# ACTIVE POWER OPTIMIZATION BASED ON NON ADAPTIVE IMMUNE ALGORITHM

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*Abstract* - **This paper presents a study of active power optimization based on non adaptive immune algorithm (NAIA) in power system. The aim of active power optimization is to reduce the power loss by controlling the active power scheduling on the generators. Simulation are carried out on standard IEEE 30-bus system and results are presented. All the process and development is done using MATLAB 7.0. Result obtained from the simulation indicated that the developed engine managed to minimize the losses in the system.**

*Index Terms* – **Non Adaptive Immune Algorithm, Active Power Optimization.**

## I. INTRODUCTION

Electric energy is the most popular form of energy. In 1882, the first electric network in United States was established at the Pearl Street Station in New York City by Thomas Edison. This has been reported by [1]. Electric power today plays an exceedingly important role in the life of community and in the development of various sectors of economy [8]. In fact the modern economy is totally dependent on the electricity as a basic input [8].

Today, the demand for electric energy has been increasingly acute. Due to this reason the optimal operation of the power system network is of most important. Generally, power losses in transmission of electrical energy results in a loss of revenue due to an increased generation capacity requirement. Thus, it is important to minimize the loss because it will also lead to the economic operation of the power system. Many algorithm have been reported as solution to minimize the losses.

There are many methods for solving power optimization, such as linear programming, non-linear programming, secondary programming, sensitive analysis and mixed integer planning [4-7]. These method are generally based on some presumptions and some defects. The non adaptive immune algorithm (NAIA), is based on an immunological system. NAIA is similar to Immune Algorithm (IA). IA refer to the mechanism of the amalgamation between antigen and antibody in biologic immune system and it has been focused recently. IA has a faster computation speed and a better convergence than GA and other stochastic type algorithm, due to its characteristic of having two layers of optimization[3].

This paper presents active power optimization based on non adaptive immune algorithm. The study involved the development of an algorithm to optimize the active power on all generators in minimizing the power losses in the system.

## II. NON ADAPTIVE IMMUNE ALGORITHM

NAIA involves several operators namely, initialization, fitness computation, cloning process, mutation and selection. This section will explain individual operator in details. In this paper, a modified technique of population of antibodies or random number is applied. 20 random antibodies are generated. Figure 1.0 show process of initializing the antibodies for NAIA.

### a) Initialization

The antibodies or generated random number is placed in the bus data (IEEE 30) no. 2, 5, 8, 11 and 13. Figure 3.0 illustrates the single line diagram for IEE 30-bus RTS. This data bus is a generator bus or PV bus. For this bus, voltage magnitude, real power generation and the minimum and maximum limits of the megavar demand must be specified. These random numbers are the possible active power. This random number is placed in column five which is the column for active power for load.

For every possible antibody or active power, the total line loss is calculated using Newton Raphson load flow method's developed by [1]. When the loss is obtained, it is compared with the actual loss for IEEE 30-bus system. If the loss is less than the actual loss, the row of antibodies or active power is accepted. But if the loss is higher than actual loss, a new set of random number is generated until the condition is fullfill. Number of iteration depends on the number of antibodies generated. For this initialization process, it is decided that 20 antibodies to be generated, then there will be 20 iterations.

The size of matrix during initialization is 20 × n; therefore the general equation for initial population is λ :

$$\lambda = \begin{bmatrix} X_{11} & X_{12} & X_{13} & X_{14} & \dots\dots\dots\dots\dots & X_{1N} \\ X_{21} & X_{22} & X_{23} & X_{24} & \dots\dots\dots\dots\dots & X_{2N} \\ X_{31} & X_{32} & X_{33} & X_{34} & \dots\dots\dots\dots\dots & X_{3N} \\ & & \vdots & & & \\ X_{m1} & X_{m2} & X_{m3} & X_{m4} & \dots\dots\dots\dots\dots & X_{mN} \end{bmatrix} \quad (1.0)$$

Size = [m × N]

Where :

N = Number of control variables.

m = Population size.

In this case, N is five (5) to indicate five control variables; while m is twenty (20) to indicate twenty population. $X$ values will be assigned as the active power at the generator. These random numbers must be subjected to the generator limits; or called as the inequality constraints. The mathematical equation is given as :

$$P_{gmin(i)} \leq P_{g(i)} \leq P_{gmax(i)}$$

Where :

$P_{gmin(i)}$ = minimum limit for $P_g$ at generator i

$P_{gmax(i)}$ = maximum limit for $P_g$ at generator i.

### b) Cloning Process

Cloning is a process to copy or clone the population by certain multiplies. In this case 10 is chosen as the suitable cloning multiplier. When cloning process is performed to the population, the matrix size will be larger.

