Research Journal of Applied Sciences, Engineering and Technology 7(17): 3529-3538, 2014
DOI:10.19026/rjaset.7.705
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: October 31, 2013 Accepted: December 02, 2013 Published: May 05, 2014

Research Article

Problem Analysis of Unit Commitment of Powerhouse with Regard to Different Constraints

[1]Ali Kashiha, [2]Hasan Keshavarz Ziarani, [3]Hamdi Abdi and [2]Mohammad Ferdosian
[1]Department of Electrical Engineering, Kermanshah Science and Research Branch, Islamic Azad University, Kermanshah,
[2]Ghiaseddin Jamshid Kashani Institute of Higher Education, Abyek,
[3]Department of Electrical Engineering, Faculty of Engineering, Razi University, Kermanshah, Iran

Abstract: The network reliability is one of significant characteristics of operation of the power system that plays an important role in designing a standard electricity market especially in case of unit commitment. In the present article, a power network with maximum load 2700 MW is considered. For calculation of produced energy of each power plant and cost of production for 1 year, this network is examined in two modes with and without considering emergency exit of production units. Regarding the characteristics of production units like number, capacity and cost of production with zero probability of emergency exit for each of them and considering network peak load that is determined by the user. For computation cost of production of each power plant in the network and calculation of its cost of production, a graphical program is provided by Graphical User Interface (GUI) environment and MATLAB software, which computes the energy and costs of production of the system as well as rate of reliability indexes LOLP and EENS. According to such results, it can be concluded that the charged cost to the system for mode A that all production costs are entered the circuit without considering probability of their emergency exit (FOR = 0) and only based on their own production cost (or their biding prices in the market of electricity) will be much lesser than mode B, which units participate in supplying network load in the electricity market on the basis of their probability of presence (FOR ≠ 0).

Keywords: Different constraints, graphical user interface, MATLAB, powerhouse

INTRODUCTION

The problem of unit commitment, which has a significant role in daily operational planning, determines hour order of unit commitment of production units for providing predicted load during time range 24 h of a day or 168 h of a week. Meanwhile, the spinning reserve for covering unpredicted events like sudden increase in load, or/and loss of generators or required lines. In most of traditional Unit Commitment (UC) models, different criteria are considered for specification of needed spinning reserves such as a fraction of peak load, production of the largest generator on unit commitment, the incident of withdrawal of the largest generator and/or line or a combination of the mentioned measures. However, the major drawback in these measures is that they do not reflect the random nature of the system components. Instead, due to simplicity of operations they are broadly used in the electricity market.

Probabilistic nature of reserves in optimizing of the unit commitment problem of the units and their dispatching possess a greater level of complexity, though it represents the complete distribution of the system outage probability and leads to reservation distribution for access to an acceptable rate of reliability. The chief problem in indirect presentation of these standards comes from this fact that there is no instrument for including Capacity Outage Probability Table (COPT) in UC optimization problem. Within last 40 years, many different techniques and strategies have been provided aiming at considering probable standards of reserve in formation of the UC problem under the reserve constraints (Chattopadhyay and Balclick, 2002; Billinton and Karki, 1999).

In some of these methods, the definite criteria have been accumulated with probability indexes (Chattopadhyay and Balclick, 2002). The COPT method in the UC problem under the reserve constraints are provided as a function of relevant variables to UC of the units. Also, a simple statistical approximation is presented for including probable index of loss of load in optimizing the UC problem. In Bouffard and Galiana (2004) problems related to market transactions based on reliability constraints are shown in partner power bases

Corresponding Author: Ali Kashiha, Department of Electrical Engineering, Kermanshah Science and Research Branch, Islamic Azad University, Kermanshah, Iran

without obligation. In Simopoulos *et al*. (2006) a method based on probability due to regarding lack of access to the production units as well as uncertainty in load prediction in solving short-time UC problem, but reliability of the transmission network has not been included in.

In Kazarlis *et al*. (1996), the principle methods for the UC problem are listed as Priority List (PL), Dynamic Programming (DP), Lagrangian Relaxation (LR) (Wang *et al*., 1995), branch and bound and port isolation are classified. In recent years, methods based on artificial intelligence like baking metal (Simopoulos *et al*., 2006; Purushothama and Jenkins, 2003; Wong, 1998), storage systems (Wang and Shahidehpour, 1992), neural network (Ouyang and Shahidehpour, 1992; Sasaki *et al*., 1992) and genetic algorithm (Kazarlis *et al*., 1996; Damousis *et al*., 2004; Cheng *et al*., 2000) were used for this purpose. The genetic algorithms are optimizing methods based on principles inspired by gradual evolution of live creatures derived from mechanisms like natural selection, genetic mating and reproduction. Ability of these methods in solving combinatorial optimization and complex nonlinear constraints problems have caused to use them.

Here, a power network whose load according to the pattern of testing system of Institute of Electrical and Electronics Engineers (IEEE) with maximum load 2700 MW is selected. If characteristics of electricity generating units based on the 32 unit system of IEEE and cost of production per group in power plants are the same as below, for calculation of the produced energy of each power plant and production cost of one year in the network are considered in two modes of with and without emergency exit of the production units. Indeed, we are going to investigate if a hydroelectric plant with capacity 350 MW and low current production cost will be available instead of unit group 8 and annual production rate is 0.35, how will be the optimal production program for this unit and in this condition how much will be annual production cost of this network (with considering emergency exit of the production units)?

