A NEW APPROACH FOR TRANSMISSION EXPANSION PLANNING FOR IEEE 24 BUS RTS USING BFOA

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ABSTRACT

Socio Economic development of any country depends on Availability of Electric Power and Per capita energy consumption of that country. Availability of Electric Power depends on one of the factor is pumping capacity of the power to the end users i.e. transmission capacity. Hence it shows the importance of transmission lines in any country. Therefore, planning of transmission lines plays key role in maintaining sufficient power in any country and also planning of transmission lines plays vital role in having stable and reliable power supply. Transmission Expansion Planning (TEP) has to be prepared by analyzing various scenarios and contingencies. TEP is prepared in this paper by considering load growth as well as generation growth. It is required to consider both economical and technical criteria's for better TEP. TEP is prepared in this paper for IEEE 24 bus Reliability Test System (RTS) using Genetic Algorithm (GA) and Bacterial Foraging Optimization Algorithm (BFOA). The Results obtained for TEP using above said methods are compared.

Keywords: TEP, GA, BFOA, load growth, generation growth, RTS.

INTRODUCTION

In view of Industrial and Commercial growth in the country, it was observed that India's GDP has up-swung by 6.3% [1] during 2011-2012 and 5% during 2012-2014. During this period Non-refundable income has been increased by 19.1% and population growth was by 15 million [1]. Due to this escalation in economy, it has witnessed hike in power demand during this period was 7% [2]. Even though India has power generation capacity of 225 GW and energy requirement of 135 GW, country has witnessed peak energy deficit of 9% [2]. It was due to imbalance in power generation and power pumping capacity in the country i.e. due to insufficient transmission capacity [2]. Chhattisgarh was Energy rich state during that period but it is unable to pump the power due to insufficient transmission capacity during that period in that state [2]. It was planned to enhance power generation capacity to 388 GW by 2022, hence transmission capacity has to be enhanced along with generation capacity to match it [2].

To supply reliable and quality power to the consumers, it is required to have sufficient transmission capability in planning of transmission lines. It is required to have proper TEP in maintaining stable and reliable power infrastructure. TEP for the upcoming events is a very intricate job which needs a synchronized and systematic analysis of different situations and incidents. Therefore best possible plan of transmission system expansion is a significant element of the overall planning job of electrical power system. The TEP crisis of electrical power system comprises in identifying the transmission network lines and transformers. TEP should lessen investment price and operational price along with satisfying different limits during regular and unforeseen events. TEP should not breach the fundamental limits i.e. the thermal capacity of Transmission lines. The TEP should be prepared in such a way that it has to satisfy load as well as different constraints. In this paper, it is focused to prepare suitable assessment technique to identify a fruitful among various TEP options based on economic and technical criteria. In this paper it is classified TEP into two criterions like economic and technical criteria. Different options are assessed for TEP with less cost by satisfying all constraints. In this paper, we have executed a method for TEP which considers load growth as well as generation growth. The optimization of the TEP is prepared with GA and BFOA for a 24 bus RTS. The TEP mentioned by GA and BFOA are compared in terms of number of new lines, length of new lines and the total cost of expansion.

Literature Survey is explained as follows: The TEP is considered as an optimization issue with an objective function constrained to so many power system constraints. The TEP has to be prepared by considering the different power system constraints. Different techniques like LP [3], DP [4], NLP [5] and MIP [6] are explained for TEP. Benders decomposition for TEP is explained in the paper [7] and BBA for TEP is also explained in [7]. Two mathematical models for TEP considering uncertainty in load is explained in [8]. We present a bilevel model for TEP is presented in [9]. Taguchi's orthogonal Method for TEP is explained in [10]. Ordinal optimization for multilayer TEP is explained in [11]. TEP is explained for hike in laod and generation using various methods is explained in [12].

