IMPACT OF WIND ENERGY INTEGRRATION ON ECONOMIC AND RELIABLE OPERATION OF ELECTRICAL NETWORS

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Abstract

In this paper, an integration of a wind farm designed at the installation site of a new city with conventional power generation (CPG) is presented. Two scenarios are suggested to integrate this wind farm with CPG. The impact of this integration on the economic operation of the electrical network is studied using two proposed scenarios. Also, the impact of this integration on the reliable operation of the electrical network is introduced. A long-term load forecasting of the Egyptian electrical network is presented to be helpful in introducing the impact of wind farm integration on the reliable operation of the electrical network. The impact of wind energy integration on economic and reliable operation of electrical networks is applied to the new Borg El-Arab city in Egypt. The results show the capability of the two proposed scenarios.

Keywords : Economic Operation, Wind Farms, Conventional Power Generation, Interconnection of Power Networks, Reliability and Long-Term Load Forecasting.

ملخص: تأثير تكامل طاقة الرياح على التشغيل الإقتصادى و الإعتمادى للشبكات الكهربية

فى هذه المقالة، يتم عرض تكامل لمزرعة رياح مصممة عند موقع إنشاء مدينة جديدة مع مولدات القدرة التقليدية. كما يتم إقتراح سيناريوهين لتكامل هذه المزرعة مع مولدات القدرة التقليدية. و يتم دراسة تأثير هذا التكامل على التشغيل الإقتصادى للشبكة الكهربية بإستخدام السيناريوهين المقترحين. و أيضاً يتم تقديم تأثير هذا التكامل على التشغيل الإعتمادى للشبكة الكهربية. كما يتم عرض لتوقع طويل المدى لحمل الشبكة الكهربية المصرية ليكون بمثابة آداة مساعدة لإستعراض تأثير تكامل مزرعة الرياح على التشغيل الإعتمادى للشبكة الكهربية. و من هنا يتم تطبيق دراسة تأثير تكامل طاقة الرياح على التشغيل الإقتصادى و الإعتمادى للشبكات الكهربية على مدينة برج العرب الجديدة فى مصر. كما تظهر النتائج كفاءة كل من السيناريوهين المقترحين.

1. Introduction

The net effects of renewable energy sources (RESs) on the environment are far less problematic than those of nonrenewable energy sources [1]. Economic issues of wind energy systems are multidimensional. For a wind turbine, the fuel is free, but the capital investment is high. The variable production cost of wind is virtually zero and so with increasing wind penetration the total system fuel cost would be expected to fall. Hence, the savings in fuel costs for thermal plant arising from the installation of wind farms. On the other hand, the additional capital costs associated with integrating wind power generation into a conventional generation system may cause an increase in the overall cost that exceeds the savings in fuel costs [2].

The challenge facing a wind developer, and indeed any new generation resource, is whether it can interconnect to the electrical network or not [3]. Economically, the challenge facing the wind developer is to maintain the economic operation of

the electrical network after the interconnection process because this process needs many interconnection requirements such as, it needs to two stages to raise wind generation voltage to the transmission voltage of the electrical network. Hence, the impact of electrical network interconnection of wind farms on economic operation of the electrical network should be studied. Also, another challenge facing the wind developer is to maintain the reliable operation of the electrical network after the interconnection process where this process have possible impacts on electric power system operations resulting from wind's variability and variations in electricity demand [3, 4].

In this paper, two scenarios are proposed to integrate a large scale wind farm nearby the new Borg El-Arab city in Egypt to feed its load with CPG. An economic investigation is introduced to show the best proposed scenario that the operator can choose according to the operating conditions of the power

system. Also, the impact of electrical network interconnection of this wind farm on reliable operation of the electrical network is studied. A reliability study is carried out to find the capability of the wind energy to supply the electrical network of Egypt for two proposed operation scenarios.

2. Problem Formulation

Two processes are formulated to achieve the economic and reliable operation for power system as follows:

2.1 Economic operation of wind farms with CPG

Many studies were done on integration of RESs with CPG to study the impact of this integration on the required power from CPG, fuel consumption and environment. Also, when large amounts of renewable energy are integrated with CPG, it is very important to study the impact of this integration on the system economy [5 - 8]. Two proposed scenarios are presented as:

1) When the whole wind farm is totally designed and integrated with CPG.

