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Research Paper

Effect of Wind Penetration and Transmission Line Development in order to Reliability and Economic Cost on the Transmission System Connected to The Wind Power Plant

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Abstract

Energy consumption is one of the criteria for determining the level and quality of life in a country. Continuity of energy supply and long term access to resources needed for a comprehensive energy plan. For this reason, energy planning, the undeniable economic imperative, national and strategic, is considered. In recent years, the production of electricity from wind energy is taken into consideration. Wind turbines are one of the most widely used energy units are in the world. Wind power must be employed in an area that has good potential of wind. The best conditions for installation of wind power are, thus,in remote areas free of obstacles, and consequently with low population density. Reliability benefits, environmental benefits and operating cost savings from wind power integration should be compared with the associated investment costs in order to determine optimum transmission facility for wind power delivery. Determining an adequate transmission system to deliver wind power to a power grid is a difficult problem. Designing a transmission system to match the wind farm's installed capacity can lead to over investment. In this paper, the reliability indices such as: LOLP, LOLE, EENS, using MATLAB software to COPT table in the presence and absence of wind power is calculated and the results compared. Also, the use of these indicators, the economic analysis of the project is done. Because, designing a transmission system to match the wind farms installed capacity can lead to over investment.

Keywords: Delivery, Reliability, Wind power, Cost, LOLE, EENS

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1. Introduction

With growing energy and industrial development, the need to increase energy production and expansion of production units, is felt more than ever before. Power generation from renewable sources grows by the day for various reasons. However, the use of wind power due to the high volume of power generation is cheaper and more pervasive access to the source of the wind, more attention has been placed. Power system reliability is the measure of the ability of the system to deliver electricity as demanded to various points of utilization within acceptable standards. Power system reliability can be described by two important attributes: adequacy and security. Adequacy is the measure of a power system to satisfy the consumer demand in all steady state conditions. Security is a measure of the system

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ability to withstand a sudden & severe disturbance in the system while maintaining system integrity [1]. Modern power systems are generally complex, integrated and very large. It is not practical to conduct an adequacy evaluation of an entire power system. This paper is related to the adequacy of the long-distance transmission line is related to the wind power plant is connected to a power system network. Most of the electric utilities do not consider wind power in generation planning. Wind power has significant effect in improving system reliability up to a certain level. High penetration of wind power can also cause various problems related to system operation and power quality. Wind power affects power system dynamics and stability, reactive power control, voltage control and flickering. Wind power generation can also contribute to overall system reliability, and help in reducing customer cost of electric power interruption. Offsetting conventional fuel consumption means reducing harmful emissions produced by fuel and therefore, providing environmental benefits [2]. On the other hand, it is important to provide fair access to the power transmission network to all the participating power producers in many power systems [3]. There has not been sufficient work done in this area [4]. Suggested few solutions to overcome deficiency of delivery system from wind farms in areas that might not be dimensioned to accommodate additional large-scale power plants. Presents reliability evaluation techniques that include the transmission of wind power in a load center. There has been significant work done for economic assessment of wind energy utilization in power systems.

2. Results and Discussion

2.1 System modelıng and evaluatıon method

Wind power system evaluation model consists of three major steps:
1) Wind speed modeling 2) WTG† system modeling 3) system risk modeling.

2.2 Wind Speed Modeling

Wind power generation is proportional to the cube of the wind speed. It indicates that accurate wind speed modeling is essential for studying wind power effect on system reliability and cost. Hourly wind speeds for a selected wind farm site were simulated using a time series Auto Regressive Moving Average (ARMA) model [5], which is mathematically expressed in Eq. (1).

$$y_t = \varepsilon_t + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} \tag{1}$$

Where, y_t is the time series value at time t, φ_i (i = 1,2,3…n) and θ_j (j=1,2,3…. m) are the auto regressive and moving average parameters of the model respectively. {αt} is a normal white noise with zero mean and a variance of σ_a^2 (i.e. αt ∈ NID (0, σ_a^2)), where NID denotes Normally Independently Distributed. The simulated wind speed SW_t at the t^{th} hour can be obtained using Equation 2 from the historical mean speed μ_t, standard deviation σ_t and the time series values y_t.

$$SW_t = \mu_t + \sigma_t \times y_t \tag{2}$$

2.3 WTG System Modeling

2.3.1 Wind Power Generation

The main characteristics that influence the WTG generated power are the cut-in speed (V_{ci}), cut-out speed (V_{co}), rated speed (V_r), and the rated power P_r of the WTG. Wind power generation varies non-linearly with the wind speed and can be obtained from the power curve of a WTG and mathematically expressed by Eq. (3).

$$p_t = \begin{cases} o, & o \subseteq swt \subseteq v_{ci} \\ A + B \times SW_t + C \times SW_t^2 & vci \subseteq swt \subseteq v_r \\ p_r & v_r \subseteq swt \subseteq v_{co} \\ o, & vco \subseteq set \end{cases} \tag{3}$$

Where P_t is the wind power output at the t^{th} hour. The constants A, B and C can be found in, using V_{ci}, and V_r [6].

