*International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622*
*National Conference on Advances in Engineering and Technology*
*(AET- 29th March 2014)*

RESEARCH ARTICLE OPEN ACCESS

# Transmission Network Planning Using Evolutionary Programming

Rajanish kumar Kaushal*, Tilak Thakur**
*(Department of Electrical Engineering, PEC University of technology, Chandigarh (India)
Email: rajnish.nitham@gmail.com)
** (Department of Electrical Engineering, PEC University of technology, Chandigarh (India)
Email: tilakthakur20042005@yahoo.co.in)

ABSTRACT
This paper presents an application of Evolutionary Programming (EP) to solve Transmission Network Planning (TNP) in order to obtain the minimum cost solution while meeting the other constraints such as thermal, reliability criteria. The non-convexity that has been observed in the TNP cannot be solved effectively by conventional mathematical methods. EP has the ability to find the global optimal point in such a non-convex function. As there are no fractional transmission lines, TNP becomes a very complex mixed integer non-linear programming problem. EP can be used to select the optimal new transmission lines network with the least investment cost, while meeting the total load demands without any load curtailment.
***Keywords –*** Evolutionary Programming, Minimum Cost, Transmission Network Planning

## I. Introduction

India as a developing country, should improve the electricity supply all over the country. Because the amount of electricity supply is proportional to the economical, social development of a country. TNP is a very important topic considering India. If we can reduce the TNP cost while meeting the total load demands without any load curtailment and keeping maximum utilization of the total network capacity, will reduce the cost of electricity production. It is recognized that the allocation of transmission cost in a competitive environment requires careful evaluation of alternative transmission network plans. As a result, the need for methods that are able to synthesize optimal transmission network plans has become more important than ever. Unfortunately, practice has shown that conventional optimization procedures are unable to produce optimal solutions for networks. The reason is that the TNP problem is a hard, large-scale combinatorial problem. The number of options to be analyzed increases exponentially with the size of the network. The objective of TNP is to determine the installation plans of new facilities (mainly transmission lines) so that the resulting bulk power system may be able to meet the forecasted demand at the lowest cost, while satisfying prescribed technical, financial and reliability criteria. Although the conventional methods are somewhat successful in TNP, some problems still exit; Non-convexity: Due to non-convexity of TNP problem the Success of the search largely depends on the starting point. Therefore, the optimization process sometimes stops at non-optimal solutions. Non-linearity:
increases the iterations of the optimization algorithm and sometimes causes divergence [1].

A lot of research has been done using conventional mathematical methods to solve the TNP problem and some of the methods are:

Linear programming [2], Branch and bound [3], Benders and hierarchical decomposition [4], Heuristic and meta-heuristic methods [5], Simulated annealing [6], Hybrid Mathematical and Rule-based system [7], Tabu search [8], Genetic algorithms [9], Ant colony system algorithm [10].

## II. Introduction To Transmission Expansion Planning

The purpose of TNP is to determine the type of new transmission facilities required in order to provide adequate transmission network capacity to cope with the future generating capacity additions and load flow requirements. Main objectives of TNP are finding out the transmission network required to ensure reliable and stable power system while utilizing the maximum capacity of the network and estimating the minimum investment cost for the transmission network. This research work mainly focused on two transmission planning criteria named thermal criteria and minimum cost criteria.

$$Pp = \sum_{q=1}^{n} \{ep(epGpq + fqBpq) + fp(fpGpq - epBpq)\} \quad (1)$$

$$Qp = \sum_{q=1}^{n} \{fp(epGpq + fpBpq) - ep(fpGpq - epBpq)\} \quad (2)$$

$$V_p^{\,2} = e_p^{\,2} + f_p^{\,2} \quad (3)$$

Where Pp and Qp are active power component and these three sets of equations (1), (2) and (3) are the load flow equations and it can be seen that they are non-linear equations in terms of the real and imaginary components of nodal voltages. Here the left hand quantities i.e. Pp, Qp (for a load bus) and Pp and Vp for generator bus are specified and ep and fp are unknown quantities. For an n-bus system, the numbers of unknowns are 2(n-1) because the voltage at the slack bus is known and is kept fixed both in magnitude and phase. Therefore, if bus 1 is taken as the slack, the unknown variables are (e2, e3..., en l, en, f2, f3... fn l, fn). Thus to solve the problem for 2(n-1) variables we need to solve 2(n-1) set of equations.

