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Planning of Transmission Network Expansion and Increasing the Capacity of Production of Units in the Long Term by Considering the Response Load Based on System Reliability

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Abstract: In this study, planning operations for expansion of transmission network as the most important part of the power systems planning has been investigated. The overall aim of this article is to find new lines that are required for the network at the lowest investment cost by taking into account indices such as system reliability and capacity expansion of production units in an economical and cost effective manner. For this matter a new method for planning the expansion of the transmission network has been proposed. Taking into account the objective function of the proposed plan, the cost of achieving the targets outlined in this new plan, cost of increasing the capacity of production units, operation costs as well as those loads sensitive to cost and future energy requirements have all been taken into consideration. In the following, the response load and its distribution within the optimal required load, its effect on future operation of the transmission network and indices of transmission system reliability by using intelligent genetic algorithm and intelligent simulation of objective functions under four different scenarios have been analyzed and investigated. To achieve the targeted response load and the planned increase in the production capacity, intended indices have been obtained.

Key words: Transmission Network Planing (TEP), reliability, intelligent genetic algorithm, static and dynamic development, EENS

INTRODUCTION

Strategic long term planning, in order to reform and optimize the current transmission expansion planning models loads an optimized process of expanding and strengthening of existing lines for softy the future loads in a safe and cost efficient manner which itself requires production of a new model for the network. In the proposed model, effects of response load by using parameters such as price capital TEP model's output and the challenges of improving the reliability of the system have been investigated. By using intelligent genetic algorithm and simulation, this model is suitable for future policy making and planning for production.

Problem statement: This study tries to find an optimized model for power network expansion that answers the following questions: How the current and future associated costs such as current costs, investment costs, cost of increasing the capacity of production units and operation costs are to be kept to a minimum level at the same time that the system offers the highest possible reliability. Is it possible to simulate the performance of power transmission network by using intelligent genetic algorithm?

Importance of this research

Transmission network expansion planning: In the planning for the future development of transmission network, importance of planning for developing the network by taking into account the overall view of predicted required future load determines the optimization process. Therefore, different TEP models have to be reviewed not only from the viewpoint of certain or possible models, traditional views and competitive environment but also the overall static and dynamic views over the period of 20 year must also be taken into consideration. As the optimization is considered over the period of 20 year, dynamic expansion of transmission network for planning and calculating the associated costs via a mathematical model has been considered. There are only a few articles in the literature that have studied the dynamic expansion of transmission network.

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What has been considered by this study is one of the most important constituting factors for distribution networks and creating an intelligent response load (Rahimi and Ipakchi, 2010). Optimization of system reliability reduction of production costs in the market and reduction in the need for increasing the capacity of the system are some of the most important factors to be considered for response load of the system. Taking into account the previous statements, operation costs are calculated by using the following relationships:

$$MinC(Pg_i) = a_{gi}Pg_i^2 + b_{gi}Pg_i \quad (1)$$

Where:

$C(Pg_i)$ = Operation cost of generator (i)

Pg_i = The production power of generator (i)

a_{gi} and b_{gi} = The Coefficients of generator (i)

In this equation: When the system loads are sensitive to the price (response load) they will be the target function of objective optimal power flow as shown by Eq. 2:

$$\begin{aligned} &Min\{C(Pg_i) - B(Pd_j)\} \\ &= Min\begin{cases} (a_{gi}Pg_i^2 + b_{gi}Pg_i) \\ -(a_{dj}Pd_j^2 + b_{dj}Pd_j) \end{cases} \end{aligned} \quad (2)$$

Where:

Pd_j = Consumption power in bass (j)

a_{dj} and b_{dj} = Coefficients for consumption bass (i)

In the second sentence $B(Pd_j)$ in target function of (2) is usually referred to as the benefit or the value of consumed electricity for the consumer. This definition has been used in various studies (Xian *et al*., 2004).

Literature review: In studies, Latorre *et al*. (2003), Fang and Hill (2003) and Kim *et al*. (2002) uncertainty of information in competitive transmission network development environments as a principal parameter has been investigated. In study, Hemmati *et al*. (2013) planning for development of transmission network from different viewpoints has been studied. However, the response load in development of transmission network has not been investigated. The principal innovation offered by this article has been applied to the safety and the optimal load diffusion model. Refereeing to studies (Condren *et al*., 2006) that have been reviewed and evaluated previously the results of all the reviewed articles are general and significant. However, the aim of the researcher of this study has been the importance of response load in intelligent networks and the relationship between these two subjects.

MATERIALS AND METHODS

Different methods of problem solving: So far different and diverse methods such as classical mathematics and non-classic mathematics such as study (Verma *et al*., 2010) have been adopted for modeling of production and transmission however, these articles have only considered a number of restrictions. It is possible to use other methods such as linear programming, nonlinear programming dynamic programming, and mixed integer programming. In study (Latorre *et al*., 2003) tree structure and a point-to-point search method for construction of new lines and CHOPIN Model for TEP have been used.

