# APPLIANCE OF METAHEURISTIC ALGORITHMS FOR IMPROVING THE DESIGN OF A WIND POWER GENERATION SYSTEM IN THE INDIAN STATE OF TAMIL NADU

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**Abstract**

Wind power is significant and consistently expanding renewable energy generation technology. For progressing the environment-friendly changeover of the electricity generation trades as recommended by the Paris agreement of 2015, wind power generation farms need to remain financially viable through effective optimization of their layouts. This paper aspires to enhance the annual profit of an onshore wind power generation site at Kayathar town in the Indian state of Tamil Nadu by employing artificial intelligence-enabled metaheuristic algorithms like Genetic Algorithm and Binary Particle Swarm Optimization Algorithm. The optimization outcomes have been compared for three randomly selected terrain settings. The evaluation solutions confirm the enhanced capability of the Genetic Algorithm over the Binary Particle Swarm Optimization Algorithm for improving the profitability of the proposed wind farm in India.

**Keywords**: Annual Profit, Binary Particle Swarm Optimization, Genetic Algorithm, Profit Expansion, Wind Farm.

**JEL Classification**: -

## 1. Introduction

The utilization of energy is regarded as one of the several crucial facets of the fiscal expansion of every present-day nation. As the global energy generation expanded from 8794 Mtoe in 1990 to 14410 Mtoe in 2019 with the intensification of economic activities, the conventional energy reserves are exhausting at an unprecedented pace. Renewable energy generation methods suggest a prosperous substitute amidst escalating worldwide anxiousness for the undependable supply of hydrocarbon-based fuels and their menacing consequences on the environment. The outlay of wind power has decreased noticeably over the preceding decades around the globe. Outstandingly, throughout the Covid-19 linked

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restraints in 2020, the appliance of renewable power technologies underwent a surge of 3% while the requirement of all hydrocarbon-based fuels nosedived throughout the world.

The incessant discharge of $CO_2$ and other greenhouse gases into the atmosphere due to human actions are escalating average surface air temperature and abnormal weather patterns which further cause the climate change of the Earth. Due to the worldwide concern for the limited reserve of traditional fossil fuels and their critical consequences on ecology, renewable energy resources present prosperous substitutes for the international scientific society.

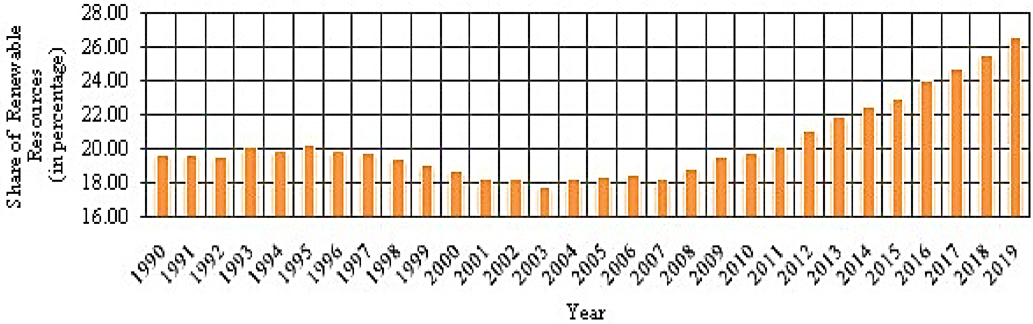


Figure 1: Yearly Statistics of Share of Renewable Resources in Global Energy Production from 1990 to 2019

