Artificial Immune System Optimization Technique for Optimal Location and Parameter Setting of UPFC

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Abstract – **This project paper is about to find optimal location for parameter setting of Unified Power Flow Controller (UPFC) at line data in transmission line from bus system by using Artificial Immune System (AIS) programming technique. The performance of this technique was tested on IEEE 26-Bus reliability test system. The minimum total losses and total cost are determined and the lowest values is selected as the best optimal location to place UPFC at 3 lines of transmission line.**

Keywords: Unified Power Flow Controller (UPFC), Artificial Immune System (AIS). Flexible AC Transmission Systems (FACTS).

I. INTRODUCTION

FACTS devices is a device that have a large potential ability to make power systems operate in a more flexible, secure and economic way. Unified power flow controller (UPFC) is the most powerful device in power flow control in FACTS family. The injection power and control parameters of UPFC were introduced into the optimal power flow problem [1]. UPFC also have the capability to control voltage magnitude and phase angle. By using the UPFC the total losses and cost can be reduce into optimal value. There are many ways to represent UPFC into the bus system. In this paper the UPFC is present by controlling the value of impedance at line data by using Artificial Immune System (AIS) based on optimization technique to find the optimal location.

II. UNIFIED POWER FLOW CONTROLLER UPFC

A. Operating principle of UPFC

A theory mathematical model for UPFC which will be referred as UPFC injection model is derived. This model is helpful in understanding the impact of the UPFC on power system. UPFC consists of two switching converters. These converters are operated from a common dc link provided by a dc storage capacitor which is illustrated in Figure 1.

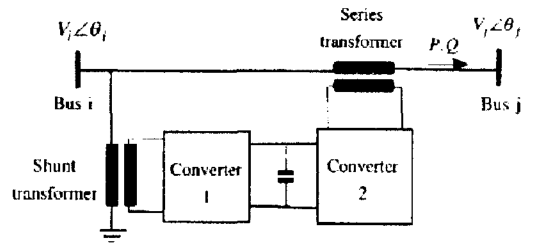

Figure 1: UPFC model

Converter 2 provides the main function of the UPFC by injecting an ac voltage with controllable magnitude and phase angle in series with the transmission line via a series transformer. The basic function of converter 1 is to supply or absorb the real power demand by converter 2 at the common dc link. It can also generate or absorb controllable reactive power and provide independent shunt reactive compensation for the line. Converter 2 supplies or absorbs locally the required reactive power and exchanges the active power as a result of the series injection voltage [2].

B. Series Model of UPFC

The series voltage source converter can be modeled with an ideal series voltage $\bar{V}_S$ in series with a reactance X_s. A series connected voltage source is located between nodes i and j. The injection model is obtained by replacing the voltage source $\bar{V}_S$ by the current source $\bar{I}_S = -jb_s\bar{V}_S$ in parallel with the line where $b_s = 1/X_s$.

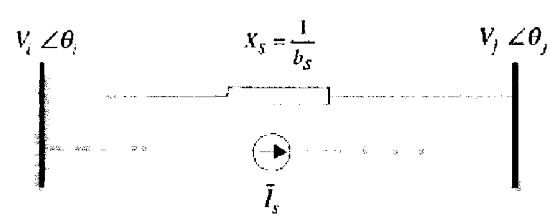

Figure 2 : Replacement of a series voltage source by a current source

The current source $\bar{I}_S$ corresponds to the injection powers $\bar{S}_{is}$ and $\bar{\bar{S}}_{js}$ where:

$$\bar{\bar{S}}_{js} = \bar{V}_i\,(-\bar{I}_S)^*$$
$$\bar{\bar{S}}_{js} = \bar{V}_j\,(\bar{I}_S\,)^*$$

The injection power $\bar{S}_{is}$ and $\bar{\bar{S}}_{js}$are simplified to:

$$\bar{S}_{is} = \bar{V}_i\,[jb_s r\bar{V}_i\,e^{j\gamma}]^*$$
$$= -b_s r V_i^2 \sin\gamma - jb_s r V_i^2 \cos\gamma$$

If we defined : $\theta_{ij} = \theta_i - \theta_j$ we have:

$$\bar{\bar{S}}_{js} = \bar{V}_j[-jb_s r\bar{V}_i\,e^{j\gamma}]^*$$
$$= b_s r V_i V_j \sin(\theta_{ij} + \gamma) + jb_s r V_i j\cos(\theta_{ij} + \gamma)$$

From the equation above, the series voltage source is considered as two-voltage dependent loads. Therefore, the equivalent reactance, Xs will alter the effective parameter of the transmission line. This will effect the amount of power flow through the line, which will give the impact to the voltage at the receiving bus [3].