PROBLEM DEFINITION

Different problems are affecting Transmission Expansion Planning in Deregulated Power Systems in our country. TEP has to suggest a plan such a way that it has to satisfy the limits at the same time produce minimum cost plan. The Principal cost plays vital role in identifying a new transmission line using TEP techniques. Various cost effective factors to be considered in this work are Principal cost, cost owing to Maintenance, cost owing to Operation, cost incurred owing to Project Delay, cost incurred owing to Inflation and cost incurred owing to

Right of Way. The objective function is defined for TEP is:

$$C_i = \sum_{i=1}^{nT}(C_{iIt} + C_{iMt} + C_{iOt} + C_{iDt} + C_{iRoWt} + C_{iInft}) \quad (1)$$

Where,

C_i : The total Cost owing to Plan i.
C_{iIt} : Principal cost.
C_{iMt} : Cost owing to Maintenance.
C_{iOt} : Cost owing to Operation.
C_{iDt} : Cost owing to Project Delay.
C_{iRoWt} : Cost owing to Right of Way.
C_{iInft}: Cost owing to Inflation.
nT : Number of years for planning.

In this work Cost owing to Project Delay can be taken as 7% of Cost of TEP [13], Cost owing to Inflation can be taken as 5% for every year of planning horizon [14] and Cost owing to Right of Way can be taken as10% of Cost of TEP [15].

The objective function (1) is constrained to the following limits to prepare proper TEP:

Power balance equation

Power Balance equation can be given as [1]:

$$P_{Gj}=P_{Dj}+Pj \quad (2)$$

for j=1, 2 ….NB

P_{Gj}, P_{Dj} and P_j are Generation of Real Power, Demand for Real Power and Real Power losses at bus j, respectively.

Real thermal power limits for transmission lines

Real Thermal Power Limits for Transmission Lines of transmission lines [1] can be given as:

$$|P_{xy}| \le (n_{xy}^0 + n_{xy})P_{xy}^{max} \quad (3)$$

P_{xy}, P_{xy}^{max}, n_{xy} and n_{xy}^0 are total Real Power in line x-y, maximum Real Power in line x-y, number of lines can be augmented in line x-y and number of lines in actual system [1], respectively.

Real Power generation limits

Real Power Generation Limits for TEP is defined as [1]:

$$P_{gj}^{min} \le P_{gj} \le P_{gj}^{max} \quad (4)$$

P_{gj}, P_{gj}^{min} and P_{gj}^{max} are Real Power Generation at bus j, the minimum and maximum Real Power Generation limits at bus j, respectively.

Right of way

Right of way has to be included in TEP which gives information about number of lines shall be added to existing system without violating any limits [1]. Right of Way for TEP is given as [1]:

$$0 \le n_{xy} \le n_{xy}^{max} \quad (5)$$

n_{xy} and n_{xy}^{max} are the total number of lines shall be augmented across line x-y and the maximum number of lines available in line x-y, respectively.

Voltage phase angle limit

Voltage Phase angle Limit plays key role TEP, hence it has to be incorporated in transmission planning. Voltage phase angle limit is given as [1]:

$$|\alpha_j^{cal}| \le |\alpha_j^{max}| \quad (6)$$

α_j^{cal} is voltage phase angle obtained from load flow study which has to be less than α_j^{max} which is specified voltage phase angle at a particular bus.

Some of the contingencies are to be considered for TEP which gives stable and Reliable plan as mentioned below:

Generator outages

Generator outages are to be considered for proper TEP which occurs due to internal outages, planned outages; repairs etc. owing to outages of generators, imbalance in generation and demand causes reliability issues in the system [16].

Line outages

One of the important outage that has to be incorporated in TEP is Line outage which occurs due to foul weather conditions, over loading of lines, imbalance of generation and demand, etc which has to be considered for stable and reliable TEP [16].

Uncertainties in load

Load is a random parameter, it has to be forecasted accurately because to obtain stable and reliable TEP i.e. load forecasting should be more accurate [16], hence it is also to be included in TEP.

