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A special method for simultaneous optimization of electrical grid interconnections and cable size in wind farms

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ABSTRACT

Modern wind farms are considered one of the most important sources of energy today. The biggest cost of the farm is the cost of electrical connection to the farmers (constituting the largest part of the aesthetic cost of the farm) and finding the best method for electrical connection (the optimal method) for wind turbines (WTS), as well as the optimal size and measurement of electrical cables. Here, the (harmonious) search algorithm solves the optimization problem and the method of digging the soil in order to lay the cables in it. Two cases will be discussed in order to calculate the optimal size of the cables, namely partial calculation and optimal calculation for connection schemes in the best method for wind farms (OWFS). Also, the total cost, shipping methods, methods of digging extensions into the soil and the different classifications for turbines (wind turbines) will be addressed in order to obtain the best investment for them, so that we reach the optimal delivery and the lowest possible cost in a coordinated and thoughtful manner.

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1. INTRODUCTION

Wind energy is considered a revolution in the field of electric power production in the modern era and the fastest developing technology around the world [1], [2]. It is able to reduce pollution to the environment, and by relying on offshore wind farms [3], we are able to reduce gas emissions and thus reduce global warming by up to (40%) [4]. From a special point of view, this study and the proposed method are among the modern and most important methods, as on the other hand, they study and explain a new and modern innovative method in order to achieve the best yield from the extraction of electrical energy generated from wind farms.

Many studies expect to reach an electric production capacity of approximately 65 gigawatts by next year, and the wind speeds will be stronger and more stable in marine areas because they are open areas free from obstacles [5]. Therefore, the turbines design could be with lower weights and higher speeds, but the cost issue remains. It is the main obstacle in this field, and the electrical installations to the beach, and as these challenges grow, new methods and techniques have emerged in order to solve these problems and reduce the standard cost of energy (LCOE) [5]. We can also represent and install electrical turbine delivery systems for offshore wind farms in several styles and shapes, including radial, annular (circular) and star-shaped, all of which follow the specific reliability level that must be reached [6]. We know that the possibility of faults, especially in the cable buried at the bottom (under the surface of water) is a very small possibility [7]. It was the old wind farms limited in size with low power ratings of less than 4 megawatts, so there was no need to study the optimal formations and connections at the time.

Many works and studies have been done to improve all aspects of offshore wind farms [8]–[10]. Some studies focused on the optimal model for electrical interconnection operations in order to reduce the length of drilling [7]. As for this study, this model of the design proposes a new and single loop design (repeated) in order to reduce the cost related to cables. This study, also in addition to the above, propose a new algorithm in order to find a central point called (intermediate point) connecting an intermediary in order to reduce as much as possible the process of digging coastal trenches. Therefore, we note that the existing optimization methods or the previously proposed models according to the previous studies, models and schemes, are completely unsatisfactory due to the reason for searching and finding the best planning for the electrical interconnection process away from manipulating the sizes of cables all lead us to a significant increase in the dimensions of the system as a whole and the cable entanglement [5], [7]. In addition, when trying to reduce the size of the problem in any way without paying attention to WTS integration is not enough to reach a better and optimal solution [11].

The steps covered in this study: i) Finding a pattern for the interconnection for (OWF) in two ways [7], as we mentioned a complete method and a partial method in terms of cable size; ii) Check and study the power rates in order to get the layout with the best connection pattern; iii) Using a special algorithm called (harmonious) search (HS) [7], [12] which is a high-performance algorithm for the problem, and there is no need for an aggregation method; iv) Detection and avoid junctions in cables; and v) Finding a new tool in order to find the best types of electrical connections in offshore wind farm systems in all forms of distribution [12].

2. THE HARMONIZED SYSTEM AND ITS ALGORITHM (H-S)

We note that optimization and development algorithms are cases resulting from nature (metaheuristic), which include many aspects here, such as human memory and the memory of living organisms in research [12], annealing and developments in the biological field, so that the HS algorithm is a new method for improving quality and efficiency and has been actually learned for solve the obstacles related to the various improvement processes by finding the best solution to the problem in both TSP (WDS) and other methods and algorithms of optimization [7], [13].

The steps involved in the algorithm work: i) Memory initialization process; ii) Create a new pattern from (HM) whether random or coordinated pattern; iii) If the new pattern is better than the lowest quality of the previous pattern [13], the new pattern is taken instead of the worst pattern; and iv) When the stopping conditions are not met, the move to the second step is carried out [12], [13].