III. ARTIFICIAL IMMUNE SYSTEM (AIS)

There are several computational techniques that look to biology for inspiration such as Artificial Immune System (AIS). Based on the immune system network some mathematical immune algorithm is obtained [4]. The immune system is a complex of cells, molecules and organs which is proven capable to have many potential applications, like pattern recognition, distributed and adaptive control, machine learning, fault detection, computer security, generalization, optimization and distributed system design [5].

IV. METHODOLOGY

The overall process for using AIS method in this project is shows in flowchart in Figure 3. The process of AIS flows started from generate initial population then to the clone process, mutation, rank process, selection for the best 20 numbers, convergence test and end the process.

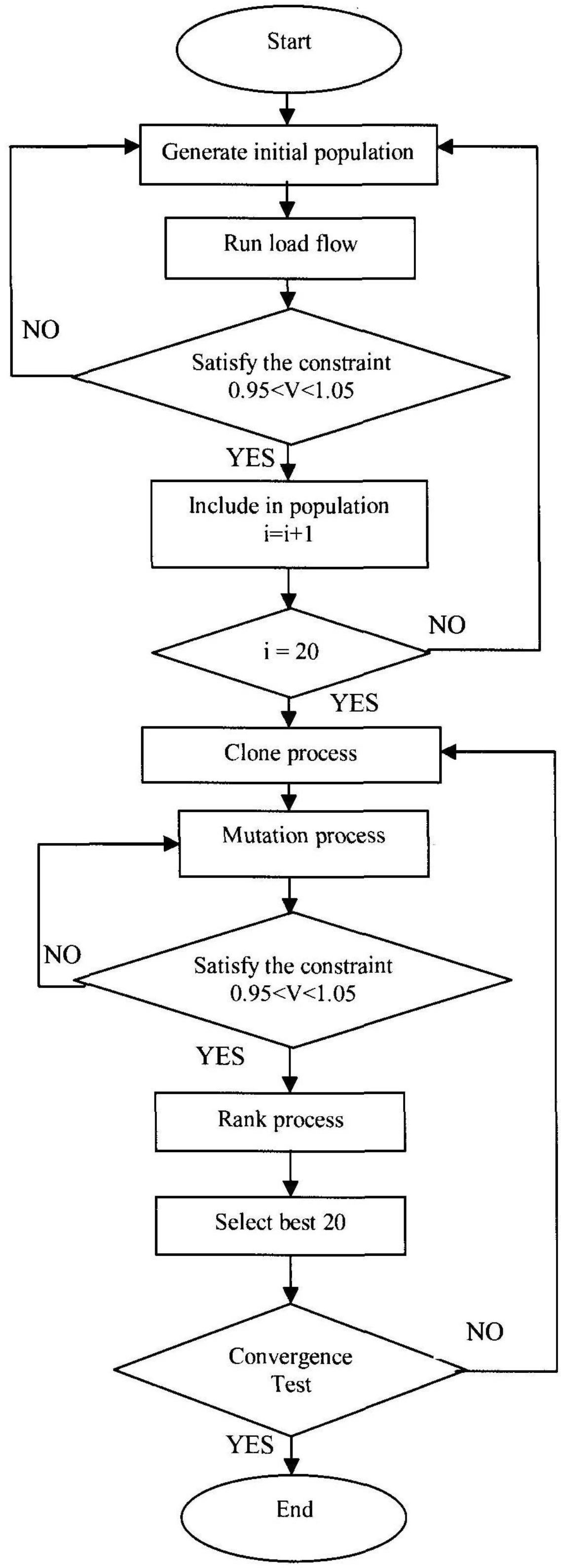

Figure 3 : Overall flowchart for AIS

A. Generate Initial Population

This is the part where a certain number is generating randomly to initialize the early value of a population. During initialization, random number will be generated which represent the control variable for value resistor R and impedance X which used to determine the objective function. This two generated value of R and X will replace the old value of R and X at line data that have been chosen. The 3 line data with new value of R and X randomly is represented as UPFC. Normally, 20 numbers of control variable function will be generated. There are 2 single objective function and 2 multi-objective function have been considered below :

Objective Function 1, F1 : Total losses
Objective Function 2, F2 : Total cost
Multi Objective Function 3, Fm1 : α(F1)+(1-α)F2
Multi Objective Function 4, Fm2 :α(F1)+β(F2)

B. Clone

The clone selection principle is an algorithm used by the immune system to describe the basic features of an immune response to an antigenic stimulus. The clone selection algorithm reproduces those individuals with higher affinity and selects their improved matured offspring, where single members will be locally optimized and the newcomers yield a broader exploration of the search space. The cloning in this process will copy the control variable of R and X value that have been generated early. 10 cloned populations will produced and the results will be 200 numbers because the number of parents is 20.

