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# Enhancement of Annual Profit of a Wind Farm Using Artificial Intelligence-Based Meta-heuristic Methodology

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*Abstract*—**As greenhouse gas emission is initiating climate change, renewable power resources like wind energy are aiding nations to accomplish the carbon neutrality goal as proposed in the Paris treaty of 2015. In this paper, a novel dynamic assignment process of factors for crossover and mutation methods of genetic algorithm for expanding the yearly profit of a wind farm at Jafrabad of India. The research solutions confirm the supremacy of the proposed technique over the standard static process of allocating the probabilities of crossover and mutation methods of genetic algorithm to augment the financial profitability of the wind power generation system.**

***Keywords***—Artificial Intelligence, Genetic Algorithm, Layout Optimization, Profit Maximization, Wind Farm.

## I. Introduction

Relentless release of Green House Gases (GHGs) is contributing to global climate change [1]. Because of the untrustworthy supply of hydrocarbon-based fuels and GHG emission aftereffects, the electricity industries are steadily endeavoring for efficient usage of renewable energy resources. Wind power, vitally, is a significant and pragmatic technique for electricity generation [2]. The expenditure on generating electricity from wind has wilted markedly throughout the last few decades across many countries [3].

Researchers have scrutinized and determined the reliable locations for offshore wind energy generation in India [4]. In another study, the offshore wind power generation capacity in India was deliberated through the OSCAT statistics [5]. The offshore wind power generation capacity of India was valued and the generation outlay was optimized [6]. As the method of wind farm design necessitates multifaceted computing effort, traditional optimization techniques are incapable to maximize financial profitability. In this paper, an innovative AI-based method has been applied to maximize the yearly profit of an Indian nearshore wind farm in Jafrabad, Gujarat.

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## II. Problem Statement

The present study has been aimed at increasing the yearly profit of the nearshore wind power generation system. The objective function is stated as follows.

$$Maximize\ P_{yearly} = [M - C] \times G_{yearly} \qquad (1)$$

where $P_{yearly}$ represents the yearly profit of the wind farm, $M$ implies the marketing cost per unit of wind power, $C$ symbolizes the generation expense per unit of wind power and $G_{yearly}$ denotes the wind power generated per year. The generation expense of wind power has been calculated as per the cost function presented by an established function [7]. In this research work, the wind energy generation capacity of Jafrabad has been studied. The airflow pattern of the generation site has been presented in Fig. 1.

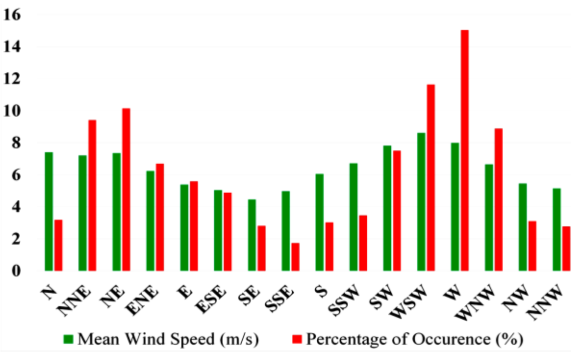


Figure 1. Wind Flow Pattern of Jafrabad, Gujarat

The considered layouts have been shown in Figs. 2 and 3.