### c) Mutation Process

Mutation process is a process to breed off springs or children from the parents. There are several mutation techniques available namely, gaussion, cauchy and levy. In this study, Gaussion Mutation Technique is employed.

For the NAIA, the key parameters which are selection rate, extension radius and mutation radius, are fixed. Mutation process has created antibodies that no inheritance information. Suppose there are $X_i$ individuals and $X_i$ is mutated and assign to $X_{i+m}$ in accordance with the equation :

$$X_{i+m,j} = X_{ij} + N\left(P_m\left(X_j^{max} - X_j^{min}\,0\right)\frac{f_i}{f^{max}}\right) \quad (2.0)$$

$j$= 1,2,3,4………

Where

$X_{ij}$ = $j_{th}$ element of the $i_{th}$ individual

N = Gaussian random variable with mean μ and variance σ²

$f_i$ = the fitness value of the $i_{th}$ individual

$f^{max}$ = the maximum fitness value of old generation

$X_j^{max}$ = the maximum limit of the $j_{th}$ element

$X_j^{min}$ = the minimum limit of the $j_{th}$ element

$P_m$ = the mutation scale in the range between 0 and 1

Mutated population will have the same size as the cloned population because mutation is performed to the cloned population. Figure 2.0 indicates the overall process for NAIA in this study.

### d) Fitness Computation

The fitness for this study refers to the real power loss in the system. Several programming codes have been developed for the power flow solution of practical system. Some pre-developed programming codes are extracted form [1] . The program for Gauss-Seidel method is *lfgauss*, which is preceded by *lfybus* and is followed by *busout* and *lineflow*. *lfybus*, *busout* and *lineflow* are designed to be used with two more power flow programs. These are Newton-Raphson method and decouple for the fast decoupled method.

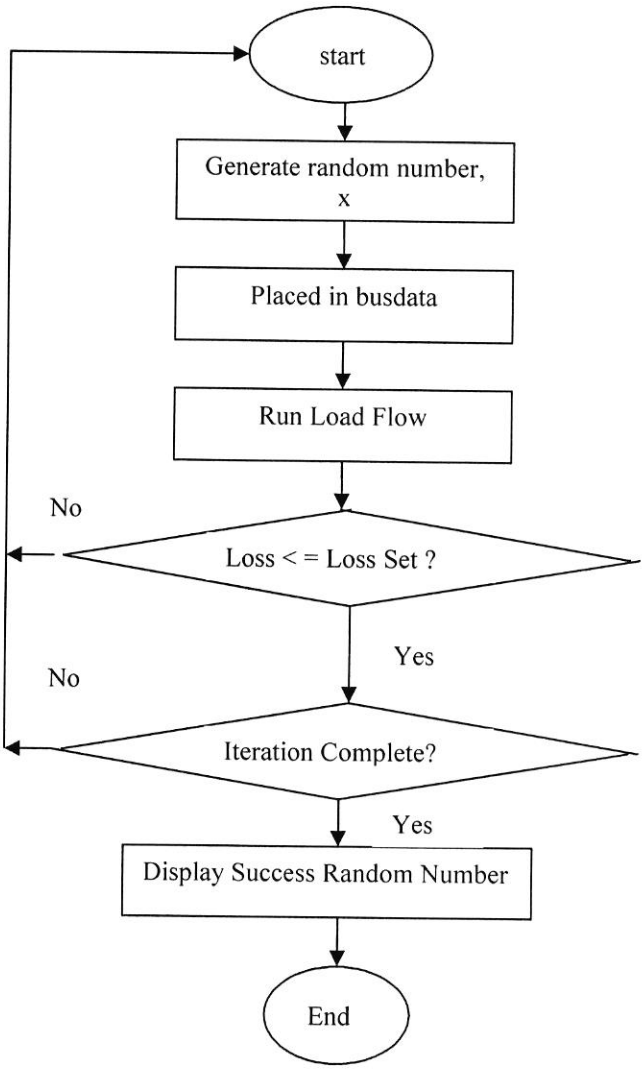


*Fig. 1.0 : Process Of Initializing The Antibodies In NAIA*

## III. THE MATHEMATICAL MODEL FOR ACTIVE POWER OPTIMIZATION

The objection function of this active power support control is to minimize the loss, which can be described in mathematical equation as shown below:

Minimize :

$$F = P_L + \gamma_\mu \sum \left( \frac{V_i - V_i^{lim}}{V_{i,max} - V_{i,min}} \right)^2 +$$

$$\gamma_Q \sum \left( \frac{Q_{G,i} - Q_{G,i}^{lim}}{Q_{G,i,max} - Q_{G,i,min}} \right)^2$$

$$V_i^{lim} = \begin{cases} V_{i,max} & V_i \geq V_{i,max} \\ V_{i,min} & V_i \leq V_{i,min} \end{cases}$$

$$Q_{G,i}^{lim} = \begin{cases} Q_{G,i,max} & Q_{G,i} \geq Q_{G,i,max} \\ Q_{G,i,min} & Q_{G,i} \leq Q_{G,i,min} \end{cases}$$

| | | |
|---|---|---|
| $P_L$ | = | the total real power loss of the system |
| $V_i$ | = | voltage of PQ bus |
| $V_{i,min}$ | = | lower limit of of PQ bus |
| $V_{i,max}$ | = | upper limit of of PQ bus |
| $Q_{G,i}$ | = | input reactive power of PV bus |
| $Q_{G,i,max}$ | = | lower limit of of PV bus |
| $Q_{G,i,min}$ | = | upper limit of of PV bus |

## V. RESULTS AND DISCUSSION

The developed NAIA have been tested on the IEEE 30-Bus Reliability Test System (RTS). The system consist of 5 generators, 1 swing bus, 4 transformer tap setting, 2 shunt compensation devices and 41 lines.

The generator-bus voltage magnitudes are treated as continuous control variables and others are treated as discrete control variable. For this study, adjustment is made for two different areas : 1) different loading condition value at the same bus number and 2) different loading condition at the same bus number with one of the generator bus in faulty mode. The purpose of this adjustment is to analyze and observe the behaviour of the standard IEEE 30 -bus system based on NAIA.

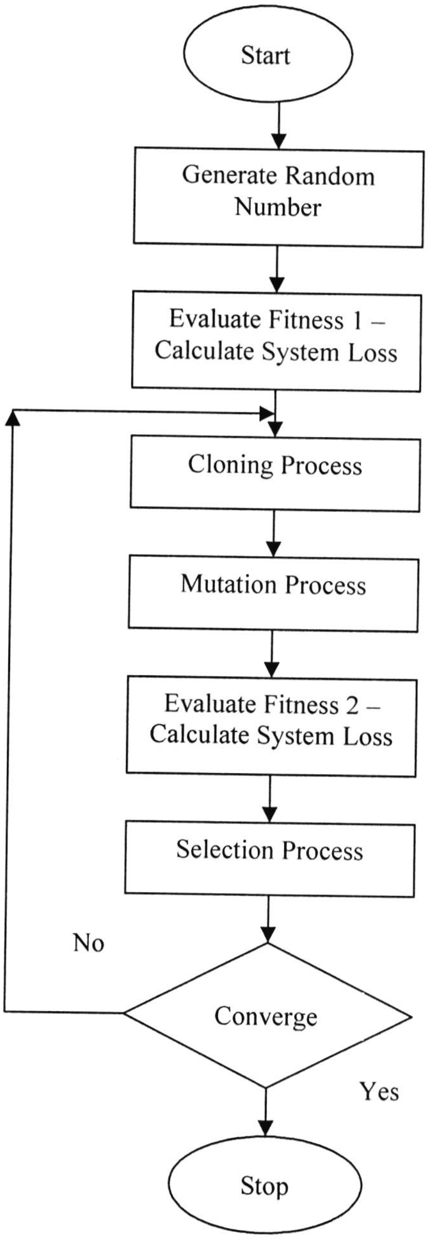


*Fig. 2.0 – Process Of The Non Adaptive Immune Algorithm*

Table 1
Data of the total losses before and after NAIA at bus 30

| Load value (MW) | Total Loss (MW) Before | Total Loss (MW) After | Total Loss Less (MW) | % Total Loss Less | Iteration | Computation Time (s) |
|---|---|---|---|---|---|---|
| 10 | 17.4880 | 5.42 | 12.0680 | 69.00 | 11 | 145.896 |
| 20 | 19.7953 | 5.91 | 13.8853 | 70.14 | 11 | 149.943 |
| 30 | 22.9831 | 6.46 | 16.5231 | 71.89 | 11 | 150.955 |
| 40 | 27.6751 | 7.06 | 20.6151 | 74.49 | 11 | 148.595 |
| 45 | 31.2605 | 7.43 | 23.8305 | 76.23 | 11 | 146.160 |

Fig. 4 illustrated the profile of loss variation for the pre and post optimization process using NAIA. It is observed that the profile for loss value with respect to load variation is lower for the post-optimization. The losses have been reduced significantly.