Other optimization methods such as genetic algorithm in study harmony search algorithm (Verma *et al*., 2010) Annealing simulation (Romero *et al*., 1996) branch and bound technique theoretical methods of phase sets (Latorre *et al*., 2003) games theory (Contreras and Wu, 2000) intelligent systems (Teive *et al*., 1998) and Imperialist competitive algorithms have been used to solve this problem.

Table 1 advantages and disadvantages of different point of views are presented. As it can be observed, multiple views of transmission network development planning have been reviewed and numerous solving methods have been investigated. However, there are a few studies on response load of transmission network development planning.

Recommended models in this study: In this study for the transmission development project the author has considered the optimal investment cost as well as the operation cost of the network in the presence of the cost of response load and system reliability and genetic algorithm is used for simulation within the software environment.

In the proposed objective function for construction of the new network and increasing the capacity of the production units, operation and paid costs for Expected Energy of (EENS) have also been taken into consideration.

The framework of the proposed model in this study is based on a model mentioned in study which is expanded via three directions. The presented objective function in the stated study only minimizes blackouts during normal conditions. However, the proposed model of this study firstly intents to minimize the EENS and secondly in the previous model the elastic loadin response to the price has been considered and thirdly, the ability to increase the capacity of production

Table 1: Comparison of different innovative and mathematical methods

Variables	Mathematical methods	Innovative methods
Target	Optimization of cost function consisting of losses, construction and operation costs	Achievement of optimized structure based on the evaluation criteria
Constrains	Economic and technical	Economic and technical
Evaluation criteria	Reduction of differences between two solutions to a minimum defined level	Increase or reduction in sensitivity coefficients according to the case
Starting Point	Taking into account the target function, mathematical rules are determined by the designer	The initial scenario is determined by the designer
Disadvantages	Convergence problems (due to the use of DC load distribution)	Reliance of final solution on the initial defined scenario
	Increase in time and calculations volume while using discrete variables	Need of enumeration of different scenarios
	Achievement of optimised solution due to non-linear nature is difficult	Numerous simplifications in modelling the actual conditions
	Numerous simplifications in modelling the actual conditions	In majority of cases the obtained solution is semi-optimal
Advantages	Achieving an efficient solution is possible	Time consumed for solving problems is less than mathematical methods

have been applied intelligently to the objective function. In summary, the innovations of this study are as follow:

- Consideration of EENS (as an important index of reliability) in objective function of TEP
- Taking into account the responsive load in the TEP problem and considering its effect
- Increasing the capacity of production unit and its effect on objective function of TEP

In most presented models for planning of the expansion of transmission network investment cost for construction of new lines and the cost of operation of the network are also considered in the objective function. The operation cost of the network is usually achieved via an optimal load program. Paying attention to the possible accidents within the power system considering lines and generators forced shutdowns and the cost of possible blackouts in the optimal loaddistribution objective function, makes the problem more realistic. The proposed objective function for the development of transmission network is as follow:

$$\text{Minf} = \text{Inv} + \text{EOC} + \alpha \times \text{EENS} + \beta \times \text{Cpg} \tag{3}$$

Where:

Inv = The cost of investment in new lines
EOC = The waiting operation cost
EENS = The cost of possible blackouts
α = Penalty for results containing blackouts
Cpg = Total cost of increasing the capacity of production units
β = Cost penalty for every megawatt added to the capacity of production unit

In effect this function considers every single plan for expansion or development (Every plan for development consists of one or more new lines to be added into the network). "α" is the penalty weight of results that contain high number of blackouts and the reasons for using a penalty coefficient for possible blackouts is to consider and controlling the blackout rate in the objective function. In other words the value of numerical solutions to the problem for every proposed objective function is different and surely the investment cost of the new lines and the associated operation cost as stated in Eq. 3 are higher than the blackout rates during incident free and incidental conditions of the network. In this problem the value of "α" of penalty coefficient is considered to be 3000. Despite existence of technical and geographical conditions for increasing the capacity of every production units, β coefficient is taken for the capacity increase of production units.

The planning for solving this problem is performed by adopting a time based static vision view and all the obtained results for the costs of investment in the new lines and the expected amount of operation cost as well as possible blackouts for the ending of the time vision shall be calculated.

The most important part of the proposed objective function is the second, third and fourth sentences that describe the expected EOC operation cost and the amount of ENS and the cost of increasing the capacity of production units by considering the overall cpg cost which is obtained from solving a second degree QP planning problem. The method of its calculation is described in details.

