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GENETIC ALGORITHM BASED STUDYING OF BUNDLE LINES EFFECT ON NETWORK LOSSES IN TRANSMISSION NETWORK EXPANSION PLANNING

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Transmission network expansion planning (TNEP) is a basic part of power system planning that its task is to minimize the network construction and operational cost, while meeting imposed technical, economic and reliability constraints. Recently, many methods have been introduced for solution of the static transmission network expansion planning (STNEP) problem. However, in whole of them, the effect of bundle lines on network losses has not been investigated. For this reason, in this paper, STNEP problem is being solved considering the effect of bundle lines on the network losses in a transmission network with different voltage levels using decimal codification genetic algorithm (DCGA). Finally, the effectiveness of proposed idea is tested on an actual transmission network of the Azerbaijan regional electric company, Iran. The results analysis reveals that bundle lines have important effect on the network losses in STNEP problem. Moreover, considering the bundle lines in a power system with various line voltage levels are caused the operational costs is decreased in addition to reduce of the total expansion costs. Thus, the effect of bundle lines on the network losses is caused the total expansion costs (expansion cost of lines and substations) are calculated more exactly and therefore the transmission expansion planning is optimized.

K e y w o r d s: STNEP, bundle lines, network losses, investment return, genetic algorithm

1 INTRODUCTION

Transmission network expansion planning (TNEP) is an important part of power system planning that its main objective is to acquire the most optimal plan for the network expansion. It determines where, when and which kind of transmission line must be added to the network. TNEP should be satisfied required adequacy of the lines for delivering safe and reliable electric power to load centers along the planning horizon [1–3]. Calculation of investment cost for network expansion is difficult because it is dependent on the various reliability criteria [4]. Thus, the longterm TNEP is a hard, large-scale combinatorial optimization problem. Transmission expansion planning is a hard and highly non-linear combinatorial optimization problem that generally, can be classified as static or dynamic. Static expansion determines where and how many new transmission lines should be added to the network up to the planning horizon. If in the static expansion the planning horizon is categorized in several stages we will have dynamic planning [5, 6].

In the majority of power systems, generating plants are located far from the load centers. In addition, the planned new projects are still far from completion. Due to these factors, investment cost for transmission network is huge. Thus, the STNEP problem acquires a principal role in power system planning and should be evaluated carefully because any effort to reduce transmission system expansion cost significantly improves cost saving. After Garver's paper that was published in 1970 [7], much research has been done on the field of TNEP problem. Some of them such as [1–3], [6], [8–25] is related to problem solution method. Some others, proposed different approaches for solution of this problem considering various parameters such as uncertainty in demand [5], reliability criteria [4, 26, 27], and economic factors [28]. Also, some of them investigated this problem and generation expansion planning together [29, 30]. Recently, different methods such as GRASP [3], Bender decomposition [6], HIPER [17], branch and bound algorithm [31], sensitivity analysis [15], genetic algorithm [1, 11, 20], simulated annealing [16, 25] and Tabu search [12] have been proposed for the solution of STNEP problem. In all of them, the problem has been solved regardless to effect of bundle lines in transmission expansion planning considering network losses. In [8], authors proposed a neural network based method for solution of the TNEP problem with considering both the network losses and construction cost of the lines. But the role of bundle lines on network losses has not been investigated in this study. In [10], the network expansion costs and transmitted power through the lines have been included in objective function and the goal is optimization of both expansion costs and loading of lines. In addition, the objective function is different from those which are represented in [6, 11, 12], [15–17], [20, 31]. However, the effect of bundle lines on the network losses has not been studied. In Ref. [32], the voltage level of transmission lines has been considered as a subsidiary factor but its objective function only includes expansion and generation costs and one of the reliability criteria *ie*: power not supplied energy. Moreover, expansion planning has been studied as dynamic type and the effect of bundle

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lines on network losses has not been considered. Finally, in pervious author's papers [33, 34], the expansion cost of substations with the network losses have been considered for the solution of STNEP problem. The results evaluation in [33] was shown that the network with considering higher voltage level save capital investment in the long-term and become overload later. In [34], it was shown that the total expansion cost of the network was calculated more exactly considering effects of the inflation rate and load growth factor and therefore the network satisfies the requirements of delivering electric power more safely and reliably to load centers.