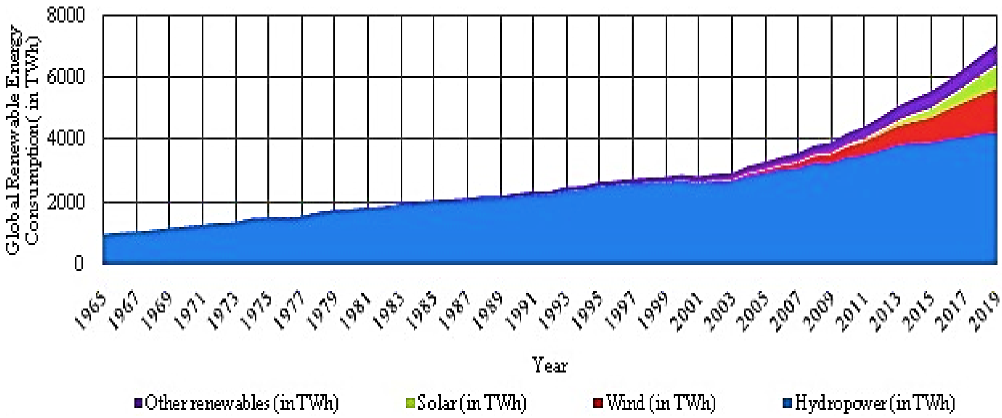


Figure 2: Yearly Statistics of Global Renewable Energy Consumption from 1965 to 2019

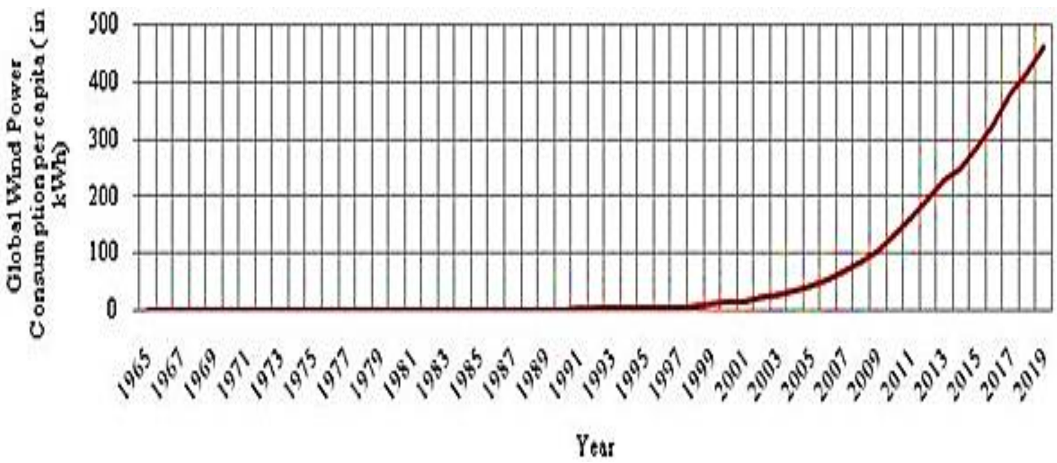


Figure 3: Yearly Statistics of Global Wind Power Consumption Per Capita from 1965 to 2019

The Wind Power Generation (WPG) market, which remained principally dominated by European nations and the USA till the first decade of the present century, is at present tremendously influenced by Asian countries like the People's Republic of China (Global 1$^{st}$ in WPG) and India (Global 4$^{th}$ in WPG) with 36.3% and 5.8% WPG capacity share respectively. Along with low GHG emission advantage, renewable energy solutions like WPG systems are needed to remain feasible by proposing economical generation costs through superior reliability and minimal cost of maintenance to facilitate the de-carbonization of worldwide energy systems to a greater extent.

Murali et al. scrutinized and calculated the credible sites for offshore WPG. The economic applicability was also assessed. Nagababu et al. measured the offshore WPG ability in India and calculated it with the OSCAT satellite statistics. Singh and Kumar S.M. attempted the assessment of the offshore WPG capability and reduce the generation expenditures. The development of financial effectiveness of the Indian offshore WPG enquires more study aids the green switch of the Indian electricity segment.