METHODOLOGY

Genetic algorithm (GA)

The fundamental inspiration of GA is to reproduce the process of regular selection which is mostly depended on survival of the fittest. GA cadges a group from the procedure of natural selection and progression. In GA, each solution might be exposed as a Chromosome [17]. These Chromosomes are evaluated for their fitness and are ranked in correspondence with its fitness value. Parent Chromosomes are defined as arbitrary generation of Chromosomes in the early stage and next generation of Chromosomes are called as Child or off-springs [17]. The fundamental principal of GA is to engage better Parent with an endeavor to create better Children. In GA, better Chromosomes are moving to upcoming scenarios and remaining will be excluded from the system [18]. In GA, three special operators like selection, crossover and mutation are used to produce better solutions. In this work paper, GA is implemented for TEP using MATLAB. The GA parameters used in this work are given below:

Population size	20
Elite count	10%
Selection	Tournament based selection
Mutation	Adaptive feasible mutation
Mutation factor	0.20
Crossover probability	0.80

The algorithm for TEP using GA is explained below [18]:

Step 1: Assuming GA parameters for TEP.
Step 2: Generating a random Transmission Expansion Plan.
Step 3: Simulating power flow study to verify various constraints mentioned.
Step 4: Finding value of Fitness function by evaluating Objective Function for particular TEP.
Step 5: Identifying the Ranks of the transmission expansion plans produced by GA and in turn applying all the three operators selection, Crossover and Mutation to get ultimate plan or forwarding to subsequent step.
Step 6: Verifying the stopping criteria. If stopping criteria is fulfilled than go to step 7 otherwise go to step 3.
Step 7: Obtaining stable and reliable transmission expansion plan.

BACTERIAL FORAGING OPTIMIZATION ALGORITHM (BFOA)

The foremost benefits of BFOA are its capability to have similar distribution processing, inattentiveness to primary value and ability to accomplish global Optimization [19]. In BFOA, the bacteria experiences four stages like Chemotaxis, Swarming, Reproduction and Elimination and Dispersal [19]. The duty of Chemotaxis is to hunt for the solution space. The reproduction operator ensures that the identification of fitter individuals to take part in subsequent phases of progression [20]. The Elimination and Dispersion operator ensures global Optimization and avoid untimely convergence. Chemotaxis is accomplish the two moments swim or tumble and Bacteria exchanging between these two approaches of process i.e. swims or tumbles, in its entire life cycle, so, it make sure the progression of bacteria on the way to locating the nutrients (solutions) [21]. In this work, BFOA is simulated using MATLAB and the parameters of BFOA for stable and reliable TEP is mentioned below:

The number of Bacteria	50
Number of Chemotaxis steps	20
Limit length of a swim	4
The number of reproduction steps	4
The number of Elimination-Dispersal events	2
The number of bacteria reproductions	2
The Probability of Elimination /dispersion	0.2

The algorithm for TEP using BFOA is mentioned as follows:

Step 1: Assuming BFOA parameters for TEP.
Step 2: Generating Random Transmission Expansion Plan.
Step3: Simulating Power Flow Study for checking various limits.
Step 4: Calculating the Fitness value using Objective Function for TEP.
Step 5: Assuming Chemotaxis Tumble / Run for TEP.
Step 6: Verifying for End of Chemotaxis if say yes move on to Step 7 else move on to Step 4.
Step 7: Initializing the Reproduction.
Step 8: Verifying if it is conclusion of Reproduction as initiate, if yes move on to Step 9 else move on to Step 4.
Step 9: Starting Elimination and Dispersion procedure.
Step 10: If it is conclusion of Elimination and Dispersion then move on to next Step, or else move on to Step 4.
Step 11: Producing the Optimized Transmission Expansion Plan.