Since the TNP problem is nonlinear, iterative methods should be used to solve the problem. In this work the Newton-Raphson method has been used to solve the power flow problem. Newton-Raphson method is an iterative method which approximates the set of non-linear simultaneous equations to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first approximation.

## III. OVERVIEW OF EP'S THEORY

More than 45 years ago, several researchers from US and Europe independently came up with the idea of minimizing the mechanism of biological evolution in order to develop powerful algorithms for optimization and adaptation problems. This set of algorithms is known as evolutionary algorithms (EA). One of the most commonly used evolutionary algorithms is evolutionary programming (EP). The mathematical model of EP places emphasis on the biological linkage between parents and their offspring. EP obtains solutions to optimization problems using two basic operators: the mutation operator, which generates offspring by adding noise to the original structure of their corresponding parents; and the selection operator, which compares each member of the population (parent + offspring) with a number of randomly chosen opponents (from the population) to pick the individuals that will become parents for the next generation. This procedure is repeated for several generations, resulting in an evolutionary process that typically converges toward an optimal value.

The structure of the evolutionary programming [11] algorithm is shown in Fig 1. In this approach, the real-valued decision variables to be determined are represented as a trail dimensioned vector. Each vector is an individual of the population to be evolved. The major steps involved in the evolutionary programming approach are explained as follows:

### 3.1 Initialization

An initial population of parent individuals ($PA_i$, $i$ = 1, 2, 3 …$K$) is generated randomly within a feasible range in each dimension.

### 3.2 Creation of offspring (mutation)

Each parent vector $PA_i$ generates an offspring vector by adding a Gaussian random variable with zero mean and pre-selected standard deviation to each individual of $PA_i$. The $K$ parents create $K$ offspring thus resulting in $2K$ individuals in the competing pool.

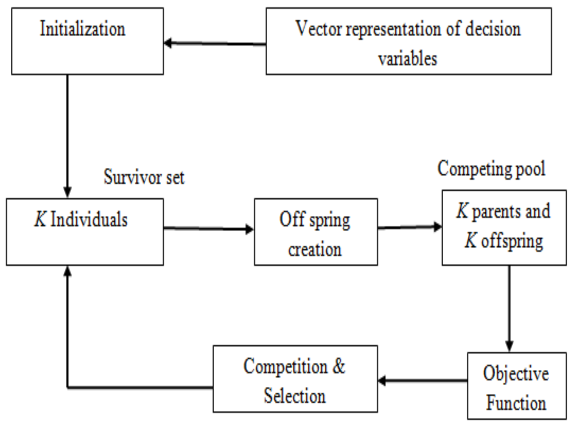


Fig 1: Structure of Evolutionary Programming

### 3.3 Competition and Selection

Each individual in the competing pool is evaluated for its fitness. All individuals compete with each other for selection. The best $K$ individuals with maximum fitness values are retained to be parents of the next generation. The process of creating off spring and selecting those with maximum fitness are repeated until there is no appreciable improvement in the maximum fitness value or it is repeated up to a pre specified number of iterations.

## IV. THE APPLICATION OF EP THEORIES TO SOLVE TNP PROBLEM (IMPLEMENTATION)

Fig 2 describes the steps of the implementation of the work "Transmission Network Planning using Evolutionary programming".