Or if we use this hydroelectric plant as the base load unit (that is this unit is in the circuit all the time with identical and limited production) or use it as the production unit of supplying peak load (deliver whole energy in the peak hours) will demonstrate what differences with the previous mode? What will be the effect of presence of two hydroelectric plants one with 350 MW capacity and low current production cost and annual production rate 0.35 instead of unit group 8 and another with 155 MW capacity and low production cost and annual rate 0.3 instead of one of units of group 6? How will be optimal production program of these two units and inn this state how much will be annual production cost of this network (With regard to emergency exit of the production units)?

Objective of the study is problem analysis of unit commitment of powerhouse with regard to different constraints.

FRAMEWORK OF SOLVING UC PROBLEM

Goal function: The goal function consists of fuel cost for production of electricity and cost of Commissioning of each production unit in the favorite period that is stated through relations (1) and (2) respectively. The fuel costs are computed using heat rate of units as well as data related to the cost of fuel. The commissioning costs are also stated as a function of number of hours the units were out of circuit:

$$\mathrm{TC} = \sum_{i=1}^{NG}\sum_{t=1}^{T} \mathrm{FC}_{i,t}(\mathrm{Pg}_{i,t}) \times \mathrm{I}_{i,t} + \mathrm{I}_{i,t} \times (1 - \mathrm{I}_{i,t-1}) \times \mathrm{SUi,t} \quad (1)$$

$$\mathrm{FC}_{i,t}(\mathrm{Pg}_{i,t}) = \mathrm{A_i Pg}_{i,t}^2 + \mathrm{B_i Pg}_{i,t} + \mathrm{C_i} \quad (2)$$

$$\mathrm{SU}_{i,t} = \alpha_i + \beta_i[1 - \exp(\frac{X_i^{off}(t)}{\tau_i}] \quad (3)$$

For combining the reliability constrain EENS in structure of the UC problem, the RIV quantity as the fines of excess from the limit of reliability index is used that by adding to the total cost (1), the completed goal function is resulted:

$$\mathrm{TC_{sup}} = \mathrm{TC} + \mathrm{PF} \times \mathrm{RIV} \quad (4)$$

where, PF equals dynamic penalty coefficient that is introduced in Simopoulos *et al*. (2006) and RIV is achieved from the following formula:

$$RIV = \begin{cases} (EENS_{tot} - EENS_{max})^2, if \ EENS_{tot} > EENS_{max} \\ 0 \qquad , otherwise \end{cases} \quad (5)$$

Way of applying the completed goal function TC_{sup} will be examined in below section.

UC constraints: constraints related to the UC problem are as follows:

- Power balance in the network:

$$\sum_{i=1}^{NG} \mathrm{Pg}_{i,t} = \sum_{j=1}^{NB} \mathrm{PD}_{i,t} \ t \in [1, \mathrm{T}] \quad (6)$$

- Constraint related to total minimum production capacities:

$$\sum_{i=1}^{NG} \mathrm{Pg}_{i\,min} \times \mathrm{I}_{i,t} \leq \sum_{j=1}^{NB} \mathrm{PD}_{j,t} \quad (7)$$

- **Spinning reserve requirement system:** As it was mentioned before, spinning reserve can be considered both with definite variables and methods based on probability. For probability based examination, the above parameter can based on appropriate level of reliability in the production and transmission network and by use of reliability constraints are determined, these constraints include:

$$LLP_t \leq LLP_{max} \quad (8)$$

$$EENS_{tot} \leq EENS_{max} \quad (9)$$

According to the constraints (8) and (9) and use of the completed goal function (4) we get more confident of possibility of final solution to the UC problem.

- Constraints related to the production capacity of units:

$$Pg_{i\,min} \times I_{i,t} \leq Pg_{i,t} \leq Pg_{i\,max} \times I_{i,t} \quad t \in [1, T], i \in NG \quad (10)$$

- Constraints related to increase or decrease of production capacity o units:

$$-DR_i \leq Pg_{i,t} - Pg_{i,t-1} \leq UR_i \; t \in [1, T], i \in NG \quad (11)$$

- Constraints related to number of on/off hours of units:

$$(Ton_{i,t-1} - Tup_i) \times (I_{i,t-1} - I_i) \geq 0 \;\; t \in [1, T], i \in NG \quad (12)$$

$$(Toff_{i,t-1} - Tdown_i) \times (I_{i,t-1} - I_i) \geq 0 \; t \in [1, T], i \in NG \quad (13)$$

- Constraints related to the transmission network:

$$P_{jk,t} \leq P_{jk\,max} \;\; t \in [1, T], j, k \in NG \quad (14)$$

We have some production units and consumption need for a time period is estimated. In addition to cost of operation of units, a few other costs and constraints have been taken into consideration. Cost of starting, cost of removing a unit, spinning reserve, stop and activity time, etc., the presented definition shows that it is impossible to enter the circuit some specific units and exploit them. therefore, it is necessary to take necessary policies in advance and based on the predicted load and existing constraints, the units must be entered the circuit (and those should be removed from circuit) are determined. When minimizing cost matters, first cheap units get into circuit and expensive units get into circuit only when the load is high.

Spinning reserve (difference l between Potential active capacity, total load and system losses) in case of losing one unit, sufficient reserve must be available in the system for supplying load in specific time. the spinning reserve is determined based on a special rules as: percentage of peak consumption, equivalent to the largest power plant unit, a function of expectation of Losing Load (LOLP), (or probability of lack of enough production for supplying load), in addition to spinning reserves, inactive reserves are also considered in the UC problem:

- Diesel units with quick launch
- Gas turbines, 3
- Pumped storage hydropower

The probability-based approach takes into account not only likelihood of access to the production units presented in Simopoulos *et al.* (2006) but also unavailability of transmission lines in solving the UC problem. in addition, evaluation of needed spinning reserve with posing reliability constraints on probability indexes of loss of load and expected energy will be preformed and calculation of these parameters ends to application of a new method based on linear planning where the favorite indexes are computed in a way that an optimal quantity of the spinning reserve and consequently an optimal cost for programming UC under the reliability constraints will be created.

