Generation Scheduling in Large-Scale Power Systems with Wind Farms Using MICA

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Abstract

The growth in demand for electric power and the rapid increase in fuel costs, in whole of the world need to discover new energy resources for electricity production. Among of the non-conventional resources, wind and solar energy, is known as the most promising devices electricity production in the future. In this thesis, we study follows to long-term generation scheduling of power systems in the presence of wind units considering demand response programs for a power generation system with the conventional structure containing 10 units of thermal power plants, 2 units of large-scale wind farms, with regard to demand response programs. In this study, the model of equation order 2, used to model the cost of thermal power plants. Due to the apparent wind farm modeling of wind speed in the months of the year has been used the productivity of each month. For modeling the demand, response of the concept of virtual generation demand resources is used and production costs of the final objective function are applied. All simulations, performed in MATLAB. The results showed that the cost of basic state allocated more values by itself, by considering responding load would be happened the cost reduction and the amount of this reduction changes with participation value and increases amount of lower cost by increasing participation value.

Keywords: Planning production, wind farm, Imperialist Competitive Algorithm, responding load, request resource

1- Introduction

By paying attention to extend using of new energy for producing power and explainable economic of using wind turbine, power grid wind power plants will doubtlessly, allocate the share of electric power generation in the future [1]. Imperialist Competitive Algorithm (*ICA*) is the method in the field of evolutionary calculations considered to find optimal response of various problems. In the terms of application, this algorithm, presented in the category of evolutionary optimization algorithms such as genetic algorithms (*GA*), particle swarm optimization (*PSO*), Ant Colony Optimization (*ACO*) [2]. Imperialist Competitive Algorithm optimizes the primitive responses (countries) and totally provides appropriate response of optimization problem (desirable country).

In this research, first, presented the Modified Imperialist Competitive Algorithm in order to fast convergence in terms of cost what is called *MICA*.

Then, a power generation system with the traditional structure consists of 10 units of thermal power plants, 2 units of large-scale modeled wind farm (standard model *IEEE*) and planning problem of large-scale power systems in the presence of wind resources as a linear optimization problem is modeled with integer and will be implemented then by using of *MICA* method.

2- Reviews

In recent years by paying attention to growing market, the electrical energy and the rapid increase in fossil fuel costs, provided the necessary requirement to discover new energy sources for producing electricity. There is solar and wind energy as a favorable energy sources can generate the power. Determining the practical optimal solution of production planning is possible in power systems in the presence of wind energetic stations [3]. Responding to load or responding to request is set of actions that implemented for changing patterns of power consumption in order to optimize the network reliability and preventing price hike, especially in the peak hours of network load (peak hours of consumption). The response of request to change the power consumption in end user-customers considered as a contemporary consumption pattern that this changing consumption is in response to price changes during the time or considered encouragement payments. However, to deal with the uncertainty of the wind, we need to use special models and techniques in participatory planning units [5] in [6] the accidental optimization method used in departments participatory planning in order to determine the timing of power generation per unit time. This programming consist of implementing by paying attention to units' constraints and power limit transmission and assumed amount possibility of wind blowing as a normal probability distribution function. It modeled as scenario tree and at the following. In addition, the scenario possibility and lost wind cost entered into the objective function, also planning participatory of units due to the uncertainty of wind power generation and load, implemented by using of phase optimization and presented the Planning of Installations planning method for considering cost target functions and publicizing contaminant has been on it.

3- Mathematical model and suggested algorithms

3-1 Imperialist Competitive Algorithm

Imperialist Competitive Algorithm uses the *PSO* and *GA* methods for receiving to answer of evolutionary systems [7]. In these problems in considering to the algorithm has insufficient information such as research space and responding definition for main problem, can move in way of finding better answer by providing accidental answers and make good progress in the search space as much as possible. The total Imperialist Competitive Algorithm method is the way that it is started in the first stage some initial population what is called country algorithm and then investigated objective function value of the Problem will be obtained for each of countries. It must be attended that whatever power of a colonial country is more (having better objective function) covered so many colonial countries.

In here, stronger colonial country, having the most overcoming of the countries colony with same colored circles has been showed by bigger stars and weaker colonial country, having the fewest overcoming of the countries colony has been showed by smaller stars. In the second stage the Colonial countries are trying to associate colonized country with changing the culture and customs of that country what it called the absorption function. In third stage, some of colonized country may have revolution based on natural process and can take the empire power.

