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Application Evolutionary Methods in the Location and Choice of Wind Farms

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Summary. In Poland, the production of electricity mainly uses coal, brown coal and natural gas. Regular wear in above mention raw materials is forcing us to look for other sources of energy. One of them is wind power, which involves the construction and installation of wind farms. The process of building a wind farm is very complex and involves many scientific and technical disciplines. One of the many stages of the construction of the farm is the stage of the design and choice of location. The paper presents the concept of selection of the wind farms using evolutionary methods.
Key words: multi-criteria optimization algorithm VEGA, a wind farm, renewable energy sources.

INTRODUCTION

Currently in the country to produce electricity mainly are used conventional energy sources i.e.: hard coal, brown coal, or natural gas [3]. Following the recommendations of the European Union member states are required to reduce CO2 emissions, where by 2020 to reduce emissions must reach 20% in the EU. Poland is therefore committed to the use of renewable energy sources as an alternative to obtain electricity [9]. The possibilities of using renewable energy sources are quite large; we can specify here, among others biomass, biogas, geothermal resources, and wave, tidal, solar and wind [5]. Wind power is growing rapidly and is used in the production of electricity on the growing trend [1]. The potential for energy development in our country is quite large, evidenced by the results of research conducted by the Institute based on observations of wind speed and direction carried out by the Institute of Meteorology and Water Management. According to the report best in terms of wind resource areas are:

- middle, the northernmost part of the coast from Koszalin to Hel,
- area of the island of Wolin,
- Suwalki,
- Greater middle and Mazovia,
- Beskid Slaski and Zywiec,
- Bieszczady Mountains and foothills Dynowskie.

As it turns out, the wind velocity distribution is dependent on the local topographic conditions.

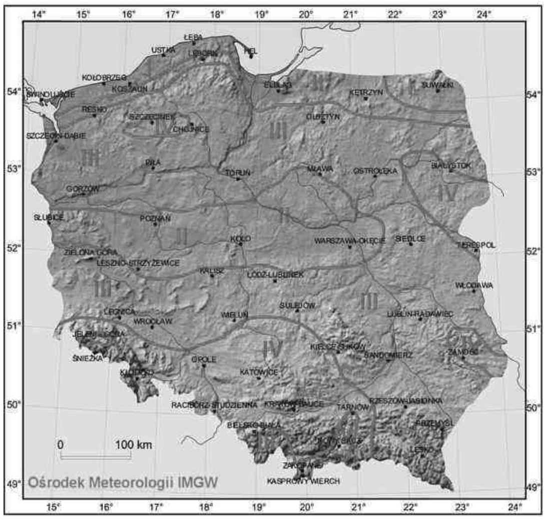

Fig. 1. Energy Zones wind conditions [7]

According to data from the Polish IMWM area can be divided into five zones energy wind conditions:

- Zone I – very favorable,
- Zone II – very favorable,
- Zone III – beneficial,
- Zone IV – less favorable,
- Zone V – unfavorable.

The measurements and tests on the above mention places in the country should be the basis for decision-making on the construction and installation of wind turbines [7].

DESIGN OF THE WIND FARMS – AN ANALYSIS OF THE CRITERIA

The construction of the wind farm is a very complex process and complicated, where already at the design stage should be taken into account several criteria. Even taking into account the large size, moving parts design, noise, flicker and other aspects such as: natural, cultural or tourist. The installation of wind farms should be planned on agricultural land, wasteland or Greenfield sites for housing development. When planning the location of the wind farm we must also pay attention to the nature conservation area and woodland. Not without significance is the issue of the minimum distance from the farm locations inhabited areas. Too small distances may potentiate the effect of noise or strobe effect. Another criterion, considering the area attractive to tourists is the color of construction, tower height and the distance between the turbines.

ASSESSMENT OF WIND ENERGY RESOURCES

It is estimated that in Poland, almost 40% of the country can be used for wind energy, taking into account the criterion of profitability in 1000 kWh / m² / year, assuming 30 m above the ground and “0” class roughness.

Wind speed should exceed at least 3 m /s. On wind speed and direction at a given site consists of many factors, including:

– terrain,
– air temperature,
– local equilibrium atmosphere,
– the type of land cover (roughness),
– the presence of bodies of water,
– different types of obstacles (buildings, trees, etc.).

Wind speed is constantly changing; different is at day and at night, moreover, other speed recorded in the summer of others in winter. During the day, the highest wind speed is achieved in the afternoon, then also turbulence may occur, even in the winter season appears to be at higher wind speeds. In the case of investment planning in the area are mounted measuring masts which within a year measure wind speed and direction [6].