Expected operation cost (by considering the responsive load): Firstly, applied indices in objective function are introduced:

- i: Indices related to each generator (N_g: Total number of generators)
- j: Indices related to each load (N_d: Total number of loads)
- l: Indices related to each line (N_L: Total number of lines)
- k: Indices related to each incident (K: Total number of incidents) indices of zero is for normal condition

The considered incidents are during the event of the exit of high load lines and exit of production units). The expected amount of operation cost by taking into account the likely incidents in the system is calculated via Eq. 4. In reality this equation calculates the mathematical expectation of operating costs by considering the output incidents therefore the effect of increasing cost during the occurrence of blackouts in proportion of the likelihood of the occurrence of that specific incident is described in Eq. 4. In this equation, π_0 is the possibility of existence of a normal condition (without incidents) that is calculated by Eq. 5:

$$EOC = \pi_0.C_0 + \sum_{k=1}^{K} \pi_k.C_k = \sum_{k=0}^{K} \pi_k.C_k \quad (4)$$

$$\pi_0 = 1 - \sum_{k=1}^{K} \pi_k \quad (5)$$

Where:

π_k = Likelihood of occurrence of incident k

C_0 = Operation cost under normal condition (no incidents)

C_k = Operation cost during occurrence of an incident k

Before stating the operation cost formula, method of modelling the responsive loads is described. In this research it has been assumed that a percentage of system's load ($0 \le \alpha_{DR} \le 1$) are sensitive to elastic price that are presented as "Pde" in Eq. 6. The rest of the loads (inelastic) are shown as "Pdu" in Eq. 7. Therefore, if the total consumed loads in bass "j" are shown with "Pdj" we shall have:

$$Pde_j^{Max} = \alpha_{DR}.Pd_j \quad (6)$$

$$Pdu_j = (1 - \alpha_{DR}).Pd_j \quad (7)$$

Where:

"Pde_j" = In effect is the amount of elastic load in bass "j" that based on price conditions can have the values in-between zero

"Pdu_j" = The inelastic load that has to be satisfied in bass "j" unless blackouts will occur

The value of operation cost during each event (including normal condition and the outputs) means that C_k is calculated via (Eq. 8). The first line in this equation in the production cost relationship and the second line is the benefit level of electricity consumers that is sensitive to the price (responsive loads) that are considered in Eq. 9 and 10, respectively.

$$C_k = Min\left\{\sum_{i=1}^{N_g} C(Pg_i^k) - \sum_{j=1}^{N_d} B(Pde_j^k) + \sum_{j=1}^{N_d} VOLL_j.UP_j^k\right\} \quad (8)$$

$$\forall k = 0, 1, 2, \ldots, K$$

$$C(Pg_i) = a_{gi}.(Pg_i)^2 + b_{gi}.Pg_i \quad (9)$$

$$B(Pde_j) = a_{dj}.(Pde_j)^2 + b_{dj}.Pde_j \quad (10)$$

Where:

Pg_i^k = Production power of generator "i" during the occurrence of incident k

Pde_j^k = Amount of consumed elastic load in bass "j" during the occurrence of incident k

Up_j^k = Unserved power in bass "j" during incident k

$VOLL_j$ = The value of lost load in bass "j"

The issue of equality constrains of DC distribution load are:

$$B^k\theta^k = Pg^k - Pde^k - Pdu + UP^k \quad (11)$$

$$P_l^k = P_{mn}^k = \frac{\theta_m^k - \theta_n^k}{x_{mn}} \quad (12)$$

Where:

B^k = Susceptance matrix of the network

θ^k = Basses voltage degrees during incident k

Pg^k = Generator's power during incident k

Pde^k = Elastic power rate during incident k

Pdu = Inelastic power rate (unresponsive)

P^k_{mn} = Rate of power from through the line "mn" (in per-unit or Pu)

x_{mn} = Reactance of line "mn"

In this equality constrains: The value of inelastic load (Pdu_j) during all conditions remains constant, therefore this parameter has no "k" indices in Eq. 11. In the presented model for expansion of transmission network, instead of Ac load flow, DC load flow is used. Equation 11 that describes the production and consumption balance during each incident and bass by using matrixes is one of the main constrains for direct load flow. Power flow rate through line "mn" is calculated by Eq. 12 (the values of power are in per-unit or Pu). Unequal constrains of this problem are:

$$Pg_i^{min} \le Pg_i^k \le Pg_i^{Max} \quad (13)$$

$$P_{l-min}^k \le P_l^k \le P_{l-max}^k \quad (14)$$

$$0 \le UP_j^k \le Pdu_j^{Max} \quad (15)$$

$$0 \le Pde_j^k \le Pde_j^{Max} \quad (16)$$

Constrain (Eq. 13) shows the minimum and maximum limits of generators production power at each incident. The limitations of power flow through transmission lines are provided in constrain (Eq. 14). Constrain (Eq. 15) shows the upper limit of unserved power in each bass during different incidents that in this case, the maximum blackout rate can be as much as the inelastic load. Related limits of responsive load is presented in constrain (Eq. 16) that its maximum value can be as much as the elastic load.