2.3.2 Wind power generation model

The wind farm generation model consists of a number of different power generation states and their corresponding probabilities. The probability p_{wi} of a simulated wind speed S_{Wi} is given by Eq.(4).

$$pwi = \frac{N_i}{(N \times 8760)} \tag{4}$$

Where N is the number of simulation years, and N_i is the number of occurrences of wind speeds in the range (S_{Wj}, S_{Wj+1}), where

$$sw_i = \frac{(sw_j + sw_j + 1)}{2} \tag{5}$$

The power generated Pi by each individual WTG in the wind farm was calculated using Eq. (3), and aggregated to obtain the wind farm generation model which consists of the wind farm power generation states W_{Pi} and their corresponding probabilities p_i. W_{Pi} corresponding to wind speed S_{Wi} is given by Eq. (6) (Table 2).

$$Wp_i = \sum_n p_i \quad (6)$$

Where n is the number of WTG in the wind farm [7].

Table 1. Models of wind farm production.

(Pi) Probability considering transmission line unavalabilit	Wind Power Generation State (WPi)
0.1373664	0
0.4875411	42
0.3337295	115
0.0401198	240
0.0012432	250

2.3.3 Wind generation/delivery system model

The next step of the evaluation process is to develop the wind farm generation model at the grid access point. This model incorporates the transmission line, its power transfer capability and forced outage probability of which constrains the wind farm generation model. The wind power available at the grid access point W_{PGi} is constrained by the transmission line capacity T_{cap} as expressed in Eq. (7):

$$\begin{array}{ll} \text{for } wp_i \leq T_{cap} & wp_{Gi} = T_{cap} \\ \text{for } wp_i \geq T_{cap} & wp_{Gi} = wp_i \end{array} \quad (7)$$

The probability p_{Gi} of the generation state W_{PGi} is given by Eq. (8).

$$\begin{array}{ll} p_{Gi} = U_T + (1-U_T)\times p_i & Wp_{Gi} = o \\ \quad = (1-U_T)\times p_i & Wp_{Gi} < T_{cap} \\ \quad = (1-U_T)\times \sum_{j=1}^{s} p_j & Wp_{Gi} = T_{cap} \end{array} \quad (8)$$

Where U_T is the transmission line forced outage probability, S is the total number of j generation states constrained by the line transfer capability. Transmission system failure rate (λ) and average repair time(r) were extracted from Egyptian Electric Holding (EEHC) data. Transmission system unavailability UT was calculated 0.02 (Figure 1). In this way, Eqs. (6)–(8) were used to determine the different power generation states W_{PGi} and their corresponding probabilities P_{Gi} at the grid access point. This model was used to determine the EPO using Eq. (9) (Table 3).

$$EPO = \sum_{i=1}^{s} wp_{Gi} \times p_{Gi} \quad (9)$$

2.4 System risk modeling

The overall system generation model incorporating conventional and wind generation/delivery systems is finally convolved with system load model to obtain the system risk and energy based indices. The EEHC electrical power system load varies with time and that variation can be represented by a load model. Fig. 1 shows the EEHC load duration curve model (Figure 2).

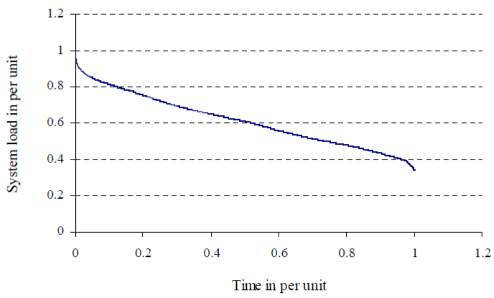

Figure 1. Model of Load Curve EEHC.

2.5 The impact of the measures of the reliability of wind power

Using table 2, we discuss the measures of reliability. This is done using mathematical listed once individually and once the wind farm is calculated by combining the results, we will compare. It should be noted that the peak load is equal to net: 60 MW, 80 MW, 100 MW, 150 MW, and 200 MW. Considering the trend of increasing peak load of the network, we calculate the index in the table 2:

Table 2. Data of a power system

Unit size in (MW)	Number of unit	(FOR)
12	5	0.02
20	4	0.10
50	6	0.01
76	4	0.02
100	3	0.04
155	4	0.04
197	3	0.05
350	1	0.08
400	2	0.12

Table 3. Values of the index of a power system.