2) When the wind farm is designed and integrated with CPG step by step according to the peak load forecasted of the new city for every year.

2.1.1 Saving in total annual cost (TAC) of CPG

Saving in TAC results from the integration of a large scale wind farm with CPG, because the load, which is required to be fed from CPG, will be fed from the wind farm instead of CPG [9]. TAC includes the annual capital cost (ACC) and the annual variable cost which includes the annual operation cost (AOC) and the annual fuel cost (AFC). AOC is very small with respect to AFC, hence it can be neglected. Therefore, the annual variable cost can be represented as AFC only [10].

Annual capital cost of CPG (ACC_C) is obtained from the following equation:

$$ACC_C = L_f * C_c * P_L \tag{1}$$

Where, L_f is the levelizing factor for conventional power stations and conventional fuel at the end-of-year cost. C_c is the ACC per 1 MW of CPG, $/MW. P_L is the load which will be fed, MW.

The amount of the required fuel (F_C) for CPG is given from the following equation:

$$F_C = (K_f/H_f) * (E_c/\eta_o) \tag{2}$$

Where, K_f is the heat rate; kcal/MWh. H_f is the heat value for 1 ton of F_C, kcal/ton. E_c is the output energy of CPG; MWh. η_o is the overall efficiency of CPG.

The annual fuel cost of CPG (AFC_C) is obtained from the following equation:

$$AFC_C = L_f * C_f * F_C \tag{3}$$

Where, C_f is the cost per 1 ton of F_C, $/ton.

Then, TAC for CPG (TAC_C) is the sum of ACC_C and AFC_C which is obtained from the following equation:

$$TAC_C = ACC_C + AFC_C \tag{4}$$

2.1.2 Integration of large scale wind farm with CPG

The impact of this integration is determined in case of the previous two proposed scenarios.

2.1.2.1 First proposed scenario

In the first proposed scenario, a large scale wind farm is totally designed and integrated with CPG. The load will be fed and the surplus of the wind farm power will be delivered to the electrical network.

TAC of the wind farm (TAC_{WF}) is given from the following equation:

$$TAC_{WF} = N_T * TAC_{WG} \tag{5}$$

Where, TAC_{WG} is TAC of the wind generator. N_T is the number of the whole wind farm turbines.

In order to make an electrical network interconnection for the wind farm, it is required to transform the generation voltage of wind generator to suitable medium voltage and then to the high voltage of the electrical network. Hence, step-up transformers are needed for this task [11]. The cost of these transformers certainly will affect on the economic operation of the overall system, where it will be added to the TAC of the wind farm. The number of step-up transformers (N_{Tr1}), which is required to transform the generator voltage to a suitable medium voltage, is equal to the number of wind generators

and is divided into two parts. The first part is (N_{Tr1a}) which will feed the city load and the second part is (N_{Tr1b}) which will feed the electrical network. Also, the number of step-up transformers (N_{Tr2}), which is required to transform the medium voltage to the high voltage of the electrical network, is determined according to the wind farm power which will be delivered to the electrical network and the power of the transformer which will be chosen. The actual number of these transformers ($N_{Tr2\ (Act)}$) is the result of subtraction for the number of step-up transformers (N_{Tr2}) minus the number of transformers which feeds the city load now ($N_{Tr\ (In\ Service)}$) which is calculated from the following equation:

$$N_{Tr2\ (Act)} = N_{Tr2} - N_{Tr\ (In\ Service)} \qquad (6)$$

The costs of these transformers are the summation of the running cost and the fixed cost of them. The running costs of the transformers are the operation and maintenance costs that can be neglected because they are very small costs. The fixed costs of the transformers are the capital costs of it. Hence, the TAC of step-up transformer is the annual capital costs of it (ACC_{Tr}) which are obtained from the following equation:

$$ACC_{Tr} = DR * CC_{Tr} \qquad (7)$$

Where, CC_{Tr} is the price of the transformer. DR is the annual discount rate and given by the following relation [12]:

$$DR = r\,(1 + r)^n / [(1 + r)^n - 1] \qquad (8)$$

Where, r is the interest rate. n is the life-time of the transformer.