In this paper, the effect of bundle lines on the network losses in static expansion planning of a transmission network with various voltage levels is investigated. For this reason, the losses cost and also the expansion cost of related substations from the voltage level point of view is included in the objective function. The studied voltage levels are 230 and 400 kV and these voltages are extendable to another voltage levels, too. The proposed method is tested on a real transmission network of the Azerbaijan regional electric company. This network has been located in northwest of Iran. The results evaluation reveals that considering the effect of bundle lines for solution of the STNEP problem is caused that the network losses is decreased more than lines which have no bundle conductor and subsequent the total expansion of the network is reduced. In addition, construction of bundle lines in transmission network with different voltage levels increases the network adequacy and prevents useless expansion of unbundle lines in separate corridors.

2 MATERIALS AND METHODS

The STNEP problem is a mixed-integer nonlinear optimization problem. Due to evaluating effect of the bundle lines on the network losses in static expansion planning of a transmission network with various voltage levels and subsequent adding expansion cost of substations to expansion costs, the proposed objective function is defined as follows

$$C_T = \sum_{i,j\in\Omega} CL_{ij} n_{ij} + \sum_{k\in\Psi} CS_k + \sum_{i=1}^{NY} C_{\mathrm{loss}_i}\,, \quad (1)$$

$$CL_{ij} = CL_{ij1} + CL_{ij2}\,, \quad (2)$$

$$C_{\mathrm{loss}} = loss \times C_{MWh} \times K_{\mathrm{loss}} \times 8760\,, \quad (3)$$

$$loss = \sum_{i,j\in\Omega} R_{ij} I_{ij}^2\,. \quad (4)$$

Where:

C_T : Total expansion cost of network.
CL_{ij1} : Total construction cost of each 230 kV line in branch i-j.
CL_{ij2} : Total construction cost of each 400 kV line in branch i-j.
CS_k : Expansion cost of k^{th} substation.
C_{loss} : Annual loss cost of network.
$Loss$: Total loss of network.
C_{MWh} : Cost of one MWh ($US/MWh).
K_{loss} : Loss coefficient.
N_{ij} : Number of all new circuits in corridor i-j.
R_{ij} : Resistance of branch i-j.
I_{ij} : Flow of branch i-j.
Ω : Set of all corridors.
Ψ : Set of all substations.
NY : Expanded network adequacy (in year).

The calculation method of CS_k is given in [33].

Several restrictions have to be modeled in a mathematical representation to ensure that the mathematical solutions are in line with the planning requirements. These constraints are as follows (see [5, 33] for more details)

$$Sf + g - d = 0\,, \quad (5)$$

$$f_{ij} - \gamma_{ij}(n_{ij}^0 + n_{ij})(\theta_i - \theta_j) = 0\,, \quad (6)$$

$$|f_{ij} \le (n_{ij}^0 + n_{ij})\overline{f_{ij}}\,, \quad (7)$$

$$0 \le n_{ij} \le \overline{n_{ij}}\,, \quad (8)$$

$$0 \le g \le \overline{g}\,, \quad (9)$$

$$Line\_Loading \le LL_{\max}\,. \quad (10)$$

Where, $(i,j) \in \Omega$ and:

S : Branch-node incidence matrix.
F : Active power matrix in each corridor.
G : Generation vector.
D : Demand vector.
θ : Phase angle of each bus.
γ_{ij} : Total susceptance of circuits in corridor i-j.
n_{ij}^0 : Number of initial circuits in corridor i-j.
$\overline{n_{ij}}$: Maximum number of constructible circuits in corridor i-j.
$\overline{g}$: Generated power limit in generator buses.
$\overline{f_{ij}}$: Maximum of transmissible active power through corridor i-j which will have two different rates according to voltage level of candidate line.
Line_Loading: Loading of lines at planning horizon year and start of operation time.
$LL_{\max}$: Maximum loading of lines at planning horizon year.

In this study, the objective function is different from those which are mentioned in [1–20], [23–28], [30, 31] and in part of the problem constraints, $\overline{f_{ij}}$ and *Line_Loading* have been considered as two new additional conditions. It should be noted that $LL_{\max}$ is an experimental parameter that is determined according to load growth coefficient (see [34] for more details).