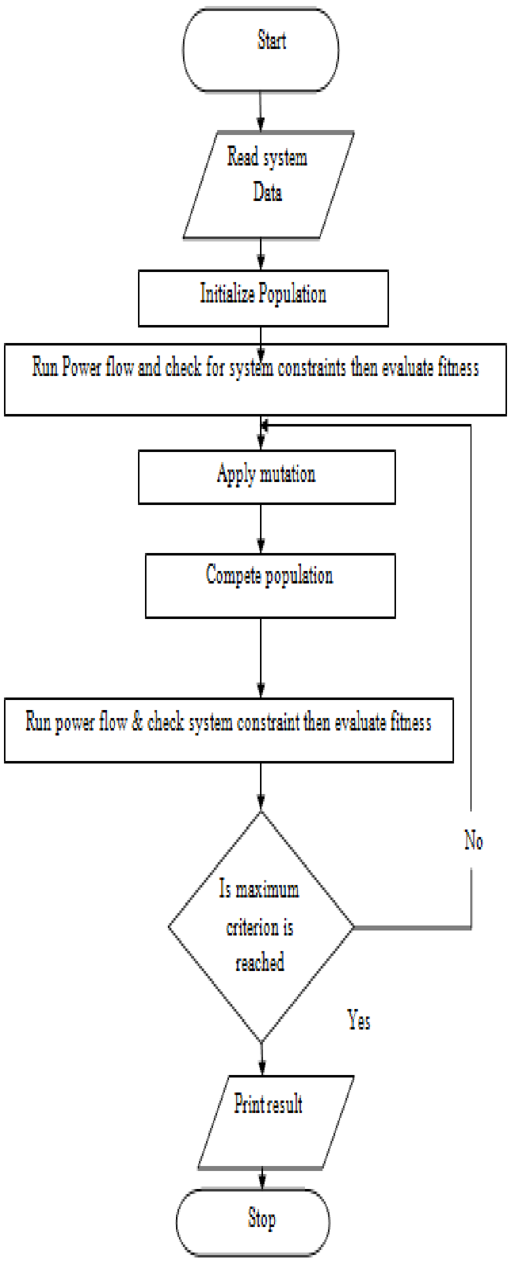


Fig 2: Flow chart of EP-TNP

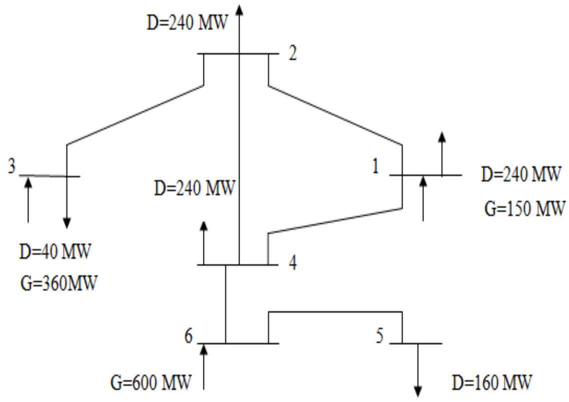


Fig 3: Six bus bar network

## 4.1 Initialize the population

### 4.1.1Representation

The value encoding method is used to represent the chromosomes. Each chromosome has 15 values to represent the all-possible transmission lines among six numbers of bus bars. The six bus bar network [1] as shown in Fig 3, has been used for this work.

The program has used 10 different types of transmission cable types, i.e. lxZebra, 2xZebra, lxGoat, Lynx, Bear, 350 Oil Filled, 500 Oil Filled,300 XLPE, 500 XLPE, 800 XLPE. To represent those line types 1 to 10 integers are used and to represent 0-line condition 0 integer is used in the program. The generations and loads of the six bus bar system are given in Table 1 and the properties of the line types are given in Table 2.

Table 1: Generation and Load

| Bus | Generation capacity (MW) | Load(MW) |
|---|---|---|
| 1 | 150 | 240 |
| 2 | - | 240 |
| 3 | 360 | 40 |
| 4 | - | 240 |
| 5 | - | 160 |
| 6 | 600 | - |

Table 2: The Properties of the Line Type

| Line Type | Capacity (MVA) | Cost/km (Million Rs) | R Pu/km | X Pu/km |
|---|---|---|---|---|
| 1xZebra | 165 | 6 | 0 .003 | 0.002 |
| 2xZebra | 330 | 8 | 0.002 | 0.002 |
| 1xGoat | 150 | 7 | 0.143 | 0.406 |
| Lynx | 105 | 5 | 0.001 | 0.002 |
| Bear | 130 | 7.5 | 0.075 | 0.190 |
| 350 Oil Filled | 160 | 4.5 | 0.060 | 0.099 |
| 500 Oil Filled | 120 | 4 | 0.051 | 0.095 |
| 300 XLPE | 130 | 5 | 0.078 | 0.198 |
| 500 XLPE | 160 | 4 | 0.048 | 0.182 |
| 800 XLPE | 225 | 4.5 | 0.031 | 0.165 |

One of the possible chromosome ≡
100305600010060
1-2 Branch: 1xzebra, 1-5 Branch: 1xGoat, 2-3 Branch: Bear, 2-4 Branch: 350 Oil Filled, 3-5 Branch: 1xZebra, 4-6 Branch: Oil Filled and all other branches are not connected by a transmission lines.

### 4.2 Population Size

This parameter specifies the number of individuals in each generation of the EP. There are 20 chromosomes in a single population. So initial population is 2D matrix, the initial population is selected randomly. Size of the population doesn't change over time.

### 4.3 Load Flow Calculation

For the load flow calculation Newton raphson method has been used. Main aim of performing the load flow calculation is to find the MVA flow in lines.