IEEE 24 BUS RELIABILITY TEST SYSTEM (RTS)

In this work TEP is evaluated for different scenarios for IEEE 24 Bus Reliability Test System (RTS). IEEE 24 bus RTS is explained as follows:

IEEE 24 Bus RTS was introduced in the year 1979; it consists of total peak load demand of 2,850 MW [102]. It has 32 Generators with a total generating capacity of 2,970 MW. Generators are mix up of Thermal, Hydro and Nuclear power plants. It has 24 buses with 38 transmission lines and transformers. It consists of both 138 KV and 230 KV transmission lines. IEEE 24 bus RTS comprises of 20 number of load points providing various load centers. The single line diagram of the IEEE 24 Bus RTS is shown in Figure-1.

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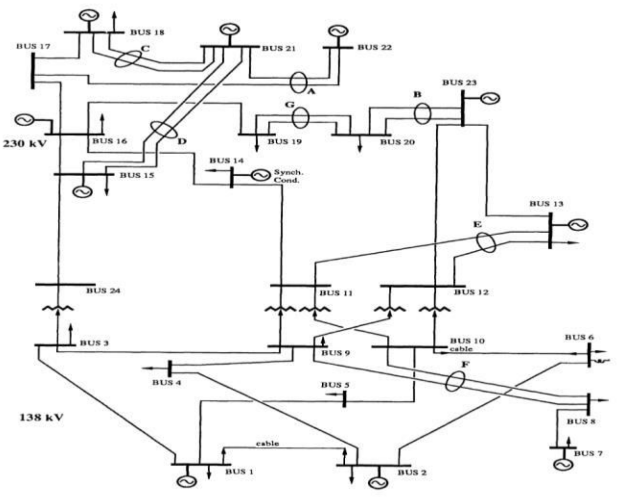

Figure-1. Single line diagram of the IEEE 24 Bus RTS.

RESULTS AND DISCUSSIONS

Case 1:

In this work, one of the situations i.e. 20% of hike in load along with 20% hike in generation is assumed. This situation shows upcoming transmission expansion plan for the coming 4 years i.e. there will be a load hike of 5% in each and every year [24]. In this paper, TEP is calculated for homogeneous rise in load and generation. By observing Table-1, the plan suggested by GA augmented 3 new lines with a length of 97.6 CKm which costs 294.13 Crore Rupees which is summation of Investment cost for addition of new transmission lines which is around 214.72 Crore Rupees, cost due to inflation is 42.92 Crore Rupees, cost owing to project delay is 15.02 Crore Rupees and Cost due to Right of Way is 21.47 Crore Rupees. The Transmission Expansion plan proposed by BFOA enhanced 2 new transmission lines with a length of 72.0 CKm which Costs 217.0 Crore Rupees which is summation of Investment cost for addition of new transmission lines which is around 158.4 Crore Rupees, cost due to inflation is 31.68 Crore Rupees, cost owing to project delay is 11.08 Crore Rupees and Cost due to Right of Way is 15.84 Crore Rupees. It can be observed that TEP specified by BFOA is better compared with result produced by GA. The Figure-2 gives length of new lines added and its related Cost for plans proposed by GA and BFOA. The Table 6.10 gives the new lines added by GA and BFOA for this case.

Table-1. TEP for IEEE 24 bus RTS for 20% hike in both load and generation.

Parameter /Method	GA	BFOA
N_{new}	3	2
L_{new} CKm)	97.6	72.0
C_{new} (CroreRupees)	214.72	158.4
C_{inf} (Crore Rupees)	42.92	31.68
C_d (Crore Rupees)	15.02	11.08
C_{RW} (Crore Rupees)	21.47	15.84
C_{total} (Crore Rupees)	294.13	217.0

Table-2. New lines added after TEP for IEEE 24 bus RTS for 20% hike in both load and generation.

