ARTIFICIAL INTELLIGENCE-DRIVEN COMPETENT PLAN OF AN INDIAN WIND FARM

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Abstract

India is at the moment the fifth largest economy and sustains the second biggest population in the world. To uphold its phenomenal economic growth, it would need cheap and reliable energy resources in the coming decades like any other nation. Moreover, the central government of India has announced its goal to attain carbon neutrality by 2070 following the pledges of the Paris treaty of 2015. To realize such a great aim, India needs to use its environment-friendly energy generation technologies rapidly and efficiently. Wind energy can help coastal states of India to generate electricity with a minimal carbon footprint and boost their economic progress. This current paper focuses on designing a wind farm in the western part of India using artificial intelligence methodologies. An innovative technique to escalate the efficiency of the genetic algorithm has been proposed to augment the economic output of the wind farm.

Keywords: Annual Profit, Genetic Algorithm, Indian Power Generation Businesses, Profit Development, Wind Energy.

JEL Classification: O13, Q42

1. Introduction

The wind power generation market used to be dominated by the United States of America and European nations till the initial years of the current century. It is at present enormously guided by Asian countries like the People's Republic of China and India. Due to high industrialization and economic advancement in the past few decades, they are consuming an unprecedented amount of energy every year.

The rapid influx of fossil fuels is expediating the greenhouse effect and is greatly responsible for the abnormal increase of the surface air temperature of the planet. This temperature increment is also affecting the weather patterns and causing Climate Change in every continent of the Earth.

To restrain the calamitous effect of Climate Change, most of the members of the United Nations have agreed to sign an international treaty in Paris in 2015. This agreement mandates the efficient usage of renewable resources like wind energy to check the emission throughout the Globe.

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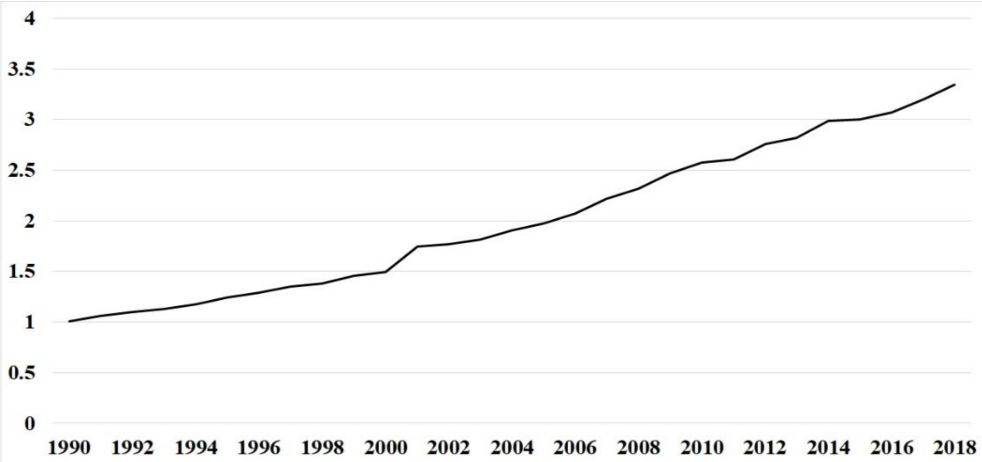

Figure 1: Total Greenhouse Gas Emissions of India in Billion-Ton from 1990 to 2018

One of the most alluring qualities of wind energy in India is that the generation expenditure is nearly 35% lesser than the electricity produced by thermal power plants, and this is projected to drop by 7% by the end of this year.

In 2020, Moth Flame Optimization Algorithm was utilized for the power generation capacity of both onshore and offshore places in India. In the similar year, a bigger offshore wind farm arrangement for the western shore of Gujarat was evaluated with weather analysis and generation outlay was predicted.