The goal of the STNEP problem is to obtain number of lines and their voltage level to expand the transmission network in order to ensure required adequacy of the network along the specific planning horizon. Thus, problem parameters of the problem are discrete time type and consequently the optimization problem is an integer programming problem. For the solution of this problem, there are various methods such as classic mathematical and heuristic methods [5–21]. In this study, the decimal codification genetic algorithm is used to solve the STNEP problem due to flexibility, simple implementation and the advantages which were mentioned in [33]. In the proposed method, expansion and completion of objective function (for example, adding the network losses to objective function, extending the studied voltage levels to another levels and *etc*) would be practicable.

3 DCGA AND PROCESS OF GENETIC OPERATORS

Standard genetic algorithm is a random search method that can be used to solve non-linear system of equations and optimize complex problems. The base of this algorithm is the selection of individuals. It doesn't need a good initial estimation for sake of problem solution, In other words, the solution of a complex problem can be started with weak initial estimations and then be corrected in evolutionary process of fitness. The standard genetic algorithm manipulates the binary strings which may be the solutions of the problem. This algorithm can be used to solve many practical problems such as transmission network expansion planning [33, 34]. The genetic algorithm generally includes the three fundamental genetic operators of reproduction, crossover and mutation. These operators conduct the chromosomes toward better fitness.

There are three methods for coding the transmission lines based on the genetic algorithm method [33, 34]:

1) Binary codification for each corridor.
2) Binary codification with independent bits for each line.
3) Decimal codification for each corridor.

Although binary codification is conventional in genetic algorithm but in here, the third method has been used due to to following reasons [34]

1) Avoiding difficulties which are happened at coding and decoding problem.
2) Preventing the production of completely different offspring from their parents and subsequent occurrence of divergence in mentioned algorithm.

In this method crossover can take place only at the boundary of two integer numbers. Mutation operator selects one of existed integer numbers in chromosome and then changes its value randomly. Reproduction operator, similar to standard form, reproduces each chromosome proportional to value of its objective function. Therefore, the chromosomes which have better objective functions will be selected more probable than other chromosomes for the next population (*ie*, Elitism strategy). In the following, the process of genetic operators such as selection, crossover and mutation and end condition are explained.

3.1 Selection process

This operator selects the chromosome in the population for reproduction. The more fit the chromosome, the higher its probability of being selected for reproduction. Thus, selection is based on the survival-of-the-fittest strategy, but the key idea is to select the better individuals of the population, as in tournament selection, where the participants compete with each other to remain in the population. The most commonly used strategy to select pairs of individuals that has applied in this paper is the method of roulette-wheel selection. After selection of the pairs of parent strings, the crossover operator is applied to each of these pairs.

3.2 Crossover process

The crossover operator involves the swapping of genetic material (bit-values) between the two parent strings. Based on predefined probability, known as crossover probability, an even number of chromosomes are chosen randomly. A random position is then chosen for each pair of the chosen chromosomes. The two chromosomes of each pair swap their genes after that random position. Crossover may be applied at a single position or at multiple positions. In this work, because of choosing smaller population multiple position crossovers are used with probability of 0.3. Each individuals (children) resulting from each crossover operation will be subjected to the mutation operator in the final step to forming the new generation.

3.3 Mutation process

The mutation operator enhances the ability of the GA to find a near optimal solution to a given problem by maintaining a sufficient level of genetic variety in the population, which is needed to make sure that the entire solution space is used in the search for the best solution. In a sense, it serves as an insurance policy; it helps prevent the loss of genetic material. This operator randomly flips or alters one or more bit values usually with very small probability known as a mutation probability (typically between 0.001 and 0.01). In a binary coded GA, it is simply done by changing the gene from 1 to 0 or vice versa. In DCGA, as in this study, the gene value is randomly increased or decreased by 1 providing not to cross its limits. Practical experience has shown that in the transmission expansion planning application the rate of mutation has to be larger than ones reported in the literature for other application of the GA. In this work, mutation is used with probability of 0.1 per bit.

