ISSN (Print): 0974-6846 ISSN (Online): 0974-5645

Optimal Wind Turbine Micrositing: A Case of Multi-Directional and Uniform Wind Speed

Samina Rajper* and Aijaz A. Kalhoro

Department of Computer Science, Shah Abdul Latif University Khairpur, Sindh, Pakistan; samina.rajper@gmail.com, aijazkalhoro@gmail.com

Abstract

Objectives: Wind turbine micro siting is a major issue while an appropriate wind farm layout is required in terms of maximum generation of energy and lowest cost investment. The energy production majorly depends upon the demographic conditions of the location while the investment involves the major expenses like civil works, wind turbine acquisitions etc. Many research studies have been undertaken to cope with the problem of acquiring the appropriate wind farm layout development by optimizing the wind turbine micrositing. The objective of the study is to find the optimized cost per unit power if the wind speed is constant but multi-directional. **Methods/Analysis:** The Jansen's analytical model is used to undertake the study problem for the case when the wind is at constant speed but multi-directional. **Findings:** An optimal layout for the considered problem is proposed where the wind is considered from all directions. **Novelty/Improvement:** A wind farm layout consists of 34 wind turbines producing 77760 KW per year at $311x10^{-3}$ cost per unit power is acquired that is an improved solution to optimal wind turbine micrositing for the mentioned case.

Keywords: Micrositing, Energy, Optimization, Wind Turbines, Wind Farms

1. Introduction

Wind is one of the most important form of greener solutions to the energy production. Wind farms installation depends upon lengthy and careful studies of the wind availability to the location. The wind farms can be either offshore or onshore¹. Many research studies have been undertaken to find an optimal solution for wind turbine micrositing, i.e.,²⁻⁷. The past studies (1, 4) provided the optimal solution for wind farm installation for the case if the wind speed is constant and uni- direction. In⁸ proposed the first systematic method to provide optimal solution for wind farm micrositing. The present study is undertaken to find an optimal solution for wind turbines micrositing if the wind speed is uniform but the wake is muti-directional. Jansen's Analytical wake effect model⁹ is used for the present study.

2. Materials and Methods

The present study considered the problem, i.e., "If the

wind direction is variable but the wind speed is constant" to provide the optimal layout for wind farm installation. While the wind farm layout was considered as a square grid with a separating of 200 meters and a square framework with 100 matrix areas was used. While, features of wind turbines are presented using the Table 1.

Table 1. Represents the characteristics/features of the wind turbines

Characteristics	Variable used	Value assigned
Hub Height	Z	60 meter
Rotor Radius	rr	40 meter
Thrust Coefficient	CT	0.88

2.1 Jansen's Wake Effect Model

Jansen's analytical wake effect model⁹ is used because in this model momentum is thought as conserved inside wake. Also the considered wake effect model has a general applicability in past research studies. Figure 1 is used to show the Jansen's model.

^{*} Author for correspondence

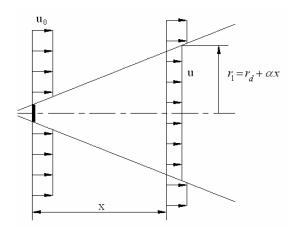


Figure 1. Schematic of wake model (9).

This model assumed that wake is turbulent. The wakes actually expand linearly downstream distance so that the model is well suited for the far wake regions. The radius of wakeat the wind turbine is equal to radius of turbine rr, and r1 is considered as the radius of wake in this model. Bitz Theory is used for determining the wind speed after the rotor; i.e.,

Equation (1) is used to calculate the wind speed where x is downstream distance of wind turbine, initially the wind speed was initially taken as 12m/s:

$$u = u_0 \left[1 - \frac{2a}{1 + \alpha(x/r_1)}\right] \tag{1}$$

Here

 u_0 = mean wind speed.

a = the axial induction factors.

While r1 can be calculated using Equation (2)

$$r_{1} = r_{r} \sqrt{\frac{1-a}{1-2a}} \tag{2}$$

 α , can be calculated using Equation (3).

$$\alpha = \frac{0.5}{\ln(z/z_0)} \tag{3}$$

In Equation (3), z_0 is value of surface roughness. In this study, plain terrain is considered thus 0.3 will be used for z_0

There is an extension for the cases when the wind turbines encounter multiple wakes from various directions.

$$u_{i} = u_{0} \left[1 - \sqrt{\sum_{i=1}^{Nt} (1 - \frac{u}{u_{0}})^{2}}\right]$$
(4)

2.2 Equation for Produced Power

Equation (5) is used to calculate the power produced

$$Power _ produced = 0.3u^3 KW$$
 (5)

2.3 Cost Model Used

The following equation is used for calculating cost of the wind turbines, this model is used in various past studies, i.e., 1,4,8,10,11.