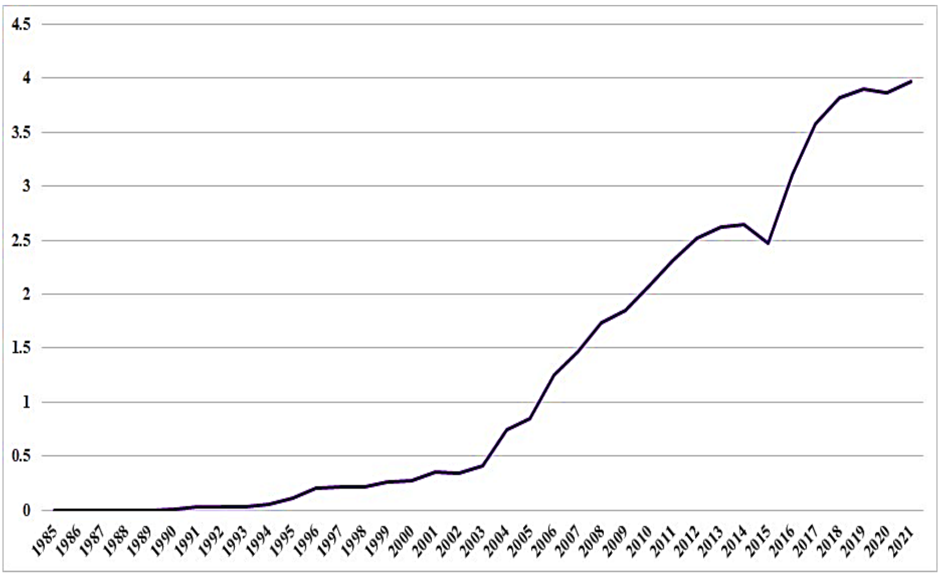

Figure 2: Portion of Electricity Generation from Wind in Percentage

Researchers have tried to improve the design of wind farm layouts and enhance financial efficiency. The assessment of the offshore wind energy generation capacity and restriction of the generation expenditure in the Indian shoreline region through conventional algebraic modelling have been endeavored. The wind energy generation possibility in the Jafrabad area of India has been discovered with Artificial Intelligence-based techniques.

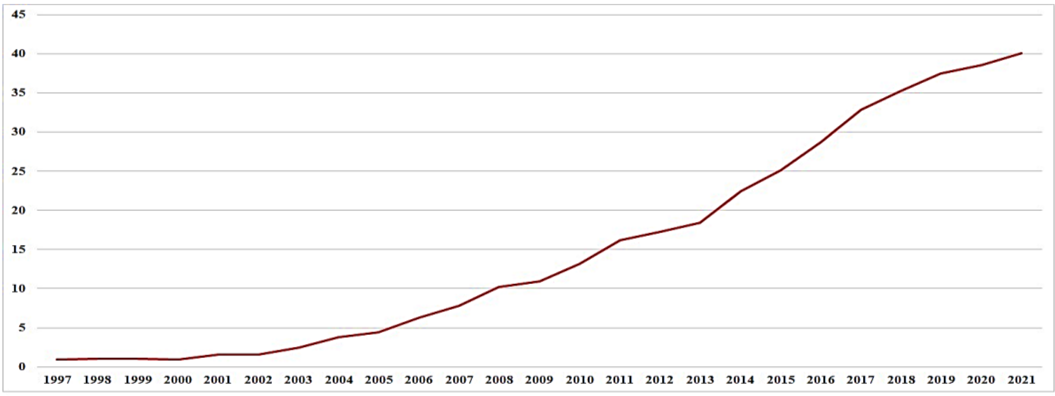

Figure 3: Growth of Indian Wind Power Installed Capacity in GW

2. Objective Formulation

The objective of the current study is to enhance the yearly financial output of the wind farm and it can be calculated as per Eq. (1).

$$Maximize\ A = [B - C] \times E_{yr} \tag{2}$$

Where A represents the annual profit, B suggests the selling charge per unit of wind power, C signifies the generation charge per unit of power and E_{yr} terms the annual generated wind energy. The present study deemed the expenditure function acknowledged by Wilson et al. (2018) for the Jafrabad area. The flow of air form deemed in the existing study has been shown in Fig. (4).