PEAK LOAD	LOLP	LOLE (hour/year)	EENS (MWh/year)
60	0.24	2104	697.5
80	0.52	463.9	2633
100	2.094	18345	6826
150	2.098	18385	15937
200	2.101	18406	37636

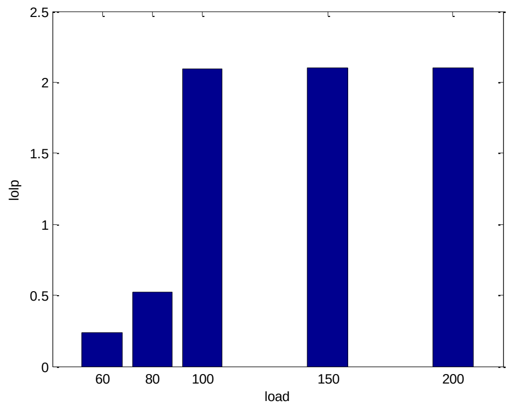

Figure 2. Effect of increasing the peak load on the LOLP.

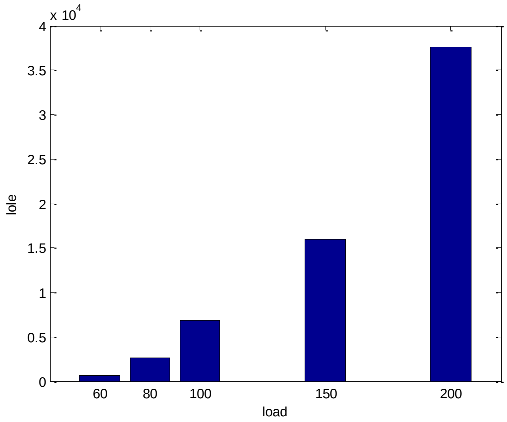

Figure 3. Effect of increasing the peak load on the LOLE.

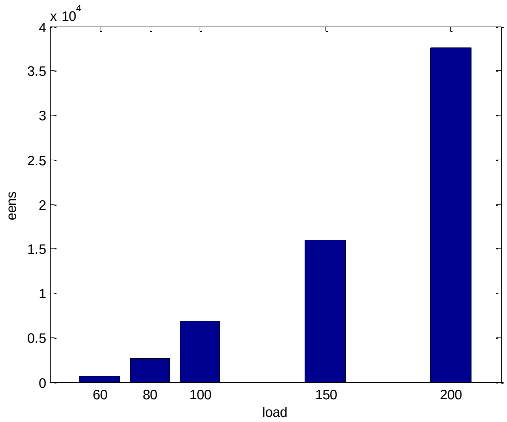

Figure 4. Effect of increasing the peak load on the EENS

Table 4. Values of the index of a power system with wind power integration

PEAK LOAD	LOLP	LOLE (hour/year)	EENS (MWh/year)
60	0.06	537.07	77.97
80	0.2	1796	411.3
100	0.34	2978	953.3
150	1.24	10936	6799
200	1.58	13853	14069

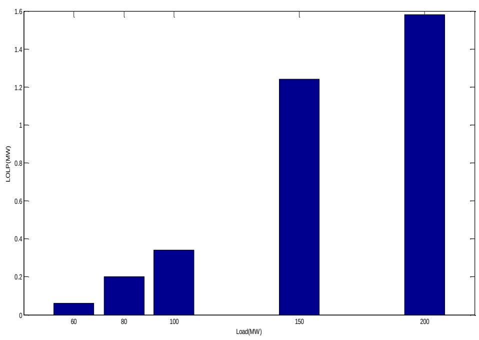

Figure 5. effect of increasing the peak load LOLP integrating wind farm.

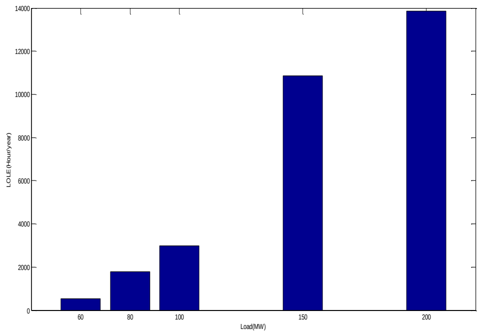

Figure 6. Effect of increasing the peak load on the LOLE integrating wind farm.