Distribution pattern of common optimal power solves problem of economic dispatching with regard to security constraints of the network in the steady states Wood and Wollenberg (1996). Simulations results indicate great significance of combination of reliability constraints of the production and transmission networks in solving the UC problem. In the UC problem, being on/off units, rate of their production capacity in condition of satisfying constraints like production, consumption and supplying spinning reserve constraints are required in 24 h are performed with least possible cost (Wood and Wollenberg, 1996). Short-time planning of the power plant units with attention to the role of electric cars are connectable to the network is solved in Ghanbarzadeh *et al.* (2011) by optimizing method PSO or the goal function of cost reduction in Saber and Kumar (2009a) with goal function of minimizing cost and pollution in Saber and Venayagamoorthy (2009b) as well as goal function of reliability constraint. In source (Keyhani and Marwali, 2011) formulation of the UC problem is conducted with presence of wind and solar renewable sources and the presence of a battery as energy saver.

MATERIALS AND METHODS

In this condition due to considering probability of emergency exit of production units for UC process it is enough first enter the cheapest production units the network, then continue until the most expensive units. Therefore, according to Table 1 is derived from production characterizes of the book Modern Power System Planning written by Mac Don, power plants can be a candidate of presence in the network. That is, from the cheapest to the most expensive units until when the network load is supplied. Thus, it is possible that the last units. Which are the most expensive units do not

Table 1: Characteristics of electricity production units and cost of production per each power plant

Group 1: 12 MW	5 Rial/kWh	Group 2: 12 MW	0 Rial/kWh
Group 3: 12 MW	55 Rial/kWh	Group 4: 12 MW	50 Rial/kWh
Group 5: 12 MW	45 Rial/kWh	Group 6: 12 MW	40 Rial/kWh
Group 7: 12 MW	35 Rial/kWh	Group 8: 12 MW	30 Rial/kWh
Group 9: 12 MW	25 Rial/kWh		

Table 2: Order of entering the circuit of production units based on their prices

Capacity of (MW) production unit	Number of units	FOR	Cost (Rial/kWh)
400	2	0.12	25 (the cheapest)
350	1	0.08	30
197	3	0.05	35
155	4	0.04	40
100	3	0.04	45
76	4	0.02	50
50	6	0.01	55
20	4	0.10	0
12	5	0.02	5 (the most expensive)

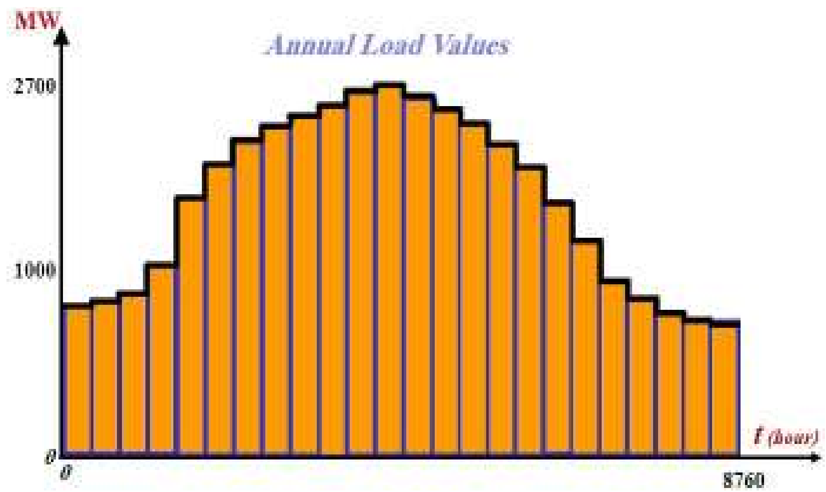

Fig. 1: Curve of the network load changes during 1 year

enter the circuit for specific amount of consumption load and cannot sell their electricity and afford consumers.

For calculation of production energy of each unit we require to determine Load Duration Curve (LDC) of the network. However, according to need for computation of reliability indexes LOLP, LOLE and EENS of power system were specified and the MATLAB software in this area with title LDC.m was provided that according to daily, weekly and annual peak loafs it is much easy to define LDC and its fitted curve. Consequently, here again we used this program and only annual peak load of network which is 2700 MW was induced as the input data. It should be mentioned here that the program code LDC.m with other written programs related to this research are presented in appendix. Order of entering the circuit of production units based on their prices is shown in Table 2.

The Fig. 1 symbolically shows the curve of annual changes of the network load. for determination of produced energy of each unit, it is better to have curve of load continue, which this curve is achieved through movement o each load point from big to small like Fig. 2 in a way that space below curves of Fig. 1 and 2 that represent load consumed energy of the system for 1 year are equal.

