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## **An Innovative Artificial Intelligence-Driven Metaheuristic Approach for Boosting the Profitability of Wind Power Generation Systems**

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### **ABSTRACT**

*When climate change is prompting cataclysmic repercussions of various human activities universally, wind power generation systems propound a pertinent substitute to traditional hydrocarbon-based fuels for dwindling greenhouse gas discharges. Financial effectiveness is a crucial aspect of carbon-neutralization of power generation industries as propositioned in the Paris accord of 2015. The present study intends to boost the yearly profit of wind power generation systems by implementing an innovative transformation of the Genetic Algorithm approach. A novel dynamic method for apportioning the crossover and mutation probabilities has been applied to optimize the deemed objective. Authentic air-flow form of an onshore wind power generation site in India has been engaged for computing the yearly profit. The study outcomes substantiate the advantageous capability of the proposed innovative approach for increasing the financial viability of wind power generation systems with two randomly chosen topography situations*

***Index Terms** Crossover, Genetic Algorithm, Mutation, Profitability Maximization, Wind Farm.*

***Reference** to this paper should be made as follows: D. Wilson, S. Rodrigues, C. Segura, I. Loshchilov, F. Hutter, G. L. Buenfil, A. Kheiri, E. Keedwell, M. Ocampo-Pineda, E. Özcan, S. I. V. Peña, B. Goldman, S. B. Rionda, A. Hernández-Aguirre, K. Veeramachaneni and S. Cussat-Blanc, "Evolutionary computation for wind farm layout optimization," *Renewable Energy*, Vol. 10, No. 1, pp. 18-27., 2018.*

### **1 INTRODUCTION**

The interminable discharge of greenhouse gases is raising the atmospheric temperature and uncharacteristic climatological circumstances activating the largescale weather shift of the world [1]. Renewable power generation methods recommend a booming substitute in the middle of the constantly swelling intercontinental apprehension for the unreliable reserve of hydro-carbon fuels and their horrifying minuses on the biosphere [2]. Phenomenally, the application of renewable energy escalated by 3% in 2020, although the requirement of hydrocarbon-based fuels diminished as a result of pandemicallied restraints [3]. Together with minimal emission benefit, non-traditional energy sources like wind energy are entailed to remain sustainable by suggesting economical generation expense by superior reliability and minimal expenditure for repairs to further de-carbonization of energy generation sector [4].

The Wind Power Generation (WPG) expenditure has diminished significantly over the previous few years intercontinentally [5]. Scholars from each corner of the world are persistently struggling to enhance the cost-effectiveness of WPG trades to empower countries in accomplishing their emission curtailment ambitions as rapidly as practicable [6].

Artificial Intelligence (AI)-based meta-heuristic methods like Genetic Algorithm (GA) have been utilized for WPG project in Gökçeada isle [7]. Saroha and Aggarwal [8] presented a recreation envisioned for WPG assessment with GA and Neural Network (NN). An NN-endowed system with well known Meta-heuristic techniques like Swarm Intelligence (SI) and GA has been recommended for the WPG forecast [9]. Roy and Das [10] have implemented GA with SI for WPG outlay curtailment. A relational analysis of GA and Binary SI has been also offered to restrain the WPG expenses [6].

While the maximum number of studies aspired for shrinking the WPG expense, more studies are to be directed toward widening the scope of economic stability for wind power enterprises for

accomplishing the 2015 Paris treaty pledges made by several governments and international associations.

This study intends to attain higher yearly profit at a nearshore WPG site in India and two randomly designated terrain settings. Owing to the convolution of the WPG method, traditional optimization approaches are incompetent to operate at such circumstances. AI-based meta-heuristic procedures have been formerly utilized in diverse industrial disciplines and are pertinent for the current optimization condition for their robustness and rapid calculation strength [11] - [16].

## **II. PROBLEM PREPARATION**

The wind power engrossed by WPG system is formulated as follows.

$$P_w = \frac{1}{2} \rho_a A v^3 C_p \cos \alpha \quad (1)$$

where,  $P_w$  stands for the generated wind power,  $\rho$  is the density of flowing wind,  $A$  signifies the swept area,  $v$  is the speed of air,  $C_p$  denotes the Betz constant and  $\alpha$  is the angular fault of yaw system [6], [17].

The present study is aimed for augmenting the yearly profit of a wind farm. The objective function is computed as follows.

$$f_{yr} = [S_M - G] \times P_{annual} \quad (2)$$

where  $f_{yr}$  stands for the annual profit,  $S_M$  is the vending charge per unit of wind energy,  $G_w$  signifies the generation charge per unit of wind energy and  $P_{annual}$  symbolizes the wind energy generated annually.

The generation cost of wind energy has been computed as per the cost function presented by Wilson *et al.* [18]. In this paper, the WPG competence of Jafrabad, a nearshore city of India, has been explored.