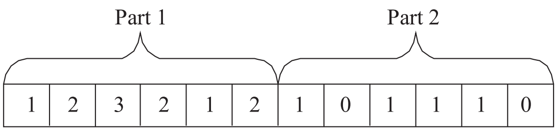

Fig. 1. Typical chromosome structure in case 1

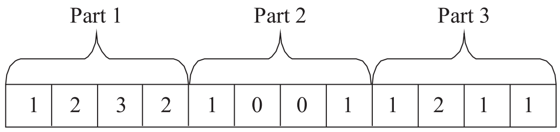

Fig. 2. Typical chromosome structure in case 2

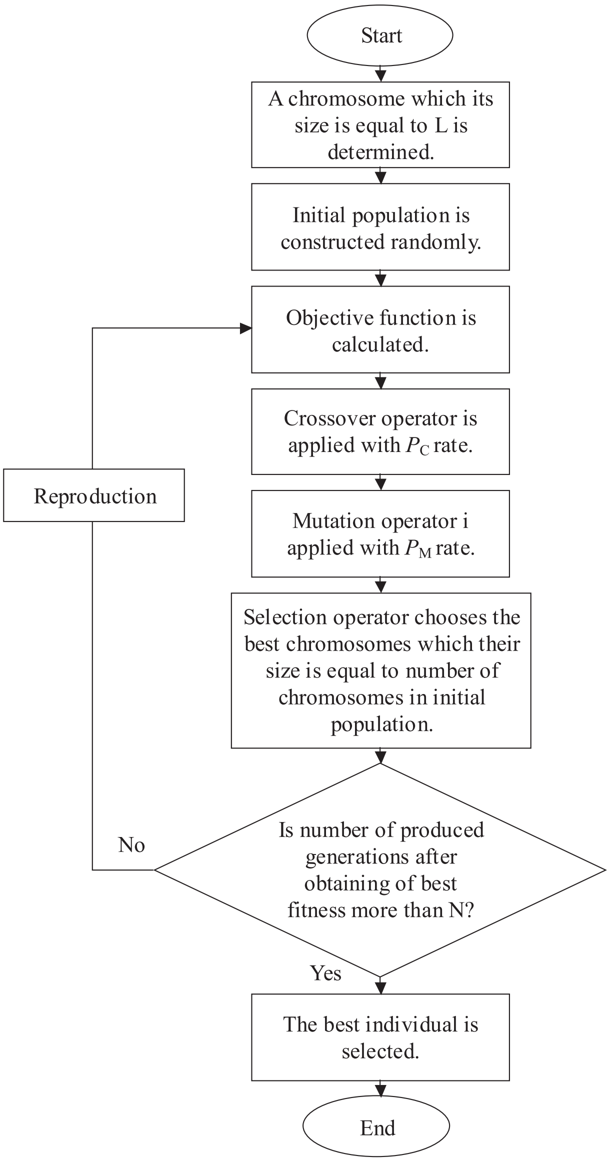

Fig. 3. Flowchart of the proposed GA based method

3.4 End condition

After mutation, the production of new generation is completed and it is ready to start the process all over again with fitness evaluation of each chromosome. The process continues and it is terminated by either setting a target value for the fitness function to be achieved, or by setting a definite number of generations to be produced. Due to the stochastic nature of the GA, there is no guarantee that different executions of the program converge to the same solution. Thus, in this study, the program has been executed for four times as continual i.e. after running of the genetic program, obtained results are inserted in initial population of next run and this process is iterated for three times. In addition to this continual run, a more suitable criteria termination has accomplished that is production of predefined generations after obtaining the best fitness and finding no better solution. In this work a maximum number of 3500 generations has chosen.

4 CHROMOSOME STRUCTURE OF THE PROBLEM

In order to study the effect of bundle lines on network losses in transmission expansion planning the chromosome structure is represented based on two cases. In case 1, the bundle of lines has not been considered in chromosome structure, but in case 2, the bundle of lines has been included in chromosome. In the following the details of these cases are given.