New lines added after TEP for IEEE 24 bus RTS for 20% hike in both load and generation	
GA	**BFOA**
7-8	14-16
14-16	16-17
16-17	

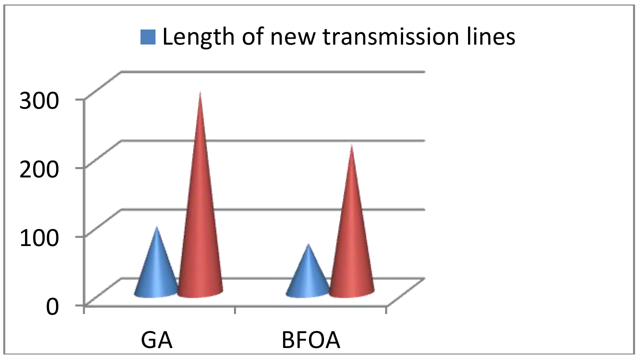

Figure-2. TEP Length and Cost for IEEE 24 bus RTS for 20% hike in both load and generation.

Case 2:

In this work, one of the situations i.e. 45% of hike in load along with 45% hike in generation is assumed. This situation shows upcoming transmission expansion plan for the coming 9 years i.e. there will be a load hike of 5% in each and every year [24]. In this paper, TEP is calculated for homogeneous rise in load and generation. By observing Table-3, the plan suggested by GA augmented 8 new lines with a length of 326.8 CKm which costs 1164.70 Crore Rupees which is summation of Investment cost for addition of new transmission lines which is around 718.96 Crore Rupees, cost due to inflation is 323.53 Crore Rupees, cost owing to project delay is 50.32 Crore Rupees and Cost due to Right of Way is 71.89 Crore Rupees. The Transmission Expansion plan proposed by BFOA enhanced 5 new transmission lines with a length of 262.4 CKm which Costs 935.17 Crore Rupees which is summation of Investment cost for addition of new

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transmission lines which is around 577.28 Crore Rupees, cost due to inflation is 259.77 Crore Rupees, cost owing to project delay is 40.40 Crore Rupees and Cost due to Right of Way is 57.72 Crore Rupees. It can be observed that TEP specified by BFOA is better compared with result produced by GA. The Figure-3 gives length of new lines added and its related Cost for plans proposed by GA and BFOA. The Table-4 gives the new lines added by GA and BFOA for this case.

Table-3. TEP for IEEE 24 bus RTS for 45% hike in both load and generation.

Parameter / Method	GA	BFOA
N_{new}	8	5
L_{new} (CKm)	326.8	262.4
C_{new} (Crore Rupees)	718.96	577.28
C_{inf} (Crore Rupees)	323.53	259.77
C_d (Crore Rupees)	50.32	40.40
C_{RW} (Crore Rupees)	71.89	57.72
C_{total} (Crore Rupees)	1164.70	935.17

Table-4. New lines added after TEP for IEEE 24 bus RTS for 45% hike in both load and generation.

New lines added after TEP for 45% hike in both load and generation	
GA	**BFOA**
6-10	5-10
7-8	13-23
10-11	14-16
10-12	15-24
13-23	16-17
14-16	
15-24	
16-27	

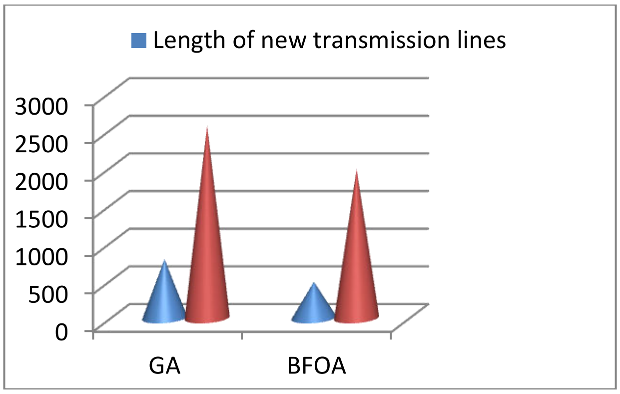

Figure-3. TEP length and cost for IEEE 24 bus RTS for 45% hike in both load and generation.

