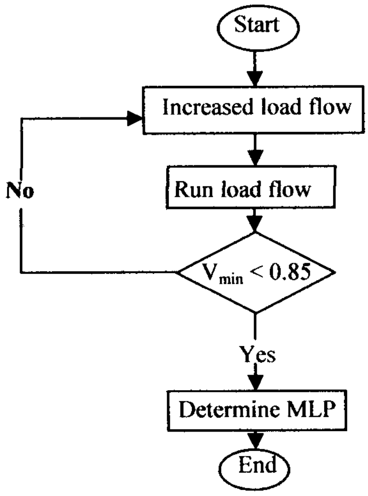

Fig.4. flowchart to determine the MLP [8]

From the fig.5, the all process of load margin improvement using MAIEP is conduct with the integrates the EP, AIS and MAS technique to optimize the objective function.

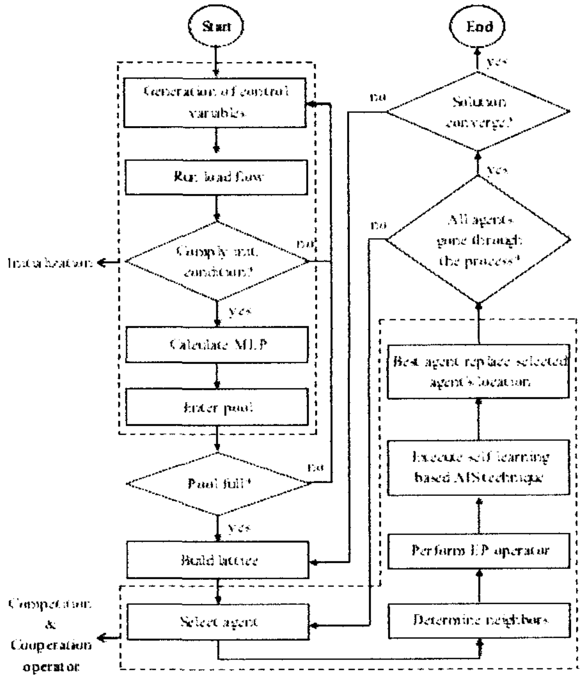

Fig.5. the all process of load margin improvement using MAIEP [2]

V. 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 to 3. The program was developed by using MATLAB software.

i. Pre optimization

At pre-optimization stage, system's condition is identified and also the critical bus base on load margin evaluation. In this project, the increments of Q_{load} are considered. The evaluation on the load improvement is monitored at the critical bus which is bus 26 and increased by (5%). Table I shows the result for maximum load of pre-optimization. From the result in table I, MLP is taken as a reference by comparison with optimization stage. Point A from fig.2 is actually the result during this pre-optimization result.

TABLE I
PRE-OPTIMIZATION RESULTS

		MLP (MVar)	**V_{min} (p.u)**	**V_{max} (p.u)**
(Bus 26)	**Q_{load}**	**18.300**	**0.8557**	**1.082**

ii. Post optimization

In this stage, the RPD utilized with EP and MAIEP technique to improve the load margin system. The value of load margin is improved during this stage. From fig.2 Point A and Point B are actually the results during this stage. Point A represent as pre-optimization technique meanwhile Point B represents as post optimization technique.

Table II present the result obtained during pre and post-optimization techniques considering maximizing loading point as objective function with the increment of Q_{load} at Bus 26. The overall result reflects that there was substantial improvement in load margin as well as the total system losses and voltage profile as compared to pre-optimization. In general, the total system losses utilizing EP and MAIEP technique were reduced up to 24.86% and 25.16% respectively, compared to pre-optimization stage and maximum loading point utilizing EP and MAIEP technique with improvement 15.63%. However, RPD with MAIEP technique was capable to offer faster computation time compared to EP. In percentage, MAIEP is 21.91% faster than EP in RPD approach.

TABLE II

PRE AND POST-OPTIMIZATION RESULT CONSIDERED Q_{LOAD} INCREASED WITH MAXIMIZING LOADING POINT WITH (EP) AND (MAIEP) TECHNIQUE

		RPD	
Optimization technique	**Pre-optimization**	**EP**	**MAIEP**
Reference Loading (MVar)	*18.300*	-	-
Loss (MW)	*19.402*	*14.579*	*14.520*
Loss reduction (%)	-	*-24.86*	*-25.16*
V_{min} (p.u)	*0.8557*	*0.8600*	*0.8614*
V_{max} (p.u)	*1.082*	*1.091*	*1.091*
Maximum loading (MVar)	*18.300*	*21.689*	*21.689*
MLP improvement (%)	-	*15.63*	*15.63*
Computional time (s)	-	*194.504*	*151.878*

Fig.6 below shows graph to compare the pre and post-optimization technique for improve the load margin as a objective function. From the graph, its shows that post optimization technique produced optimum result rather than pre optimization.