It is necessary to mention that for UC to happen, the network load must be estimated according to past information of the system through one of introduced methods. Here, it is assumed that estimation computations of load are performed for one next year and now with knowing about future load of the network, we are going to plan to enter production units into the network. By running the LDC.m program, following polynomial is fitted for the load continue curve and then presented:

$$t_{LDC} = (-3.82 \times 10^{-11})P^4 + 3.28 \times 10^{-6}P^3 - 0.015547P^2 + 17.7632463P + 2964.18297$$

Curve of load continue is shown in Fig. 3, fitness of load continue curve is shown in Fig. 4 and order of

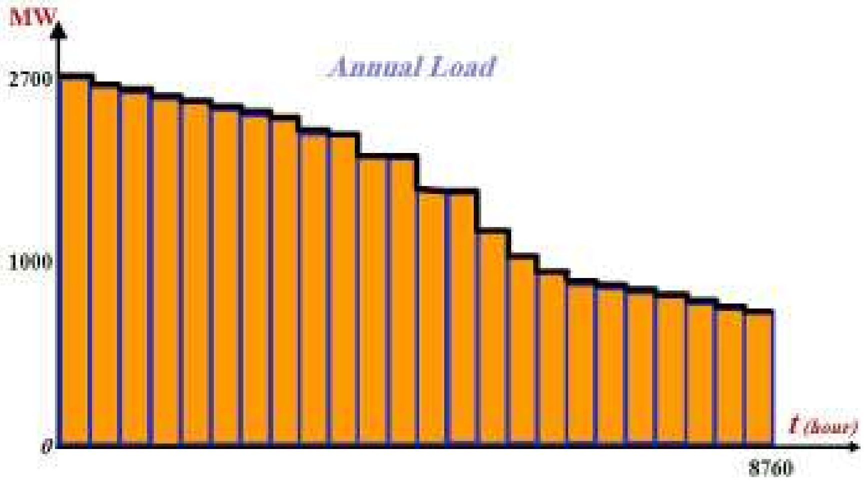

Fig. 2: Curve of network load continue during 1 year

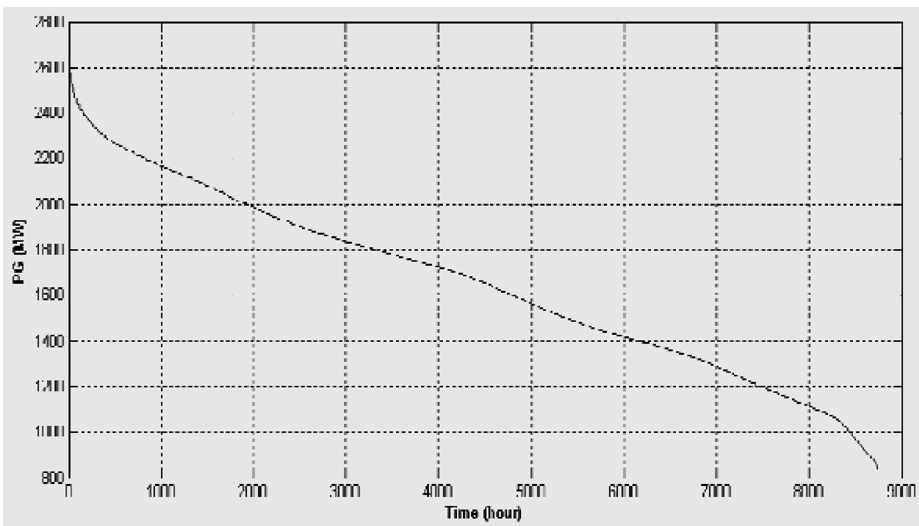

Fig. 3: Curve of load continue (power in terms of time)

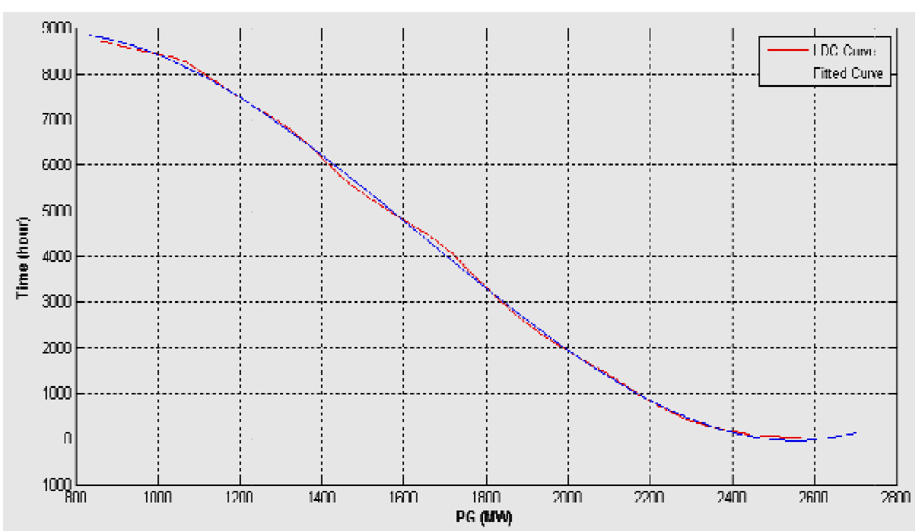

Fig. 4: Fitness of load continue curve (time in terms of power)

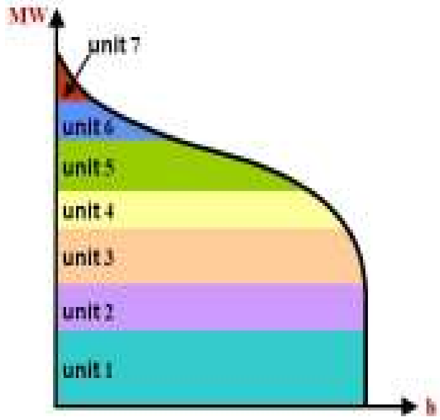

Fig. 5: Order of unit commitment of power plant units from the cheapest to the most expensive

unit commitment of power plant units from the cheapest to the most expensive is shown in Fig. 5.

After this stage, it is time to replace the production units according to their biding price in a way that first the cheap power plants supply base load, then power plants with higher price provide intermediate load and finally, peak load is supplied by expensive power plants. This subject is represented in Fig. 5.