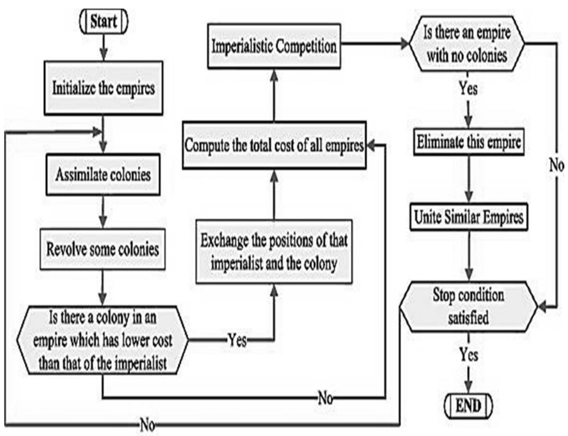

Fig.1. The ICA algorithm process

In the fourth stage, total power of empire land defined as a set of colonized countries purposed function in addition to coefficient in the average of its colonization's purposed function.

3-2 The mathematical model and purposed function

Each wind farm consists of many wind turbines. Production capacity wind turbines change as function of wind speed. The feature of each turbine allocated turbine that shows the power of output generation Depending on wind speed.

This diagram, having been shown in fig 2, the turbine in cut-in speed starts to provide the power (*Vci*) and in the Cut-out speed is stopped (*Vco*). When wind speed is between nominal wind speed (*Vr*) and speed is cut-out, the generation power of turbine is over the nominal power. The relationship between output power and turbine speed in condition of wind speed is among of the speed that the first time, the turbine starts to switch on and produce the power and nominal speed is the non-linear relation; therefore the turbine output power can be modeled over the certain speed as followed bellow:

$$P_{out} = P_{rated} \times \begin{cases} 0 & 0 \le WS < W \\ A + B \times WS + C \times WS^2 & V_{ci} \le WS < V_{Rated} \\ 1 & V_{Rated} \le WS < V_{CO} \\ 0 & V_{CO} \le WS \end{cases} \qquad (1)$$

P_{out}: wind turbine output power, P_{rated}: wind turbine nominal power, V_{ci}: the speed of stating, V_{rated}: wind turbine nominal speed, V_{co}: cut-speed, W_S: wind turbine instantaneous velocity. *A*, *B* and *C* is constant values and calculated by following bellow:

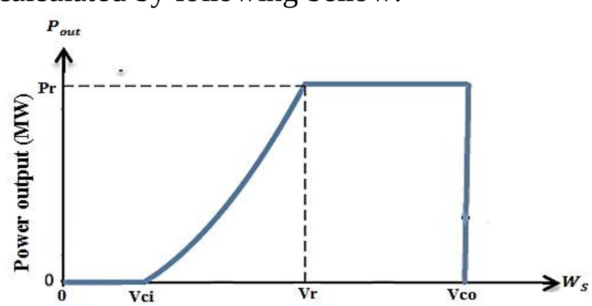

Fig.2. Wind turbine power curve

$$A=\frac{1}{(V_{ci}-V_{rated})^2}\left\{V_{ci}\left(V_{ci}+V_{rated}\right)-4V_{ci}V_{rated}\left[\frac{V_{ci}+V_{rated}}{2V_{rated}}\right]^3\right\} \qquad (2)$$

$$B=\frac{1}{(V_{ci}-V_{rated})^2}\left[4\left(V_{ci}+V_{rated}\right)\left[\frac{V_{ci}+V_{rated}}{2V_{rated}}\right]^3-3\left(V_{ci}+V_{rated}\right)\right] \qquad (3)$$

$$C=\frac{1}{(V_{ci}-V_{rated})^2}\left\{2-4\left[\frac{V_{ci}+V_{rated}}{2V_{rated}}\right]^3\right\} \qquad (4)$$

3-2-1 production programming

The aim of this research is to minimize the total operating cost of power system production during the planning period when the limitation of operation, provided. Fuel cost, the main cost of thermal units, is the function of output functions. Fuel cost of each thermal unit is as follows:

$$F_t^i=a_{gi}+b_{gi}\times P_t^i+c_{gi}\times\left(P_t^i\right)^2;i=1,2,3,\ldots,N_{gth} \qquad (5)$$

i: index of thermal units, j: index of wind farms, F_t^i: cost thermal of power plants i^{th} in time t, P_t^i: output power plant i^{th} at time t, N_{gth}: the number of thermal plants, a_{gi}, b_{gi} and c_{gi}: cost coefficients of thermal units. The variable cost of one month for i^{th} unit at time t, expressed as follows:

$$\left(C_V\right)_t^i=\left[P_t^i+\left(R_{thermal}^i\right)_t\right]\times OMVC_i\times 720\text{A}. \qquad (6)$$