- **Case 1**

In this case, with respect to neglecting the effect of bundle lines on network losses for solution of STNEP problem in a transmission network with various voltage levels and also simplicity in programming, selected chromosome is divided to following parts as shown in Fig. 1 for a network with 6 corridors. In part 1, each gene includes number of existed circuits (both of constructed and new circuits) in each corridor. Genes of part 2 describe voltage levels of existed genes in part 1. It should be noted that the binary digits of 0 and 1 have been used for representing voltage levels of 230 and 400 kV, respectively. If other voltage levels exist in the network, the numbers 2, 3 and *etc*, can be used for representing them in the genes of part 2. Therefore, the proposed coding structure will be extendable to other voltage levels.

In Fig. 1, in the first, second, third corridor and finally sixth corridor, one 400 kV, two 230 kV, three 400 kV and two 230 kV transmission circuits have been predicted, respectively.

- **Case 2**

In this case, with respect to considering the effect of bundle lines on network losses and also simplicity in programming, selected chromosome is divided to following parts as shown in Fig. 2. In part 1, each gene includes number of existed circuits in each corridor. Voltage levels and number of corresponding bundle lines of existed genes in part 1 is represented as genes of part 2 and part 3

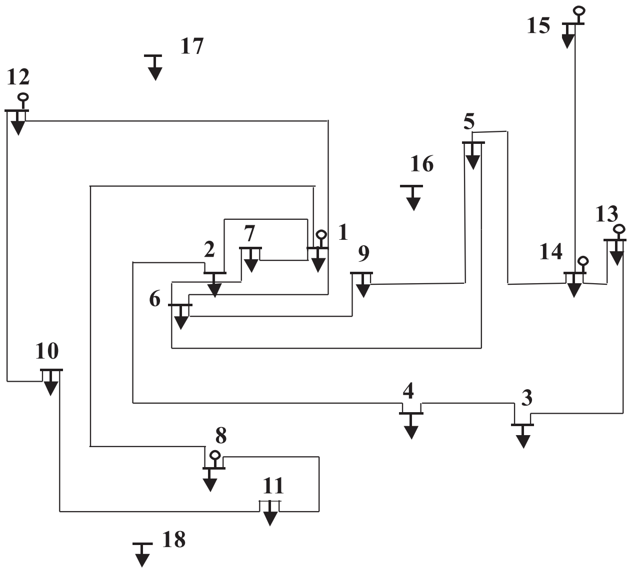

Fig. 4. Transmission network of the Azerbaijan regional electric company

respectively. A typical chromosome for a network with 4 corridors has been shown in Fig. 2.

In the first, second, third and finally in the forth corridor one 400 kV line with one bundle conductor, two 230 kV lines with two bundle conductors, three 230 kV lines with one bundle conductor and two 400 kV transmission circuits with one bundle conductor have been predicted, respectively. Figure 3 shows the flowchart of the proposed GA based method for the solution of STNEP problem. It should be noted that in Fig. 3, value of L is different for each case, *ie* in case 1, L is twice more than the number of corridors while in case 2, it is three times more than the number of corridors.

5 RESULTS AND DISCUSSION

The transmission network of the Azerbaijan regional electric system is used to test and evaluation of the proposed method. This actual network has been located in northwest of Iran and is shown in Fig. 4. The network characteristics and required data are given in Appendix A. In order to evaluate the effect of bundle lines on the network losses and subsequent transmission expansion planning, the proposed idea is test on the case study system, considering and neglecting the network losses for two scenarios. In scenario 1, STNEP problem is solved regardless to bundle lines while in scenario 2, the static expansion planning is carried out considering this type of lines. It should be noted that the planning horizon year and maximum loading of lines and substations are 15 (year 2023) and 30 % for both scenarios, respectively.

- **Scenario 1**

In this scenario, with respect to neglecting the effect of bundle lines in this scenario, chromosome structure is similar to case 1. The proposed method neglecting the bundle lines is applied to above-mentioned test network and the results (lines which must be added to the network up to planning horizon year) are given in Tables 1 and 2. Also, Tables 3 and 4 show the expansion costs.