Then, the total annual capital cost of the transformers ($ACC_{Tr\ (T)}$) is obtained from the following equation:

$$ACC_{Tr\ (T)} = (N_{Tr1a} + N_{Tr1b}) * ACC_{Tr1}$$
$$+ N_{Tr2\ (Act)} * ACC_{Tr2} \qquad (9)$$

From equations (4), (5) and (9), the net saving in CPG costs (S_N) after adding the transformers is obtained from the following equation:

$$S_N = TAC_C - \left(TAC_{WF} + ACC_{Tr\ (T)}\right) \qquad (10)$$

The wind power saved (P_{WS}), which will be delivered to the electrical network, is given from the following equation:

$$P_{WS} = P_{WF} - P_L \qquad (11)$$

Where, P_{WF} is the whole wind farm power.

The percentage of this power with respect to the whole wind farm power ($P_{P_{WS}}$) is obtained from the following equation:

$$P_{P_{WS}} = (P_{WS}/P_{WF}) * 100 \qquad (12)$$

2.1.2.2 Second proposed scenario

In the second proposed scenario, the wind farm is step by step designed and integrated with CPG according to the annual increasing of the load. This load will be fed and the surplus of the wind farm power will be delivered to the electrical network. The number of wind farm turbines for every year (N_{TA}) is increased according to the load which is calculated from the following equation:

$$N_{TA} = N_T * P_L/P_{WF} \qquad (13)$$

The total annual cost of the wind farm (TAC_{wf}) is obtained from the following equation:

$$TAC_{wf} = N_{TA} * TAC_{WG} \qquad (14)$$

In this scenario, the surplus of the wind farm power, which will be delivered to the electrical network, is very small and it can be neglected. Hence, the number of step-up transformers (N_{Tr}) is the number of the transformers which is required to transform the generator voltage to the suitable medium voltage only and is equal to the number of wind generators that is required to feed the city load for every year and is increased according to the increasing of the load for every year. From equation (7), ACC_{Tr} can be calculated taking into account the new price of the transformer for every year ($CC_{Tr\ (new)}$) which is calculated from the following equation:

$$CC_{Tr\ (new)} = CC_{Tr\ (old)} + P_{inc} * CC_{Tr\ (old)} \qquad (15)$$

Where, $CC_{Tr\ (old)}$ is the price of the transformer in the previous year. P_{inc} is the percentage increasing of the transformer price for every year.

$ACC_{Tr\ (T)\ (new)}$ for every year up to year 2035 is calculated from the following equation:

$$ACC_{Tr\ (T)(new)} = ACC_{Tr\ (T)(old)}$$
$$+ N_{Tr\ (add)} * ACC_{Tr\ (new)} \qquad (16)$$

Where, $ACC_{Tr\ (T)\ (old)}$ is the total annual capital cost of the transformers in the previous year. $N_{Tr\ (add)}$ is the number of the added transformers for every year. $ACC_{Tr\ (new)}$ is the annual capital cost of the added transformer.

From equations (4), (14) and (16), the net saving in CPG costs (S_N) after adding the transformers is obtained from the following equation:

$$S_N = TAC_C - \left(TAC_{wf} + ACC_{Tr\ (T)(new)}\right) \qquad (17)$$

The wind farm power (P_{wf}), according to the load for every year, is given from the following equation:

$$P_{wf} = N_{TA} * P_{WG} \qquad (18)$$

Where, P_{WG} is the average output power of the wind generator.