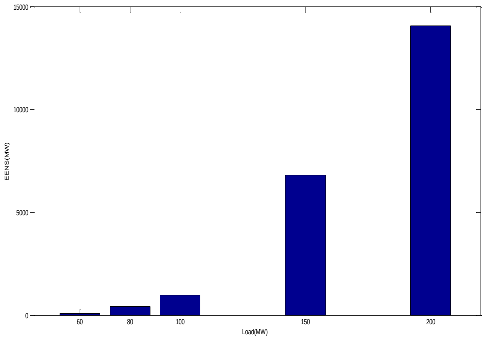

Figure 7. Effect of increasing the peak load on the EENS integrating wind farm.

2.6 Comparison of the effect of adding wind power to improve the reliability index

Blue arrows, measures the absence of wind farms, and green shows the comparison of the same parameters in the presence of a wind farm shows. Clearly, we see that all the system reliability when the peak load is increased, the presence of the wind farm, has dramatically improved (Figure 3 and 4).

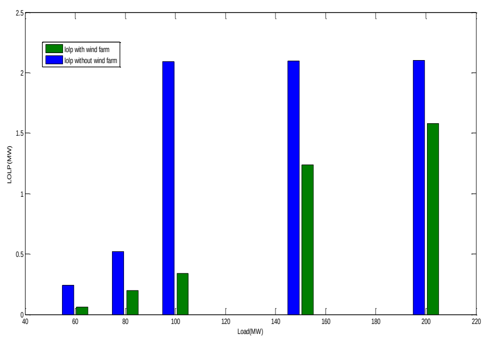

Figure 8. Comparison of the effect of increasing the peak load on the LOLP in the presence and absence of wind plant.

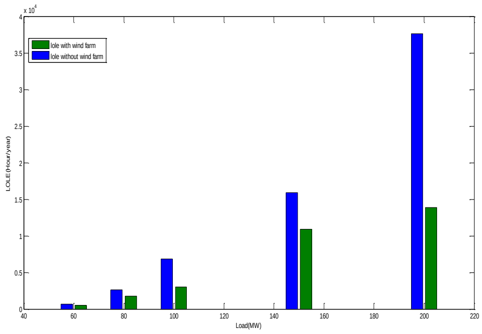

Figure 9. Comparison of the effect of increasing the peak load on the LOLE in the presence and absence of wind plant.

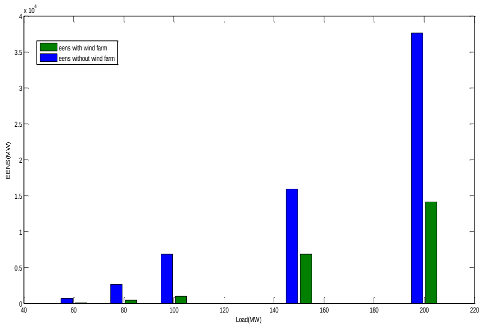

Figure 10. Comparison of peak load on EENS increases in the presence and absence of wind plant.

2.7 Effect of Transmission Line Capacity

It is necessary to analyze the effect of transmission line parameters on system reliability in deciding appropriate transmission line capacity connecting a particular wind farm to a power grid. The reliability indices obtained from reliability analysis can provide useful information in deciding the optimum transmission line. The effect of varying line capacity on the system LOLE is shown in Figure 11. It can be seen from the figure that the system risk increases with increase in peak load for a given line capacity. The curves in the figure shift downwards as the system load decreases. The lowest curve shows the system LOLE for a peak load of 60 MW (Figure 5, 6 and 7).

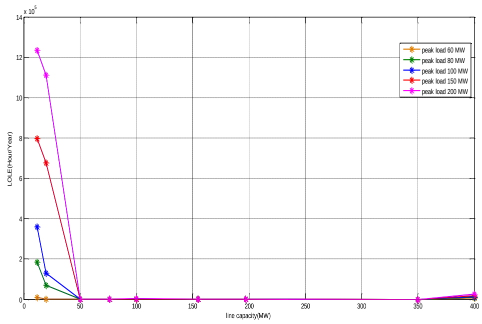

Figure 11. Variation in system LOLE with line capacity of the wind farm.

Economic Assessment of a Wind Power Delivery System

The final decision on the appropriate transmission system requires a trade-off between cost and reliability of the system will be. The financial benefits of wind power delivery system with transmission investment costs are compared. Different transmission capabilities of the estimated in order to determine the appropriate investment in transmission lines generally linearly by increasing the capacity of transmission line will be increased (Figure 8).