In our study, we relied on that the upper limit of repetition is equal to (N, 2N×103) and the assumption of (HMS) so that the symbol (N) expresses the variables and their number responsible for the improvement, as Figure 1 shows (AHM + HMS) Consists of four digits and options, it expresses a memory where there are all vectors that represent a solution and the corresponding fitness values (HM = GA), that is, we have three variables for the optimization process [14]. Four values (vectors) for harmony and randomness are entered into memory (CEG). With (BDA) With (CFA) With (DGB) [14].

	north	south	east		optimization
Level one	C	E	G		excellent
Level two	B	D	A	⟷	Very well
Level three	C	F	A	⟷	Moderate
Level four	D	G	B	⟷	Acceptable

Figure 1. Consistency memory architecture

In our study, this improvement in the method of connection and in relation to the size of the cables are all factors affecting the length and method of digging trenches in order to extend the cables and in order to reduce the cost for operation and also save on shipping costs and others. Since the pattern of trenching (CCP) has a significant impact on the improvement [15], so we will suggest two methods for it: first, full sizing for the cable so that this is done according to the dimensions specified for each branch and secondly, the partial (incomplete) sizing of the cable urges the change to include a limited number of cable dimensions and thus.

3. METHOD

The research aims, in general, to improve the methods of connection and connection in a sequential and simultaneous manner within the electrical cables in the wind farms for the generation of electric power and to find the optimal connection method for the center node of the center and the connection with the beach (the central node). of the proposed linking method. For mathematical solution to the problem and before starting our algorithm, we define a special reduction algorithm (Pi) for the configuration problem in the cabling connections for (WT) and this algorithm can be defined for two cases [15], [16], either the similar or the dissimilar pattern for (O-WF) and taken as new data each of the coordinates for the establishment and the system for the operation of the process.

In order to improve the electrical connection problem, we have the symbol (yi) expressing the adjacent node and we can take the value of this symbol from the options of a separate set for (PA) with the tests (Ki).

$$yi = \sum_{x=1}^{Ki} \beta_x B_i(x) \;\; \forall B_i \subseteq \{1, \dots\dots N+1\} \tag{1}$$

$$S.T. \sum_{X=1}^{Ki} \beta_x = 1 \; \forall \beta_X \in \{0,1\} \tag{2}$$

$$\delta_n = \begin{cases} 1 & \text{locn} = \text{loc N} + 1 \\ 0 & \text{with other} \end{cases} \tag{3}$$

Where, the symbols (loci) represent the universal sites that fall under the name Cartesian and the good choice.

$$\text{Bi} = \sum_{n=1\; n\neq 1}^{N+1} \delta n \text{ N } \; \forall \in \{1, \dots\dots \text{N}\} \tag{4}$$

$$\text{S.T.} \sum_{n=1}^{N+1} \delta_n = \text{Ki} \; \forall \delta_n \in \{0,1\} \tag{5}$$

Where, i: is the indicator for WT, n: a node-specific recording, N: expresses the total number of WTs, Ki: The range of options for each decision, N+1: indicates the operating system, and δ_n: a variable that takes one of two values, either 0 or 1.

When we assume a constant voltage for each node [15], we have then after finding the binding pattern and defining the variable (Yi) we then assign the amplitudes to each branch (I, yi) and thus:

$$\text{I}_{\text{iyi}} - \sum_{i=1}^{N} \sigma\text{ij} \,.\, \text{I}_{\text{ij}} = \text{I}_{\text{G}} \; \forall \text{ij} \in \{1, \dots.\text{N}\} \tag{6}$$

where, I_G: is current generated by (W-T), I_{ij}: represents the capacitance of the electrical circuit from (W-T) to (ith; σj), σj: a variable that can be one of two states (0 1): $\sigma ij = \begin{cases} 1 & yi = i \\ 0 & yi \neq i \end{cases}$

$$\begin{cases} \text{Csi} = \sum_{d=1}^{m} \lambda\text{i(ad)ad} \; \forall \text{Csi} \in \text{A} \\ \text{S.T.} \sum_{d=1}^{m} \lambda\text{i(ad)} = 1 \; \forall \lambda\text{i} \in \{0,1\} \end{cases} \tag{7}$$

The full method depends on finding the value (CSA) of the cable for each branch according to the capacitance, and in the partial method [17], the diane has a finite number of dimensions and the dimensions are determined for each branch. D: goodl cable dimensions, A: how many dimensions are there for our cables CIi: special dimension for cable λi (a,d): 0, 1.

$$\lambda\text{i(ad)} = \begin{cases} 1 & \text{I}_{d-1}^{\max} < \text{I}_{\text{iyi}} \leq \text{Id}^{\max} \\ \text{o} & \text{with other} \end{cases} \tag{8}$$

Where, Id^{max} denotes the power of the pointer coil (DTH) for extended cables.