The wind power saved, which will be delivered to the electrical network, is given from the following equation:

$$P_{WS} = P_{wf} - P_L \qquad (19)$$

Also, the percentage of this power with respect to the whole wind farm power is obtained from the following equation:

$$P_{P_{WS}} = (P_{WS}/P_{wf}) * 100 \qquad (20)$$

2.2 Impact of wind farms integration on reliable operation of the electrical network

The impact of the wind farms integration on reliable operation of the electrical network can be determined by calculating the percentage improvement of reliability for the two previous proposed scenarios. The percentage improvement of reliability of the electrical network is the ratio between the wind power, which will be delivered to the electrical network, and the electrical network power [13].

2.2.1 Electrical network peak load forecasting

The electrical network peak load can be estimated for a group of years in the future by using load forecasting techniques. The basic concept of these techniques depends on the existence of the historical data of the peak load of the electrical network for a group of years in the past. Then, these data can be represented by a suitable mathematical equation according to the nature of the electrical

loads increasing on the network. Knowing this equation, the peak load for the electrical network for a group of years in the future can be estimated. Extrapolation of trend curves technique as a conventional technique and genetic algorithm (GA) and particle swarm optimization (PSO) technique as modern techniques of long-term load forecasting with linear and exponential regression models can be used for this purpose.

2.2.2 Percentage improvement of the electrical network reliability

The percentage improvement of the electrical network reliability can be calculated for the two previous proposed scenarios as:

i. First proposed scenario

In this proposed scenario, the generated power from the wind farm is very large with respect to the city load, especially in the first years of integration. Hence, the percentage improvement of the electrical network reliability will be large. This percentage is calculated from the following equation:

$$PIENR\ (\%) = [(P_{WF} - P_{FL})/P_{FLN}] * 100 \qquad (21)$$

Where, P_{WF} is the total wind farm power, P_{FL} is the forecasted load of the city and P_{FLN} is the forecasted peak load of the electrical network for every year.

ii. Second proposed scenario

In this proposed scenario, the amount of wind power, which will be delivered to the electrical network, will be very small and the percentage improvement of the electrical network reliability also will be closed to zero. Then, it can be deduced that there is no improvement in the electrical network reliability in this proposed scenario.

3. Applications

In this paper, the impact of integration of a large scale wind farm at the new Borg El-Arab city with CPG on the economic and reliable operation of the overall system using two proposed scenarios is studied.

3.1 Economic operation of wind farms with CPG

The net saving in CPG costs and the amount of the wind power saved, which will be delivered to the Egyptian electrical network, after feeding the new

city for the two previous proposed scenarios are calculated considering the following main data for the chosen transformers [14]:

– Tr_1: 1.05 MVA, 0.69/22 KV and its price is equal to 26666.667 $.

– Tr_2: 25 MVA, 22/66 KV and its price is equal to 833333.333 $.

3.1.1 Annual cost saving calculation in TAC for CPG

Equations from (1) to (4) are applied considering the following values:

– The value of L_f in equations (1) and (3) is taken as 1.05 and 1.1, respectively.

– The values of C_c and C_f in equations (1) and (3) are taken as $1800 * 10^3$ $/MW [15] and 100 $/ton, respectively.

– The values of K_f, H_f and η_o in equation (2) are taken as $860 * 10^3$ kcal/MWh, $11500 * 10^3$ kcal/ton and 0.55, respectively.

– The values of P_L in equation (1) are the forecasted peak load demand for the new Borg El-Arab city (P_{FL}) from year 2012 to year 2035.

– The values of E_c in equation (2) are the output energy of CPG corresponding to P_{FL} for every year.

The annual cost saving in TAC for CPG from year 2012 to year 2035 is given in Fig. (1). From this Figure, it can be found that the annual cost saving in TAC for CPG is increased with increasing of the forecasted peak load demand of this city. This is because of the increasing of the forecasted peak load demand of this city for every year, which will be fed from the wind farm instead of CPG.
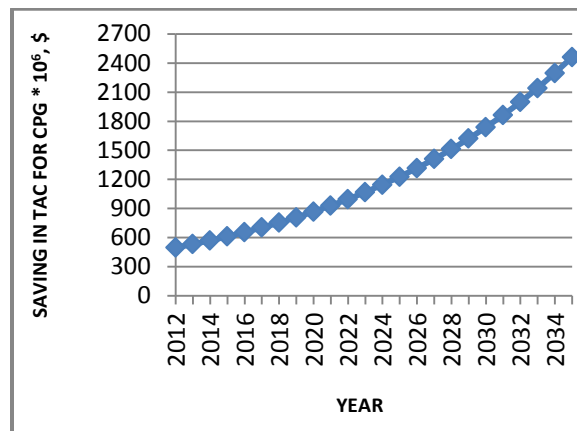