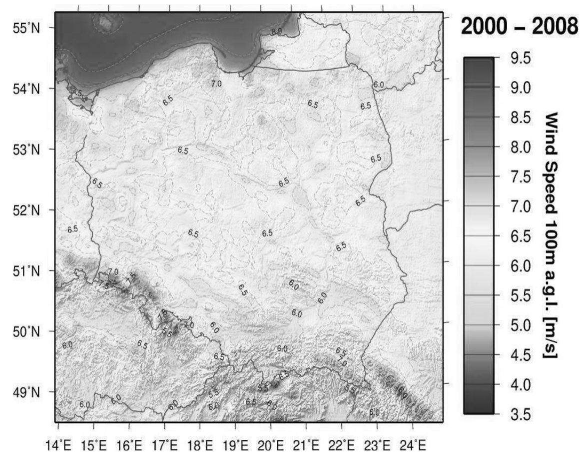

Fig. 2. The annual average wind speed at a height of 100 m (Anemos) [6]

NATURE AND LANDSCAPE ASPECTS OF WIND FARMS

When planning the location of the wind farm we must also exclude wetlands, woodlands, valuable plant communities, bodies of water, a place attractive to birds. It is assumed that the minimum distance of a wind farm of ecological corridors should reach 800 m.

Wind farms may reach about 160m able erected propeller rotor, which is not without significance for the landscape, taking into consideration a large number of turbines, so when planning the location of the farm should be taken into account aesthetic criterion. In addition, at the design stage it is recommended to bypass areas of climb or descent of aircraft. In addition, it is worth paying attention to land use plans, which we are planning to install a wind farm [6].

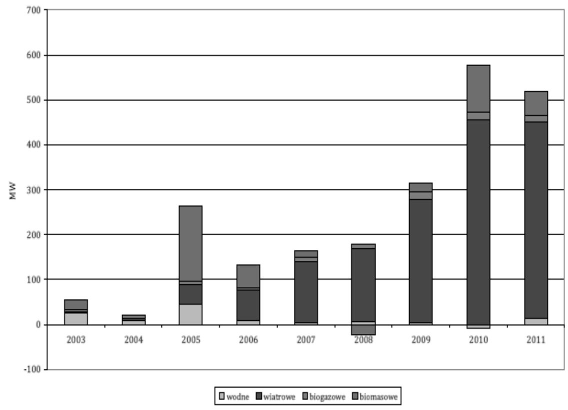

Fig. 3. Renewable energy sources – capacity installed in Poland in the years 2003-2011 [6]

METHODS OF MULTI-CRITERIA OPTIMIZATION

One of the many stages of the construction of wind farms is its design. Process is very complex and involves many scientific and technical disciplines. Given the large number of criteria that should be considered at the design stage of the wind farm location and their diversity, we are faced with the problem of decision-making related to the selection of the appropriate method to solve our problem. One of them is the problem of the diversity criterion, the part is expressed in m/s, for example, wind speed, and the second part is in polish zloty in the case of land prices.

In the case of criterion-related the distance from residential areas will be a meter in the case of roughness will be a class. In addition, by analyzing our criteria, it turns out that some of them will maximize, for example, the distance from built-up areas or wind speed. In contrast, some of them as noise, rough terrain, flickering, or the price of land we want to minimize.

In a situation where we have to consider many aspects of the criteria and the traditional optimization methods do not produce the expected results we apply evolutionary algorithms, which often allow us to get better results than traditional methods.

BASIC CONCEPTS

Single-Optimization With the Single Optimization we mostly dealing in a situation where the objective function always returns a single value, the selection is done on the basis of one criterion.

Multi-criteria Optimization

The technical issues we often meet with a number of criteria that must be considered at the same time, and then we are dealing with a multi-criteria optimization (polio optimization). The multi-criteria optimization to find the optimal solution is not as simple as in the case when we consider one of the criteria and are looking for the highest or lowest value of the objective function [19, 20]. The aim of the multi-criteria optimization is to find the optimal solution, which is acceptable from the point of view of each criterion.

For a set of **maximization task** the objective function k:

$$f(x)=(f1(x), f2(x),..., fk(x)).$$

x is dominated solution, if there is no feasible solution y worse than x, i.e., For each objective function fi:

$$fi(x) \leq fi (y); (i=1,... k).$$

Otherwise, x is the solution **not domesticated**.
For a set of tasks to **minimize** the objective function k:

$$f(x)=(f1(x), f2(x),..., fk(x)),$$

x **is dominated** solution, if there is a feasible solution y is not worse than x, i.e., for each objective function fi:
Otherwise, x is a solution **not domesticated** [8].

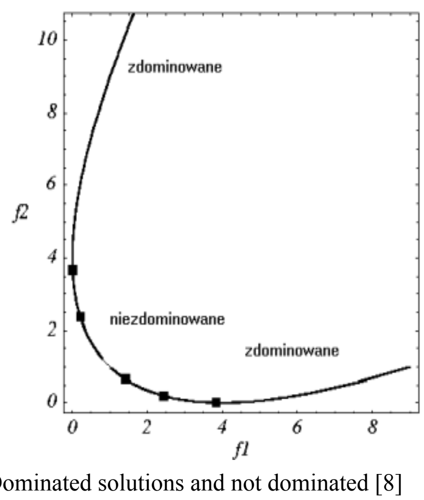

Fig. 3. Dominated solutions and not dominated [8]

VEGA ALGORITHM (SCHAFFER'S VECTOR EVALUATED GENETICALGORITHM)

The author of this method is that Schaffer [10]; it is used for solving multi-criteria tasks. The principle of action of the above mention method in the algorithm consists in the fact that the population of individuals limit is divided into a number of subsets, whose number by the number of accepted criteria.