In other words the objective function in Eq. 8 along with constrains in Eq. 11 can be implemented (k+1) times and its results are stored. Finally by considering the probability of occurrence of each incident, the mathematical expectation of operation cost is calculated by using Eq. 4.

Also by determination of the blackout rate of basses of the system in each incident (UP^k_j) the values of reliability index or EENS (by considering all incidents) are calculated from Eq. 17:

$$EENS = \sum_{k=0}^{K} \sum_{j=1}^{N_d} \pi_k \times UP_j^k \quad (17)$$

Where:

π_k = Probability of occurrence of incident k

Up^k_j = The blackout rate (unserved power) in bass "j" during the occurrence of incident k

In this equation: The blackout rate (UP^k_j) in Eq. 17 by solving Eq. 8 and by meeting the conditions of constrains Eq. 11-16 for each incident and normal condition of the network is calculated and by taking into account the probability of each incident the total of that calculation and possible blackout rates are obtained.

The "Cpg" in the proposed objective function is the total cost of increasing the capacity of production units which is obtained by the equation:

$$Cpg = \sum_{g=1}^{Ng} Pg_g new - Pg_g \quad (18)$$

In Eq. 18 the total difference between the production power of units at a new level and by considering the determined range of increased capacity is presented. In reality "Cpg" only obtains the increased amount of production units and by placing that into Eq. 9 the cost of increasing the capacity of production units is achieved. Therefore during the process of optimizing the objective function such as the amount of blackouts usually the costs of operation and development of lines are lower and are controlled by their respective importance coefficient of the plan.

Proposed algorithm: Genetic algorithm which is used in this study is based on repetition of calculations and the aim is to achieve the best conditions for the objective function. This algorithm contains the following strengths.

The genetic algorithm used in this study has a number of starting points and it has the ability to consider the problem from multiple aspects in a moment which is the main property of linearity of GA algorithm in solving the problem with a number of objectives. Therefore, the probability ofaccidental convergence of the result is reduced. In this algorithm coincidence (on a proper manner) is used for sampling in order to reach the solution to the problem.

In this problem for the coding of problem's variables and each parameter one decimal alphabet is assigned that indicates those lines that are to be added to the corresponding route.

Flowchart for problem solving: Figure 1 presents the genetic algorithm flowchart for solving the problem stated in this study. First the initial population is accidentally created that each line is like a transmission line for construction and the representative of new transmission line is one and the opposite (no new line to be constructed) is zero. Furthermore, the created population for solving the QP problem is presented and summarized in this article and the obtained results from solving the QC problem, consists of operation costs and EENS reliability index which will be used to evaluate the suitability which in this study is the objective function results for the proposed model will be referred. For this purpose, the "quadprog" load in the MATLAB software has been used. This load function is used for solving second degree problems by meeting the conditions of equality and inequality constrains.

Method of solving the problem: After careful evaluation, the cost of construction of new lines is referred to the objective function and the value of objective function is introduced and Eq. 3 is used to evaluate the suitability of individuals. As this problem is after the reduction of costs and the amount achieved from the objective function, the

Line 1	Line 2	...	Line NL

Fig. 1: Presentation of problem coding

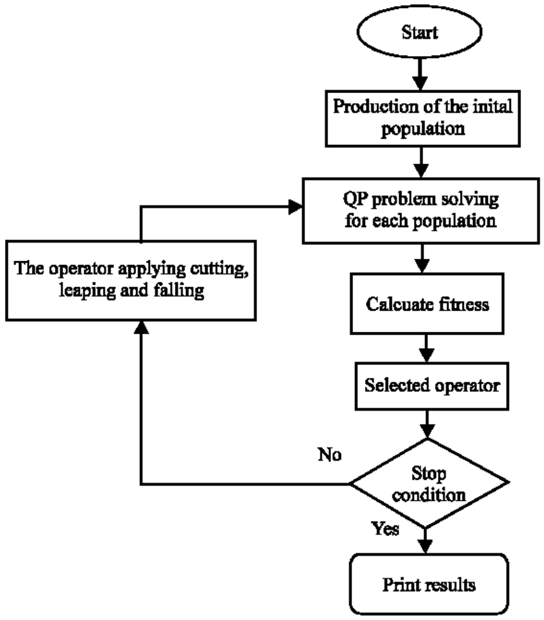

Fig. 2: Information gathering and result

selection operator will select the individual that has given the best answer to the objective function. Then for creating the next population, best introduced performers are used. It is important to note that in addition to normal genetic algorithm performers meaning selection, cuts and jumps, a new performer known as the reducer is used. The performance of this performer is in a way that due to presence of a zero bit in the chromosome or the created individual in the corresponding population by construction of a single line in an accidental manner from the bits that have a value other than zero one unit is taken away and if the value of objective function for the resulting individual is better (has a lower value) this individual will replace the previous one. If after implementation of selection operator the results of the program are unchanged the algorithm will stop.