### 4.4 Fitness Evaluation

The objective of the thesis work is to use EP to obtain the optimized solution for TNP problem while achieving the minimum cost. So when mapping this objective to a fitness function, mainly three facts are considered; 1. To minimize the cost, 2.To reduce the number of over loaded lines, 3.To increase the line fitness of the network. The fitness function must reflect both the desired and the unwanted properties of a solution [12].

### 4.5 Minimize The Cost

Here consider the cost of transmission lines of the network. Transmission line types are varying basically according to its capacity & cost. So using EP, minimum cost transmission line can be selected, which suits to transfer required power between bus bars.

### 4.6 Reduce the Number of Over Loaded Lines

A transmission line whose power flow exceeds the capacity of it, called over loaded line. Over loaded transmission line is an adverse feature of a network. That means for the optimum network solution, we have to minimize or diminish the number of over loaded lines.

### 4.7 Line Fitness

Here line fitness means the number of lines in the network. The aim of inclusion of this parameter is to develop medium number of lines in the network while achieving the minimum cost.

### 4.8 Total Fitness of Population

For one generation the program runs for '20' number of chromosomes. Total fitness (TF) gives the cumulative sum of all 20 chromosomes finesses. Then there is a condition to check whether the total fitness of the new generation has improved or not when compared to the previous generation. If the total fitness of the new generation has improved, replace the previous generation with new population and its fitness values. If it has not improved, the previous generation and fitness values are backed up as new generation [13].

### 4.9 Mutation

The mutation operator, which generates offspring by adding noise to the original structure of their corresponding parents; and the selection operator, which compares each member of the population (parent + offspring) with a number of randomly chosen opponents (from the population) to pick the individuals that will become parents for the next generation. This procedure is repeated for several generations, resulting in an evolutionary process that typically converges toward an optimal value. EP seems to be promising and still evolving. Mutation process is used for creation of offspring from the parent chromosome [11] .In this process the number of offspring chromosome will be same as parent chromosome as shown in Fig 4. The main stages of the evolutionary programming based transmission network planning (EP-TNP) including initialization; mutation and competition.

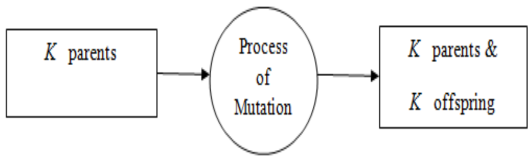


Fig 4: Creation of offsprings

## V. RESULT

The combination which has the minimum cost that will be selected as the best combination of lines for the given generation and load is such as bus 1-2: 500 Oil Filled, bus 1-3: 1xGoat, bus 1-4: 800 XLPE, bus 1-5: 500 XLPE, bus 1-6: 800 XLPE, bus 2-3: 350 Oil Filled, bus 2-4: 300 XLPE, bus 2-5: 1xGoat, bus 2-6: Bear, bus 3-4: 300 XLPE, bus 3-5: 1xZebra, bus 3-6: 800 XLPE , bus 4-6: 300 XLPE, bus 5-6: 500 Oil Filled and the total cost for this combination is 4570 millions in rupees.

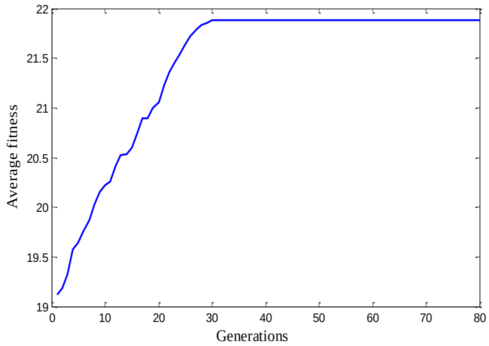


Fig 5: Average Fitness Vs Number of Generations

In Fig 5 the average fitness initially increases till approx 30 generations and it constant after approx 30 generations. It means that after, 30 generations there will be no improvement in the result, and the optimal combination of the lines for the given load and generation has been obtained.

