Layout optimization for a large offshore wind farm using Genetic Algorithm

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Wind Farm Layout Optimization Problem (WFLOP) is an important issue to be addressed when installing a large wind farm. Many studies have focused on the WFLOP but only for a limited number of turbines (10 – 100 turbines) and idealized wind speed distributions. In this study, we apply the Genetic Algorithm (GA) to solve the WFLOP for large wind farms using real wind data.

The study site is the Palk Strait located between India and Sri Lanka. This site is considered to be one of the two potential hotspots of offshore wind in India. An interesting feature of the site is that the winds here are dominated by two major monsoons: southwesterly summer monsoon (June-September) and northeasterly winter monsoon (November to January). As a consequence, the wind directions do not drastically change, unlike other sites which can have winds distributed over 360°. This allowed us to design a wind farm with a 5D X 3D spacing, where 5D is in the dominant wind direction and 3D is in the transverse direction (D- rotor diameter of the turbine - 150 m in this study).

Jensen wake model is used to calculate the wake losses. The optimization of the layout using GA involves building a population of layouts at each generation. This population consists of, the best layouts of the previous generation, crossovers or offspring from the best layouts of the previous generation and few mutated layouts. The best layout at each generation is assessed using the fitness or objective functions that consist of annual power production by the layout, cost incurred by layout per unit power produced, and the efficiency of the layout. GA mimics the natural selection process observed in nature, which can be summarised as survival of the fittest. At each generation, the layouts performing the best would enter the next generation where a new population is created from the best performing layouts.

GA is used to produce 3 different optimal layouts as described below. Results show that:

A ~5GW layout – has 738 turbines, producing 2.37 GW of power at an efficiency of 0.79
Layout along the coast – has 1091 turbines, producing 3.665 GW of power at an efficiency of 0.82.
Layout for the total area – has 2612 turbines, producing 7.82 GW of power at an efficiency of 0.74.
Thus, placing the turbines along the coast is more efficient as it makes the maximum use of the available wind energy and it would be cost-effective as well by placing the turbines closer to the shores.

Wind energy is growing at an unprecedented rate in India. Easily accessible terrestrial resources are almost saturated and offshore is the new frontier. This study can play an important role in the offshore expansion of renewables in India.