JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Expanding the Financial Profitability of an Indian Wind Power Generation System with Artificial Intelligence-Assisted Meta-heuristic Process

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Abstract: Climate change is affecting human societies universally irrespective of their socioeconomic ranks. The continuous generation of greenhouse gases is an important cause of global climate change. Several nations have committed to curtailing their greenhouse gas emission and signed the Paris accord of 2015 to constrain the upsurge of the surface air temperature of our planet. Effectual handling of resources like wind power can help the electricity generation businesses to achieve their carbon neutrality targets. Being the second most populated nation in the world, it turns out to be extremely vital for India to use its wind power generation capacity efficiently to propel its booming economy as well as fulfilling its emission cut goals. In this paper, an artificial intelligence-supported meta-heuristic tactic has been projected to augment the economic profitability of a wind power generation site near the western shore of India. The investigation outcomes verify the advantage of the proposed procedure over the conventional genetic algorithm approach for the wind farm layout optimization technique.

***Index Terms* – Artificial Intelligence, Genetic Algorithm, Meta-heuristic Technique, Profitability Expansion, Wind Farm.**

I. Introduction

Together with lower emission gain, renewable energy generation techniques like wind power are entailed to generate financial benefit for attracting the global investment towards the thriving economic superpower like India. For fulfilling the greenhouse gas release diminution commitments made by the Indian government, more cost-efficient Wind Power Generation (WPG) systems are needed to be installed and made operational throughout the country as early as possible. WPG cost has collapsed intensely over the previous few decades internationally [1]. Researchers are uninterruptedly struggling to aid the WPG industries to remain commercially reasonable while compared with the conventional hydrocarbon-based fuels through the appliance of Artificial Intelligence (AI)- sustained meta-heuristic tactics [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15].

II. Literature Review

Genetic Algorithm (GA) has been applied for WPG farm design in Gökçeada isle [16]. Saroha and Aggarwal [17] presented a model intended for WPG estimate with GA and Neural Network (NN). An NN-enabled method with Particle Swarm Optimization (PSO) and GA has been proposed for WPG forecast [18]. Roy and Das [19] have implemented GA with PSO for WPG expense curtailment. A comparative study of GA and Binary PSO has been offered to decrease the WPG spending. In this paper, a novel modification of GA has been proposed for WPG farm design for the Gulf of Khambhat region of India.

III. Problem Design

The present research has been aimed at expanding the yearly profit of an offshore WPG farm. The objective function has been expressed as follows.

$$P_Y = [S_P - G_E] \times E_Y \quad (1)$$

where P_Y signifies the annual profit, S_P is the selling value per unit of wind energy, G_E denotes the generation cost per unit of wind power and E_Y symbolizes the wind energy generated annually. The generation cost of wind energy has been computed as per the expense function presented by Wilson et al. [20]. The wind flow pattern of the Gulf of Khambhat has been offered in Fig.1