$(C_V)^i_t$: Variable Cost thermal unit i at time t, $(R^i_{thermal})_t$: requested power reserve thermal of i^{th} unit at time t, $OMVC_i$: variable cost of operation and maintenance of i^{th} thermal units and a fixed monthly fee has been presented by follows:

$$\left(C_F\right)_t^i=\frac{P_{max}^i\times OMFC_i\times 720}{8760} \qquad (7)$$

$(C_F)^i_t$: fixed Cost of i^{th} thermal unit at time t, P^i_{max}: maximum power of i^{th} thermal units, $OMFC_j$: the variable cost of operation and maintenance of i^{th} thermal units. In this research, we just considered the variable cost and the fixed cost of wind farms, ignored that is followed bellow.

$$\left(C_V\right)_t^j=P_{max}^j\times OMFC_j\times 720;\ j=1,2,3,\ldots,N_{gwind} \qquad (8)$$

$(C_V)^j_t$: the variable cost of the j^{th} wind farm in time t, P^j_{max}: maximum power of j^{th} wind farm, $OMFC_j$: fixed Cost operation and maintenance of the j^{th} wind farm, N_{gwind}: the number of wind farms. The purposed function, presented by using of relations (5-3) to (5-8) for programming by follows:

$$Obj.Fun=\sum_{i=1}^{N_{gth}}\sum_{t=1}^{T}F_t^i+\sum_{i=1}^{N_{gth}}\sum_{t=1}^{T}\left(C_V\right)_t^i\ldots$$
$$\ldots\times U_i(t)+\sum_{i=1}^{N_{gth}}\sum_{t=1}^{T}\left(C_F\right)_t^i\times U_i(t)+\ldots \qquad (9)$$
$$\sum_{j=1}^{N_{gwind}}\sum_{t=1}^{T}\left(C_V\right)_t^j\times V_j(t)$$

Ui (t): the presence of i^{th} thermal units at time *t*, $V_j(t)$: the presence of j^{th} wind farms in time *t*, *T*: duration of the planning horizon. The objective function described in equation (9) by providing operational constraints relevant to our study.

Constraints of optimization problem are as follows:

To supply demand of the system and the balance between produced power and demand power, following constraint should be provided.

$$P^{i}_{min} \le \left(P^{i}_{t} + \left(P_{reserve}\right)^{i}_{t}\right).U_{i}\left(t\right) \le P^{i}_{max}\ ; \quad \forall i = 1,2,3,\dots,N_{g}, t = 1,2,3,\dots,T \tag{10}$$

P^{demand}_{t} : Power demand in time t

The output Power of production should be between the maximum and minimum limits.

P^{i}_{min}: Minimum power of thermal units i^{th},

P^{i}_{max}: Maximum power of thermal units i^{th},

$\left(P_{reserve}{}^{i}_{t}\right)$: of thermal units at time t.

The other main constraint of this problem is required reserve. Reserve power in the system is necessary to provide the unforeseen production disruptions.

$$P^{j}_{t}.V_{j}\left(t\right) \le P^{j}_{max} \quad \forall j = 1,2,3,\dots,N_{gwind}, t = 1,2,3,\dots,T \tag{11}$$

$$\sum_{i=1}^{N_{gth}} P^{i}_{t} \times U_{i}\left(t\right) + \sum_{j=1}^{N_{gwind}} P^{j}_{t} \times V_{j}\left(t\right) = P^{demand}_{t} \quad \forall t = 1,2,3,\dots,T \tag{12}$$

Either load or Wind speed forecasting accuracy (power), basically affected of the reserve system levels. When wind capacity increases. The system reserve level increase In this study, The system reserve contains two parts: first part is based on total system load and second part is additional reserves for compensating error of predication accuracy of wind power.

There are several methods for system reserve with wind farms such as random programming, Monte Carlo simulation. In this study, duration of planning is one month and speed of wind energy is displayed with main speed. In the medium-term production planning, slope rate of thermal units is negligible. Reserve Power requirements should be displayed as follows:

$$\sum_{i=1}^{N_{gth}} \left(P_{reserve}\right)^{i}_{t} U_{i}\left(t\right) \ge LR \times P^{demand}_{t} + WR \times \sum_{j=1}^{N_{gwind}} P^{j}_{t} V_{j}\left(t\right) \tag{13}$$

In this equation *WR* is constant value for compensating the non-predictive error based on the of wind farms. *LR* is a fraction of the load of the whole system unpredictive production disruptions. In this study LR is equal to 5 percent and WR is equal to 10 percent of whole power of wind farms load.