The wind-flow form of Jafrabad city has been offered in Fig.1.

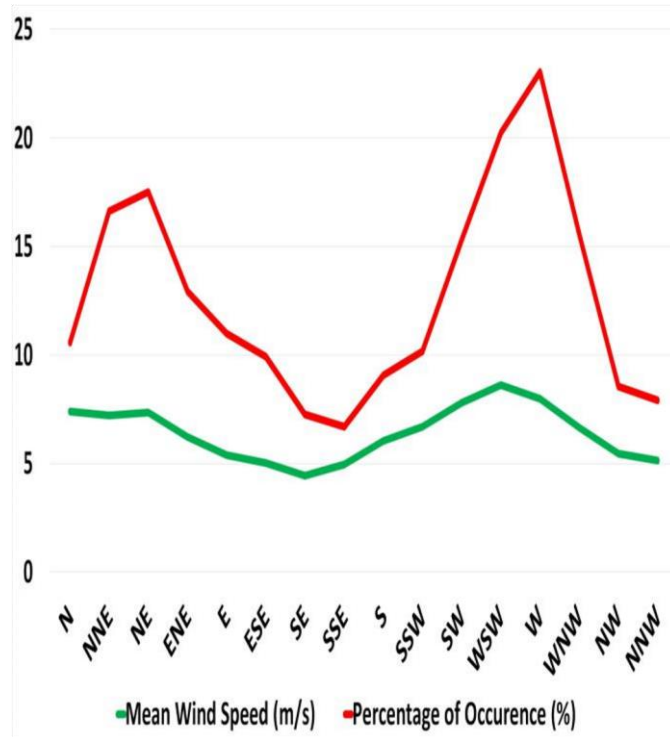


Fig. 1. Wind Flow Pattern of Jafrabad, Gujarat

The considered layouts for evaluating the objective have been shown in Figs. 2 and 3.

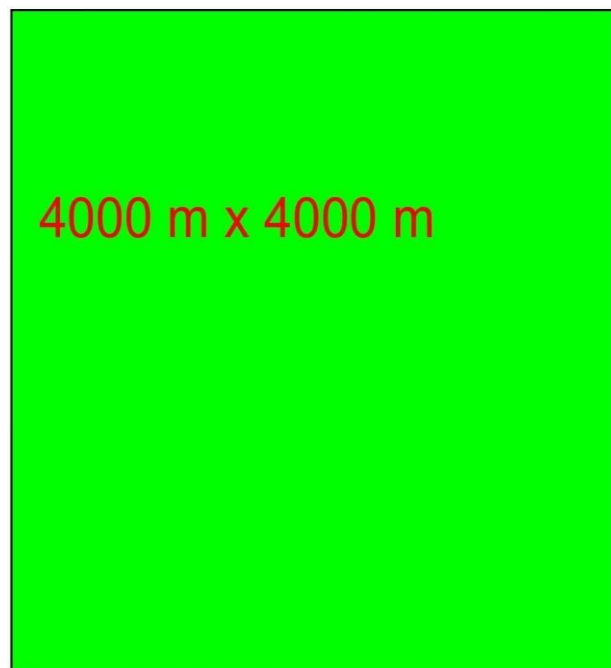


Fig. 2. Layout 1 without Obstruction

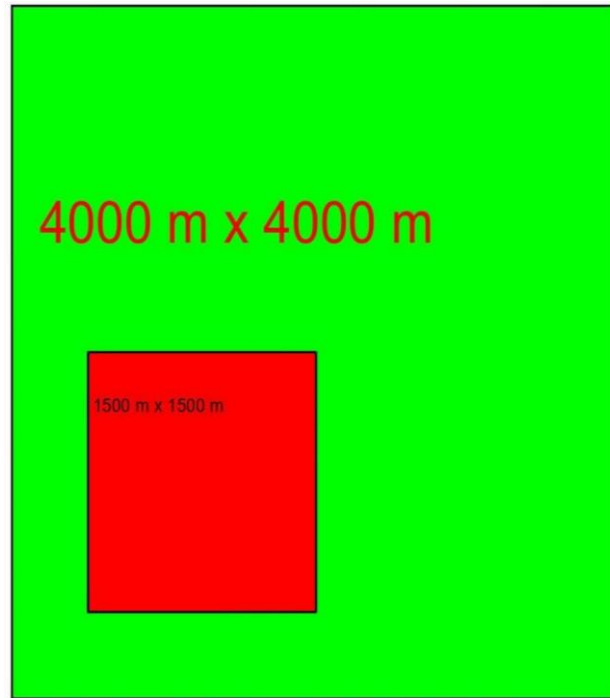


Fig. 3. Layout 2 with an Obstruction of 1500 m x 1500 m

### **III. OPTIMIZATION ALGORITHM**

GA has been exercised in the present study to evaluate the optimum yearly profit of the wind farm for the air flow form of Jafrabad and two dissimilar terrain situations. GA is an eminent AI-abetted meta-heuristic process mimicking the progression of biological preference and supervening the intent of distinguished inventor Alan Turing to develop an 'information machine' [19].