Fig. (1) Annual cost saving in TAC for CPG from year 2012 to year 2035 without wind farm integration

3.1.2 Calculations of first proposed scenario

The whole wind farm, which will be integrated with CPG, gives 1262.195 MW with number of wind turbine generators of 1853 units. Also, the TAC of the wind generator used is equal to 354480 $. From the equations from (5) to (10), the TAC for the whole wind farm is 656851440 $ and the annual net costs saving in the TAC for CPG after adding the transformers cost from year 2012 to year 2035 is shown in Fig. (2). From this Figure, it can be found that there is no net cost saving in the first five years because the construction cost of the wind farm and the transformers cost are more expensive than the cost saving of CPG for these years.

Also, the percentage of the wind power, which will be delivered to the Egyptian electrical network with respect to the whole wind farm power, is calculated by using the equations (11) and (12) and is shown in Fig. (3). From this Figure, it can be found that the highest percentage of the wind power, which will be delivered to the Egyptian electrical network, is in the first year of 2012 and this percentage is decreased to reach the lowest percentage in the year of 2035. This is because the forecasted peak load demand of the new city, which is totally fed from the wind farm, is increased through the load forecasted period (2012 – 2035) and the wind power, which will be delivered to the Egyptian electrical network, is decreased.
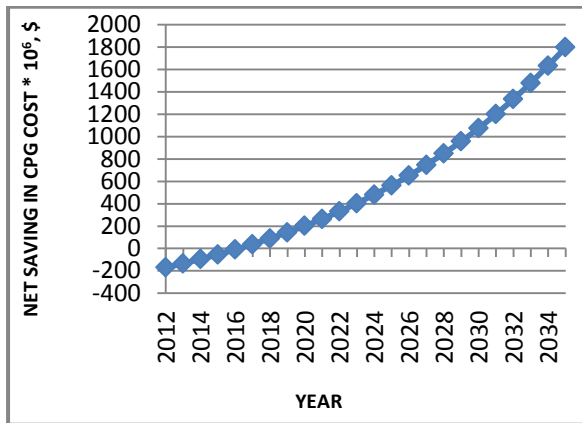
Fig. (2) Annual net costs saving in TAC for CPG from year 2012 to year 2035 using the first proposed scenario
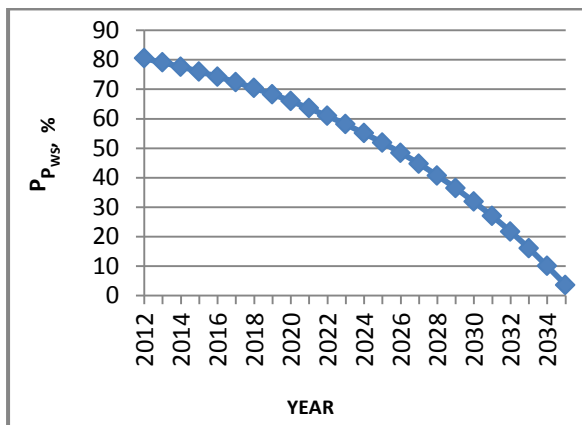

Fig. (3) Percentages of wind power which will be delivered to the Egyptian electrical network from year 2012 to year 2035 using the first proposed scenario

3.1.3 Calculations of second proposed scenario

In this proposed scenario, the number of the wind turbine generators for every year through the load forecasted period (2012 – 2035) must be determined at the beginning of calculations. The number of step-up transformers is equal to the number of wind generators which is required to feed the city load for every year. From the equations from (13) to (17), the annual net costs saving in the TAC for CPG after adding the transformers cost from year 2012 to year 2035 is shown in Fig. (4). From this Figure, it can be found that there is a large net costs saving is obtained from the first year of the load forecasted period 2012. This net costs saving is

increased according to the increasing of the peak load forecasted of the new city.