C. Mutation

Mutation is the process to introduce variability in a solution population and to avoid search stagnation in a non appropriate region of the search space. Calculated fitness value will be used for the mutation process. The random number, n was performed on mutation to produce offspring. For AIS method it will mutate the numbers from the clone population to produce offspring which is 200 new numbers are produced.

The equation for mutation can be derived as:

$$\eta'_i = \eta'_i(j)\exp\left[\tau' N(0,1) + \tau Nj\,(0,1)\right] \ldots(1)$$

$$x'_j = x_i(j) + \eta'_i(j)Nj\,(0,1) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where τ and τ' is

$$\tau = [(2(n)^{\frac{1}{2}})^{\frac{1}{2}}]^{-1} \ldots\ldots\ldots (3)$$

$$\tau' = [(2(n)^{\frac{1}{2}}]^{-1} \ldots\ldots\ldots\ldots (4)$$

η_i = strategy parameter distributed random number.
η_i' = mutated strategy parameter
x_i' = mutated random number

D. Selection

In selection, the offspring produced by mutation process will be sort and the best twenty values are chosen from two hundred values of the offspring which are from the minimum values to the maximum values. The objective functions will select the best minimum fitness value.

E. Convergence test

Convergence is describes as limiting behavior, particularly of an infinite sequence or series toward some limit. The criteria for convergence is specified when the value of difference between maximum fitness and minimum fitness is less than 0.5. The process will be repeated if it is not converge or satisfied the difference value.

V. Results And Discussion

The performance of single stage AIS was tested on IEEE 26-Bus reliability test system. The objective functions are to minimize the total losses and minimize the total costs in the system. The best optimal solution was obtained from 5 times test runs with different initial random seed numbers.

TABLE I. : Objective Function 1 : F1 (Total Losses)

Number Of Running	Total Loss (MW)	Total Cost ($/hr)	Vmin (p.u.)
1	22.29341	21659.77	0.950456
2	21.95573	21652.77	0.951163
3	22.06372	21655.01	0.951589
4	21.8563	21650.72	0.950749
5	**21.67634**	21647.00	0.950601

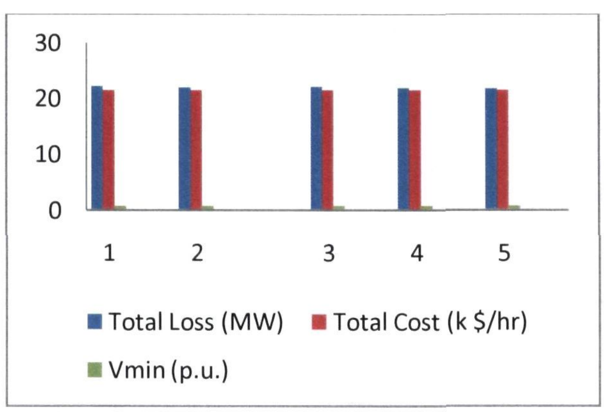

Figure 4 : Graph of Objective function 1 (F1) for total losses

From the Table 1, it shows the minimum total losses (F1) as objective function by using single stage AIS technique. From the results, the best minimum total losses after 5 times running is 21.67634 MW and the best value for R and X to get the minimum total losses for Line 1, Line 2 and Line 3 are shown below:

TABLE II. : THE BEST VALUE OF R AND X AS PARAMETER FOR UPFC

Line 1		Line 2		Line 3	
R1	*X1*	*R2*	*X2*	*R3*	*X3*
0.00023	0.02954	0.00675	0.11266	0.02480	0.45305

TABLE III. OBJECTIVE FUNCTION 2 : F2 (TOTAL COSTS)

Number Of Running	Total Loss (MW)	Total Cost ($/hr)	Vmin (p.u.)
1	21.70817	21647.65	0.950164
2	21.70381	21647.56	0.950221
3	21.67685	21647.01	0.952339
4	21.57067	**21644.81**	0.950263
5	21.6376	21646.19	0.950403