GA has been employed in the existing study along with a relative evaluation of two dissimilar techniques for selecting the possibilities of crossover and mutation procedures. The algorithm has been succinctly presented in the following manner [12].

- 1) Create the rudimentary features like populace magnitude, reiteration amount, prospects for crossover, and mutation.
- 2) Form the populace arbitrarily.
- 3) Compute the appropriateness of all discrete chromosomes.
- 4) Complete the arithmetic crossover method as follows.
  - a) Elect a numeral randomly between 0 and 1. If it is less than the possibility of the crossover method, recommend the parental component.
  - b) Commence the crossover action.
  - c) Reassess the significance of the descendants.
  - d) If the inheritor is realistic, integrate it into the latest population.
- 5) Attain the mutation technique in the following manner.
  - a) Designate a numeral randomly between 0 and 1. If it is less than the probability of the mutation method, recommend the parental chromosome.

- b) Commence the mutation activity.
- c) Review the suitability of the mutated elements.
- d) If the mutated unit is practical, insert it into the unsullied populace.
- 6) Determine the suitability of the fresh components formed by crossover and mutation approaches.
- 7) Choose the most leading outcome realizing the preference of the choice-maker.

Along with the recognized system of allocating static values, this study has employed a pioneering dynamic technique for appointing the parameters of crossover and mutation. The dynamic crossover chance has been calculated in the following manner.

$$cd = cx + \{(cx - cy)(Rc / Rmax)^{1/2}\}$$

(3) where cd is the dynamic crossover possibility. cx and cy are the bounds of the crossover parameter. Rc is the present recurrence number and Rmax stands for the highest recurrence limit. The dynamic mutation possibility has been computed as per the following manner.

$$md = mx + \{(mx - my)(Rc / Rmax)^{1/2}\}$$

(4) where md is the increasing mutation chance. mx and my are the limits of the mutation factor.

#### IV. RESULTS AND ANALYSIS

Meta-heuristic tactics have been employed extensively in the WPG farm design. The intention of the present study is to increase the yearly profit of WPG system at Jafrabad, In-dia using an innovative bio-motivated meta-heuristic method. Jafrabad is a nearshore city in the Indian state of Gujarat. The marketing price of wind power in India has been deemed as USD 0.033/kWh [20]. In cooperation with the novel dynamic technique, the typical fixed allocation approach for crossover and mutation probabilities has been considered to compute relative capability. The values of several parameters allied to the deemed optimization procedure have been shown in Table 1

TABLE I VALUES OF DIFFERENT FACTORS RELATED TO THE PROPOSED META-HEURISTIC METHOD

Parameter	Corresponding Value
$c_x$	0.45
$c_y$	0.35
$m_x$	0.045
$m_y$	0.035
Populace Dimension	20
Maximum Generation Number	50
Static Crossover Probability	0.35
Static Mutation Probability	0.035
Turbine Output	1.5 MW
Blade Diameter	77 m
Inter-Turbine Space	308 m
Least Operative Wind Speed	12 km/hr
Highest Operative Wind Speed	72 km/hr
Capital Expenditure per Turbine	USD 750,000
Expense per Sub-Station	USD 8,000,000

*Regression Based Sub – Image Matching Methodology For Recognizing An Indian Paper Bill With A Partially Captured Bill Image*

Annual Operational Expense	USD 20,000
Interest Rate	3%
Expected Working Life of Wind Turbine	20 years
Wind Turbine per Sub-Station	30