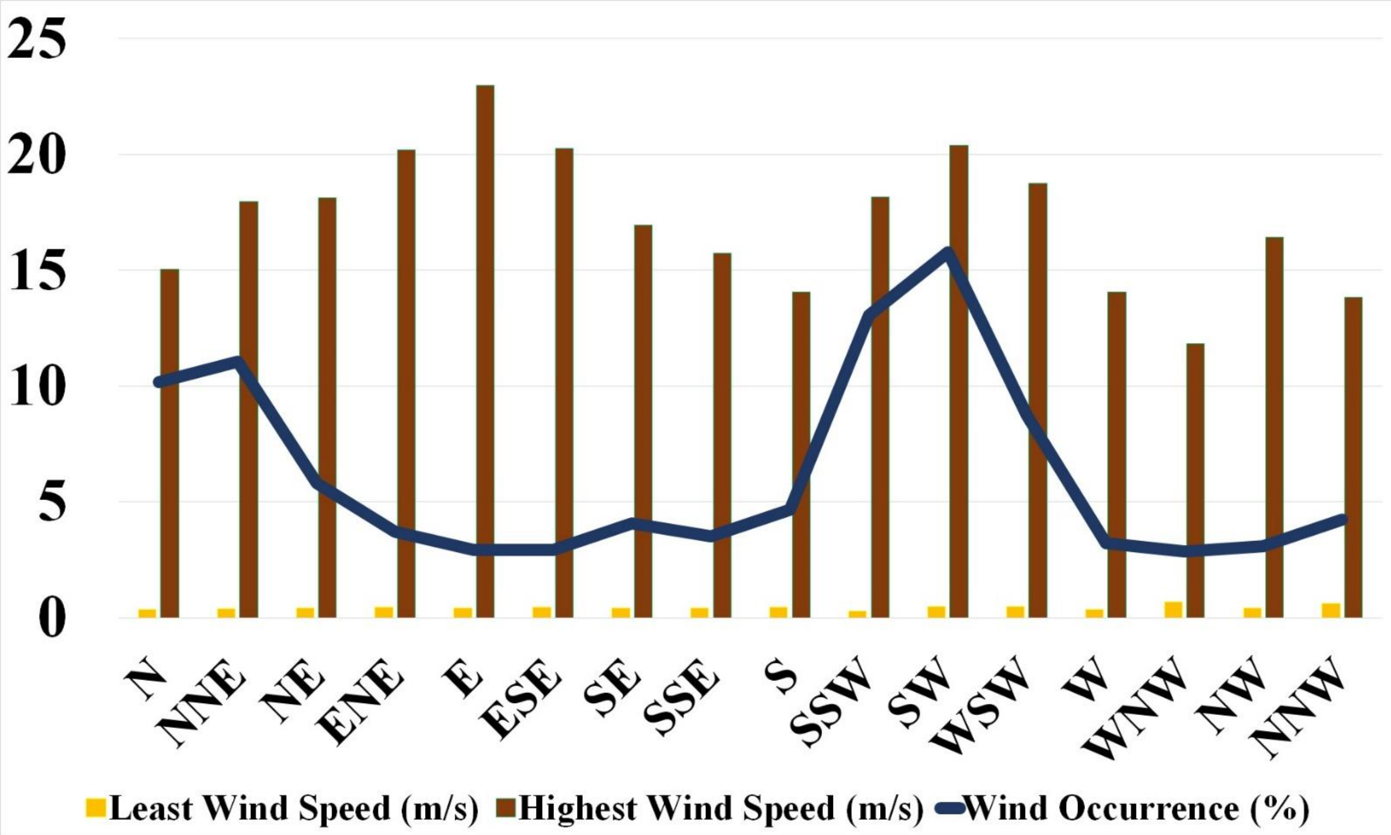

Figure 1. Wind Flow Pattern at the Gulf of Khambhat, India

IV. Terrain Settings

Two randomly chosen terrain conditions have been selected for computing the yearly profit of the WPG farm. The terrain conditions have been presented in Figs. 2 and 3.