4- The results and discussions

In this section, the presented formulation performance, evaluated by using of Simulink. The test system, simulated in the presence of large-scale wind farms and load responding according to the defined scenarios.

In addition, due to the long distances in long-term planning, the solution of this problem independently implemented and totally, the results annually presented. It is need to mention that the whole powers are megawatt (*MW*). The sample test system, having 12 generation units consisted of 10 thermal units and 2 wind farm. The generators datum for this system, presented in table (1) [8-9].

It has been assumed by simulation results:

1. The system load peak is 1500 megawatt.
2. The power output of wind farms is assumed to be constant.
3. 5% of total system demand, considered as the supply system in addition to unexpected saving wind energy.
4. 10% of the total wind energy planned reserve the unexpected has been assumed, in other words, *WR* is assumed to be 10%.
5. Capacity of wind farms are 80 *MW*.
6. Duration of planning horizon is assumed to be one year.
7. All simulation is implemented in *MATLAB* software.
8. The Modified Imperialist Competitive Algorithm (*MICA*) used for problem optimization.

In table.2.monthly demand shown as a percentage of annual peak loads with wind speed and wind energy.

In this section, the thermal plants have been considrated in four scenarios, implemented in the first scenario the presence of wind farms and without load responding and second scenario with the presence of wind farms and without load responding third scenario without wind farms and with load responding and fourth scenario with the presence of wind farms and by considering load responding. In other words, only thermal power plants participate in the production planning. In addition, in order that there is possibility to have a comparison with the next scenario, the amount of required reserve has been considered by 4 scenarios in according to numerical value. Amount of plants participating to supply the demand in the first scenario, shown in table 3.

Table.1. Generators features and cost functions coefficients

Units	$P_{G\max}$ [MW]	$P_{G\min}$ [MW]	$a(\$/h)$	$b(S/MWh)$	$c(\$/MW^2h)$	$OMVC$ $(\$/MWh)$	$OMFC$ $(\$/MW-year)$
Unit 1	5000	0.3	0.00048	16.19	1000	150	455
Unit 2	5000	0.3	0.00031	17.25	970	150	455
Unit 3	7000	0.8	0.002	16.6	700	20	130
Unit 4	7000	0.8	0.00211	16.5	680	20	130
Unit 5	7000	0.8	0.00398	19.7	450	25	162
Unit 6	8500	0.9	0.00712	22.26	370	20	80
Unit 7	10000	0.8	0.00079	27.74	480	25	85
Unit 8	10000	0.9	0.00413	25.92	660	10	55
Unit 9	10000	0.9	0.00222	17.27	665	10	55
Unit 10	10000	0.9	0.00173	27.79	670	10	55
Unit 11	0	3.973	0	0	0	0	80
Unit 12	0	6.193	0	0	0	0	80

Table.2. Load pattern and wind farm output

Period (month)	Percentage of the maximum load bi-monthly	Wind speed[*m/s*]		The availability of wind power[*MW*]	
		Unit 11	**Unit 12**	**Unit 11**	**Unit 12**
1	87.8	5.788	8.284	3.576	16.607
2	88	5.358	8.149	2.23	15.675
3	75	5.829	9.446	3.717	25.718
4	83.7	7.193	9.134	9.817	23.0786
5	90	7.989	8.284	14.604	16.607
6	89.6	7.599	7.19	11.905	9.798
7	88	7.25	6.826	10.13	7.913
8	80	7.063	9.836	9.122	29.202
9	78	7.591	8.127	12.097	15.529
10	88.1	6.165	8.213	4.937	16.119
11	94	6.414	8.906	6.007	21.715
12	**100**	**7.035**	**10.202**	**8.973**	**32.676**

Table.3.plants participating to supply the demand in the first scenario[MW]

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Unit 1	455	455	455	455	455	455	455	455	455	455	455	455
Unit 2	455	455	455	455	455	455	455	455	455	455	455	455
Unit 3	130	0	130	130	130	130	130	130	111	130	130	130
Unit 4	130	130	130	130	130	130	130	130	129	130	130	130
Unit 5	127	130	85	85.5	135	154	130	30	0	131.5	162	162
Unit 6	20	20	0	0	20	20	20	0	20	20	53	80
Unit 7	0	0	0	0	25	0	0	0	0	0	25	25
Unit 8	0	0	0	0	0	0	0	0	0	0	0	53
Unit 9	0	0	0	0	0	0	0	0	0	0	0	10
Unit 10	0	0	0	0	0	0	0	0	0	0	0	0