As it can be observed in consistence with the flowchart of solving the problem in Fig. 2 the proposed model in Eq. 3 shall be observed and it is after further optimization in repeated sequences until it obtains the best possible result.

RESULTS AND DISCUSSION

Inputs analysis: For information gathering and results of example network for testing the proposed model, 14 bass IEEE systems in consistence to reference (Choi and Tran, 2006; Choi *et al*., 2005), single line diagram of this example network is presented in Fig. 2. Five production bass, nine consumer bass and twenty communication lines between the basses exist. The specifications of this system are as follow: considered incidents for this system are as follow:

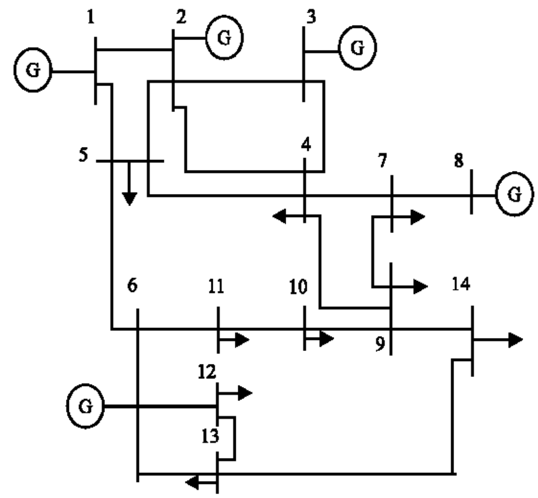

Fig. 3: Single line diagram network of standard 14 bass IEEE

- K = 0 is the corresponding normal state of the system (no incidents)
- K = 1 is the correspondent incident for the exit of high load line (6-2)
- K = 2 is the correspondent incident for the exit of high load line (6-5)
- K = 3 to k = 7 are the exit correspondents for G1 to G5 production units

The probability of occurrence of incidents is considered to be at 0.01 and the rest is the probability of normal network condition. With this assumptionthe occurrence of different values is a probability (Fig. 3). For a system with the lowest risk of blackouts, identification of identification of threats and weak points of the system is vital. In additions to these incidents of exit of high load lines in the model have been taken into account (Table 2 and 4).

In this study an average for the load growth is taken as 0.07 and the investment cost for new lines is considered to be \$200 h^{-1}. The profit function of responsive loads for consumers in the problem is defined in Eq. 10:

$$a_{dj} = -0.05\,\forall j\ (h/MW^2)$$

$$b_{dj} = 25\forall j(h\ MW^{-})$$

Table 2: Consumers specification

Bus number	The maximum consumption of the beginning of the horiz (MW)	Consumption is predicted on at the end of the horizon (MW)	The value of lost load ($/MWh)
1	0	0	-
2	50	193	600
3	120	464	700
4	90	348	400
5	40	154	400
6	20	77	600
7	0	0	-
8	0	0	-
9	40	154	800
10	15	58	400
11	10	38	400
12	25	96	600
13	20	77	500
14	20	7	600

Table 3: Lines information

Line number	Buses connected to the line	Reactance (per-unit)	Capacity (MW)
1	1-2	0.05917	50
2	1-5	0.22304	50
3	2-3	0.19797	50
4	2-4	0.17632	50
5	2-5	0.17388	50
6	3-4	0.17103	50
7	4-5	0.04211	50
8	4-7	0.20450	50
9	4-9	0.53890	50
10	5-6	0.23490	50
11	6-11	0.19890	50
12	6-12	0.25581	50
13	6-13	0.13027	50
14	7-8	0.17615	50
15	7-9	0.11001	50
16	9-10	0.08450	50
17	9-14	0.27038	50
18	10-11	0.19207	50
19	12-13	0.19988	50
20	13-14	0.34802	50

Table 4: Producers specification

Number generator	Bus number	Minimum production	Maximum production	Suggested retail price index (h/MW^2)	Suggested retail price inde xag(h/MMW^{-2})
1	1	0	250	0.01	10
2	2	0	200	0.01	10
3	3	0	100	0.01	20
4	4	0	150	0.01	15
5	8	0	100	0.01	22

For analysis of inputs in the simulation of the effect of responsive load on system reliability and then the effect of responsive load on the development plan of transmission network is investigated. Then the planning for the development of transmission network with the long term vision based on system reliability is obtained.

In Eq. 6 presented in this report, shows the level of participation in the responsive load. Due to lack of convergence of the problem where the low value of introduces a state where responsive load is approximately nonexistent. Considered values for and the calculated results are presented in Table 5 and 6.