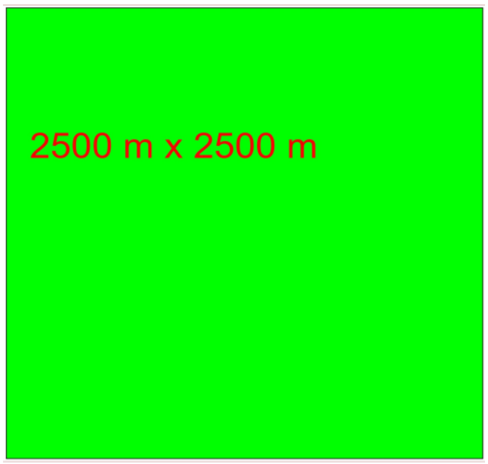


Figure 1. Layout 1 of 2500 m x 2500 m without Obstacle

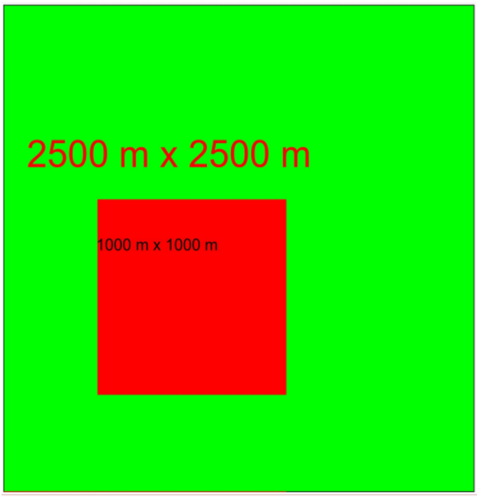


Figure 2. Layout 2 of 2500 m x 2500 m with Obstacle of 1000 m x 1000 m

## III. Optimization Algorithm

Genetic Algorithm has been employed for calculating the yearly profit of the wind farm at Jafrabad.

The algorithm has been articulated as follows [8].

1. Originate the fundamental factors.
2. Formulate the population randomly.
3. Calculate the aptness of all distinct chromosomes.
4. Accomplish the arithmetic crossover technique.
5. Complete the mutation method.
6. Find out the fitness of the fresh individuals attained by crossover and mutation methods.
7. Pick out the most excellent outcome according to the choice of the decision-maker.

Accompanied by the familiar scheme of assigning static values, this research work has engaged an original dynamic system for employing the factors of crossover and mutation.

The dynamic crossover probability has been computed as follows.

$$c_{dynamic} = c_a + \left\{(c_a - c_b)\left(R_x/R_{high}\right)^{\frac{1}{8}}\right\} \quad (2)$$

where $c_{dynamic}$ symbolizes the dynamic crossover opportunity. $c_a$ and $c_b$ indicate the confines of the crossover factor. $R_x$ represent the existing recurrence tally and $R_{high}$ is the maximum repetition bound.

The dynamic mutation probability has been calculated as follows.

$$m_{dynamic} = m_a + \left\{(m_a - m_b)\left(R_x/R_{high}\right)^{\frac{1}{8}}\right\} \quad (3)$$

where $m_{dynamic}$ denotes the growing mutation probability. $m_a$ and $m_b$ are the bounds of the mutation parameter.

## IV. Results and Discussion

In the present research, the marketing price of electricity from wind farm in India has been deemed as USD 0.033/kWh [9] [10].

In cooperation with the novel dynamic technique, the typical static assignment approach for crossover and mutation probabilities has been considered to determine relative ability.

The values of some characteristics associated with the deliberated layout design problem have been offered in Table 1.

TABLE I.

PARAMETER VALUES

| FACTOR | VALUE |
|---|---|
| $C_a$ | 0.4 |
| $C_b$ | 0.3 |
| $m_a$ | 0.04 |
| $m_b$ | 0.03 |
| Populace Size | 20 |
| Highest Generation Count | 50 |
| Static Crossover Factor | 0.4 |
| Static Mutation Factor | 0.05 |
| Turbine Power | 1500 kW |
| Blade Radius | 38.5 m |
| Inter-Turbine Gap | 308 m |
| Minimum Working Air Speed | 12 km/hr. |
| Maximum Working Air Speed | 72 km/hr. |
| Capital Cost per Turbine | USD 750,000 |
| Expense per Sub-Station | USD 8,000,000 |
| Yearly Operational Cost | USD 20,000 |
| Interest | 3% |
| Active Life | 20 years |
| Turbine per Sub-Station | 30 |

The optimum positions of turbines for both layouts using both optimization methods have been displayed in Figs. 4-7.

