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# Minimize Power Loss in Distribution System by Optimize Location and Sizing of Multiple DG with Algorithm Based Artificial Immune System

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**Abstract:** The aim of this paper is to minimize the power loss in distribution system by optimal the size and location of multiple distributed generations (DG). The optimum location and size of DGs are very challenging to minimize the power loss of the distribution system. The optimization techniques in Artificial Intelligence (AI) manage to solve such problem. The developed algorithm present in this paper which used for optimization is hybrid of based Artificial Immune System (AIS) with Genetic Algorithm (GA) which named as Three Parents Cross Transform of Artificial Immune System (X3PAIS).The proposed algorithm were tested in three benchmark mathematic test functions before apply in the distribution system. Standard IEEE-14 bus distribution system was used in this research.

**Keywords:** AIS, DG, distribution system, GA, optimization

## 1. Introduction

Power loss is a key concern about distribution systems where operated in high current and low voltage condition compared to a transmission network [1]. Because of this, it cause of increase the active power loss and voltage profile is dropped to a major level in the distribution feeder. The world distribution companies meet the biggest challenge is to reduce those losses. Therefore, minimize power losses are the principal procedure to be considered for economic action and saving of energy cost.

Distributed Generation (DG) is a technology which generates electricity at or near where it will be used. DG units may be renewable energy sources. Due to limitation of fossil fuel, renewable based DG units have become a primary choice. These DG sources guarantee an enhancement in the supply reliability due to their endless nature and reduction in greenhouse gas emissions as these are nonpolluting [2]. DG can befunctionas a single system, such as a household or a company, or it may be part of a microgrid, such as at a huge industrial facility, or a university campus.DG is helped to deliver reliable power when connected to a lower voltage distribution lines and reduce electricity losses along transmission and distribution lines. The benefit of DG technology to a distribution system are reduced the power losses, improved load factors, enhance bus voltage profile and it bring efficiency and reliability to the distribution system. To optimum the benefits of DG technology, location and load size of DG units design is playing a very important role in a distribution system.

In order to optimize the DG units in an effective manner without causing degradation of reliability, system operation and power quality, various researchers applied different approach on it. M. H. Moradi [3] proposed Pareto frontier differential evolution (PDE) algorithm to solve the optimal location and operation of DG. M. Abdel [4] presents Genetic Algorithm (GA) based method to improve the distribution system using DG sources. S. Nagaballi [5] optimum placement and sizing of DG in radial distribution system by hybrid fuzzy and Particle Swarm Optimization (PSO).S. Nawaz [6] formulated an objective function to find out the optimal size an, quantity and position of DG units for real power loss reduction and voltage profile enhancement. K. Saicharan [7] proposed to placement of Unified Power Quality Conditioner (UPQC) and DG effectively in radial distribution system to improve voltage profile and power loss can be reduced more effectively.M. Khasanov[8] proposes an application for Electrostatic Discharge Algorithm (ESDA), as a recent and efficient optimization algorithm for finding the optimal DG allocation.

This paper presents an Artificial Intelligence (AI) algorithm based Artificial Immune System (AIS) to find the optimum location and size in the distribution system to reduce the power losses. A proposed algorithm described in this paper is X3PAIS which united the mechanism of improved AIS and GA (using crossover operator). All the information of each algorithm is described in section below. The proposed algorithm will be evaluated with popular benchmark mathematics function. The proposed algorithms were used to optimize the allocation and size of DG units to reduce power losses of distribution system. Standard IEEE-14 bus distribution system was used in this paper.

### 1.1 Artificial Immune System

The idea of AIS is inspirited by the nature biological immune system. Besides that, AIS can be used in solving engineering problem with immunology theory, immune principles, models or function [9]. One of the optimization technique in AIS operation of AIS named as clonal selection algorithm (CSA) was used in this paper. For optimization, the fundamental of CSA in AIS which is the affinity maturation and clonal expansion are used [10].