The percentages of the wind power, which will be delivered to the Egyptian electrical network with respect to the whole wind farm power, are determined by using the equations (18), (19) and (20). The average output power of the wind generator used in equation (18) is equal to 681.163 kW. The percentages of wind power, which will be delivered to the Egyptian electrical network up to year 2035, are shown in Fig. (5). From this Figure, it can be found that the general behavior of these percentages is decreased for the load forecasted period. This is because the number of wind turbine generators is closely chosen according to the peak load forecasted of the new city.
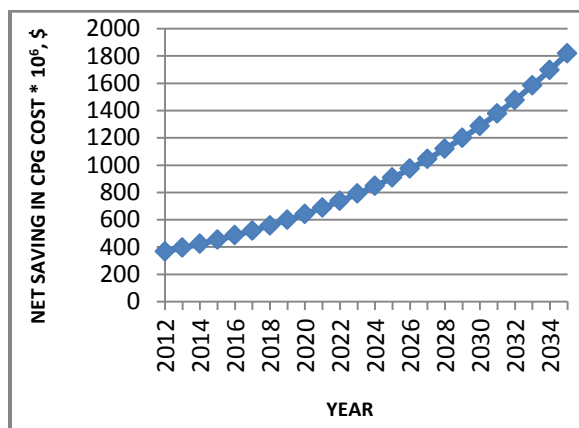

Fig. (4) Annual net costs saving in TAC for CPG from year 2012 to year 2035 using the second proposed scenario
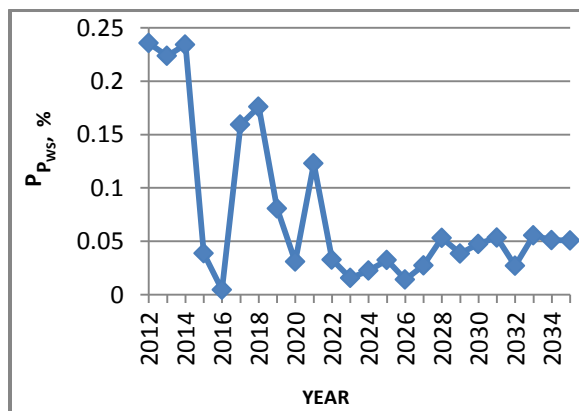

Fig. (5) Percentages of wind power which will be delivered to the Egyptian electrical network from year 2012 to year 2035 using the second proposed scenario

3.1.4 A comparison between results of two proposed scenarios

Fig. (6) shows a comparison between the net costs saving in TAC for CPG for the two proposed scenarios from year 2012 to year 2035. From this Figure, the total net costs saving in TAC for CPG up to year 2035 using the second proposed scenario is greater than that for the first proposed scenario. Also, a comparison between the percentages of the wind power, which will be delivered to the Egyptian electrical network with respect to the whole wind farm power for the two proposed scenarios, are obtained as shown in Fig. (7). From this Figure, these percentages using the first proposed scenario are larger than that using the second proposed scenario, which are extremely small.
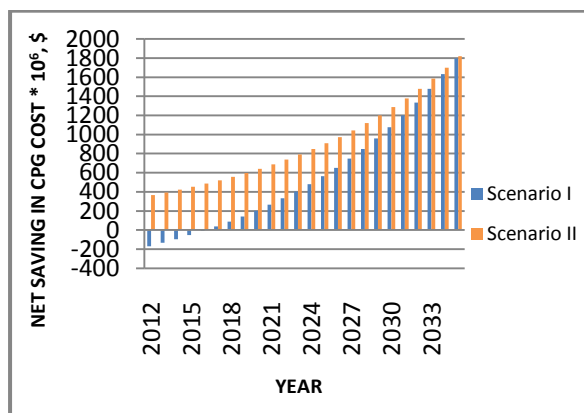