In Fig. 5 unit 1 is among the cheapest units of power plant, therefore during the year it remains in the circuit, however, unit 7 is the most expensive one and enters the circuit at time of peak load. For calculation of produced energy of each power plant unit in the network and computation of cost of production a graphical program is designed in GUI environment by MATLAB software.

The implementation of this program is described below.

To do this, for entering the initial data and reading this data, first from Excel environment the Planning.m program should be run in order to the graphic window opens similar to the picture below. On top of the window there is a space for writing rate of peak load by the user that is defined in MW scale. Then, the input data are received from Excel output and are displayed in the designed table below the display bottom. By clicking Plot and Fit, FOR, Hdyro (350 MW) 'FOR' Hdyro (350 MW), 155 MW) m the output results besides cost of power plants will be printed (Fig. 6).

Stages of computation of each step of the problem are shown in the below picture.

RESULTS AND DISCUSSION

In Fig. 7 by clicking Plot and Fit option and considering characteristics of production units like number, capacity and cost of production, assuming zero

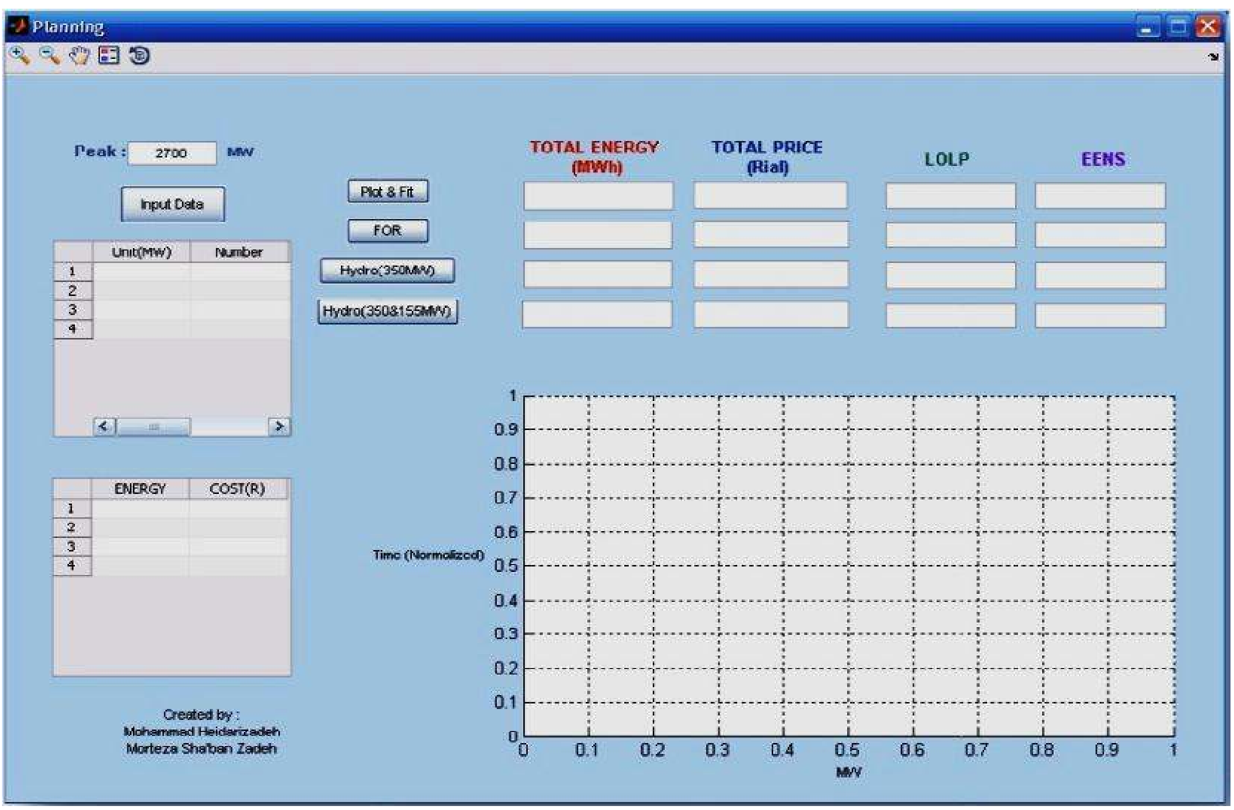

Fig. 6: The designed graphic environment for computation of number, capacity and cost of production units

probability of emergency exit for each of them as well as considering peak load of the network is defined by the user (the peak load of network is defined in default amount 2700 MW) the system energy and cost of production is calculated and rate of the reliability indexes LOLP and EENS are achieved. These values