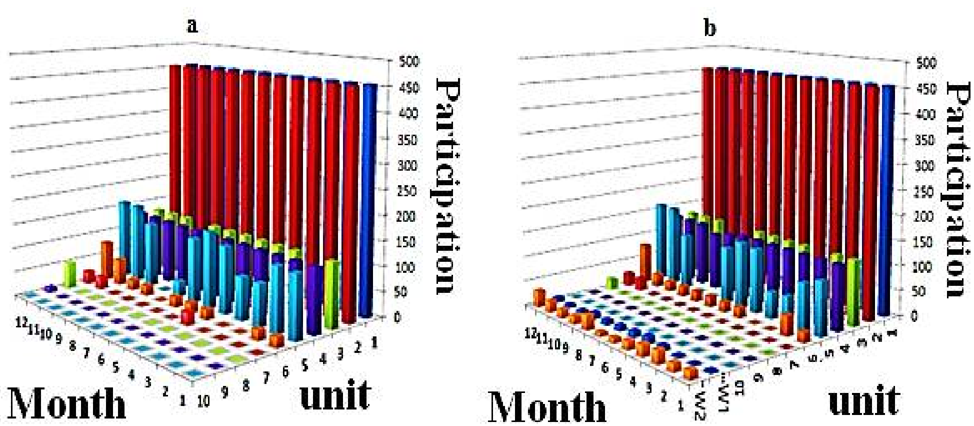

Fig.3. Participating of power plants to supply the demand: a) the first scenario, b) the second scenario

Table.4. shows participation of all scenarios in power plants reserve. In order to specify for Better results, presented the obtained results has been graphically shown in table.4. fig .5 In fig.6 has been graphically the annual cost of this plan. In second scenario, production planning has been implemented for thermal power plants with present of wind farms. The obtained results have been presented in table.5 In second scenario, the units 1 and 2 have been participated in all months same as first scenario. The units 3 and 5 have participated for providing demand at one month and two months respectively in demand supplement were equal to zero. The wind farms 1 and 2 have been participated in all months for providing demand. The units 9 and 10 have no participation in providing demand such as first scenario.

However, unit 8 had less participation than the first scenario had a little participation. Also unit 7 what had participation on three months demand supplement in pervious scenario, having participation only two months just because of with present of wind farm that has been considered in this scenario. In other words, the presence of wind farms to supply the demand, caused to decrease in participation units other than units 1 and 2 and the units 9 and 10. Fig.6. shows total annual cost of production and reserve for different months in for year. Annual cost in first, second, scenario is 249776345, 245576398 dollars respectively. In addition, very all scenarios, compared in diagram, the graphical results shape of different scenarios, presented by follows according to the total cost of production.

Table.4.Participation to supply of the power reserve in the first scenario[MW]

Unit Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
res_unit1	0	0	0	0	0	0	0	0	0	0	0	0
res_unit2	0	0	0	0	0	0	0	0	0	0	0	0
res_unit3	0	0	0	0	0	0	0	0	19	0	0	0
res_unit4	0	0	0	0	0	0	0	0	1	0	0	0
res_unit5	35	32	59.2	66.1	12.8	8	32	63.8	0	30.5	0	0
res_unit6	32.9	35.8	0	0	0	60	35.5	0	41.3	37.7	13.3	0
res_unit7	0	0	0	0	57.8	0	0	0	0	0	60	60
res_unit8	0	0	0	0	0	0	0	0	0	0	0	2
res_unit9	0	0	0	0	0	0	0	0	0	0	0	17.2
res_unit10	0	0	0	0	0	0	0	0	0	0	0	0