The present research concentrates on expanding the yearly profit of a WPG farm in Kayathar of Tamil Nadu with metaheuristic techniques like Genetic Algorithm (GA) and Binary Particle Swarm Optimization Algorithm (BPSOA). The optimization outcomes have been compared to assess their relative efficiency.

## 2. Objective Formulation

The power generated by a Wind Turbine (WT) can be computed as per Eq. (1).

$$P_{WT} = \frac{1}{2}\rho_{air} A \vartheta^3 C_{Betz} cos\varphi \qquad (1)$$

where $P_{WT}$ indicates the generated power, $\rho_{air}$ stands for the density of the flowing wind, $A$ is the swept area, $v$ signifies the speed of air, $C_{Betz}$ represents the Betz factor and $\varphi$ denotes the angular defect of the yaw system. The objective function can be computed in Eq. (2).

$$Maximize\ T = [K - L] \times P_{yr} \tag{2}$$

Where $T$ symbolizes the yearly profit, $K$ implies the selling charge per unit of wind energy, $L$ signifies the generation charge per unit of WPG and $P_{yr}$ designates the annual generated wind energy. The present study considered the WPG expenditure function acknowledged by Wilson et al. (2018) for estimating the yearly profit of a WPG farm in Kayathar, Tamil Nadu. The airflow form deemed in the current study has been displayed in Fig. (4).

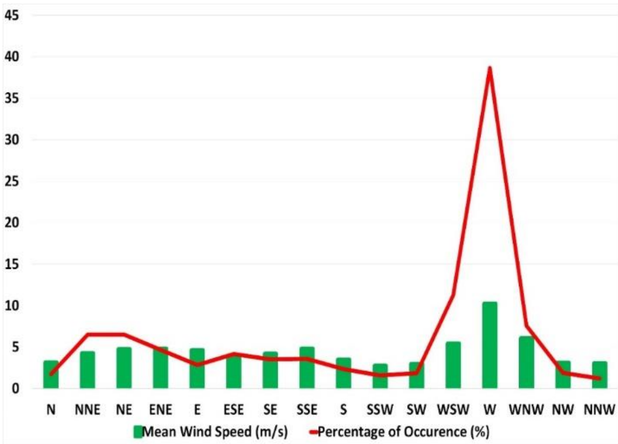


Figure 4. Wind Flow Form for Kayathar, India

The layouts considered have been exhibited in Figs. (5)-(7). One layout is without any obstruction and others are with obstructions within their bounds.