Table 1. First configuration: neglecting the network losses

Corridor	Voltage Level (kV)	Number of Circuits
1-9	230	2
2-8	400	2
4-8	230	2
6-8	230	2
7-8	400	1
8-10	230	2
5-15	230	1
1-11	230	1
1-18	230	1
10-18	230	1
11-18	230	2

Table 2. Second configuration: Considering the network losses

Corridor	Voltage Level (kV)	Number of Circuits
1-9	230	2
2-8	400	2
4-8	230	2
6-8	230	2
7-8	400	1
8-10	230	2
5-15	230	2
1-11	230	1
1-18	230	1
10-18	230	1
11-18	230	2

Table 3. Expansion cost of network with the first configuration

Expansion Cost of Substations	25.6 million $US
Expansion Cost of Lines	72.019 million $US
Total Expansion Cost of Network	96.619 million $US

Table 4. Expansion cost of network with the second configuration

Expansion Cost of Substations	25.6 million $US
Expansion Cost of Lines	73.679 million $US
Total Expansion Cost of Network	99.279 million $US

Total expansion cost (sum of expansion and losses costs) of expanded network with the two proposed configurations has been shown in Fig. 5.

It can be seen that the total expansion cost of network with the second configuration is more than that of the first one until about 8 years after planning horizon (2026), but afterward the total expansion cost of network with first configuration becomes more than another one.

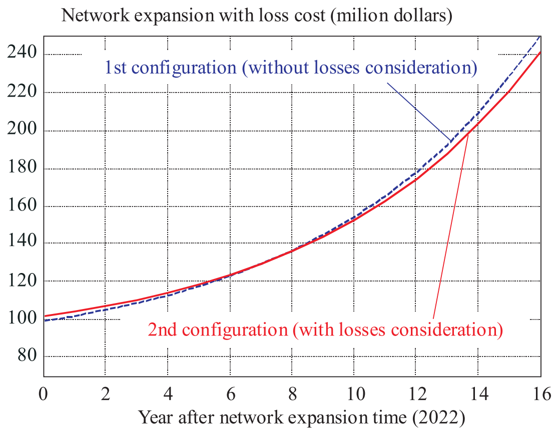

Fig. 5. Sum of expansion costs and annual losses cost of the network with the two proposed configurations in scenario 1

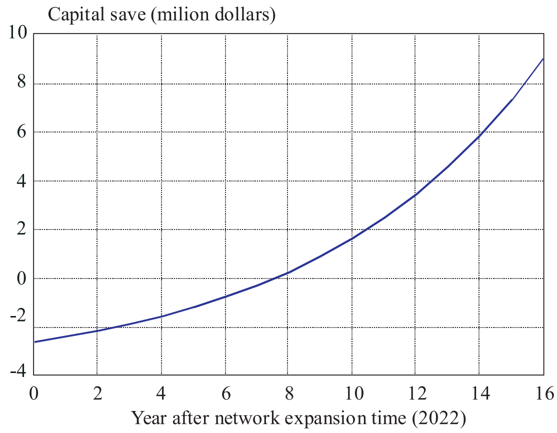

Fig. 6. Investment return curve by choosing of the second configuration in comparison with the first one in scenario 1

Table 5. First configuration: neglecting the network losses

Corridor	Voltage Level (kV)	Number of Circuits	Number of Bundle
1-9	230	1	1
8-9	230	2	2
4-8	230	1	2
2-8	400	2	3
8-18	230	1	2
11-15	230	1	2
11-18	400	1	3
1-7	230	1	2

Table 6. Second configuration: Considering the network losses

Corridor	Voltage Level (kV)	Number of Circuits	Number of Bundle
8-9	230	2	2
4-8	230	2	2
6-8	230	2	2
2-8	400	2	3
5-15	230	2	2
8-18	230	2	2
11-18	400	1	3
1-7	230	1	2
10-18	400	2	3

Table 7. Expansion cost of network with the first configuration

Expansion Cost of Substations	22.6 million $US
Expansion Cost of Lines	48.378 million $US
Total Expansion Cost of Network	70.778 million $US

Table 8. Expansion cost of network with the second configuration

Expansion Cost of Substations	19.2 million $US
Expansion Cost of Lines	64.998 million $US
Total Expansion Cost of Network	84.198 million $US

The reason is that the network losses cost of second configuration becomes less than that of first one about 8 years after planning horizon. Process of investment return for this configuration in comparison with the first one is shown in Fig. 6. In fact, this curve is equal to subtraction of cost curves of two mentioned configurations in Fig. 5. From transmitted power through the lines point of view, both configurations are overloaded 16 years after expansion time (planning horizon).