During CSA cloning process, the antigen which can be best recognize by the antibodies will proliferate. Every antigen will have their own specific immune reaction and it will be clone with recreate immune cells in tandem. When the immune cells which can be identify and compete with the specific antigen, this process only consider as success. Plasma and memory cells will be characterized when the newly cloned cells produced. Under mutation process, the plasma cells are subject to create antibody to enrich the genetic variation while the memory cells are in responsible for incursion of antigen in the upcoming immunologic response.

Henceforth in the next mechanism population, selection will depends on which greatest cells have similarity higher with the particular antigen. If mutation process still on going, the high affinity cells with hyper mutation will go into sleep mode while it will undergo withdraw through apoptosis process for the low affinity cells [11]. Theory of CSA process described in Fig. 1.Layout of pseudo code for a typical CSA process is written off as shown in Fig. 2.

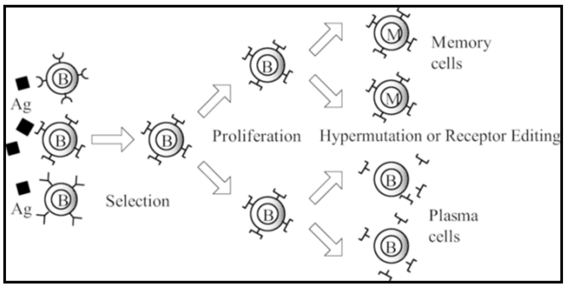


Figure 1: The clonal selection theory

```
begin AIS
  c:=0  { counter }
  Initialize  population
  Do:
    Compute affinity
    Generate clones
    Mutate clones
    Replace lowest affinity Ab with a new randomly generated Ab
   c:=c+1
  end
end AIS
```

Figure 2: Pseudo-code of the CSA

### 1.2 Genetic Algorithm

GA is the members of Evolutionary Algorithm (EA) and it was introduced by John Holland in 1960's [12-14]. GA have since long been used for optimization of high demand in searching for a design with minimal cost for performance of an enquiry [15]. GA is one of the. It used to solve assortment of problems and is proven capable in optimization of determined problem strategy. The crossover operator of GA was chosen to improving AIS algorithm where the idea is comes from the conjugation of bacterial cells.

The purpose of crossover is generates a new set of antibodies by using two or more of members which selected from current population. Crossover process is swapping the genetic criteria between chromosome of same parents or with other parents. There is few type of crossover method in GA but in this paper, the three parents' crossover method was selected to improve the optimum minimum value.

The three parents crossover means that there are three chromosomes are chosen as parents for crossover process. Every bit of each parent is comparing with each other. In the beginning of crossover process, same point of each bit from first parent and second parent go under comparison. It is used for offspring if the bits are the same; or else the third parent's bit is taking as offspring. Summarized for input and output of the each bit for three parents was represent in Fig. 3. The truth table of the process is express in table 1 below.

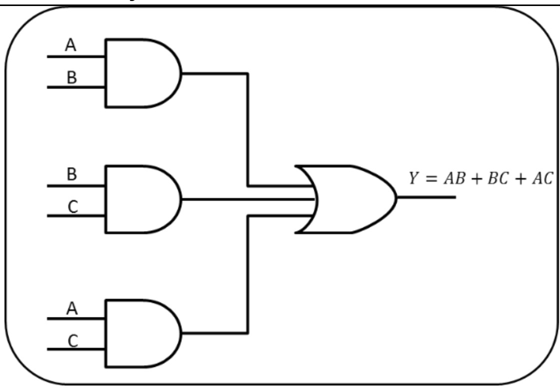


Figure 3: Logic Diagram of input & output for three parents' crossover

Table 1: Truth table for proposed cross three parents

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | **0** |
| 0 | 0 | 1 | **0** |
| 0 | 1 | 0 | **0** |
| 0 | 1 | 1 | **1** |
| 1 | 0 | 0 | **0** |
| 1 | 0 | 1 | **1** |
| 1 | 1 | 0 | **1** |
| 1 | 1 | 1 | **1** |

### 1.3 Proposed Algorithm

The idea of conjugation of three parent cells was used to enhance the AIS algorithm by improving the final result. This proposed algorithm is named as Three Parents Cross Transform of Artificial Immune System (X3PAIS). There is a lot of virus or bacteria newly transformed and evolved around us, which inspired of this develop algorithm to be born. During the evolution of the bacteria, the genetic variation of cells is affected by genetic material surrounding directly or indirectly. Transformation can also occur naturally in some species of bacteria, but it can also be affected by artificial ones.