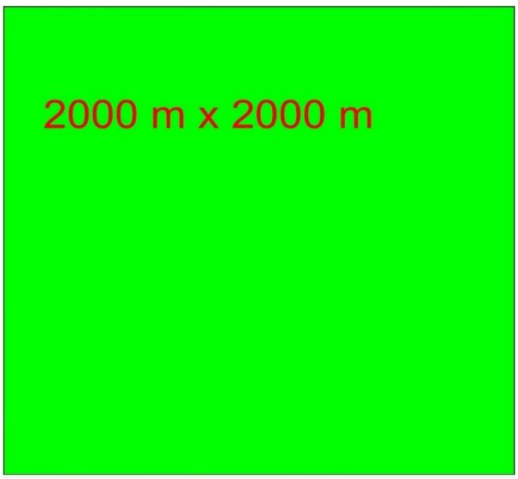


Figure 5. Layout 1 of 2000 m x 2000 m

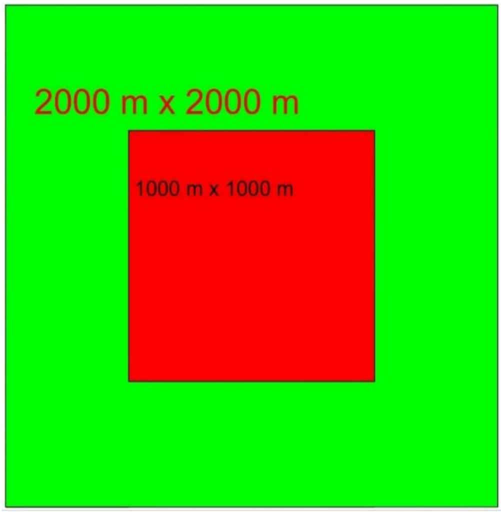


Figure 6. Layout 2 with One Obstruction of 1000 m x 1000 m

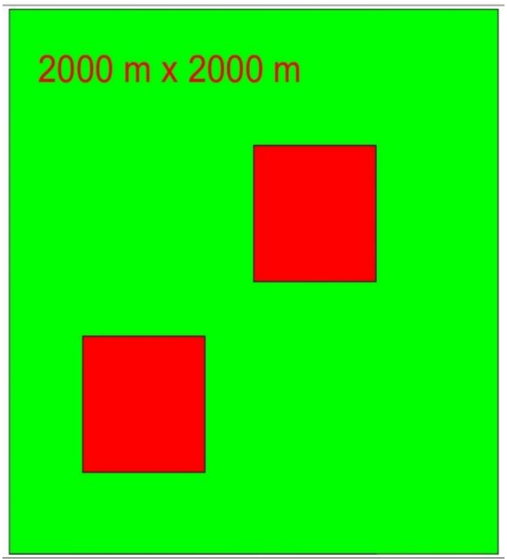


Figure 7. Layout 3 with Two Obstructions of 500 m x 500 m

**3. Genetic Algorithm**

GA is a bio-inspired metaheuristic technique to suggest outcomes for optimization problems by characterizing the development of natural partiality. It has been utilized in numerous technical domains. The algorithm has been described as follows.

1. Ascertain the vital elements like populace level and repetition amount.
2. Initiate the populace indiscriminately.
3. Inspect the appositeness of individual chromosomes.

4. Commence the crossover procedure.

5. Complete the mutation method.

6. Appraise the fittingness of the novel components formed by crossover and mutation methods.

7. Specify the most improved outcome regarding the choice-maker's preference.

## 4. Binary Particle Swarm Optimization Algorithm

Particle swarm intelligence represents the common conduct of a set of bees by connecting the necessary information associated with the universal and local optimum outcomes. The Binary Particle Swarm Optimization is a modified form of particle swarm optimization algorithm that considers all components as threads of bits. The site of a particle is reviewed through the velocity computation. The algorithm is described in the following way.

1. Arbitrarily produce a rudimentary population.

2. Aimlessly form the essential velocities within the limitations.

3. Allot the preliminary values for local and global finest sites.

4. Calculate the weights expected for velocity creation.

5. Modify the velocities of the particles consequently.

6. Swap the positions of the particles observing the velocities.

7. Terminate if the concluding circumstances are achieved, else restore to stage 3.

## 5. Results and Discussions

In this paper, the highest count of recurrences has been deemed as 50. Populace magnitude has been considered as 20. A 1500 W turbine with a rotor diameter of 77 m has been involved. For reducing the wake deficiency, the gap between two adjacent WTs has been kept at 308 m. The WPG cost-linked factors and their values compulsory for computing the generation cost function have been deemed as defined by Bhattacharjee et al. (2021). The optimal layout plans have been displayed in Figs. (8)-(13).