Cost = Nt
$$\left[\frac{2}{3} + \frac{1}{3}e^{-0.00174}Nt^{2}\right]$$

2.4 Proposed Solution for Undertaken Problem

From the past studies results, it is confirmed that power produced from the wind turbine is the function of wind speed. For the complex problem where multidirectional wind speed is encountered, acquiring optimal solution is not practical. This study attempted to propose an optimal layout for the mentioned case. It is assumed that all four directions has equal opportunity to get wind speed also the wind turbines facing the direct mean wind speed can produce more power. Therefore, the optimal layout for the undertaken problem is shown using Figure 2. Whereas the objective of the study is to find the Cost/Power total.

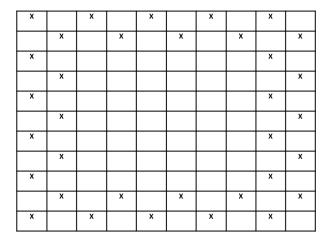


Figure 2. Optimal layout for wind farm, showing 54 wind turbines total.

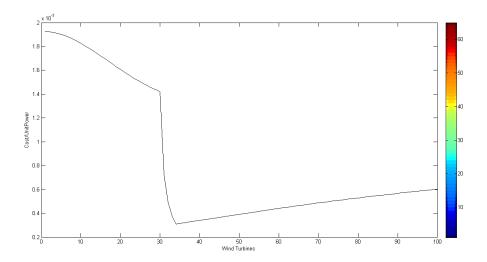


Figure 3. Shows the optimal curve for undertaken problem.

3. Results and Discussions

Using Equation (4), the objective function was acquired using 34 wind turbines. Figure 3 is used to show the resultant optimal graph for cost/unit power for each wind turbine.

The graph in Figure 2 shows that minimum cost/unit power is attained. The satisfactory power is obtained from a specific number of wind turbines. The graph shows that when the number of wind turbine increases the average cost is reducing but at 34th wind turbine the optimal results are achieved. The objective of the study was reduced cost/unit power and that is achieved. Table 2 is used to show the results of the present study.

 Table 2.
 Represents the results for the undertaken problem

Number of WT	Power Generated (KW)	Cost/unit Power
34	77760	0.000311

4. Conclusion

The undertaken has proposed an optimal wind farm layout for the case if there is uniform wind speed from various directions. At 34th wind turbine the minimum cost/unit power is achieved with maximum power generation.

5. References

1. Wagan AI, Shaikh MM, Abro R. Wind turbine micrositing by using the firefly algorithm. Applied Soft Computing. 2015; 27:450–6.

- 2. Palma J, Castro F, Ribeiro L, Rodrigues A, Pinto A. Linear and nonlinear models in wind resource assessment and wind turbine micro-siting in complex terrain. Journal of Wind Engineering and Industrial Aerodynamics. 2008; 96(12):2308–26.
- Uchida T, Ohya Y. Micro-siting technique for wind turbine generators by using large-eddy simulation. Journal of Wind Engineering and Industrial Aerodynamics. 2008; 96(10):2121–38.
- 4. Rajper S, Amin IJ. Optimization of wind turbine micrositing: A comparative study. Renewable and Sustainable Energy Reviews. 2012; 16(8):5485–92.
- Gonzalez JS, Payan MB, Santos JMR, Gonzalez-Longatt F. A review and recent developments in the optimal wind-turbine micro-siting problem. Renewable and Sustainable Energy Reviews. 2014; 30;133–44.
- Gonzalez JS, Rodriguez AGG, Mora JC, Santos JR, Payan MB. Optimization of wind farm turbines layout using an evolutive algorithm. Renewable energy. 2010; 35(8):1671– 81.
- 7. Shakoor R, Hassan MY, Raheem A, Rasheed N. The modelling of wind farm layout optimization for the reduction of wake losses. Indian Journal of Science and Technology. 2015; 8(17):1–9.
- 8. Mosetti G, Poloni C, Diviacco B. Optimization of wind turbine positioning in large windfarms by means of a genetic algorithm. Journal of Wind Engineering and Industrial Aerodynamics. 1994; 51(1):105–16.
- Jensen NO. A note on wind generator interaction; 1983. p. 1–18
- 10. Grady S, Hussaini M, Abdullah MM. Placement of wind turbines using genetic algorithms. Renewable energy. 2005; 30(2):259–70.
- 11. Marmidis G, Lazarou S, Pyrgioti E. Optimal placement of wind turbines in a wind park using Monte Carlo simulation. Renewable energy. 2008; 33(7):1455–60.