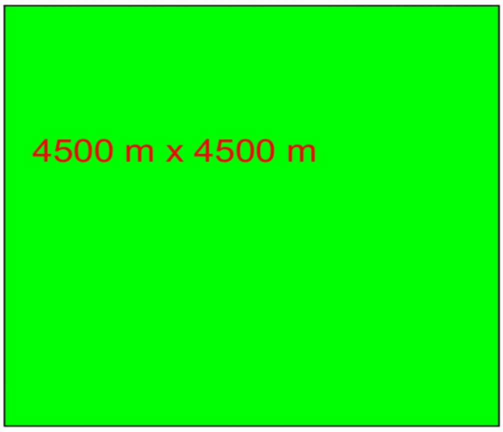

Figure 2. Layout 1 without Obstruction

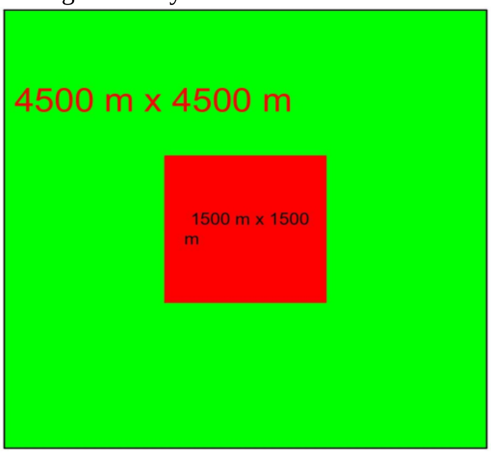

Figure 3. Layout 2 with an Obstruction of 1500 m x 1500 m

V. Optimization Algorithm

The GA has been engaged in several optimization problems for enhancing single and multiple criteria problems. The algorithm has been presented as follows [21].

1) Create basic factors like populace dimension and repetition count.
2) Form the populace randomly.
3) Compute the fitness of all distinct chromosomes.
4) Accomplish the arithmetic crossover tactic.
5) Complete the mutation method.
6) Examine the fitness of the novel chromosomes created by crossover and mutation tactics.
7) Select the most optimal result according to the decision of the choice-maker.

Together with the conventional system of considering static values, this study has engaged a novel dynamic tactic for appointing the factors of crossover and mutation. The crossover probability has been calculated as follows.

$$c_d = c_i + \left\{(c_i - c_j)(R_x/R_h)^{8/9}\right\} \quad (2)$$

where c_d denotes the dynamic crossover factor. c_i and c_j are the limits of the crossover factor. R_x is the current recurrence number and R_h signifies the highest reiteration number. The dynamic mutation factor has been calculated as follows.

$$m_d = m_i + \left\{(m_i - m_j)(R_x/R_h)^{8/9}\right\} \quad (3)$$

where m_d is the mutation factor. m_i and m_j are the limits of the mutation factor.

VI. Results and Discussion

The values of several factors associated with the considered optimization process have been exhibited in Table 1.

Table 1: Values of Factors

Parameter	Corresponding Value
c_i	0.45
c_j	0.35
m_i	0.045
m_j	0.035
Populace Dimension	20
Maximum Generation Number	50
Static Crossover Factor	0.35
Static Mutation Factor	0.035
Output	1.5 MW
Blade Radius	38.5 m
Inter-Turbine Gap	308 m
Minimum Operative Wind Flow Speed	12 km/hr
Maximum Operative Wind Flow Speed	72 km/hr
Capital Expenditure per Wind Turbine	USD 750,000
Expense per Sub-Station	USD 8,000,000
Yearly Operational Expenditure	USD 20,000
Interest	3%
Probable Life	20 years
Wind Turbine per Sub-Station	30

The marketing value of wind power has been deemed as USD 0.033/kWh. The optimal placements of Wind Turbines (WTs) for layout 1 have been shown in Figs 4-5. The optimal placements of WTs for layout 2 have been shown in Figs. 6-7.