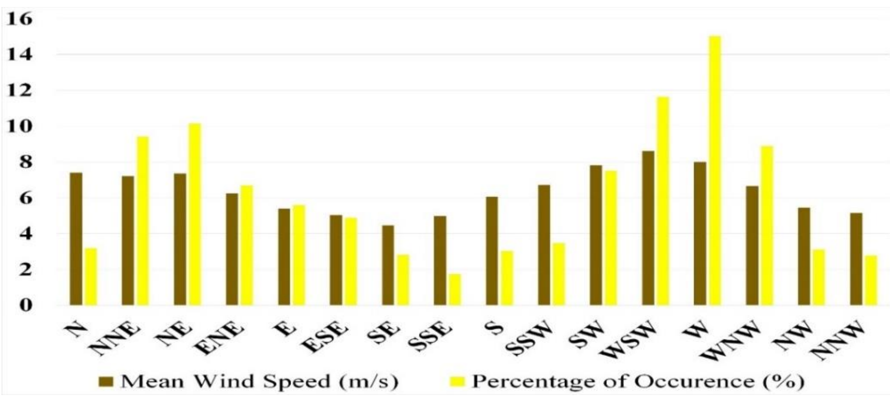

Figure 4: Wind Flow Configuration for Jafrabad Area of Gujarat, India

3. Optimization Algorithm

Genetic Algorithm (GA) has been exercised to optimize the yearly profit for onshore wind farms in Jafrabad, India. This nature-motivated Artificial Intelligence (AI) meta-heuristic algorithm has been applied in several engineering domains. GA has been briefly expressed in the following manner.

1. Determine the critical components like populace quantity and recurrence quantity.
2. Recruit the population unsystematically.
3. Review the relevance of the discrete chromosomes.
4. Start the crossover system.
5. Accomplish the mutation scheme.
6. Review the suitability of the fresh chromosomes shaped by crossover and mutation approaches.
7. Stipulate the most enhanced consequence concerning the choice-maker's fondness.

This research has betrothed a state-of-the-art dynamic technique for placing the magnitudes of crossover and mutation factors. The dynamic crossover probability has been calculated as per Eq. (2).

$$c_v = c_s + \left\{0.1 \times (R_c/R_m)^{\frac{8}{7}}\right\} \quad (2)$$

Where c_v means the growing crossover prospect. c_s denotes the static value of the crossover factor. R_c indicates the contemporary recurrence count and R_m symbolizes the maximum reiteration count. The dynamic mutation probability has been considered as per Eq. (3).

$$m_v = m_s + \left\{0.01 \times (R_c/R_m)^{\frac{8}{7}}\right\} \quad (3)$$

Where m_v means the mounting mutation prospect, m_s denotes the static value of the mutation factor.

4. Results and Discussions

1500 W wind turbine of wheel radius 38.5 m has been involved for the existing research. To decline the wake loss concern, the distance between the two nearby turbines has been upheld as 8 times the wheel radius. The cut-in airstream speed has been considered as 3.5 m/s whereas the cut-off airstream speed for the deemed turbine is 20 m/s to avert conceivable ravages.

The wind farm cost-related features and their values obligatory for calculating the generation charge function have been considered as demarcated by Bhattacharjee et al. (2021). Three layouts of dimensions 3000 m x 3000 m, 4000 m, and 5000 m x 5000 m have been considered. The static values for crossover and mutation factors have been considered as 0.4 and 0.05 respectively.

The maximum generation count has been deemed as 50. The optimal layout plans have been displayed in Figs. (5)-(10).

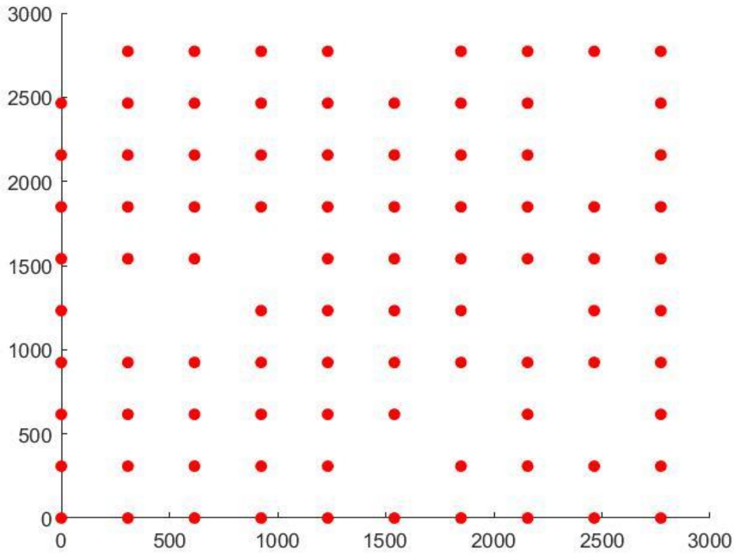

Figure 5: Optimal Placement of Wind Turbines Using Genetic Algorithm with Static Values of Crossover and Mutation Factors for Layout of Dimension 3000 m x 3000 m