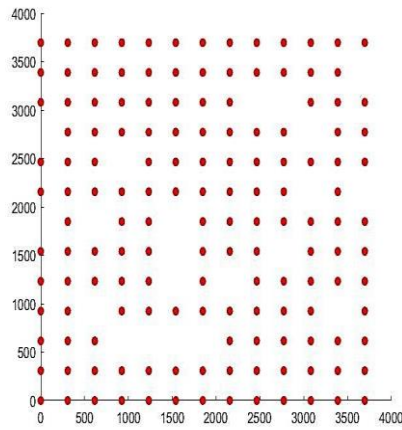


Fig. 4. Optimal Placement of WTs for Layout 1 Employing the

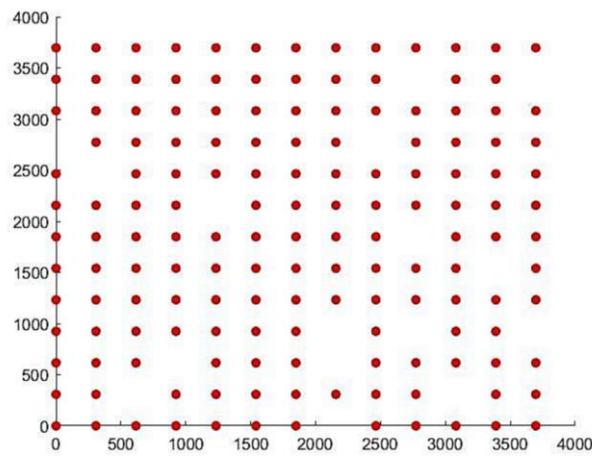


Fig. 5. Optimal Placement of WTs for Layout 1 Employing the Static Approach for Appointing the Probabilities of Crossover and Mutation Processes of GA

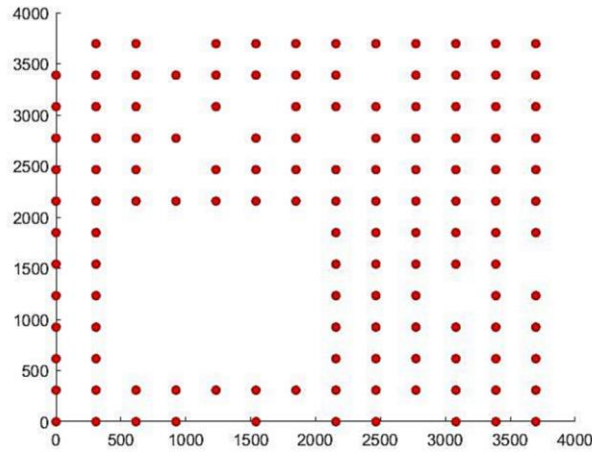


Fig. 6. Optimal Placement of WTs for Layout 2 Employing the Innovative Dynamic Approach for Appointing the Probabilities of Crossover and Mutation Processes of GA

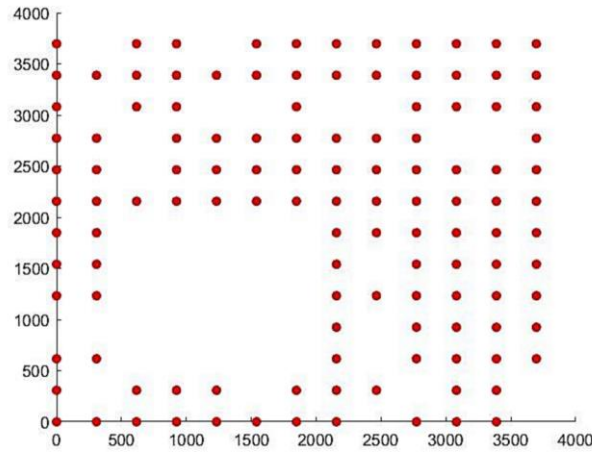


Fig. 7. Optimal Placement of WTs for Layout 1 Employing the Static Approach for Appointing the Probabilities of Crossover and Mutation Processes of GA

Comparative evaluations of the optimum annual profits and count of WTs attained by all approaches of appointing the probabilities of crossover and mutation processes of GA for both of the topography plans have been presented in Table 2.

**TABLE II ASSESSMENT OF OPTIMUM ANNUAL PROFIT ATTAINED WITH BOTH OPTIMIZATION METHODS**

Optimization Process	Layout 1	Layout 2
Static Method	USD 34,660	USD 29,006
Novel Dynamic Method	USD 35,130	USD 29,500

**TABLE III ASSESSMENT OF OPTIMUM NUMBER OF WT ATTAINED WITH BOTH OPTIMIZATION METHODS**

Optimization Process	Layout 1	Layout 2
Static Method	153	122
Novel Dynamic Method	148	131

The research solutions confirm the superiority of the proposed innovative dynamic method of allocating crossover and mutation probabilities over the recognized static approach for both layouts as it realized the greater yearly profit. The improved fiscal stability of the WPG system can support the curtailment of greenhouse gas release for the power generation industries

## **V. CONCLUSION**

Universal establishments are incessantly struggling in the course of reducing the emission by the effectual appliance of renewable energy techniques like wind energy as intended by the Paris accord of 2015. This research aims for augmenting the annual profit of the WPG system with an advanced dynamic tactic for assigning the crossover and mutation parameters. The optimization outcomes approve the improved appropriateness of the innovative dynamic method over the standard static technique for enriching the WPG layout plans with the maximum annual profit. The envisioned technique can support the WPG industries to plan a rationally viable WPG farm with the genuine contemplation of several cost-connected features and adaptable wind flow conditions. The current study can cause the immaculate potential for WPG system improvement and enable the decarbonization of the worldwide energy segment.

## **ACKNOWLEDGMENT**

The first author admits the fiscal support of the TEQIP unit of Jadavpur University for the present research effort.

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