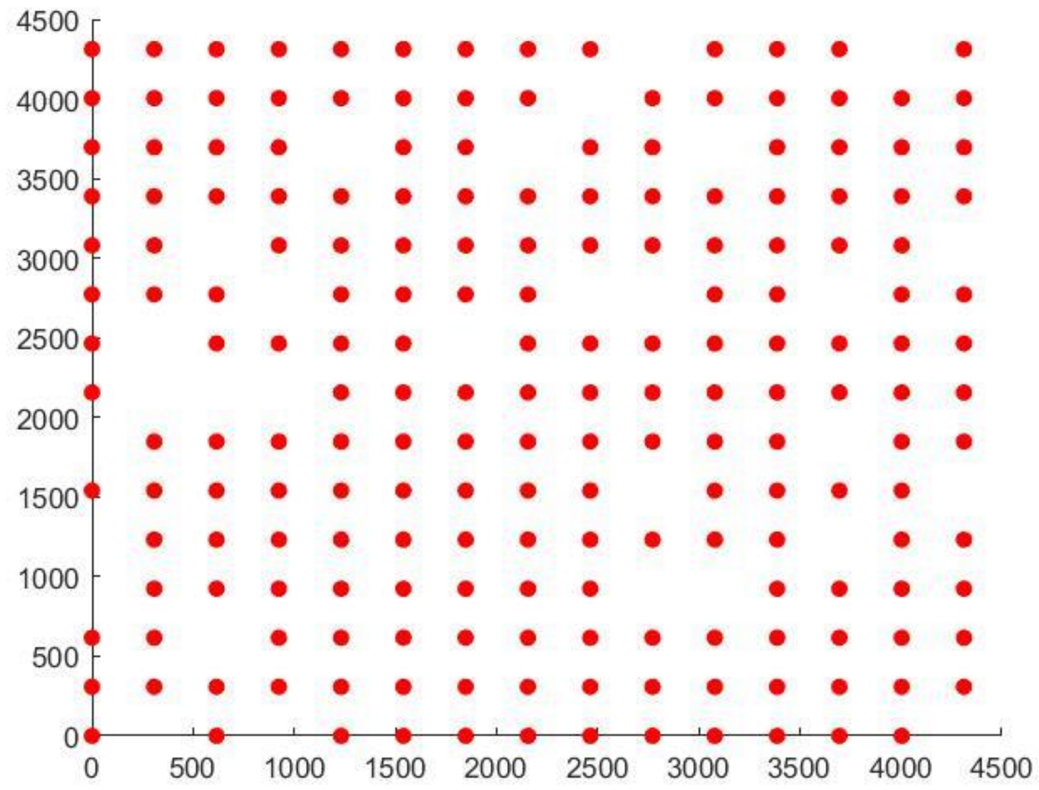

Figure 4. Optimal Placement of WTs for Layout 1 Using the Proposed Dynamic Method for Approach the Factors of Crossover and Mutation Processes of GA