Case 3:

In this work, one of the situations i.e. 70% of hike in load along with 70% hike in generation is assumed. This situation shows upcoming transmission expansion plan for the coming 14 years i.e. there will be a load hike of 5% in each and every year [24]. In this paper, TEP is calculated for homogeneous rise in load and generation. By observing Table-5, the plan suggested by GA augmented 15 new lines with a length of 781.8 CKm which costs 2552.79 Crore Rupees which is summation of Investment cost for addition of new transmission lines which is around 1719.96 Crore Rupees, cost due to inflation is 1203.97 Crore Rupees, cost owing to project delay is 120.39 Crore Rupees and Cost due to Right of Way is 171.99 Crore Rupees. The Transmission Expansion plan proposed by BFOA enhanced 9 new transmission lines with a length of 480.2 CKm which Costs 1975.53 Crore Rupees which is summation of Investment cost for addition of new transmission lines which is around 1056.44 Crore Rupees, cost due to inflation is 739.50 Crore Rupees, cost owing to project delay is 73.95 Crore Rupees and Cost due to Right of Way is 105.64 Crore Rupees. It can be observed that TEP specified by BFOA is better compared with result produced by GA. The Figure-4 gives length of new lines added and its related Cost for plans proposed by GA and BFOA. The Table 6 gives the new lines added by GA and BFOA for this case.

Table-5. TEP for IEEE 24 bus RTS for 45% hike in both load and generation.

Parameter / Method	GA	BFOA
N_{new}	15	9
L_{new} (CKm)	781.8	480.2
C_{new} (Crore Rupees)	1719.96	1056.44
C_{inf} (Crore Rupees)	1203.97	739.50
C_d (Crore Rupees)	120.39	73.95
C_{RW} (Crore Rupees)	171.99	105.64
C_{total} (Crore Rupees)	2552.79	1975.53

Table-6. New lines added after TEP for IEEE 24 bus RTS for 70% hike in both load and generation.

New lines added after TEP for 70% hike in both load and generation	
GA	**BFOA**
2-6	3-24
3-24	3-24
3-24	9-12
4-9	13-23
6-10	14-16
7-8	15-21
9-12	15-24
10-12	16-17
12-23	21-22
13-23	
14-16	
15-21	
15-24	
16-17	
21-22	

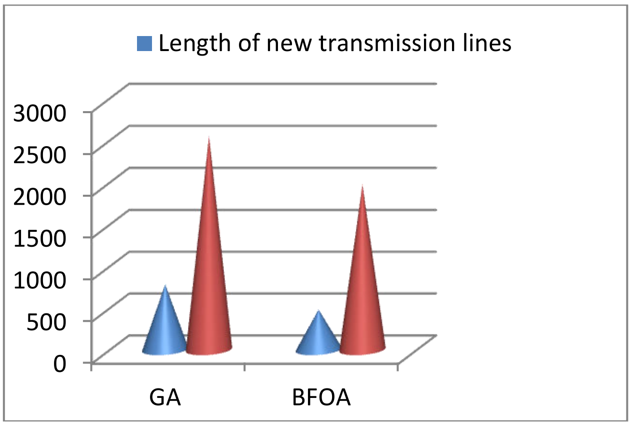

Figure-4. TEP Length and Cost for IEEE 24 bus RTS for 70% hike in both load and generation.

CONCLUSIONS

The results of TEP for IEEE 24 Bus RTS have been explained in this paper for 3 different cases like 20% hike in both in load and Generation, 45% hike in both in load and Generation and 70% hike in both in load and Generation. It can be inferred from results explained in the previous section, the performance of BFOA is better than the performance of GA. The efficiency of BFOA method by considering lesser number of lines and length of new lines particularly for higher load and generation hikes clearly indicates the aptness of this method for long-term TEP. It can be observed that, the performance of the BFOA in terms of Cost of New Transmission Lines to be installed after TEP.

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