Fig. (6) A comparison between the net costs saving in TAC for CPG for two proposed scenarios from year 2012 to year 2035
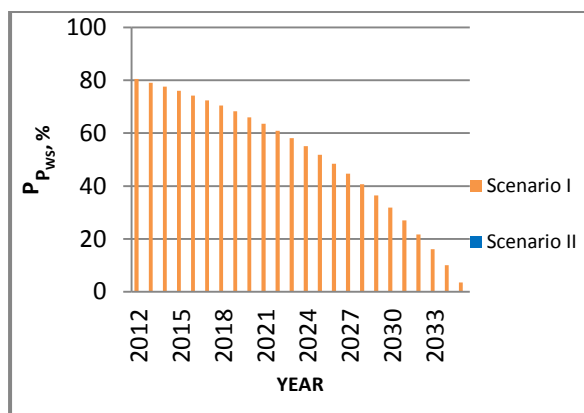

Fig. (7) A comparison between the percentages of the wind power, which will be delivered to the Egyptian electrical network from year 2012 to year 2035

3.2 Impact of wind farms integration on reliable operation of the electrical network

The impact of electrical network integration of the wind farm designed nearby new Borg El-Arab city on the reliable operation of the Egyptian electrical network is determined by calculating the percentage improvement of reliability of the Egyptian electrical network. This percentage is the ratio between the wind power, which will be delivered to the Egyptian electrical network, and the Egyptian electrical network power. The Egyptian electrical network power is the peak load of the Egyptian electrical network which should be forecasted at first as shown in details below.

3.2.1 Egyptian electrical network peak load forecasting

The historical data of the Egyptian electrical network peak load from year 2003 to year 2011 is shown from Table (1) [10]. The extrapolation of trend curves technique as a conventional technique and GA and PSO technique as modern techniques of long-term load forecasting techniques with linear and exponential regression models are applied using the historical data as shown in Table (1), the peak load of the Egyptian electrical network from year 2012 to year 2035 is obtained in Table (2). From this Table, it can be found that the peak load of the Egyptian electrical network which is obtained from GA with the exponential increasing form are the best results and will be chosen to apply because it is more accurate compared to the actual peak load of the Egyptian electrical network from year 2012 to year 2015 as shown in Table (3).

Table (1) Historical data of the Egyptian electrical network peak load

Year	P_{LN} (GW)
2005	16.019
2006	17.179
2007	18.385
2008	19.400
2009	20.270
2010	21.137
2011	21.801

Table (2) Peak load forecasting of the Egyptian electrical network from year 2012 to year 2035

| Year	Extrapolation		Genetic Algorithm		Particle Swarm Optimization	
	P_{FLN}, Linear (GW)	P_{FLN}, Exponential (GW)	P_{FLN}, Linear (GW)	P_{FLN}, Exponential (GW)	P_{FLN}, Linear (GW)	P_{FLN}, Exponential (GW)
2012	23.048	23.414	23.342	24.070	23.864	24.537
2013	24.018	24.646	24.387	25.512	25.038	26.133
2014	24.987	25.944	25.433	27.040	26.211	27.833
2015	25.957	27.310	26.478	28.660	27.385	29.644
2016	26.926	28.748	27.524	30.378	28.558	31.572
2017	27.896	30.262	28.569	32.198	29.732	33.626
2018	28.866	31.855	29.614	34.127	30.905	35.814
2019	29.835	33.533	30.660	36.172	32.079	38.144
2020	30.805	35.298	31.705	38.339	33.252	40.625
2021	31.774	37.157	32.751	40.636	34.426	43.268
2022	32.744	39.114	33.796	43.071	35.599	46.083
2023	33.713	41.173	34.842	45.651	36.772	49.081
2024	34.683	43.341	35.887	48.386	37.946	52.274
2025	35.652	45.623	36.933	51.285	39.119	55.675
2026	36.622	48.025	37.978	54.358	40.293	59.296
2027	37.591	50.554	39.024	57.615	41.466	63.154
2028	38.561	53.216	40.069	61.067	42.640	67.263
2029	39.530	56.018	41.114	64.726	43.813	71.639
2030	40.500	58.968	42.160	68.604	44.987	76.299
2031	41.470	62.073	43.205	72.714	46.160	81.263
2032	42.439	65.341	44.251	77.071	47.334	86.549
2033	43.409	68.781	45.296	81.689	48.507	92.180
2034	44.378	72.403	46.342	86.583	49.681	98.177
2035	45.348	76.215	47.387	91.771	50.854	104.564