- **Scenario 2**

In this scenario, with respect to considering the effect of bundle lines, chromosome structure is like the case 2. The proposed idea is tested on case study and the results (lines which must be added to the network up to planning horizon year) are given in Tables 5 and 6. Also, Tables 7 and 8 show the expansion costs.

According to Fig. 7, the first configuration is more economic than first one about 5 years after expansion time, but afterward second configuration becomes more economic.

Process of investment return for this configuration in comparison with the first one is shown in Fig. 8.

In this scenario, from the transmitted power through the lines point of view, the first configuration is overloaded 16 and second one is overloaded 19 years after expansion time, too.

From Figs. 5 and 7, it can be seen that start points of cost curves for both configurations in Fig. 5 are upper than similar curves for represented configurations in Fig. 7. In other words, at planning horizon year and beginning of operation, networks which have bundle lines are more economic than other ones (networks which have no bundle lines). Also, with respect to cut points of two curves in two mentioned scenarios it can be concluded that considering the bundle lines in transmission expansion planning is caused the curve of second configuration cuts the curve of first one earlier and subsequent investment return take places faster. Thus, bundle lines have important effect on network losses and subsequent type

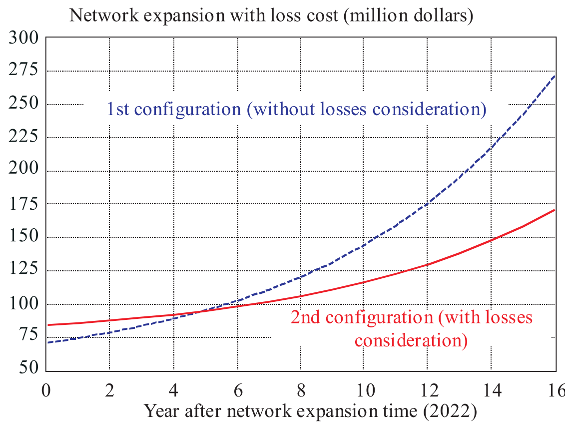

Fig. 7. Sum of expansion costs and annual losses cost of the network with the two proposed configurations in scenario 2

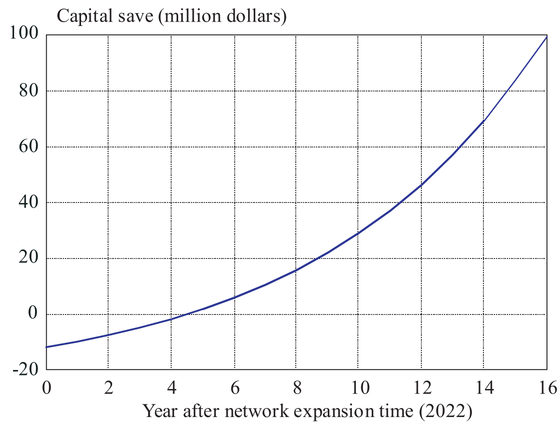

Fig. 8. Investment return curve by choosing of the second configuration in comparison with the first one in scenario 2

of network configurations. Also, construction of bundle lines in transmission network with various voltage levels is caused the total expansion cost (expansion and operational costs) is decreased and calculated more exactly. Moreover, it can be seen that most of the mentioned lines (400 and 230 kV) have been added to the network with their maximum the number of bundle conductors (2 and 3), respectively. In other words, although cost of lines which have 2 or 3 bundle conductors is more than those which have 1 conductor, but construction of these lines in transmission networks with different voltage levels prevents useless expansion of lines with 1 bundle in separate corridors and is caused the network expansion planning is optimized. Finally, it can be concluded, considering the network losses, with considering the bundle lines is caused the network lines are overloaded later. Thus, construction of these lines increases the network adequacy and consequently network satisfies the requirement of delivering electric power more safely and reliably to load centers.