In each of these subsets the following selection of the best individuals, but from the viewpoint of only one criterion in each of another subset [17, 18]. The selected best individuals are moved to a temporary population P ', where they are propagated and modified through the use of crossover and mutation operations [16, 12].

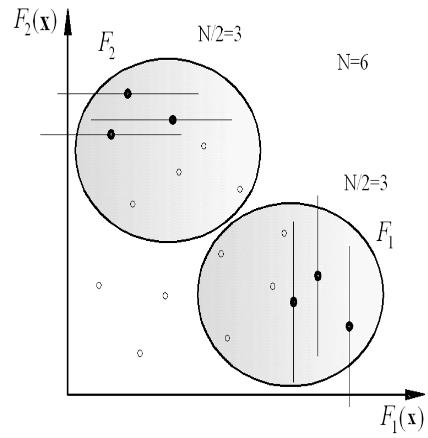

Fig. 4. Selection method VEGA [11, 14, 15]

The steps of the algorithm VEGA:

1. Population PG is divided into k subsets, where k is the number of criteria.
2. Selecting the best individuals in each k subsets considering only one of the criteria of N / k (where N – Total number of selected individuals).
3. The resulting animals are moved to a temporary population P '.
4. In the population P 'followed by an operation of crossing and mutation. Obtain new population – PG, wherein G = G + 1.
5. Dealing with points 1 – 4 is repeated until you stop algorithm (e.g. G = 400).

THE CONCEPT OF SELECTING THE LOCATION OF WIND FARMS USING EVOLUTIONARY ALGORITHMS

At the design stage of the wind farm we can assume that it is divided into many small square cells, we further determine that the cell width in the middle, in which the turbine is equal to several diameters of the rotor. Each cell can have two states: if it contains a turbine, is represented by bit 1, if there is not a turbine the bit is – 0. Figure 5 is an example of wind turbines mesh 10x10 as a binary string of 100 bits and is formed from the top bottom [2].

Using evolutionary algorithms for the calculation we obtain a set of feasible solutions that can provide some idea of the selection of the location of wind farms. In the case of a large number of non-dominated solutions in the Pareto NRGA algorithm should be used [4, 11, 13] based on the technique of reducing the number of non-dominated solutions in many populations.

Attempt selection of wind farms when considering multiple criteria is very complex and difficult, especially if we take into account the criteria, which are mutually incomparable and even contradictory. Like any technical issue you can try to solve them by traditional methods or try to exploit optimization heuristic methods, which often allow obtaining satisfactory results.

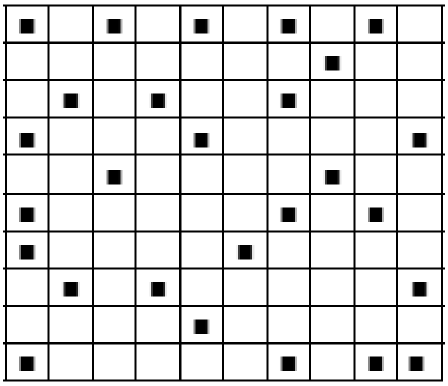

Fig. 5. Example of the arrangement of wind turbine using a binary string [2]

CONCLUSIONS

Wind energy in Poland is growing rapidly; it has great potential for the installation of the wind farms both onshore and offshore. Modern wind energy, taking into account other energy production technologies is beneficial both in terms of climate and economic future.

In addition, significantly increases the chances of regional development, creates the real conditions of employment. Presented in the article, the concept of using evolutionary algorithms to solve multi-criteria technical issues can be one of many possible solutions related to the selection of the correct location of wind farms.

Currently in Poland to produce electricity use coal, lignite, natural gas and renewable sources. Regular wear raw materials is forcing us to look for other sources of energy. One of them is wind power, which involves the construction and installation of wind farms. The process of building a wind farm is very complex and involves many scientific and technical disciplines. One of the many stages of the construction of the farm is the stage of the design and choice of location. The paper presents the concept of selection of wind farms using evolutionary methods.

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ZASTOSOWANIE METOD EWOLUCYJNYCH W DOBORZE LOKALIZACJI FARM WIATROWYCH

Streszczenie. W Polsce do produkcji energii elektrycznej wykorzystujemy głównie węgiel kamienny, węgiel brunatny oraz gaz ziemny. Systematyczne zużycie w/w surowców zmusza nas do poszukiwania innych źródeł energii. Jednym z nich jest energetyka wiatrowa, z którą wiąże się budowa i instalacja farm wiatrowych. Proces budowy farmy wiatrowej jest bardzo skomplikowany i obejmuje wiele dyscyplin naukowo-technicznych. Jednym z wielu etapów budowy farmy jest etap jej projektowania oraz doboru lokalizacji. W artykule zaprezentowano koncepcję doboru lokalizacji farm wiatrowych z wykorzystaniem metod ewolucyjnych.
Słowa kluczowe: optymalizacja wielokryterialna, algorytm VEGA, farma wiatrowa, odnawialne źródła energii.