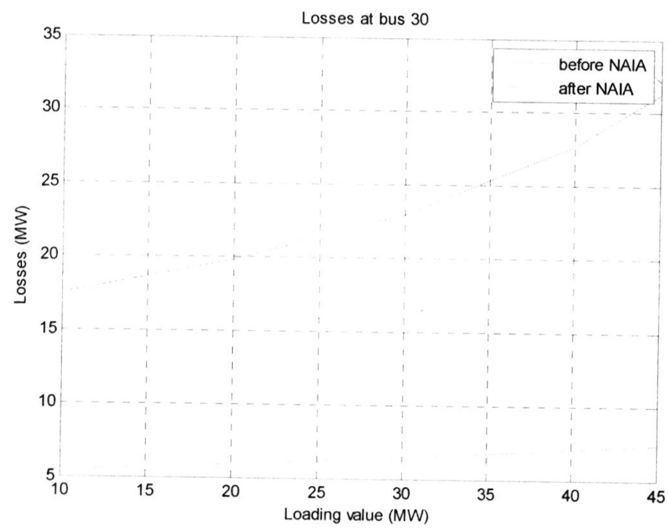


*Fig.4 : Comparison of the total loss before and after NAIA at bus*

A) Loading Condition at Bus 30

The results for loss minimization when bus 30 is subjected to load variation are tabulated in Table 1. From the table, implementation of NAIA has managed to reduce total loss at all load value.

B) Loading Condition At Bus 30 With Line 2 Is Removed

On the other hand, Table 2 tabulates the results for losses when bus 30 is subjected to load variation during faulty. In this case, one of the lines (line 2) is removed to emulate line outage contingency or fault condition. It is observed that NAIA also managed to reduces total loss. However the amount of reduction is lower as compared to Table 1, whereby the system does not experience contingency.

Table 2

Data of the total losses before and after NAIA at bus 30 with line 2 is removed

| Load value (MW) | Total Loss (MW) Before | Total Loss (MW) After | Total Loss Less (MW) | % Total Loss Less | Iteration | Computation Time (s) |
|---|---|---|---|---|---|---|
| 10 | 27.2411 | 8.35 | 18.8911 | 69.35 | 11 | 146.932 |
| 20 | 30.5501 | 9.56 | 20.9901 | 68.71 | 11 | 147.885 |
| 30 | 35.5312 | 10.93 | 24.6012 | 69.24 | 11 | 152.922 |
| 40 | 42.1987 | 12.44 | 29.7587 | 70.52 | 11 | 148.359 |
| 45 | 48.5526 | 13.25 | 35.3026 | 72.71 | 11 | 144.595 |

C) Loading Condition At Bus 30 With Line 5 Is Removed

Table 3 tabulates the results for losses when bus 30 is subjected to load variation during faulty. In this case, line 5 is removed to emulate line outage contingency or fault condition. It is observed under this condition the NAIA also managed to reduces total loss. The amount of reduction is higher as compared to Table 1 and Table 2, whereby the system also does not experience contingency.

Table 3

Data of the total losses before and after NAIA at bus 30 with line 5 is removed

| Load value (MW) | Total Loss (MW) Before | Total Loss (MW) After | Total Loss Less (MW) | % Total Loss Less | Iteration | Computation Time (s) |
|---|---|---|---|---|---|---|
| 10 | 32.155 | 6.15 | 26.0050 | 80.87 | 11 | 148.523 |
| 20 | 35.266 | 6.70 | 28.5665 | 81.00 | 11 | 150.972 |
| 30 | 39.915 | 7.31 | 32.6059 | 81.69 | 11 | 145.656 |
| 40 | 46.440 | 7.98 | 38.4606 | 82.82 | 11 | 145.2129 |
| 45 | 51.012 | 8.34 | 42.6725 | 83.651 | 11 | 145.595 |

D) Total Active Power Generated Before And After NAIA

Table 4, tabulates the results for total active power generated before and after NAIA. It is observed that the NAIA managed to reduced the total active power generated due to reduction of power loss in the system during normal and faulty condition.

Table 4

Data of the total active power generated before and after NAIA at bus 30

| Load value (MW) | Total Power Generated at Buses | | | | | |
|---|---|---|---|---|---|---|
| | Pre-contingency | | Line 2 Removed | | Line 5 Removed | |
| | Before (MW) | After (MW) | Before (MW) | After (MW) | Before (MW) | After (MW) |
| 10 | 300.288 | 152.007 | 310.041 | 155.438 | 314.947 | 153.238 |
| 20 | 312.570 | 163.004 | 323.350 | 166.655 | 328.066 | 163.790 |
| 30 | 325.757 | 173.550 | 338.331 | 178.018 | 342.716 | 174.401 |
| 40 | 340.448 | 184.152 | 354.999 | 189.530 | 359.241 | 185.072 |
| 45 | 349.060 | 189.474 | 366.353 | 195.343 | 368.804 | 190.430 |

## IV. CONCLUSION

This paper has presented active power optimization based on NAIA. From the results it is observed that NAIA managed to reduce losses of the system at all load values. Thus, NAIA is feasible to be implemented in larger system within the same scenario. Nevertheless, the developed algorithm could be modified to solve other optimization problems.

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