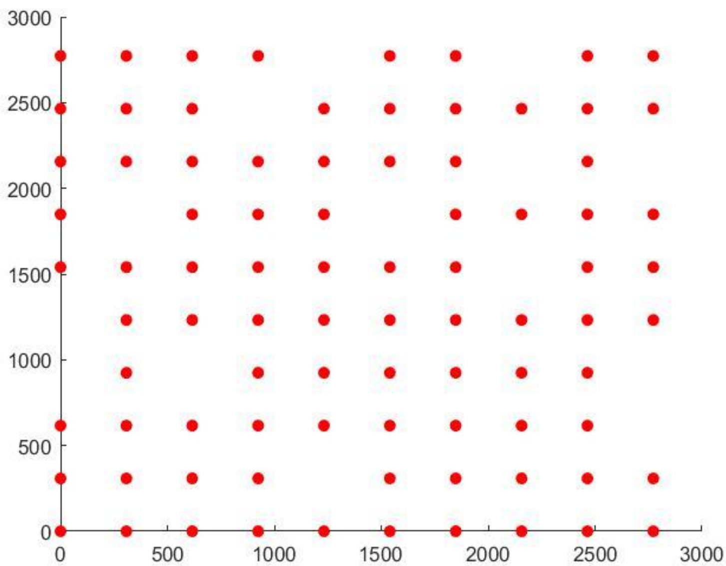

Figure 6: Optimal Placement of Wind Turbines Using Genetic Algorithm with Dynamic Values of Crossover and Mutation Factors for Layout of Dimension 3000 m x 3000 m

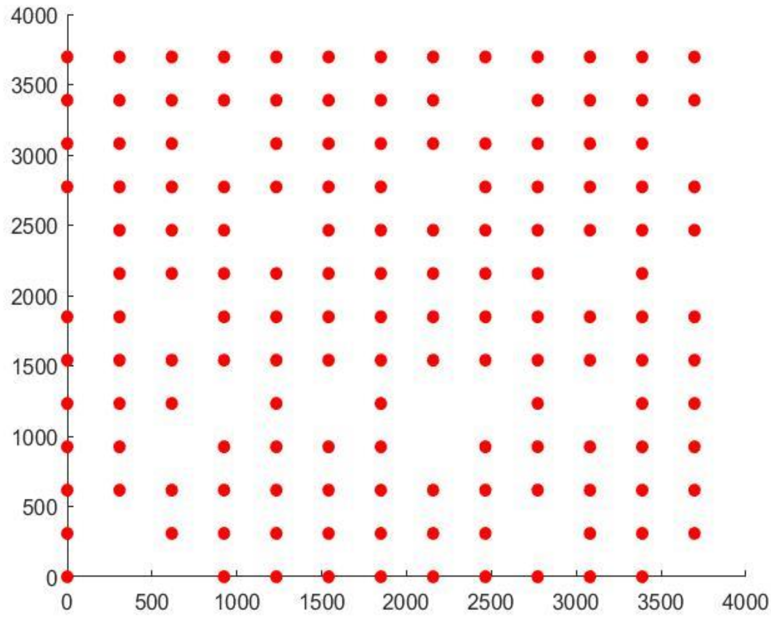

Figure 7: Optimal Placement of Wind Turbines Using Genetic Algorithm with Static Values of Crossover and Mutation Factors for Layout of Dimension 4000 m x 4000 m

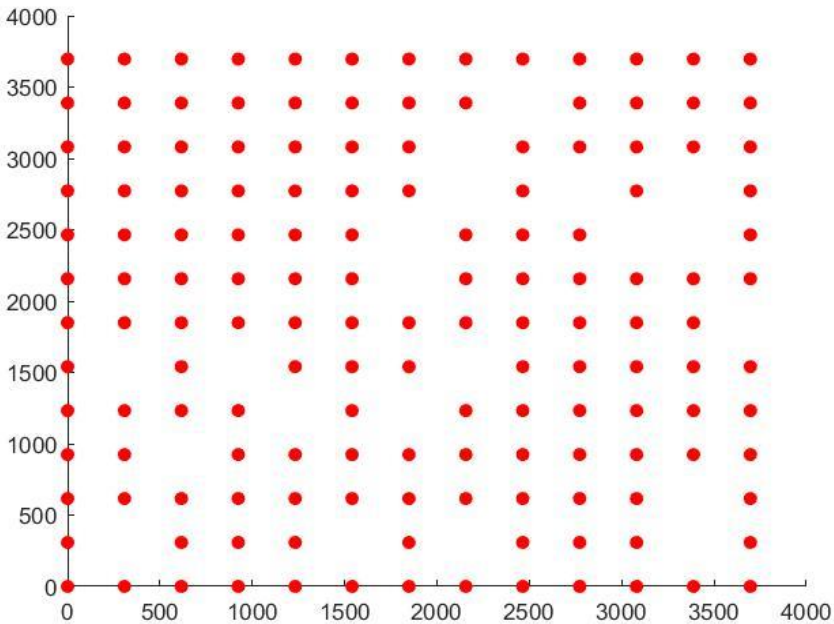

Figure 8: Optimal Placement of Wind Turbines Using Genetic Algorithm with Dynamic Values of Crossover and Mutation Factors for Layout of Dimension 4000 m x 4000 m