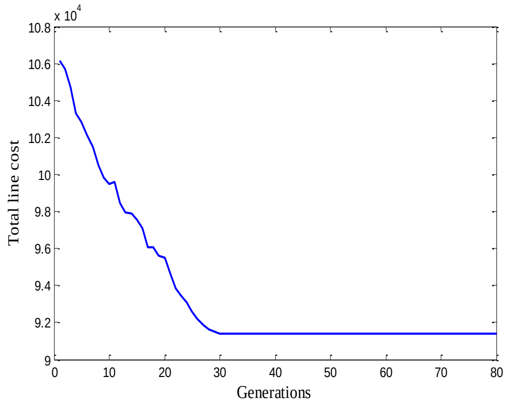


Fig 6: Total Line Cost Vs Number of Generations

Fig 6 represents the graph between total line cost and number of generations. In this the total line cost initially decreases till approx 30 generations and it constant after approx 30 generations. It means that the optimal combination of the lines for the given load and generation has been obtained. Here, total line cost is total sum of cost of parent chromosomes and fit offspring chromosomes.

## VI. CONCLUSION

The research reported in this paper clearly demonstrates that an EP approach to a TNP problem is both feasible and advantageous. It provides to optimize several parameters in the same time. Furthermore, it allows the representation of non-linearities, which are hard to include in pure mathematical programming methods; in fact, the existence of non-linearities enhances the advantages of using EP against pure mathematical programming.

The results of an EP are a generation of solutions filtered through the struggle for survival. Therefore, many interesting and valuable exercises on comparisons and tradeoffs may be executed, helping the planner to gain insight on the problem he is faced with and allowing field for better decisions to be taken. Since EP problem starts with randomly generated solutions and all other operations randomly, we can obtained several different results for the same problem.

## REFERENCES

[1] M. T. A. P. Wickramarathna and N. Wickramaarachchi, “Transmission network planning using genetic algorithm”, *IEEE/PES Transm. & Distrib. Conf. and Exposition*, 2006, 1-5.

[2] L. L. Garver, “Transmission network estimation using linear programming”, *IEEE Trans. Power App. Syst., 89 (7), 1970, 1688-1697.*

[3] S. Haffner, A. Monticelli, A. Garcia and R. Romero, “Specialised branch and bound algorithm for transmission network expansion planning”, *IEEE Proc. Gener. Transm. & Distrib., 148(5), 2001, 482-488.*

[4] S. Binato, M. V. F. Pereira and S. Granville, “A new Benders decomposition approach to solve power transmission network design problems”, *IEEE Trans. Power Syst.*, 16 (2), 2001, 235-240.

[5] R. Romero, C. Rocha, J. R. S. Mantovani and I. G. Sanchez, “Constructive heuristic algorithm for the DC model in network transmission expansion planning”, *IEEE Proc. Gener. Transm. & Distrib.*, 152 (2), 2005, 277-282.

[6] R. Romero, R. A. Gallego and A. Monticelli,“Transmission system expansion planning by simulated annealing”, *IEEE Trans. Power Syst., 11 (1), 1996, 364-369.*

[7] M. T. A. P. Wickramarathna, N. Wickramaarachchi, “Hybrid Mathematical and Rule-based System for Transmission network Planning in Open Access Schemes”, *IEEE PES Transmission and Distribution Conference Exposition Latin America, 2006, 1-5.*

[8] E. L. Silva, J. M. A. Ortiz, G. C. Oliveira and S. Binato, “Transmission network expansion planning under a tabu search approach”, *IEEE Trans. Power Syst.*, 16 (1), 2001, 62-68.

[9] D. E. Goldberg, “Genetic algorithm in search, optimization and machine learning”, *Reading M. A. Addison Wesley, 1989.*

[10] J. F. Gomez, H. M. Khodr, P. M. De Oliveira, L. Ocque, J. M. Yusta, R. Villasana and A. J. Urdaneta, "Ant colony system algorithm for the planning of primary distribution circuits", *IEEE Trans. Power Syst., 19 (2), 2004, 996-1004.*

[11] Y. R. Sood, "Evolutionary programming based optimal power flow and its validation for deregulated power system analysis", *Electrical Power and Energy Systems, Elsevier Science*, 29 (1), 2007, 65-75.

[12] J. L. Ceciliano and R. Nieva, "Transmission network planning using evolutionary programming", *Proc. of The Congress on Evolution Computation (CEC 1999), Washington DC, U.S.A., 3 (1), 1999, 1796-1803.*

[13] Z. Michalewicz and M. Schoenauer, "Evolutionary algorithms for constrained parameter optimization problems", *Evolutionary Computation, 4 (1), 1996, 1-32.*

[14] "Ceylon Electricity Board - Long Term Transmission Development Studies", *Technical Report, Asian Development Bank, 2012.*

[15] "Matpower, a Matlab Power System Simulation Package", *User's Manual, Version 2.0.*