Table 5: Effect of relatively low participation of responsive load on system reliability index and the expected cost of operation

α_{DR}	---EOC($)---		---EENS (MWh)---	
Without increasing the capacity of production units				
0.1	495570	284860	1000.40	606.98
0.15	449210	245580	908.70	527.90
By increasing the capacity of production units				
0.2	402870	206740	817.06	449.80
0.25	356600	172550	725.61	377.78
0.3	311510	131430	636.33	275.00

Table 6: Effect of higher participation of responsive load on system reliability index and the expected cost of operation

α_{DR}	---EOC($)---		---EENS (MWh)---	
Without increasing the capacity of production units				
0.001	587910	363640	1181.50	760.96
0.01	579430	356400	1165.00	747.71
By increasing the capacity of production units				
0.03	560590	340330	1128.50	718.25
0.05	541940	324380	1091.90	686.56
0.07	523390	308500	1055.30	654.52
0.09	504840	292740	1018.70	622.82

RESULTS AND DISCUSSION

Inputs results: As it can be observed, increase in participation of responsive load causes a reduction in operation costs and improves the reliability and at same time the efficient increase in capacity of production units and the expected operation cost and reliability index all experience a noticeable reduction than previously. This fact increases the importance of this research even further.

Figure 4 the effect of presence of elastic loads, values of reliability index for different values of under the scenario of no increase in capacity of production is shown.

Figure 5 the effect of presence of elastic loads, values of reliability index for different values of under the scenario of increase in capacity of production is shown. In this research the following has been considered.

As the participation of consumers in responsive load is increase, the EENS index will experience a higher reduction, therefore the results of reliability where = $\alpha_{DR} \leq 30$ is more favorable. Table 7 presents the output results of the given inputs.

Considering the inputs of this research and the outputs of the samples in Table 6, the increase in capacity of production units and the amount blackout in the incident, without increase in production is 1181.5 MWh and with production increase is at 760.96 MWh. Assuming incidents will occur, it is possible to calculate the period of blackout in each incident. In order to do this, we have used Fig. 6 and 7 to obtain the unserved power of each incident for four samples in the algorithm used in

Table 7: Results for added lines via simulation of the proposed method for TEP problem without taking into account the increase in capacity of production units when $\alpha_{DR} = 0.05$

	Years																				
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	1	0	1	0	0	1	0	1	0	0	1	0	1	1	1	0	1	1	1	1	12
2	0	1	0	0	1	0	0	0	1	1	0	1	1	1	0	1	1	1	1	1	12
3	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	0	6
4	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	4
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	3
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2
10	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	4
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
13	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	3
14	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
15	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	1	1	0	1	3	2	3	2	1	2	3	2	4	3	3	5	5	4	4	

Table 8: Numerical results for proposed function lines for TEP TEP problem without taking into account the increase in capacity of production units when $\alpha_{DR} = 0.05$

Variables	Values
Capacity increase of each production unit (MW)	0
Total cost of increasing the capacity of production units ($/h)	0
Total investment cost of lines ($/h)	102000
Optimal operating cost ($/h)	8500.7
EENS reliability index (MWh)	2.98
Total value of objective function	119562.34
Time taken to reach an optimal solution (sec)	25530

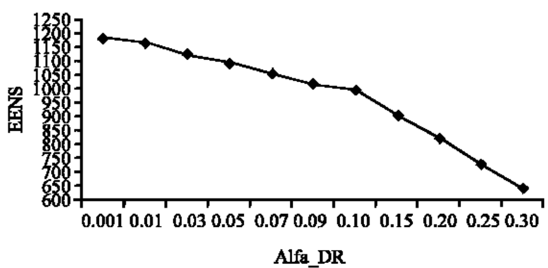

Fig. 4: Changes reliability index to increase participation in demand response

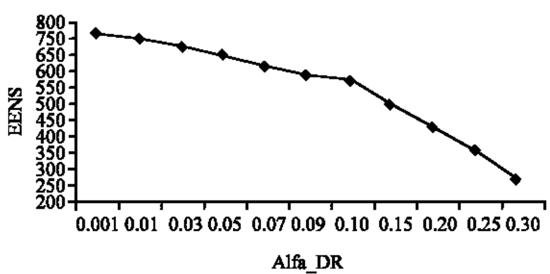

Fig. 5: Changes reliability index to increase participation in demand response and increase the capacity of the production units

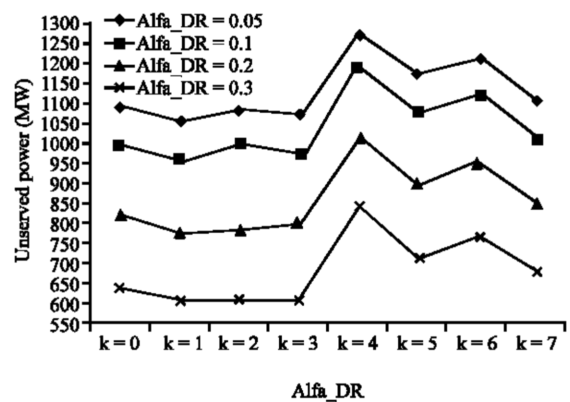

Fig. 6: Load not supplied (outage) per incident for different levels of participation responsive loads