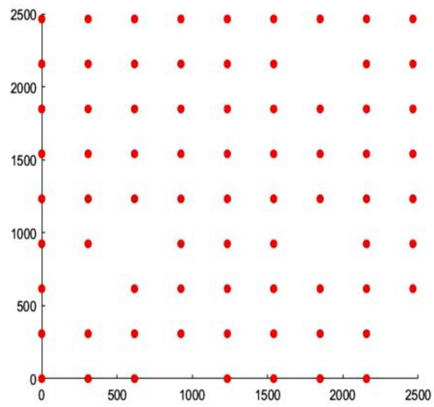


Figure 4. Optimal Placement of Wind Turbines for Layout 1 Using Novel Dynamic Assignment Method for Crossover and Mutation Factors of Genetic Algorithm

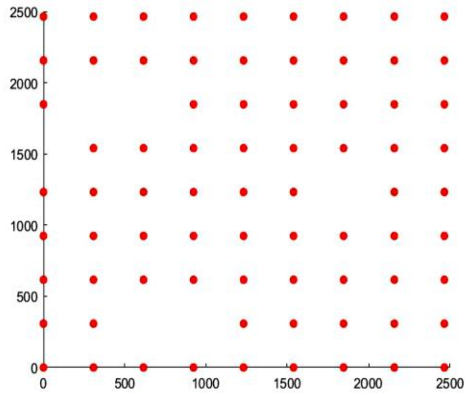


Figure 5. Optimal Placement of Wind Turbines for Layout 1 Using Standard Static Assignment Method for Crossover and Mutation Factors of Genetic Algorithm

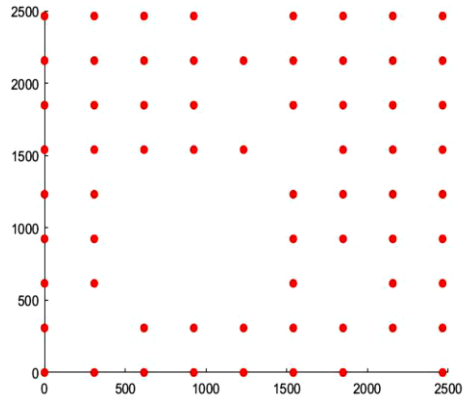


Figure 6. Optimal Placement of Wind Turbines for Layout 2 Using Novel Dynamic Assignment Method for Crossover and Mutation Factors of Genetic Algorithm

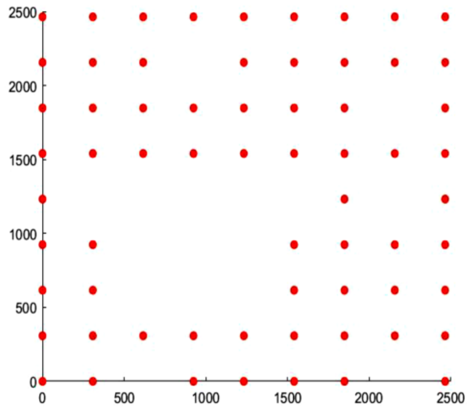


Figure 7. Optimal Placement of Wind Turbines for Layout 1 Using Standard Static Assignment Method for Crossover and Mutation Factors of Genetic Algorithm

Proportional assessments of the optimal yearly profits and number of wind turbines achieved by all methods of assigning the possibilities of crossover and mutation events of genetic algorithm for both of the landscape designs have been offered in Table 2 and 3 respectively.

TABLE II.
ANALYSIS OF OPTIMAL YEARLY PROFIT

| OPTIMIZATION METHOD | LAYOUT 1 | LAYOUT 2 |
|---|---|---|
| Proposed Dynamic | USD 17,013 | USD 15,459 |
| Standard Static | USD 16,873 | USD 15,135 |

TABLE III.
ANALYSIS OF OPTIMAL COUNT OF WIND TURBINE

| OPTIMIZATION METHOD | LAYOUT 1 | LAYOUT 2 |
|---|---|---|
| Proposed Dynamic | 74 | 66 |
| Standard Static | 75 | 65 |

The research outcomes approve the predominance of the proposed novel dynamic method of assigning crossover and mutation possibilities over the standard static method for both layouts as it achieved the superior annual profit. The enhanced economic permanence of the wind farm can aid the curbing of GHG discharge for the electricity generation businesses.

## V. CONCLUSIONS

Renewable energy solutions like wind power can help nations to achieve carbon neutrality goals as proposed by the Paris treaty of 2015. The present research proposes a novel dynamic method for assigning the factors of crossover and mutation techniques of GA with wind flow data of Jafrabad of India. The research outcomes confirm the superiority of the proposed method over the standard genetic algorithm for raising the annual profit of the proposed wind farm. The existing research can introduce immaculate openings for wind power generation system design with meta-heuristic procedure.


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