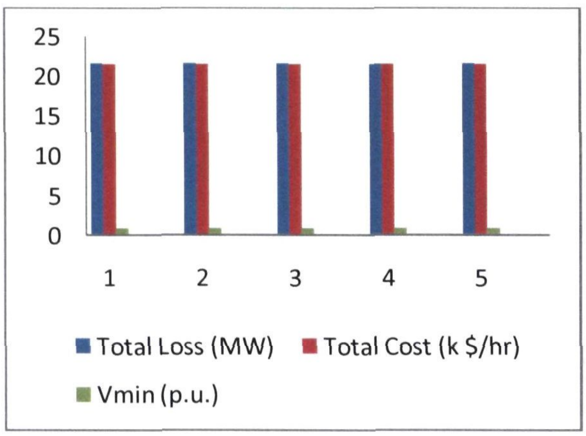

Figure 5 : Graph of Objective function 2 (F2) for total costs

From the table 3 and figure 5 above, it shows that after 5 times running for objective function 2, the best minimum total costs is about 21644.81 $/hr and the best value for R and X at Line 1, Line 2 and Line 3 to get the minimum total costs are shown below:

TABLE IV. : THE BEST VALUE OF R AND X AS PARAMETER FOR UPFC

Line 1		Line 2		Line 3	
R1	*X1*	*R2*	*X2*	*R3*	*X3*
0.00008	0.02848	0.000004	0.03471	0.02815	0.38029

TABLE V. MULTI OBJECTIVE FUNCTION 3 : FM1

Number of Running	Total Loss (MW)	Total Cost ($/hr)	Vmin (p.u)	Value Fml
1	22.95523	21673.47	0.950164	0.043637
2	22.8426	21671.14	0.950411	0.013673
3	22.44184	21662.84	0.950413	0.021601
4	22.96351	21673.65	0.952047	0.016114
5	22.92909	21672.93	0.95281	**0.010252**

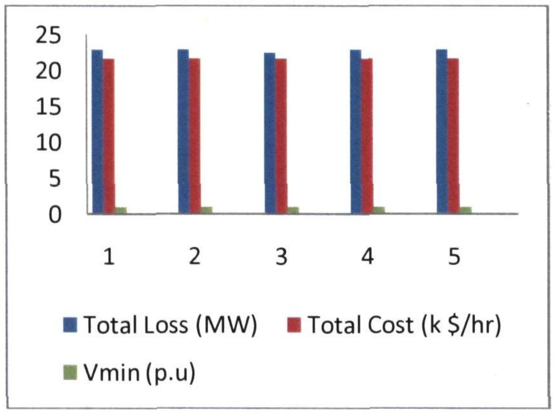

Figure 6 : Graph of Multi Objective function (Fm1)

Table 4 and figure 6 above shows the result for multi objective function Fm1 which is the equation for Fm1= α(F1)+(1-α)F2. The value for F1 and F2 must be normalize first before calculate the value of Fm1 because the difference between both value are too large. The lowest value of Fm1 after 5 times running is 0.010252 and the minimum value of α is about 0.626882. From the minimum value for Fm1, the total lost is 22.92909 MW and the total costs is 21672.93 $/hr. The table below shows the best value of impedance to get the lowest value for Fm1.

TABLE VI. THE BEST VALUE OF R AND X AS PARAMETER FOR UPFC

Line 1		Line 2		Line 3	
R1	*X1*	*R2*	*X2*	*R3*	*X3*
0.0160	0.0617	0.0603	0.4693	0.0106	0.3243

TABLE VII. MULTI OBJECTIVE FUNCTION 4 : FM2

Number of Running	Total Loss (MW)	Total Cost ($/hr)	Vmin (p.u)	Value Fm2
1	22.62867	21666.71	0.950893	0.013658
2	22.17416	21657.3	0.950354	0.013970
3	22.73167	21668.84	0.950063	0.01421
4	22.85301	21671.36	0.95281	**0.010654**
5	22.31972	21660.31	0.950413	0.011125

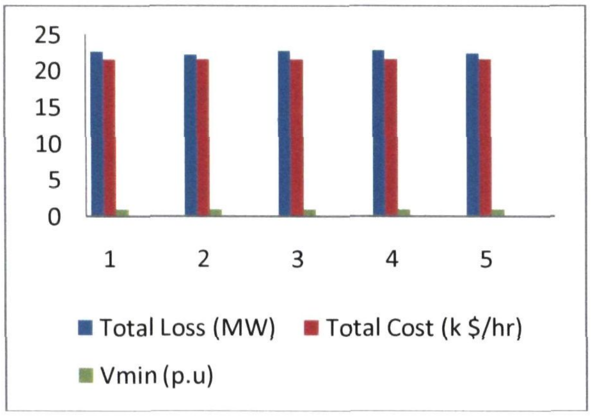

Figure 7 : Graph of Multi Objective function (Fm2)