In this paper, the transformation bacteria process is represented by conjugation of three bacterial cells, which means crossover of genetic between three bacterial cells that are in direct contact. The crossover processes in this paper represented of the conjugation of bacterial cells obtain the better results for the system. But to ensure the three selected superior genes obtain from developed algorithm have the best antibody, the better criteria of the genes population will be cloning and become the part of new genes. More mature antibodies Y will obtain after the genetics of the chosen three antibodies was swapped during the crossover process. The conjugation process will be represented by crossover process, which uses the GA operator as described previous section. The simplified process of X3PAIS was described in Fig. 4

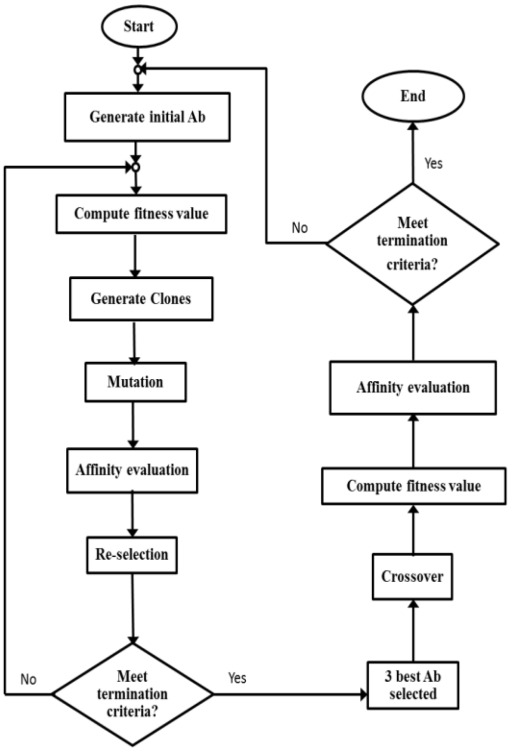


Figure 4: Flow chart of simplified X3PAIS algorithm steps

## 2. SIMULATION

### 2.1 Mathematic Test Function

There are various benchmark functions with different properties used to compare and evaluate different type of algorithm which include the basic AIS, AIS hybrid with cross two cell (TRANSAIS) and X3PAIS. To achieve the better results, some algorithm exploited the properties of the popular benchmark function. In this paper, three common mathematical test functions are used to evaluate the algorithm to obtain the minimize value. The test functions are Griewank's, Move-Axis Parallel Hyper-Ellipsoid's and Rastrigin'sfunction which described as below.

#### 2.1.1 Griewank's Function

The Griewank's function (A) is mathematically defined as below:-

$$f(x) = 1 + \frac{1}{4000}\sum_{i=1}^{n} {x_i}^2 - \prod_{i=1}^{n} \cos(\frac{x_i}{\sqrt{i}}) \quad (1)$$

Where: $-600 \leq x_i \leq 600, \; i = 1, \dots \dots .., n$
It has a global minimum at $x = 0$where $f(x) = 0$.

#### 2.1.2 Moved Axis Parallel Hyper-Ellipsoid's Function

The Moved Axis Parallel Hyper-Ellipsoid's function (B) is mathematically defined as below:-

$$f(x) = \sum_{i=1}^{n} 5i \, . \; {x_i}^2 \quad (2)$$

Where: $-5.12 \leq x_i \leq 5.12, \; i = 1, \dots \dots .., n$
It has a global minimum at $x = 0$where $f(x) = 0$.