Incorporating wind power to conventional system can be useful in supplementing energy to system and in reducing expected customer interruption cost (ECOST). The simplest way of estimating ECOST without introducing great inaccuracies is presented by Equation 10 (Table 4).

$$ECosT = IEAR \times LOEE \quad (10)$$

The IEAR represents interrupted energy assessment rate and is expressed in 3.63 $/kWh of unsupplied energy. The LOEE represents the loss of energy expectation and is also known as the expected energy not supplies (EENS) (Figure 9 and 10).

The addition of wind power to a power system will normally improve the overall system reliability. This can be quantitatively measured by the reduction in system LOLE, which can be obtained of using Equation 11.

$$\Delta LOEE = EENS - EENS_w \quad (11)$$

Where ΔLOEE is the reduction in system LOEE as a result of wind energy utilization.

EENS = Expected energy not supplied before adding wind power

EENSW = Expected energy not supplied after adding wind power

The reduction in outage cost to the customer or the benefit available from saving in ECOST can be estimated using Equation 12.

$$BOC = IEAR \times \Delta LOEE \quad (12)$$

Where , BOC represents benefits from saving in ECOST in dollars

The total benefit (Bw) from wind power can be obtained using Equation 13.

$$B_w = EES_w(Fc + wppI) + IEAR \times \Delta LOEE \quad (13)$$

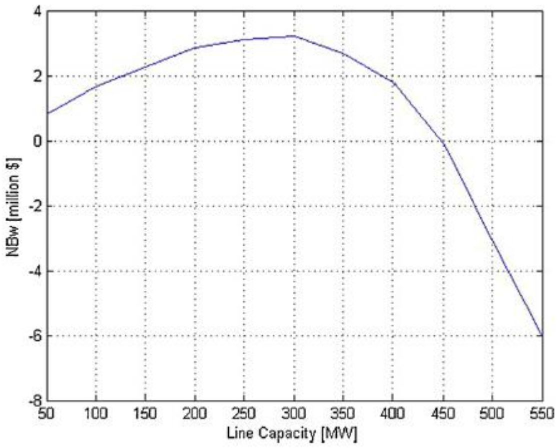

Figure 12. Net profit in the capacity of transmission line.

3. Conclusion

The application of wind power in electric power system is growing rapidly around the globe due to increasing environmental concerns and public awareness. Many large wind farms for bulk power generation are expected to be added to power systems in near future. These wind power plants require good wind resources to generate bulk power and can be away from the main grid access point. The transmission line for connecting remote wind farms to the power grid is crucial. Wind power varies randomly with the available wind speed at the wind farm site. Transmission system planning for wind power integration requires different evaluation approach compared to a conventional system. The prominent system reliability indices such as LOLE and LOEE are explained. The overall modeling process is divided into three major tasks of wind speed modeling, wind system modeling, and system risk modeling. A computer program was developed to construct a wind generation model at the grid access point. The effect of the system peak load, transmission line capacity and wind regime was studied evaluating the system risk index LOLE and power index EENS. Found that increasing the reliability of the system peak load is reduced. Adding wind farms to power system reliability indices by increasing the peak load, recover. Increase in line capacity, which helps to improve the system reliability. However, the incremental benefit of increased transmission line capacity is reduced. Also, the benefits of the various parameters of the system can be based on the results presented are estimates. The general conclusions from this study can be applied in transmission planning for wind be useful (Figure 11 and 12).

References

1. Da Silva AML, Leandro S, Rezende LS, Manso LAF, Anders GJ. Transmissionexpansion planning: a discussion on reliability and "N−1" security criteria, In: Proceedings of the 110th International Conference (PMAPS'11), ProbabilisticMethods Applied to Power Systems (PMAPS'11); 14–17 June, 2010.
2. Wang L, Singh C. Adequacy-based design of a hybrid generating system includingintermittent sources using constrained particle swarm optimization, In: Power Engineering Society IEEE; 24–28 June, 2007.
3. Matevosyan J, Ackermann T. Comparison of international regulationsfor connection of wind turbines to the network, in: Proceedings of NordicWind Power Conference (NWPC'04), Goteborg, Sweden, March; 2004.
4. Sveca J, Soder L. 2002. Wind power in areas with limited export capabilities, In:Proceedings of the World Wind
5. Fockens S, Van Wijk AJM, Turkenburg WC, Singh C. A concise method forcalculating expected unserved energy in generation system reliability analysis. IEEE Trans. Power Syst; 6August 1991.
6. Karki R, Renewable energy credit wind power growth for system reliability,Electric Power (2007) 797–803.
7. Billinton R, Yi G. Multistate wind energy conversion system models for adequacyassessment of generating systems incorporatingwindenergy. IEEE Trans.Energy Conv; 23 March 2008.
8. Billinton R, Allan RN. Reliability Evaluation of Power Systems, 2nd edn. Plenum Press; 1996.