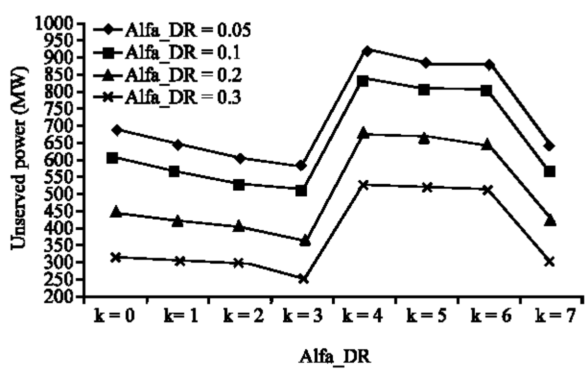

Fig. 7: Load not supplied (outage) per incident for different levels of participation and responsive load despite the increase in capacity production units

this research. Based on the obtained results, it is possible after K4, to predict incidents K5 and K6. Paying attention to the obtained results from our problem inputs in accordance to Fig. 5, if the increases in capacity of production units are to be considered, it will be possible to calculate the probability of incident G4 relative to G3. By using these inputs it is possible to obtain the value of increase in capacity of production units during reduction of blackouts. For further information on the results of simulation inputs, please contact the researchers. Figure 6 the amount of unservedload (blackout) in each incident for different level of participation of responsive load under presence of increase in capacity of production units. Figure 7 the percentage of provided responsive load in each incident for different level of participation of responsive load under presence of increase in capacity of production units.

By using Eq. 19, the ratio of total provided responsive load to the consumption peak of the system in every incident is taken as 0.1 that is plotted in Fig. 6 as two examples of α_{DR}.

As it have been presented, it is clear how the possible events for different load levels and capacity increase of production units are predictable. As stated previously, the simulation results of proposed objective function by the intelligent algorithm has been selected for solving the problem. Figure 8 the improvement rateof each generation of genetic algorithm in the stat of α_{DR} = 0.3 is shown as an example. The inputs for different examples and different values of "α" have been investigated and due to the high volume of input data, we are unable to present them in this study.

As it can be observed all the inputs are for a consecutive period of 20 year and the year of lines is used for the proposed network and intelligent genetic algorithm has been proposed.

At the end of the 20 year long term vision it can be concluded that the first and second are the most important of lines and some lines exist that do not require any additions within the next 20 year.

The numerical results of proposed function lines are presented as an example in Table 7. In this research, after repeating the results, the algorithm was unable to obtain a better solution and the original result was taken as the final result.

Evaluation of the effect of increasing the capacity of production units and responsive load on planning for development of transmission network: In this study, the obtained results of proposed objective function by intelligent genetic algorithm for the expansion of

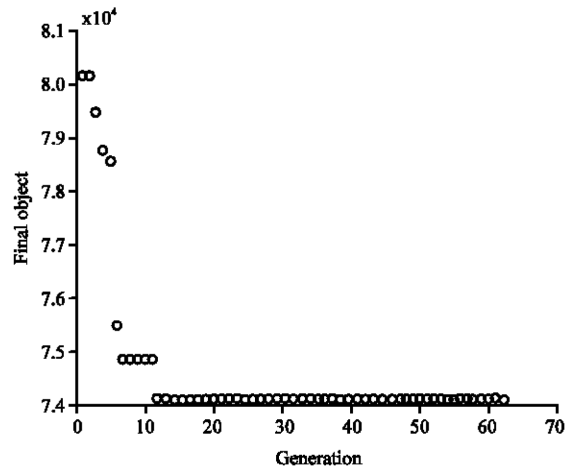

Fig. 8: Results of objective function variables during changes of genetic algorithm generations within software environment

transmission network problem at different levels of participation of responsive load and capacity increase of production units are presented.

By considering the proposed objective function in Eq. 3, the individual with the lowest value of objective response will be the solution to the problem. Due to the use of elite recognition the changes of objective function have a decreasing trend. This itself shows the performance validity of the program an as stated in chapter three, when the value of objective function remains constant after a few generations, the algorithm automatically stops.

Increasing the capacity of production units in solving the objective function of optimal operation cost is calculated by calculation of a second degree equation in an intelligent way. However, due to increase in capacity of production units is a function of different conditions and circumstances, a cost coefficient which is a function of capacity increase of production units in the overall function has been proposed so its importance is compatible with different parameters and viewpoints of the programmer.

In the following, initially, in order to see its effect on the problem, the increase capacity of production units on network development by considering low load is considered. From the obtained results of the existence of responsive load in the presence of increased capacity of production units is analyzed. The maximum capacity to be added to each unit is considered to be 200 MW and this value is proposed in the simulation model that can be applied to each changing unit.