2.1.3 RASTRIGINS FUNCTION

The Rastrigin's function (C) is mathematically defined as below:-

$$f(x) = \sum_{i=1}^{n} ( {x_i}^2 - 10 \cos(2\pi x_i) + 10 ) \tag{3}$$

Where: $-5.12 \leq x_i \leq 5.12, \; i = 1, \dots \dots \dots, n$
It has a global minimum at $x = 0$where $f(x) = 0$.

### 2.2 Distributed Generation

The main objective of this paper is to minimize the power loss in distribution system. Installation of 4 DG units with optimum size and location are able to achieve it. This paper was using the IEEE 14 bus system as show in Fig. 5. The benchmark system data was taken from IEEE where the data is on 100MVA base. Simulation is run with Matlab software.

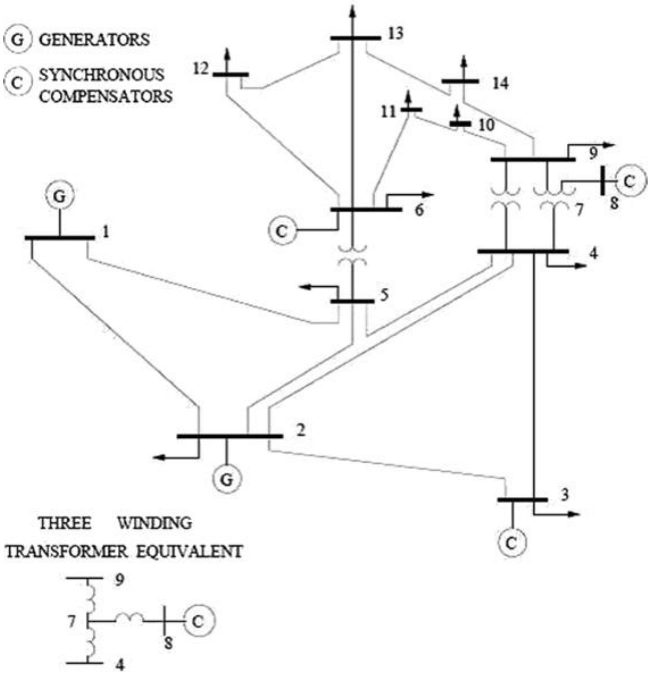


Figure 5: IEEE 14 bus system network diagram

Total active power losses in a system:

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} [\alpha_{ij} \left( P_i P_j + Q_i Q_j \right) + \beta_{ij} \left( Q_i P_j + P_i Q_i \right)] \tag{4}$$

Where,

$$\alpha_{ij} = \frac{r_{ij}}{V_i V_j} \cos(\delta_i - \delta_j) \tag{5}$$

$$\beta_{ij} = \frac{r_{ij}}{V_i V_j} \sin(\delta_i - \delta_j) \tag{6}$$

## 3. RESULTS AND DISCUSSION

### 3.1 Mathematic Functions

With the aim of validate the presentation of AIS, TRANS-AIS and X3PAIS algorithm, three benchmark mathematic test functions were chosen and the simulations are simulated by using Matlab programming language. The simulation is running under same circumstances for the three mathematic test function as described on last section.

Fig.6-8 described the simulation results of algorithm (AIS, TRANS-AIS and X3PAIS) which were simulated hundreds of iteration. As shown in the results, most of the function values are packed and as close to value zero by using X3PAIS algorithm for each mathematics test function. Comparison of the three mathematics test functions in term of minimum, mean and standard deviation are summarized in Table 2 simulated with the respective algorithm. Therefore, X3PAIS algorithm succeeds to achieve the minimum fitness value compare to others.