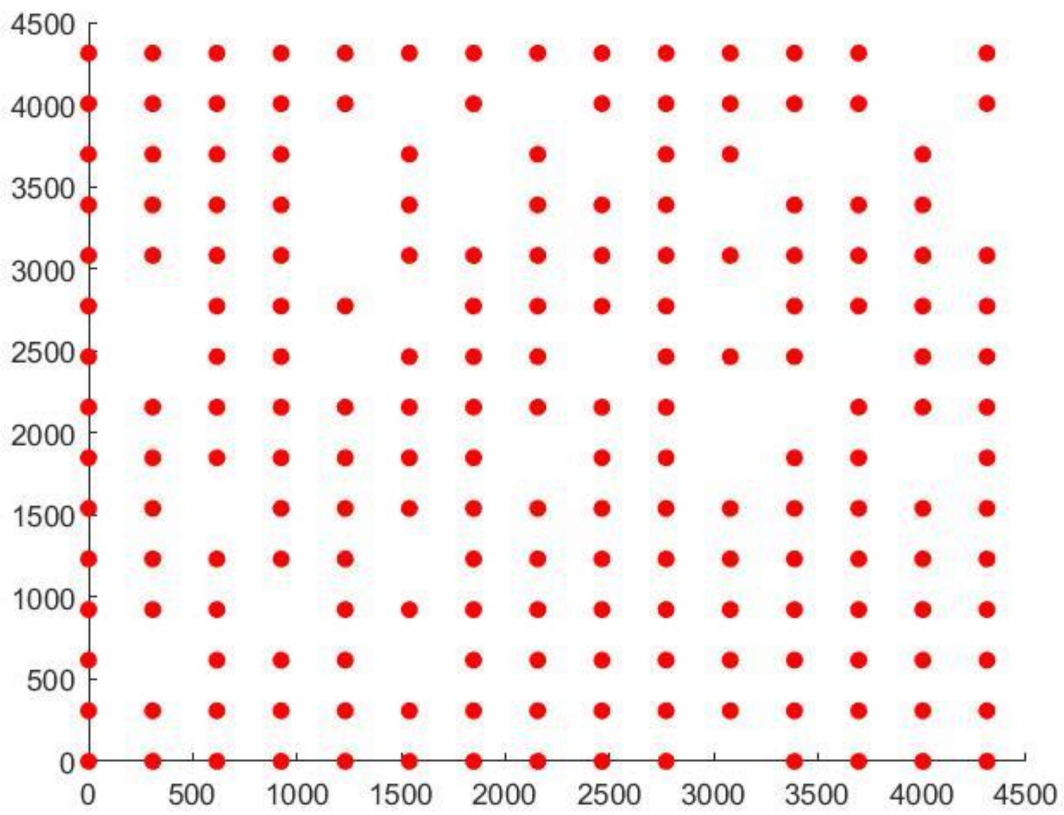

Figure 5. Optimal Placement of WTs for Layout 1 Using the Static Method for Approach the Factors of Crossover and Mutation Processes of GA

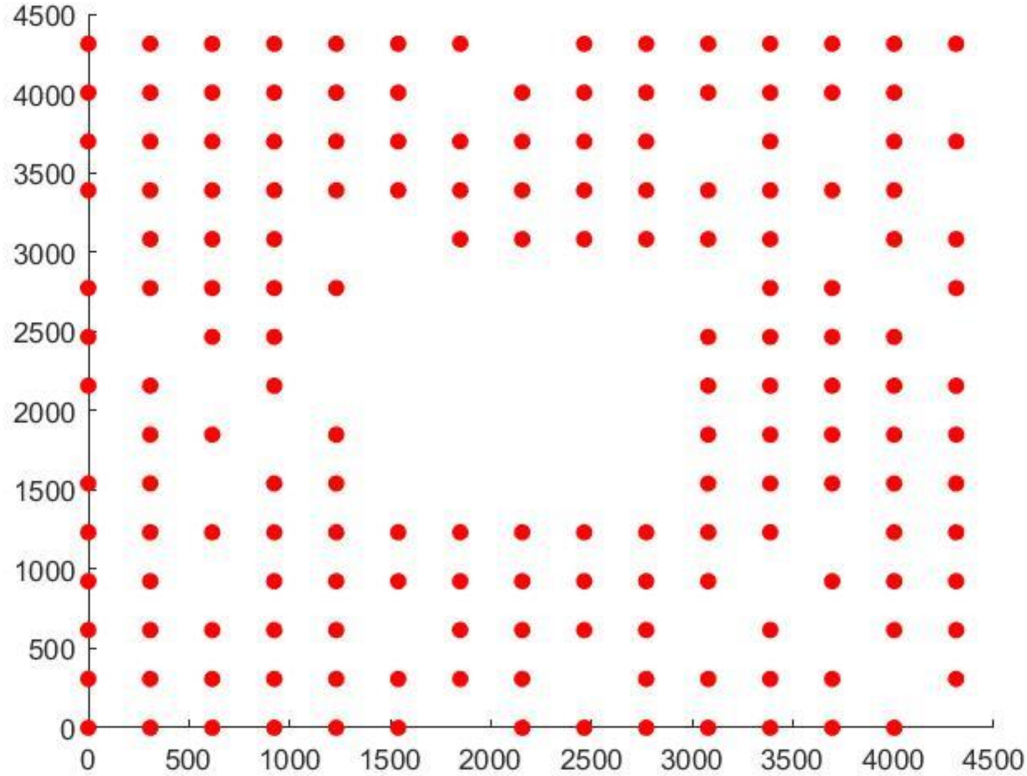

Figure 6. Optimal Placement of WTs for Layout 2 Using the Proposed Dynamic Method for Approach the Factors of Crossover and Mutation Processes of GA