Table 9: Results of added lines from the proposed simulation for TEP problem by taking into account the increase in capacity of production units when $\alpha_{DR} = 0.05$

	Years																				
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Line1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	1	1	7
Line2	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	1	1	6
Line3	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	6
Line4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	3
Line5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
Line8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Line9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Line10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	3
Line11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line13	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	4
Line14	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	4
Line15	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3
Line16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Line20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	1	0	1	1	1	1	3	0	2	1	3	1	3	3	3	3	6	7	

By comparing Table 8 with Table 9, it can be observed that the increase in capacity of production units results in reduction of line numbers in planning for network development in way that by increasing the capacity of production units in the first two years, there will be no need for additional new lines within the network.

For more information on increasing the capacity of production units within 20 year, please refer to Table 11. Table 10, capacity increase of production units via the proposed simulation for TEP problem in the upcoming years when condition is not $\alpha_{DR} = 0.05$

As it can be observed, in the fourth production unit there will be a need for capacity increase from the first year and the second and fifth production units contain the required capacity and do not require any expansion when condition is not $\alpha_{DR} = 0.05$.

If we pay attention to the final years (i.e., 7th year and after), the limitation of capacity increase of production units can be understood. As previously mentioned, the maximum limit of increasing the capacity of each unit is considered to be 200 MW that this amount can be different for every production unit.

By observing the obtain numerical results of investment costs and development of lines and cist of increasing the production units and the reliability index as well as operation costs at the end of the 20 year period will be more explicit and Table 10 considers this issue.

By comparing Table 8 and 11 with one another, the major effect of capacity increase of production units on the issue of expansion network can be understood in way that the cost of investment for construction of new lines from the initial value of 102000 has reached the value of 80000 and the reliability index from 2.98 MWh has reached 1.71 Mwh. However, as it can be seen, the capacity

Table 10: Capacity increase of production units via the proposed simulation for TEP problem in the upcoming years when $\alpha_{DR} = 0.05$

Years	G1	G2	G3	G4	G5	Total
1	0	0	0	4.509015	0	4.509015
2	0	0	0	23.04433	0	23.04433
3	0	21.99308	0	24.65744	0	46.65051
4	0	2.960817	0	25.91607	0	28.87689
5	0	71.3179	0	0	0	71.3179
6	0	3.568945	0	0	0	3.568945
7	0	0	0	0	0	0
8	0	0	104.7674	0	0	104.7674
9	0	68.09488	0	41.98248	0	110.0774
10	0	0	0	13.3568	0	13.3568
11	0	0	0	0	0	0
12	0	0	86.87745	0	0	86.87745
13	0	0	8.355108	13.41788	0	21.77299
14	0	0	0	45.64743	0	45.64743
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	7.47	0	7.47
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
Total	0	167.9356	200	200	0	

Table 11: Numerical results for proposed fiunction lines for TEP probles by taking into account the increase in capacity production units

Variables	Values
Capacity increase of each production unit (MW)	G2=167.93, G3 and G4 = 200
Total cost of increasing the capacity of production units ($/h)	9762.2
Total investment cost of lines ($/h)	80000
Optimal operating cost ($/h)	17199
EENS reliability index (MWh)	1.71
Total value of objective function	98163.06
Time taken to reach an optimal solution (Sec)	26145

increase of production units causes an increase in optimal operation cost and in general, if we consider the total cost of increasing line numbers and capacity of production units by comparing them with Table 8, the reduction in overall cost and on the other hand, reaching a better result (reduction of reliability index) can be obtained.

This will only be the case when the response load has a low participation in reliability index and system's blackout and by the increase in responsive loads as well as existence of a capacity increase area of production units in the TEP problem; it is possible to obtain better solutions.

CONCLUSION

By considering important and common reliability indexes or ENS in objective function, planning for development of transmission network as an important benefit of this research was simulated.by considering the outputs of units and the number of network lines and the possibility of occurrence of incidents in calculating the costs of operation and reduction of production and development of production lines were optimize which was the cause of a more realistic prediction of all important incidents for future 20 year development of transmission network. In this research, noticeable effect of responsive load and increasing the capacity of production units on improving the system reliability was predicted and simulated over a 20 year period.

Obtained results shows the effect of responsive load by increasing the capacity of production units on investment and safe operation costs, blackout rates in the network and prediction of future production can help to minims the objective function of costs in order to increase the stability and sustainability of the system in the long term. In the end it is hoped that by paying attention to references and simulated calculations used in this research, the long term vision of production during the transition period can be responsive to the load in an optimal manner.

Policy maker can gain a deep understanding of the system despite the existence of the responsive load in the simulation and can find suitable grounds for planning for the development of transmission network and increasing the capacity of the production units in the long term by considering responsive load based on reliability system and eventually can shift the consumption from stable state against price to being responsive to price. Finally, readers of this article are invited to contact this email address to share their suggestions, opinions or experience.

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