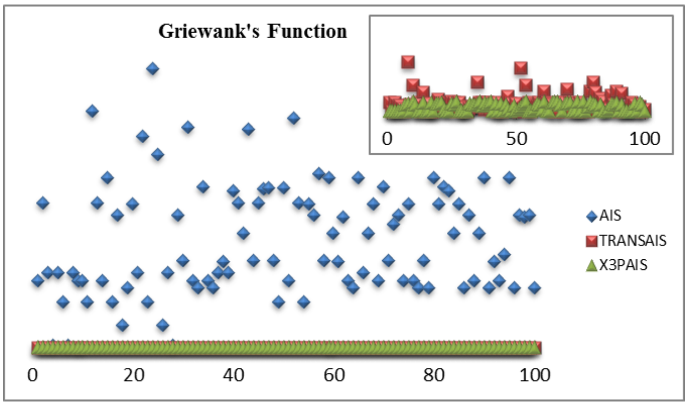


Figure 6: Griewank's Function: hundred experiments data collected

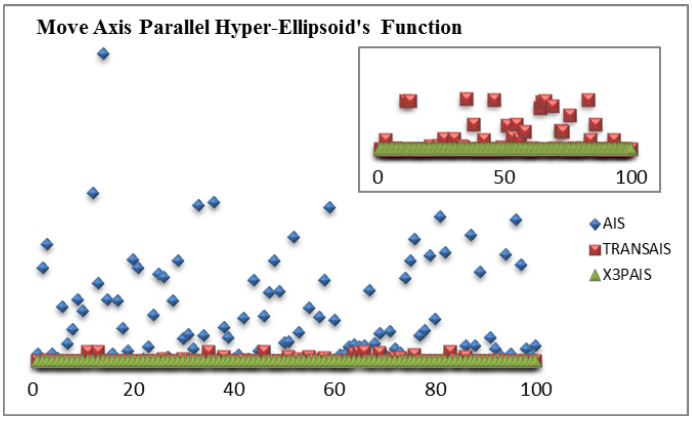


Figure 7: Moved Axis Parallel Hyper-Ellipsoid's Function: hundred experiments data collected

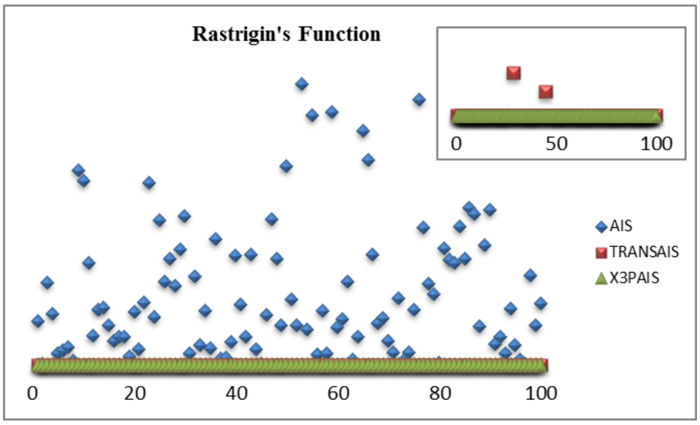


Figure 8: Rastrigin's Function: hundred experiments data collected

Table 2: Comparisons of mathematics functions results (minimum, mean and standard deviation) for each algorithm

| | | FUNCTIONS | | |
|---|---|---|---|---|
| | | *A* | *B* | *C* |
| **MINIMUM** | *AIS* | 1.250190E-03 | 7.280132E-06 | 2.903467E-03 |
| | *TRANSAIS* | 0.000000E+00 | 8.526513E-13 | 2.255263E-11 |
| | *X3PAIS* | 0.000000E+00 | 8.526513E-13 | 2.255263E-11 |
| **MEAN** | *AIS* | 1.174186E-01 | 5.204675E-03 | 2.610492E-01 |
| | *TRANSAIS* | 8.372556E-08 | 1.387818E-04 | 7.421306E-07 |
| | *X3PAIS* | 4.118649E-08 | 4.380354E-11 | 4.415802E-10 |
| **STANDARD DEVIATION** | *AIS* | 6.035374E-02 | 5.451159E-03 | 2.376589E-01 |
| | *TRANSAIS* | 9.124667E-08 | 2.820845E-04 | 5.392661E-06 |
| | *X3PAIS* | 3.861412E-08 | 7.398831E-11 | 8.837248E-10 |

### 3.2 Distributed Generation

In this paper, allocation of multiple DG units to minimize the power loss in distribution system was done by the proposed algorithm which is X3PAIS. 100 simulations ware run with Matlab software. Fig. 9 shows the results of the total power losses of the system after installation of 4 units of DG. The optimum minimum value of total power losses was found at 19$^{th}$ iteration. Fig. 10 represents the each bus voltage profile for that 19$^{th}$ iteration. The bus voltage was compare between installation of 4 DG units and without any DG in the IEEE 14 bus distribution system.