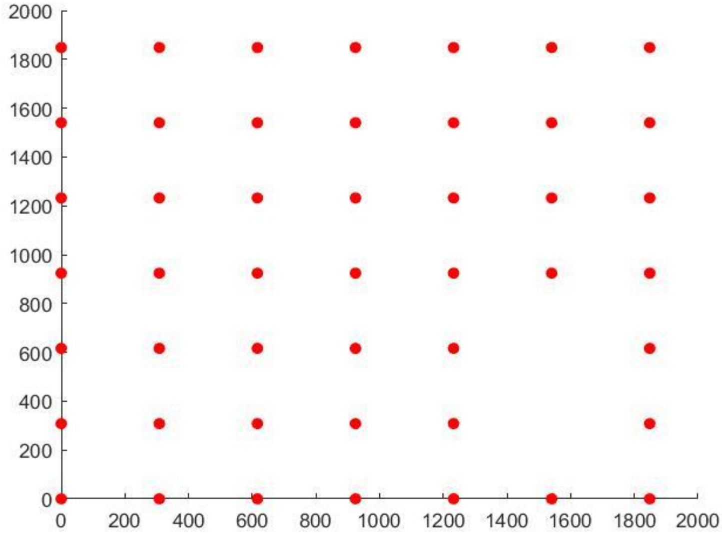


Figure 8. Optimal Placement of Wind Turbines Using Genetic Algorithm for Layout 1

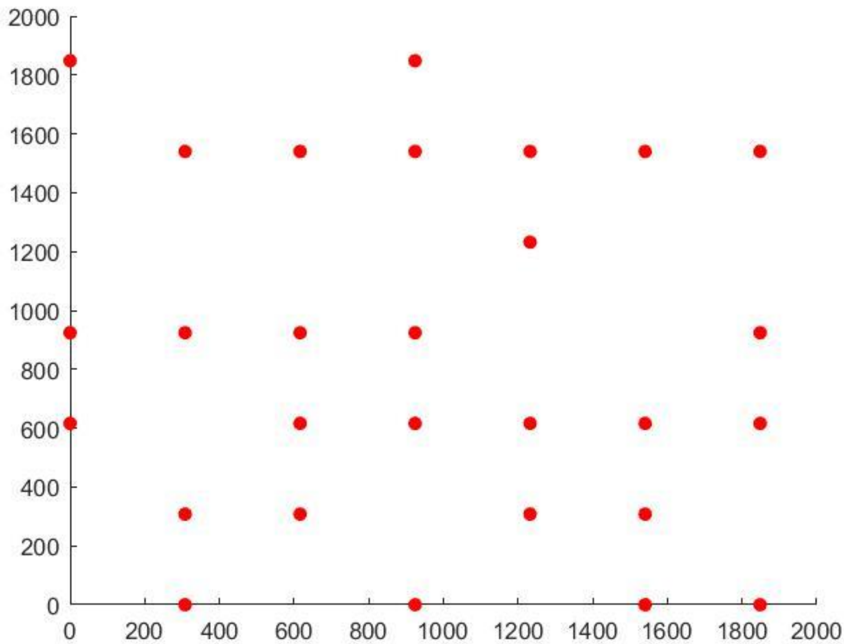


Figure 9. Optimal Placement of Wind Turbines Using Binary Particle Swarm Optimization Algorithm for Layout 1

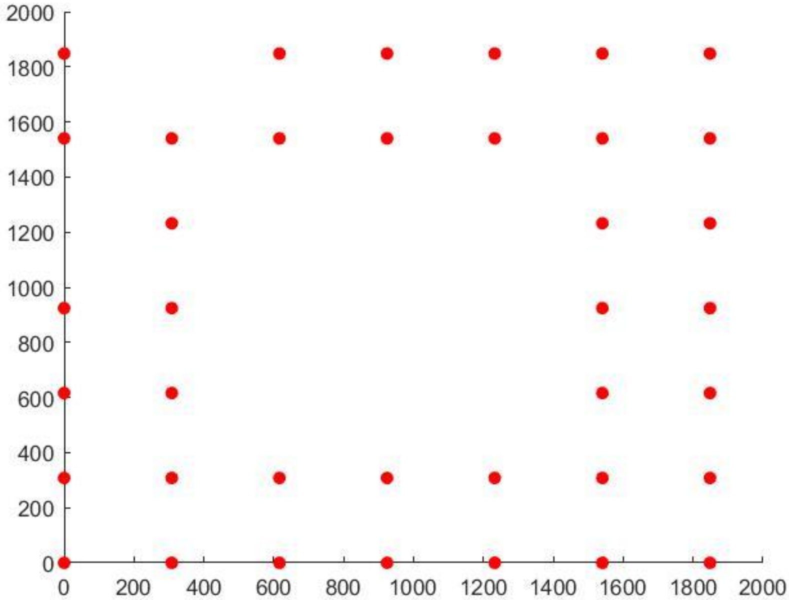


Figure 10. Optimal Placement of Wind Turbines Using Genetic Algorithm for Layout 2