Table (3) Actual and forecasted peak load of the Egyptian electrical network from year 2012 to year 2015

Year	2012	2013	2014	2015
Actual peak load demand, GW	23.88	24.86	26.69	28.19
Forecasted peak load demand, GW	24.070	25.512	27.040	28.660

3.2.2 Percentage improvement of the Egyptian electrical network reliability using the first proposed scenario

The percentage improvement of the Egyptian electrical network reliability is calculated using the equation (21). Fig. (8) shows the variation of this percentage from year 2012 to year 2035. From this Figure, it can be found that the highest value of the percentage improvement of the Egyptian electrical network reliability is in the first year of 2012, while the lowest value of this percentage is in the last year of 2035. It means that the percentage improvement of the Egyptian electrical network reliability depends on the amount of wind power which will be delivered to the Egyptian electrical network for every year. This power depends on the value of the increasing of the forecasted peak load demand of the city for every year. From this result, it can be shown that the wind farm designed nearby new Borg El-Arab city will increase the percentage improvement of the Egyptian electrical network reliability because the ability of this network to face any increasing of loads for every year will increase.
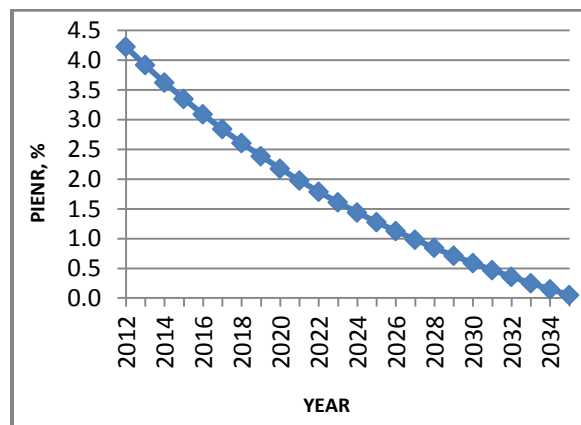
Fig. (8) Percentages improvement of the Egyptian electrical network reliability from year 2012 to year 2035

4. Conclusions

In this paper, the possibility of operating wind energy with the main conventional supply (substation) to supply new cities has been discussed. Also, the impact of integration of wind energy on the economic and reliable operation of the Egyptian electrical network have been discussed and analyzed. From this study, the following conclusions have been deduced:

1. The impact of a large scale wind farm with CPG nearby new Borg El-Arab city on the economical side of the overall system for the two proposed scenarios has been determined by calculating the net costs saving in TAC for CPG. It has been deduced that the total net costs saving in TAC for CPG for the forecasted period using the first

proposed scenario is less than that using the second proposed scenario.

2. The percentage of the wind power, which will be delivered to the Egyptian electrical network, has been obtained for the two proposed scenarios. It has been deduced that the percentage of the wind power, which will be delivered to the Egyptian electrical network using the first proposed scenario, has been extremely larger than that using the second proposed scenario.

3. The impact of wind energy on the reliable operation of the Egyptian electrical network has been determined for the two proposed scenarios. This impact has been determined by calculating the percentage improvement of the Egyptian electrical network reliability. It can be deduced that the Egyptian electrical network will be more reliable using the first proposed scenario than that using the second proposed scenario.

Therefore, the electrical network operators can trade-off between the two proposed scenarios according to the operating conditions of the power system. It means that if the operator wants to obtain a large net costs saving in TAC for CPG and the percentage of the wind power, which will be delivered to the Egyptian electrical network, is not important for him, he should choose the second proposed scenario. On the other hand, if he wants to obtain a large percentage of the wind power, which will be delivered to the Egyptian electrical network, and the net costs saving in TAC for CPG is not important for him, he should choose the first proposed scenario.

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