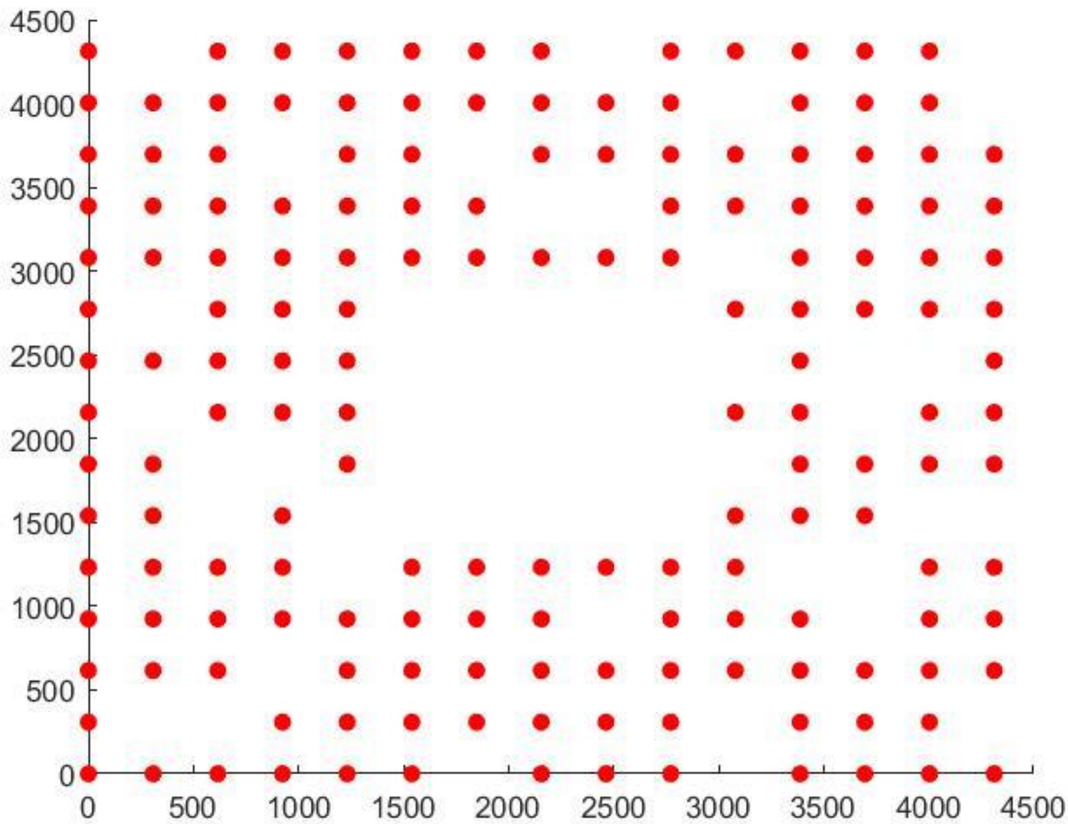

Figure 7. Optimal Placement of WTs for Layout 2 Using the Static Method for Approach the Factors of Crossover and Mutation Processes of GA

Comparative evaluation of the optimal annual profits and number of WTs attained by both tactics of appointing the factors of crossover and mutation procedures of GA for both of the terrain plans have been presented in Table 2 and Table 3 respectively.

Table 2 Comparison of Optimal Annual Profit

Optimization Method	Layout 1	Layout 2
Static Method	USD 52,896	USD 48,010
Novel Dynamic Method	USD 56,012	USD 49,464

Table 3 Comparison of Optimal Number of WTs

Optimization Method	Layout 1	Layout 2
Static Method	192	165
Novel Dynamic Method	195	170

The optimization results confirm the preeminence of the proposed novel dynamic method of appointing crossover and mutation factors over the standard static method for both layouts.

VII. Conclusion

The United Nations is continually trying for reducing the greenhouse gas emission by proficient usage of renewable resources like wind energy. AI techniques have been used in several technical fields for optimization procedures [22] [23]. This work aims for boosting the annual profit of wind farms employing a novel dynamic technique for appointing the crossover and mutation factors. The optimization outcomes validate the augmented viability of the innovative dynamic method over the static tactic for enhancing the WPG farm designs with the highest annual profit. The current work can initiate new prospects for wind farm design.

IX. Acknowledgment

The first author admits the financial contribution of the TEQIP department of Jadavpur University.

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