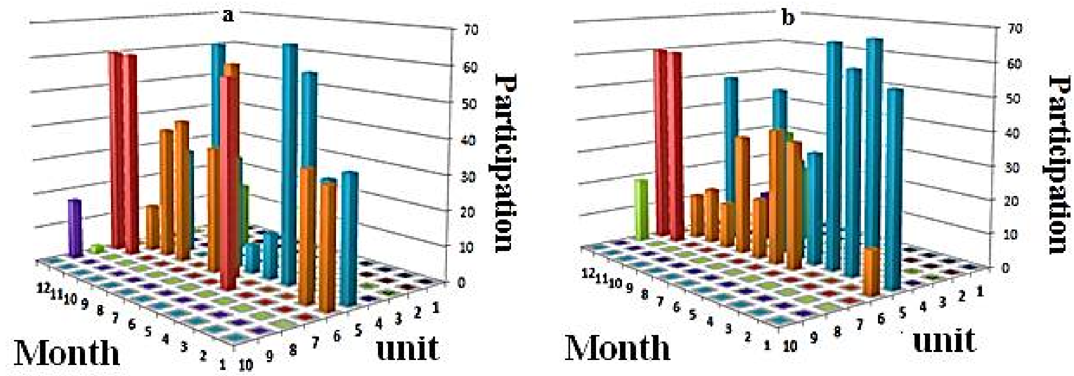

Fig.5. plants participating to supply the reservation a) the first scenario, b) the second scenario

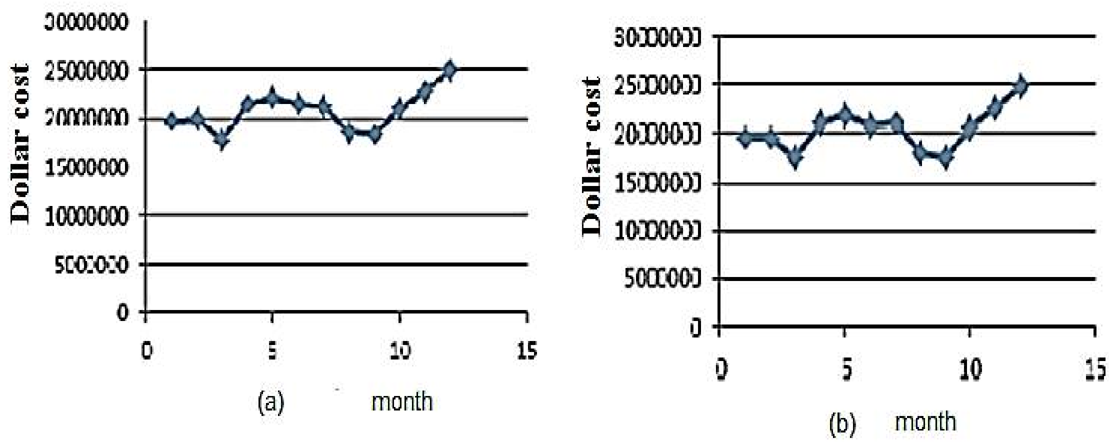

Fig.6.annual cost a) the first scenario, b) the second scenario

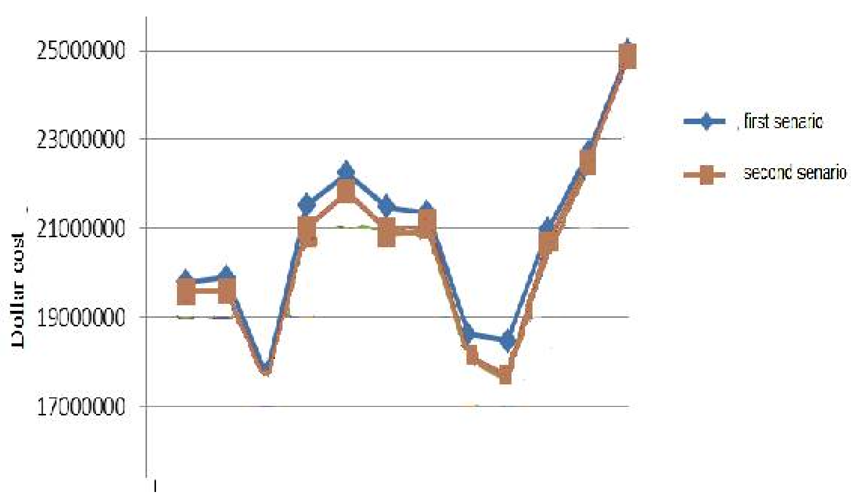

Fig .7. Comparing the total cost of production with various scenarios

5- Conclusion

The comparison of tables and forms of cost scenarios show that cost of base case, allocated the maximum amount. In second scenario, this cost has been as percentage reduced by entering wing farm with production capacity. In last scenario, Costs of production with different values constants and of shape production slope and surveyed request indicating imperceptible change compared to the previous scenario. On the other hand, in addition to reducing risen costs less power plan, shown to supply the consumer demand and power reserve.

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