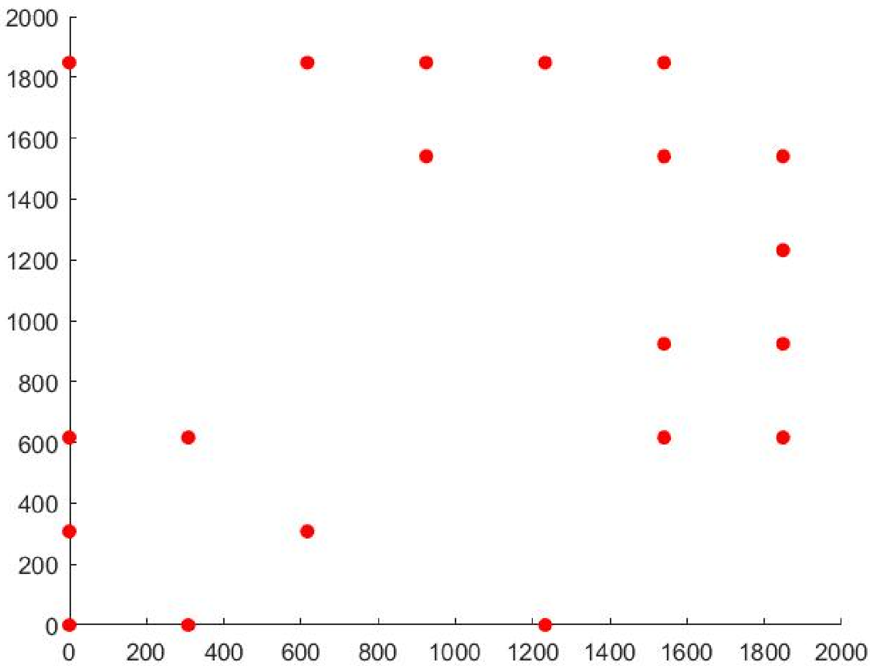


Figure 11. Optimal Placement of Wind Turbines Using Binary Particle Swarm Optimization Algorithm for Layout 2

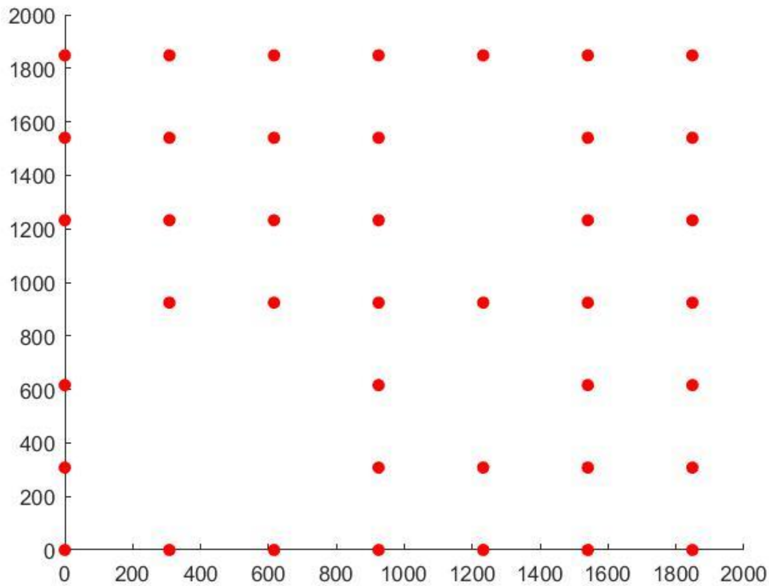


Figure 12. Optimal Placement of Wind Turbines Using Genetic Algorithm for Layout 3