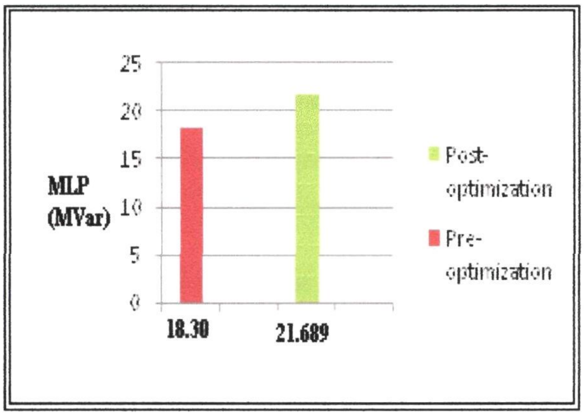

Fig.6. the graph to compare the pre and post-optimization technique

TABLE III

VALUE OF VARIABLES FOR LOAD MARGIN IMPROVEMENT BY USING MAIEP AND RPD TECHNIQUE CONSIDERING INCREMENT OF Q_{LOAD}

Opt. tech	**Variables**				
	Q_{g2}	Q_{g5}	Q_{g8}	Q_{g11}	Q_{g13}
EP	*30.638*	*25.562*	*2.4267*	*7.376*	*20.569*
MAIEP	*32.025*	*28.649*	*11.088*	*21.472*	*17.762*

Q_{g2}, Q_{g5}, Q_{g8}, Q_{g11}, and Q_{g13} represent reactive power.

VI. CONCLUSION

In this paper present the study of OPF technique utilizing EP and newly developed optimization technique known as MAIEP was implemented on the IEEE 30 bus system to improve the system's load margin. Comparison between the EP and MAIEP on the system's loadabilty, total system losses, voltage profile and total computation time. Based on the result, it can be concluded that MAIEP technique is reliable technique which capable of offering comparable result with EP technique in less computational time.

VII. ACKNOWLEDGEMENT

This project was made through support provided by author's supervisor Mrs Norziana Bt.Aminudin.Special thanks also to friends that supported on solving MATLAB programming.

REFERENCES

[1] C. S. Chang and J. S. Huang, "Worst-case identification of reactive power margin and local weakness of power systems", *Electrical Power Systems Research,* Vol. 44, pp. 77-83, 1998

[2] N. Aminudin, T. K. A. Rahman and I. Musirin are with Universiti Teknologi MARA, Shah Alam, Malaysia,"ORPP with MAIEP Based Technique for Loadability Enhancement" World Academy of Science, Engineering and Technology 50 2009.

[3] D.Baghwan Das and C. Patvardhan,"Reactive power dispatch with hybrid stochastic search technique," *International Journal of Electrical Power & Energy Systems,*vol. 24,pp. 731-736,2002.

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

[5] S. Greene,I.Dobson, and F.L Alvarado,"Sensitivity of the load margin to voltage collapse with respect to arbitrary parameters,"IEEE Transactions on a Power Systems,vol. 12 pp. 262-272,1997.

[6] Musirin, I. Rahman, T.K.A "Evolutionary Programming Based Optimization Technique For Maximum Loadability Estimation in Electrical Power System"Fac. Of Elec.Eng.Univ.Teknologi Mara, Malaysia: this paper appears in: Power Engineering Conference, 2003. PECon 2003. Proceedings. National Pubblication Date: 15-16 Dec.2003. On page(s): 205-210.

[7] Weicai Zhong; Jing Liu; Mingzhi Xue, Licheng Jiao; "A multiagent genetic algorithm for global numerical optimization" System, Man, and Cybernatic, Part B, IEEE Transactions on Volume 34, Issue 2, April 2004 Page(s): 1128-1141.

[8] Norziana Aminudin, are with Universiti Teknologi MARA, Shah Alam, Malaysia "Maximum Laodability Enhancement Of Power System Using Multiagent Immune Evolutionary Programming Optimazation Technique" Jan 2009.

[9] Yong Liu;" Evolutionary Programming with operator Adaptation" *Computer and Information Technology,* 2007. CIT 2007.7th IEEE International Conference on 16-19 Oct.2007

[10] Zhong Weichai; Liu Jing; Xue Mingzhi, Jiao Licheng;"Global numerical optimization using multi-agent genetic algorithm," *Computational Intelligence and Multimedia Applications,* 2003. ICCIMA 2003. Proceeding. Fifth International Conference on 27-30 sept. 2003.