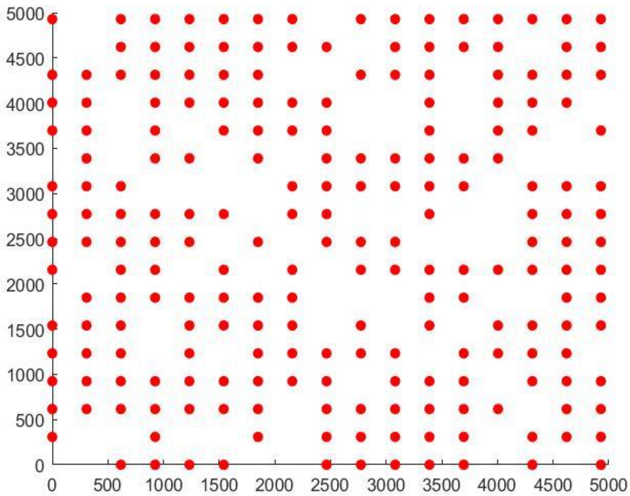

Figure 9: Optimal Placement of Wind Turbines Using Genetic Algorithm with Static Values of Crossover and Mutation Factors for Layout of Dimension 5000 m x 5000 m

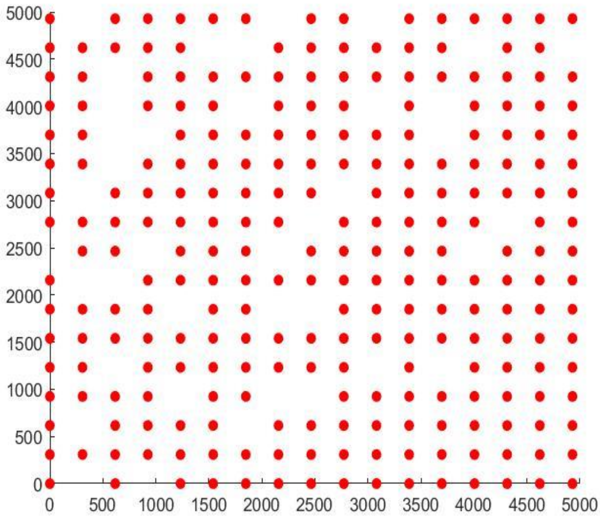

Figure 10: Optimal Placement of Wind Turbines Using Genetic Algorithm with Dynamic Values of Crossover and Mutation Factors for Layout of Dimension 5000 m x 5000 m

The selling price for wind energy in India has been considered as USD 0.033/kWh for computing the annual profit of the wind farm. The optimal values of annual profit and consequent count of wind turbines attained by both approaches of GA have been presented in Table 1.

Optimization Method	Optimal Yearly Profit for Layout of 3000 m x 3000 m (in USD)	Optimal Amount of Wind Turbines Layout of 3000 m x 3000 m	Optimal Yearly Profit for Layout of 4000 m x 4000 m (in USD)	Optimal Amount of Wind Turbines Layout of 4000 m x 4000 m	Optimal Yearly Profit for Layout of 5000 m x 5000 m (in USD)	Optimal Amount of Wind Turbines Layout of 5000 m x 5000 m
Standard GA with Static Factors for Crossover and Mutation	20647	89	32989	147	53511	213
Proposed Enhanced GA with Dynamic Factors for Crossover and Mutation	20944	86	33567	148	57885	250

Table 1 Assessment of Optimal Outcomes

The research consequences confirm the advantage of the proposed dynamic approach over the static method of appointing the factors of crossover and mutation approach for GA as it attained a better annual profit as revealed in Table 1.

5. Conclusion

The study aims to augment the yearly profit of a wind farm in Jafrabad, India. The optimization consequences approve the higher suitability of the proposed dynamic methods of allocating the prospects of crossover and mutation of GA to enhance the financial output of the farm. The present work can create immaculate possibilities for wind farm plan enrichment and monetary constancy of wind power projects.

6. Acknowledgement

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