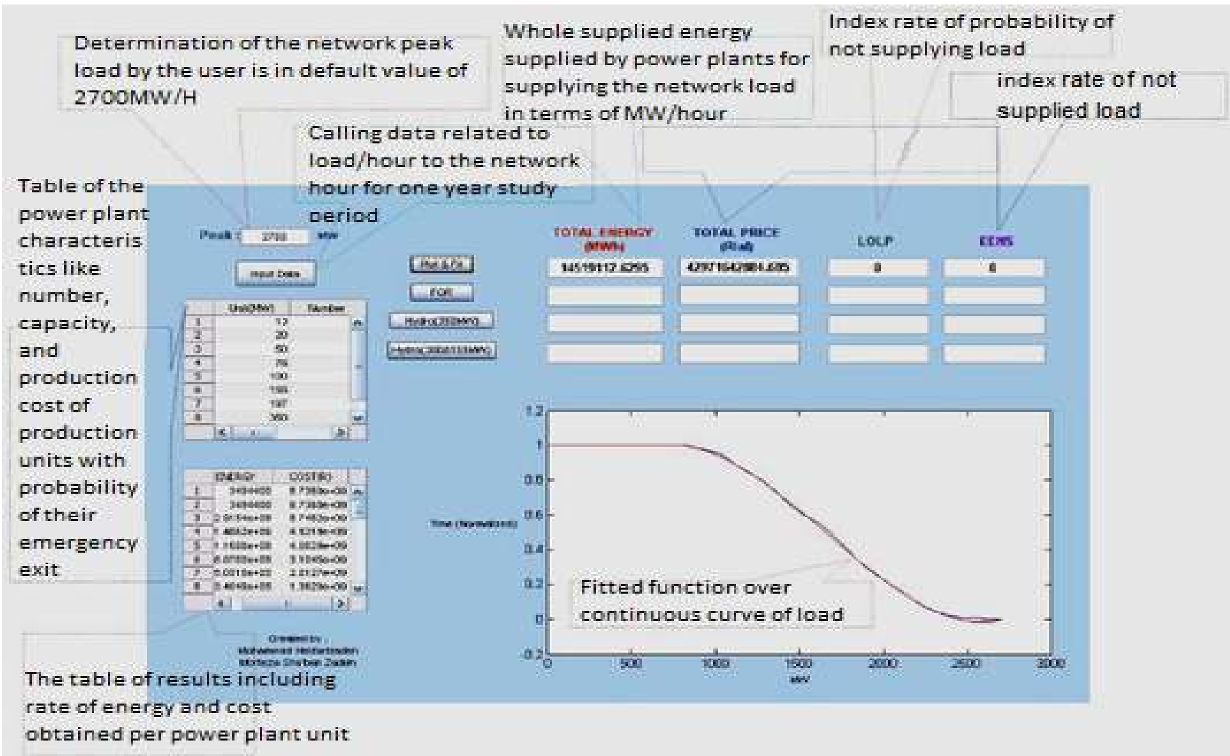

Fig. 7: Introduction of designated sections in the graphic environment

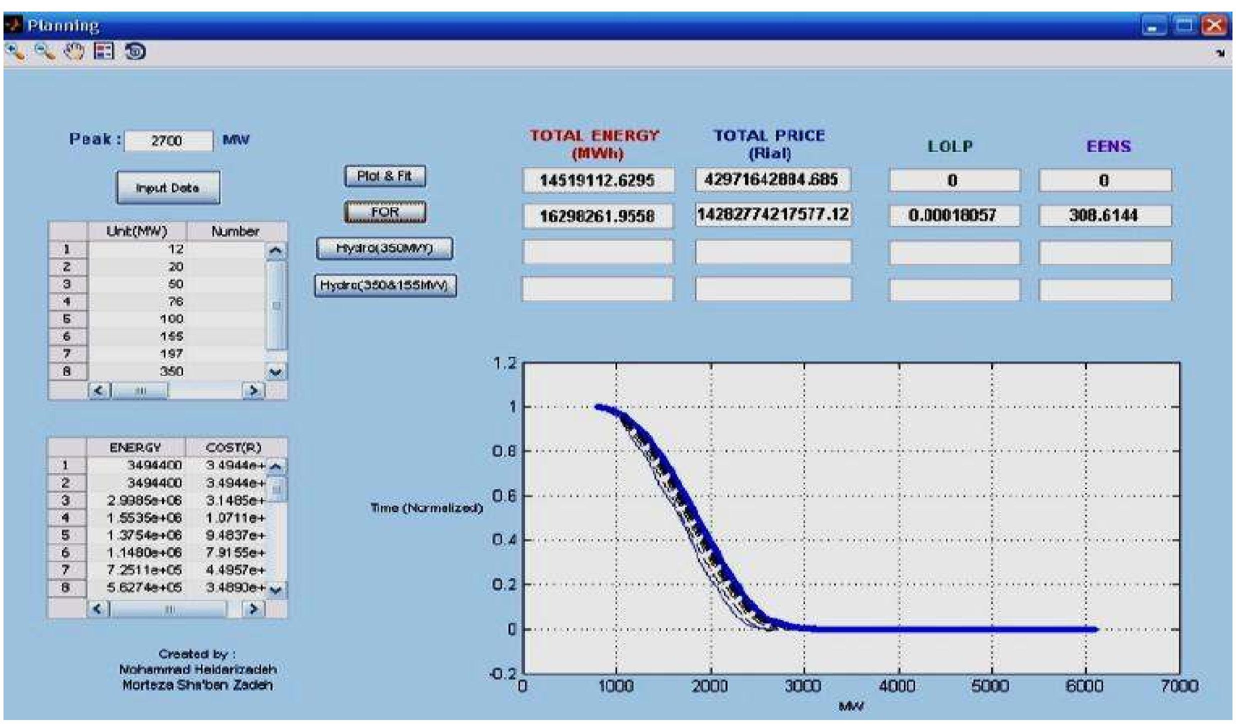

Fig. 8: Calculation of demanded parameters of problem with regard to units FOR

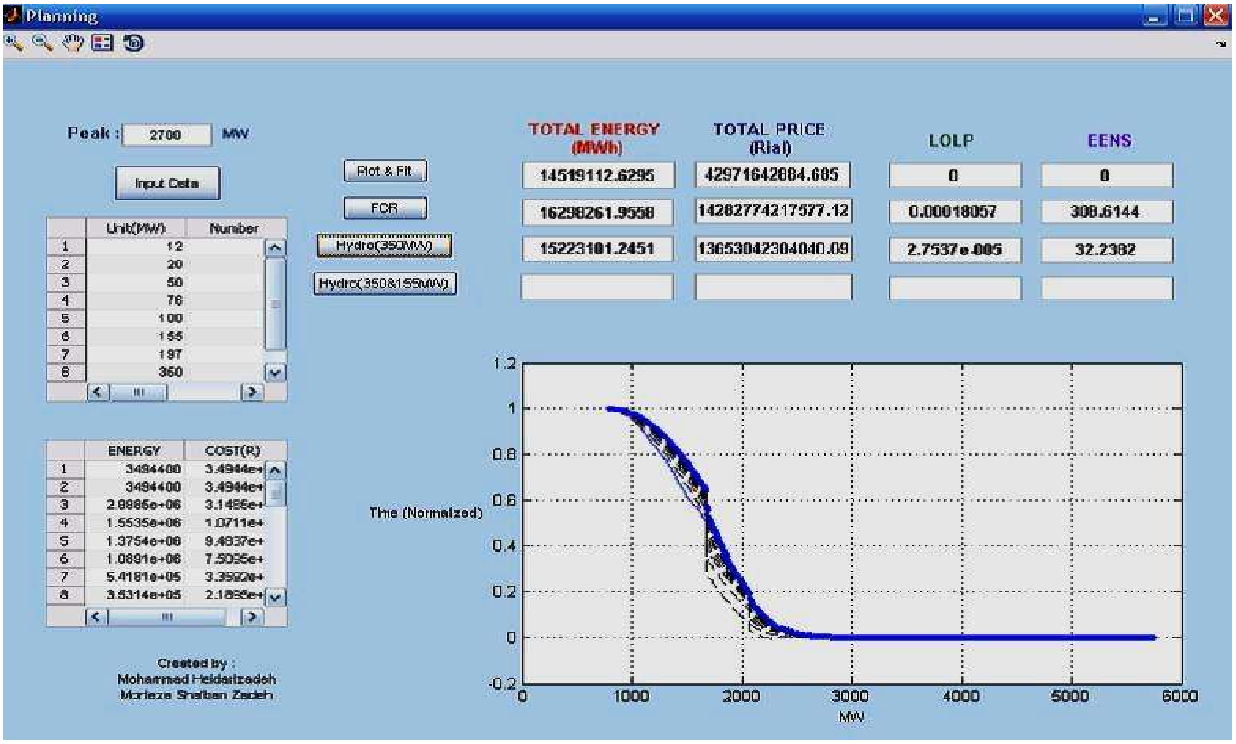

Fig. 9: Calculation of required parameters of the problem with regard to hydropower unit 350 MW instead of unit group 8

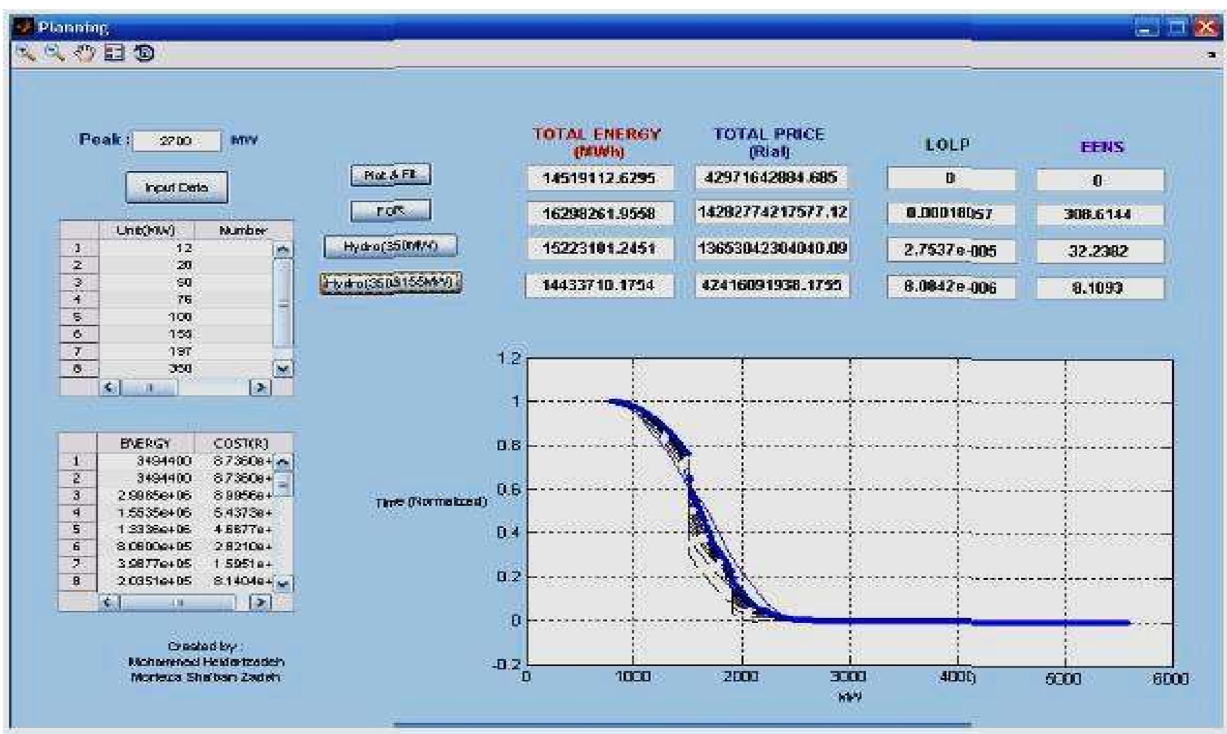

Fig. 10: The problem solution with regard to two hydropower units 350 and 155 MW in replace for units group 6 and 8

can be seen in the picture. It should be mentioned that by double clicking the table of units characteristics it is possible to change default characteristics of number, capacity FOR and cost of production of each production unit. Figure 8 shows total posed energy and cost to the power system besides computation of indexes of the reliability with regard to FOR of production units of the power plants.

