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A NEW MODEL FOR WIND FARM LAYOUT OPTIMIZATION WITH LANDOWNER DECISIONS

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Introduction

Current wind farm layout optimization research focuses on advancing optimization methods. The research includes the assumption that a continuous piece of land is readily available. In reality, wind farm development projects rely on the permission of landowners for success. When a viable wind farm site location is identified, local residents are approached for permission to build turbines on their land, typically in exchange for monetary compensation. Landowners play a crucial role in the development of a wind farm, and some land parcels are more important to the success of the project than others. In order to advance the research on wind farm optimization, this research relaxes the assumption that a continuous piece of land is available, developing a novel approach that includes landowners' decisions on whether or not to participate in the project. A Genetic Algorithm (GA) is adopted to solve the nonlinear constrained optimization problem, minimizing costs and maximizing power output of the wind farm. The optimization results of this new approach show that, for a specific wind farm layout case, we can identify the most crucial landowners prior to the negotiation process with landowners. Using this approach, a site developer can spend more resources on persuading these most-important landowners to take part in the project. This will ultimately increase the efficiency of wind farm projects, increasing energy output and saving time and money in the development stages.

Problem Formulation

The problem is formulated to answer the question: "If only a certain percentage of landowners agree to participate, which landowners are the most crucial to the success of the project?" The problem considers a plot of land owned by nine landowners, as shown in Fig. 1.

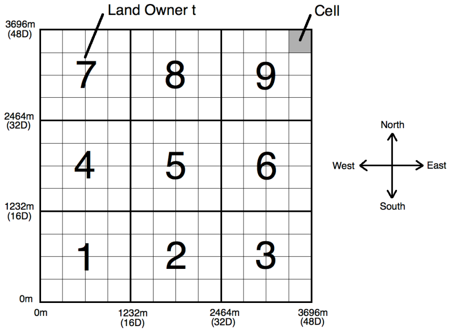

Fig.1 Problem Representation

Our objective function, similar to Mosetti et al.'s, is defined as [1]:

Minimize:

$$Cost\ of\ Energy(X) = \frac{Cost(X)}{P_{tot}(X)} = \frac{N(X)\left(\frac{2}{3}+\frac{1}{3}e^{-0.00174N(X)^2}\right)}{\sum_{i=1}^{N(X)} P_i(X)}$$

X is a 153-bit binary string design variable, shown in Fig. 2, that represents the landowners' potential decisions to participate in the project and the potential locations of wind turbines.

$$\underbrace{101111010}_{landowners'\ decisions}\quad \underbrace{0101011010\ldots\ \ldots\ \ldots 10111000}_{turbine\ locations}$$

Fig.2 Binary String Representation of X

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Wake Loss Model

When a turbine in a wind farm is extracting energy from wind, it will develop a turbulent wake that reduces the downstream wind speed [2]. Jensen's wake loss model, as shown in Fig.3, is adopted to calculate the downstream wind speed [3].

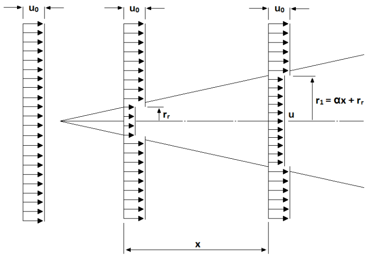


Fig.3 Wake Loss Model [2,3]

Optimization Results

Three cases are considered in this study: (a) 4 out of 9 landowners agree to participate (44%); (b) 5 out of 9 landowners agree to participate (56%); and (c) 6 out of 9 landowners agree to participate (67%). Each case takes into account three wind scenarios: 1) unidirectional uniform wind (12 m/s); and 2) uniform wind with variable direction (12 m/s from four directions), 3) non-uniform wind with variable directions (8 m/s, 12 m/s, and 17 m/s from 36 directions, as shown in Fig.4).

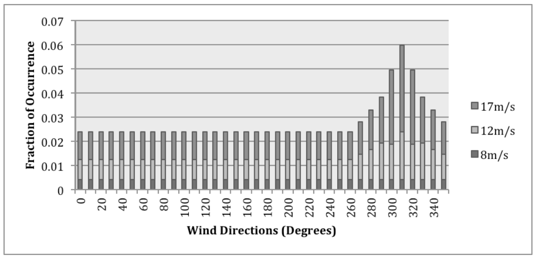


Fig.4 Non-uniform Wind with Variable Directions

The best results of the optimization program for each case study are recorded in Tab. 1:

Tab.1 Optimization Results

Unidirectional Uniform Wind Cases			
Results	Case (a)	Case (b)	Case (c)
Cost of energy	0.001740	0.001671	0.001599
Total power (megawatt)	8.09	9.97	11.84
Number of Turbines	16	20	24
Multidirectional Uniform Wind Cases			
Results	Case (a)	Case (b)	Case (c)
Cost of energy	0.001767	0.001714	0.001714
Total power (megawatt)	7.97	9.72	9.72
Number of Turbines	16	20	20
Multidirectional Non-uniform Wind Cases			
Results	Case (a)	Case (b)	Case (c)
Cost of energy	0.000851	0.000831	0.000824
Total power (megawatt)	30.31	32.40	33.34
Number of Turbines	37	39	40

Some example optimal layouts are shown as follows:

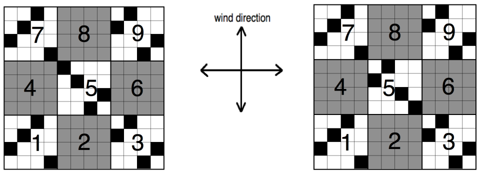
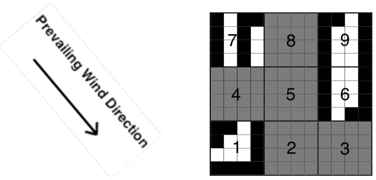
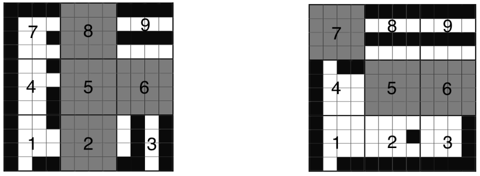


Fig.5 Multidirectional Uniform Wind Case (b)



Case (a)



Case (b) Case (c)

Fig.6 Multidirectional Non-uniform Wind Case

Conclusion

Several interesting findings can be summarized based on the results of this research:

1) More landowner participation does not necessarily guarantee less "Cost of Energy."
2) Some landowners are more crucial than others.
3) Multiple optimal layouts are available with same "Cost of Energy."

Acknowledgements

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[1] Mosetti, G., Poloni, C., and Diviacco, B., 1994, "Optimization of Wind Turbine Positioning in Large Windfarms by Means of a Genetic Algorithm," Journal of Wind Engineering and Industrial Aerodynamics, 51(1), pp. 105-116.

[2] Du Pont, B., and Cagan, J., 2010, "An Extended Pattern Search Approach to Wind Farm Layout Optimization," ASME IDETC Conference Proceedings, Aug 15-18, 2010, Montreal, Canada.

[3] Jensen, N., 1983, "A Note on Wind Generator Interaction," Risø National Laboratory, DK-4000 Roskilde, Denmark.

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