From the table 7 and figure 7 above it shows that the lowest value for multi objective function Fm2 is equal to 0.010654 after 5 times running. The total losses and total costs for the lowest value of Fm2 are 22.85301 MW and 21671.36 $/hr. The equation for Fm2 is equal to $\alpha(F1)+\beta(F2)$. The value of F1 and F2 must be normalize first because the difference number between both values are too large. The minimum of α and β to get the minimum value of Fm2 is about α=0.92756 and β=0.14135. The table below shows the best value of impedance to get the minimum value of Fm2 by using this AIS technique.

TABLE VIII. THE BEST VALUE OF R AND X AS PARAMETER FOR UPFC

Line 1		Line 2		Line 3	
R1	*X1*	*R2*	*X2*	*R3*	*X3*
0.0366	0.1955	0.000128	0.17685	0.1278	0.3736

The best result of objective functions using single stage AIS has been compared. The table and graph shows the comparison for the best optimization among objective functions using AIS technique.

TABLE IX. COMPARISON FOR THE BEST OBJECTIVE FUNCTION USING AIS TECHNIQUE

Objective Function	Total loss (MW)	Total cost ($/hr)	Vmin (p.u)
AIS F1	21.67634	21647.00	0.950601
AIS F2	21.57067	21644.81	0.950263
AIS Fml	22.85301	21671.36	0.95281
AIS Fm2	22.92909	21672.93	0.95281

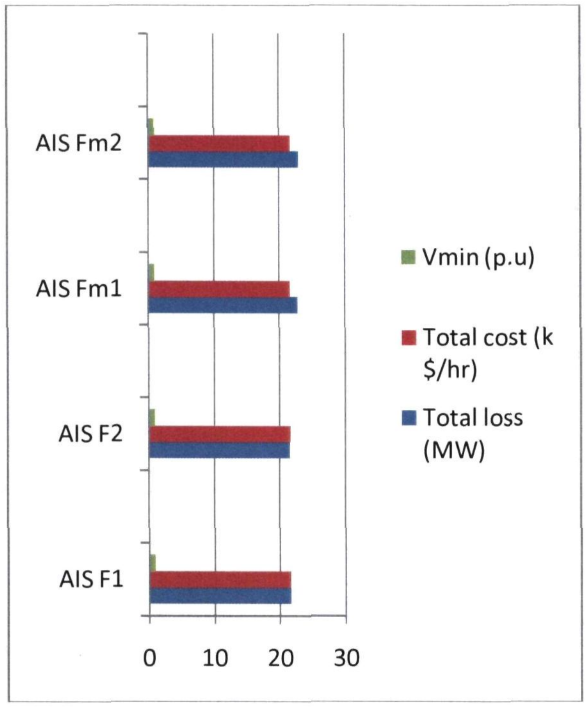

Figure 8 : Graph of Comparison For The Best Objective Function Using Ais Technique

From the table 9 and figure 8 above, the best objective function F2 is the best optimization result compared to other objective functions which gave the best minimum result of total losses, total costs and minimum voltage. The value of R and X for line 1, 2 and 3 will be the best value to decrease the total losses, total costs and to minimize the voltage for the system.

VI. CONCLUSION

The Artificial Immune System has been applied for solving optimal location problem in this project. There are 2 objective functions which are minimize the total losses (F1), minimize the total costs (F2) and 2 multi objective functions are Fm1 and Fm2.

The best objective function is F2 when comparisons were made among the other objective functions. It is because F2 gave the best result for reducing the total costs, minimizing the total losses and minimum value of the voltage for the system.

Based on the result, it can be conclude that the Artificial Immune System is the best technique to solve the optimal location and parameter setting of UPFC problem. The total losses can be reduced and the total costs can be minimize in the system by using this efficient technique.

VII. FUTURE DEVELOPMENT

For future development, the single stage AIS technique can be develop to multistage AIS technique to get the better result. This technique also can be implemented at power system network for injection of UPFC at transmission line because it has more benefits to the system like reduce the total losses and costs. Further modification should be included to get the better result by using this technique.

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