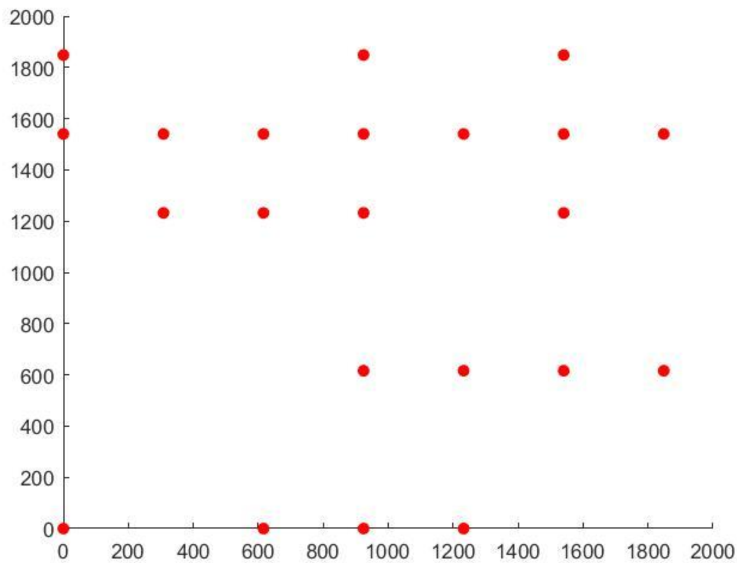


Figure 13. Optimal Placement of Wind Turbines Using Binary Particle Swarm Optimization Algorithm for Layout 3

The vending charge for WPG has been deemed as USD 0.033/kWh. The optimum values of yearly profit and subsequent tally of WTs achieved by both the algorithms have been shown in Table 1.

| Optimization Method | Optimal Yearly Profit for Layout 1 (in USD) | Optimal Amount of Wind Turbines Layout 1 | Optimal Yearly Profit for Layout 2 (in USD) | Optimal Amount of Wind Turbines Layout 2 | Optimal Yearly Profit for Layout 3 (in USD) | Optimal Amount of Wind Turbines Layout 3 |
|---|---|---|---|---|---|---|
| Genetic Algorithm | 9407.8 | 47 | 7902.4 | 38 | 8660.0 | 41 |
| Binary Particle Swarm Optimization Algorithm | 6256.4 | 28 | 5041.8 | 20 | 5451.5 | 22 |

**Table 1** Comparison of Optimum Results

The research outcomes authorize the superiority of the Genetic Algorithm approach over the Binary Particle Swarm Optimization Algorithm approach for three layouts as it achieved a higher yearly profit as shown in Table 1.

The enlarged productivity of the wind farm allows the enhanced sustainability of the WPG ventures and reinforces the progression of emission manipulation for the power generation businesses. The capable location of WTs by the projected optimization approach can benefit the WPG trades to attain elevated fiscal reimbursements without escalating the layout region and evading added outlay in terrestrial possessions.

## 6. Conclusion

International associations are persistently attempting to reduce the application of fossil fuels and use the renewable resources of energy efficiently as proposed by the Paris accord of 2015. The research work intends to increase the annual profit of a WPG farm at Kayathar, India. Metaheuristic techniques like Genetic Algorithm and Binary Particle Swarm Optimization Algorithm have been used to optimize three randomly selected terrain layouts. The optimization outcomes authorize the higher appropriateness of the Genetic Algorithm over the Binary Particle Swarm Optimization Technique for enhancing the considered objective.

The current research can originate unsullied chances for wind farm design enhancement and fiscal stability of wind power ventures.


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