Figure 9 illustrates the problem solution through entering a hydropower plant 350 MW instead of unit group 8.

Figure 10 shows the problem solution by entering a hydropower unit 350 MW in replaces for unit group 8 and a hydropower unit 155 MW instead of unit group 6.

CONCLUSION

In the present study through presenting a new method, mode of integration of the production and transmission networks reliability in solving the UC problem was examined. By use of the reliability indexes such as LLP and EENS and making corresponding constraints, rate of the spinning reserve capacity in each hour of operation was determined. The above indexes were created through formulating load distribution equations DC and entering them into the linear planning that led to an optimal planning in cost and under the reliability constraint for UC. Additionally, for solving the UC problem, a powerful genetic algorithm naming ICGA was used that considerably decreased calculation duration compared to the classic genetic algorithm.

With regard to the problem solution it can be concluded that the imposed cost on the system for mode A, all production units were entered he circuit without considering probability of their emergency exit (FOR = 0) and only based on their production cost (or the biding cost in the electricity market) were entered the circuit was much less than mode B when units participated in the electricity market on the basis of probability of their presence (FOR $\neq$ 0) in supplying the network load.

On the other hand, since cost of production for hydropower units is trivial, therefore replacement of one of the system units with one hydropower unit can principally drop off final cost of the system. Furthermore, this problem that this hydropower unit should present in the peak load or in base load, due to low cost of electricity is produced in the hydropower units in spite of inadequate production Capacity Factor (CF) as well as limited capacity of water stored in dams, there is no possibility for a continuous production annually, thus, this operation method that theoretically makes lower cost for the system versus operation mode in the network peak is ignored and ultimately, it could be said that exploitation from two relatively large hydropower units instead of two non-hydropower units with the same capacity will significantly minimize the cost.

REFERENCES

Billinton, R. and R. Karki, 1999. Capacity reserve assessment using system well-being analysis. IEEE T. Power Syst., 14(2): 433- 438.

Bouffard, F. and F.D. Galiana, 2004. An electricity market with a probabilistic spinning reserve criteria. IEEE T. Power Syst., 19(1): 300-306.

Chattopadhyay, D. and R. Balclick, 2002. Unit commitment with probabilistic reserve. Proceeding of the IEEE Power Engineering Society Winter Meeting, pp: 280-285.

Cheng, C.P., C.W. Liu and G.C. Liu, 2000. Unit commitment by Lagrangian relaxation and genetic algorithm. IEEE T. Power Syst., 15: 707-714.

Damousis, I.G., A.G. Bakirtzis and P.S. Dokopoulos, 2004. A solution to the unit commitment problem using integer-coded genetic algorithm. IEEE T. Power Syst., 19(2): 1165-1172.

Ghanbarzadeh, T., S. Goleijani and M.P. Moghadam, 2011. Reliability constrained unit commitment with electric vehicle to grid using hybrid particle swarm optimization and ant colony optimization. Proceeding of the 2011 IEEE Power and Energy Society General Meeting. San Diego, CA, pp: 1-7.

Kazarlis, S.A., A.G. Bakirtzis and V. Petridis, 1996. A genetic algorithm solution to the unit commitment problem. IEEE T. Power Syst., 11: 83-92.

Keyhani, A. and M. Marwali, 2011. Smart Power Grid. Springer, Berlin, New York.

Ouyang, Z. and S.M. Shahidehpour, 1992. A multi-stage intelligence system for unit commitment. IEEE T. Power Syst., 7: 639-646.

Purushothama, G.K. and L. Jenkins, 2003. Simulated annealing with local search: A hybrid algorithm for unit commitment. IEEE T. Power Syst., 18(1): 273-278.

Saber, A.Y. and G. Kumar, 2009a. Unit commitment with vehicle-to-grid using particle swarm optimization. Proceeding of the IEEE Bucharest Power Technology Conference.

Saber, A.Y. and G.K. Venayagamoorthy, 2009b. Intelligent unit commitment with vehicle-to-grid a-cost emission optimization. J. Power Source., 195(3): 898-911.

Sasaki, H., M. Watanabe and R. Yokoyama, 1992. A solution method of unit commitment by artificial neural networks. IEEE T. Power Syst., 7: 974-981.

Simopoulos, D.N., S.D. Kavatza and C.D. Vournas, 2006. Reliability constrained unit commitment using simulated annealing. IEEE T. Power Syst., 21(4): 1699- 1706.

Wang, C. and S.M. Shahidehpour, 1992. A decomposition approach to non-linear multi-area generation scheduling with tie-line constraints using expert systems. IEEE T. Power Syst., 7: 1409-1418.

Wang, S.J., S.M. Shahidehpour, D.S. Kirschen, S. Mokhtari and G.D. Irisarri, 1995. Short term generation scheduling with transmission and environmental constraints using an augmented Lagrangian relaxation. IEEE T. Power Syst., 10(3): 1294-301.

Wong, Y.W., 1998. An enhanced simulated annealing approach to unit commitment. Int. J. Electr. Power Energy Syst., 20: 359-368.

Wood, A.J. and B.F. Wollenberg, 1996. Power Generation Operation and Control. 2nd Edn., Wiley, New York.