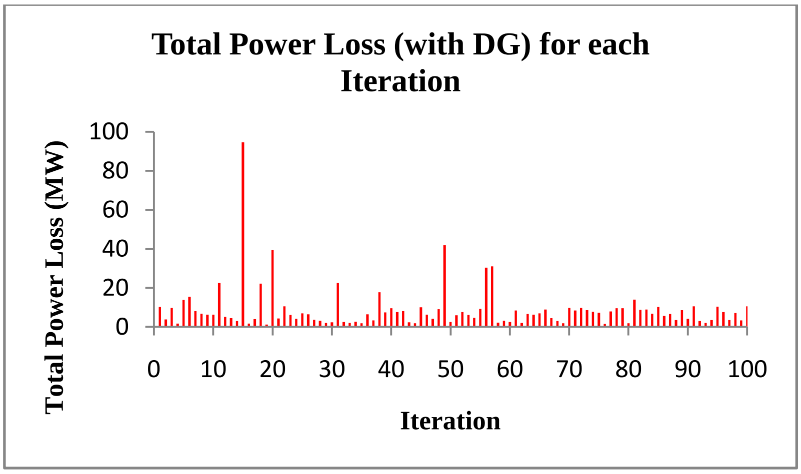


Figure 9: 100 experimental results of total power loss after installation of 4 DG units

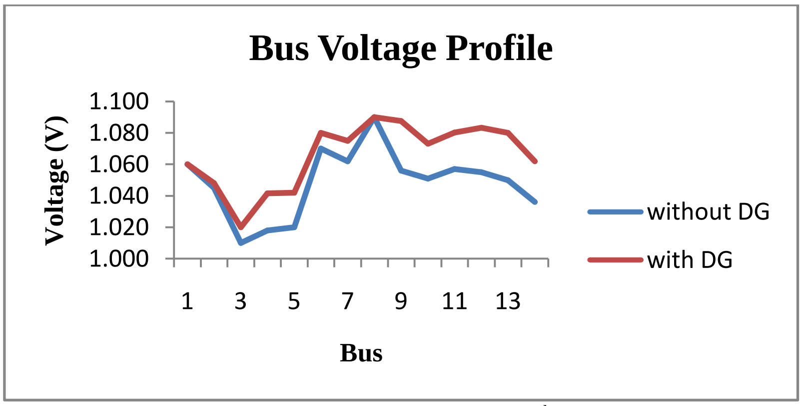


Figure 10: Bus voltage profile at 19$^{th}$ iteration

It is observed from Table 3 that the proposed algorithm has reduced the total power loss of the IEEE 14 bus distribution system. Four DG units were installed in the system at bus 2, 3, 6 and 8 with load of 0.0108MW, 0.7015MW, 0.1732MW and 0.2652MW respectively. These manage to reduce about 89% of total power loss for the distribution system. The results show the credibility of the proposed algorithm technique.

Table 3: Summarize results of power loss with and without DG installation

| **DG Case** | **Location** | **Capacity (MW)** | **Power Loss (MW)** | **Percentage Reduction (%)** |
|---|---|---|---|---|
| *without DG* | - | - | 10.5900 | - |
| *4 DGs* | 8<br>3<br>6<br>2 | 0.2652<br>0.7015<br>0.1732<br>0.0108 | 1.0789 | **89.8118** |

## 4. CONCLUSION

In this paper, an algorithm technique has been proposed to discover the optimum size and location of installation multiple DG units in order to reduce the total power loss for distribution system. The performance of develop algorithm which is X3PAIS is clearly described and demonstrate from simulation in this paper. Performance improvements of the X3PAIS algorithm still can be done by tweaking the selection criteria and parameters in future research.

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