6 CONCLUSION

In this paper, the effect of bundle lines on the network losses in static transmission network expansion planning is studied using the decimal codification genetic algorithm. The results evaluation reveals that construction of bundle lines in transmission networks with various voltage levels is caused the total expansion cost of the network is decreased. In addition, it can be concluded that bundle lines have important effect on the network losses because considering it in transmission expansion planning is caused the cost curve of second configuration cuts the curve of first one earlier and subsequent return investment value becomes more. Thus, bundle lines have important role in determining of the network configuration and arrangement. Moreover, it can be seen that although cost of lines which have 2 or 3 bundle conductors is more than those which have 1 conductor, but these lines increase the network adequacy more than lines of second type. Also, construction of these lines prevents useless expansion of lines with 1 bundle in separate corridors and is caused the network expansion planning is optimized. Finally, it can be concluded, considering the network losses, with considering the bundle lines is caused the network lines are overloaded later. Thus, construction of these lines increases the network adequacy and consequently network satisfies the requirement of delivering electric power more safely and reliably to load centers.

Appendix

A. Characteristics of case study system

Tables 9–11 show the substation information, configuration of lines, generation and loads data of the test system as given in Sec. 5.

Table 9. Arrangement of substations

Substation	Voltage Level (kV)	Substation	Voltage Level (kV)
1	400/230	10	230/132
2	230/132	11	230/132
3	400/230	12	230/132
4	230/63	13	230/63
5	230/132	14	400/230
6	230/132	15	230/63
7	230/132	16	230/20
8	230/132	17	230/132
9	230/132	18	230/132

Tables 12 and 13 describe the characteristics of the lines. Finally, the construction costs of 230 and 400 kV lines are listed in Tables 14 and 15.

Table 10. Arrangement of lines

Corridor	Length of of Corridor (km)	Voltage Level (kV)	Number of Circuit	Number of Bundle
6-1	55	230	1	1
2-1	14	230	2	1
9-6	18	230	1	1
4-2	83	230	1	1
14-5	110	230	1	1
11-8	65	230	2	1
11-10	125	230	2	1
15-14	139	230	1	1
12-1	122	400	1	2
9-5	100	230	1	1
6-5	103	230	2	1
13-3	105	400	1	2
4-3	81	230	1	1
14-13	44	230	2	1
12-10	134	230	2	1
8-1	75	230	2	1
7-6	33	230	1	1
7-1	22	230	1	1

Table 11. Generation and load arrangements

Bus	Load (MW)	Generation (MW)	Bus	Load (MW)	Generation (MW)
1	378	715	10	134	0
2	202	0	11	125	0
3	42	0	12	256	288
4	53	0	13	78	101
5	45	0	14	46	60
6	64	0	15	45	101
7	88	0	16	11	0
8	49	514	17	14	0
9	70	0	18	79	0

Tables 12 and 13 describe the characteristics of the lines. Finally, the construction costs of 230 and 400 kV lines are listed in Tables 14 and 15.

Table 12. Characteristics of 230 kV lines

Number of Line Bundles	Maximum Loading (MVA)	Reactance (p.u/Km)	Resistance (p.u/Km)
1	397	3.85e-4	1.22e-4
2	794	2.84e-4	2.44e-4

Table 13. Characteristics of 400 kV lines

Number of Line Bundles	Maximum Loading (MVA)	Reactance (p.u/Km)	Resistance (p.u/Km)
1	750	1.24e-4	3.5e-5
2	1321	9.7e-5	7,00E-05
3	1982	8.6e-5	1.05e-4

Table 14. Construction cost of 230 kV

Number of Line Circuits	Fix Cost of of Line Construction ($\times 10^3$ dollars)	Variable Cost of Line Construction ($\times 10^3$ dollars)
1	546.5	45.9
2	546.5	63.4

Table 15. Construction cost of 400 kV

Number of Line Circuits	Fix Cost of of Line Construction ($\times 10^3$ dollars)	Variable Cost of Line Construction ($\times 10^3$ dollars)
1	1748.6	92.9
2	1748.6	120.2

B. GA and other required data

Load growth coefficient = 1.08
Inflation coefficient for loss = 1.15
Loss cost in now = 36.1 ($/MWh)
Number of initial population = 5
End condition: 3500 iteration after obtaining best fitness (N=3500).

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