$$\text{CS} = \{\text{CS1}, \dots\dots, \text{CSn}\} \tag{9}$$

Figure 2 shows the diagram of the algorithm used for optimization (H-S). In this study, we assumed that the improvement takes place in two stages (from the beginning of the drilling and for the dimensions, sizes and measurements of the cables) the factor (CSB) is fixed in the length of the study [18], [19], and in order to reduce the expenses of our system and for the interconnection of electric cables we have:

$$\begin{cases} \min \sum_{i=1}^{N} \text{Diyi}(\text{CSb} + \sum_{d=1}^{m} \lambda\text{i(ab)}.\,\text{Cci(ab)}) \\ \text{S.T.} \sum \lambda\text{i(ab)} = 1 \qquad \forall \lambda \in \{0,1\} \end{cases} \tag{10}$$

where, DTH: is an available dimension for connections (cables), N: indicates the number of variables for improvement, Yi: a value specific to the optimization method, Cci: the cost of each cable belonging to a dedicated turbine, CSb: for trenching costs and freight charges, and Di: is the distance.

$$\mathrm{Diyi} = \sqrt{\mathrm{Re}(\mathrm{loci} - \mathrm{locyi})^2 + \mathrm{IM}(\mathrm{loci} - \mathrm{locyi})^2} \tag{11}$$

In order to obtain the total value of the loss [15], a special inequality relationship has been added:

$$\Delta P_{\mathrm{tot}} = \sum_{i=1}^{n} \Delta \mathrm{Pi} \leq \Delta \mathrm{Pmax} \tag{12}$$

Where, ΔP_{tot}: denotes loss of energy, ΔPmax: maximum loss, and ΔPi: energy loss in the active state of the branch and in the worst stage.

$$\Delta \mathrm{Pi} = 3\mathrm{Ri}(\mathrm{ab})\mathrm{I}_{\mathrm{iyi}}^{2}\mathrm{Diyi} \tag{13}$$

Maintenance cost will be considered fixed in the study.

$$\mathrm{C\Delta W} = 8760.\,\mathrm{LcoE}\,.\,\mathrm{CF}^2 \sum_{i=1}^{n} \Delta \mathrm{Pi} \tag{14}$$

Figure 3 expresses the characteristic (P) of the power and monkeys (Q) which is considered to be reactive for a (DFiG) turbine [20]. We notice that both the apparent and real forces have the same values through Figure 3 with the graphic plane gradually from negative values to positive values.

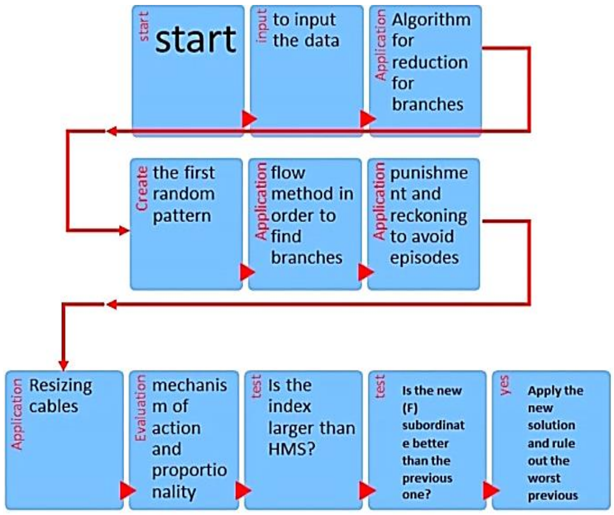

Figure 2. Diagram of the algorithm used for optimization (H-S)

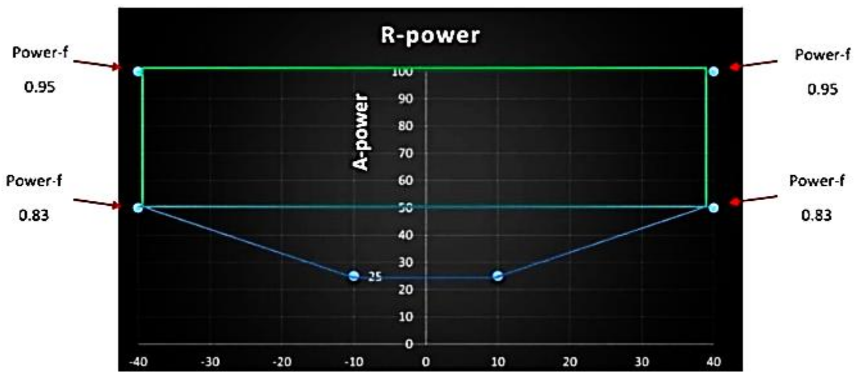

Figure 3. P and Q characteristics

4. RESULTS AND DISCUSSION

This improvement is solved in the offline mode1 for you according to the mentioned coordination algorithm and (GA) based on data and numbers [21], and each algorithm was repeated up to 1000 times in order to study it and calculate the performance [22]. In order to compare these two algorithms satisfactorily, the upper limit of each of them was set as a stop criterion so that relative similarity at operating times only [23], and in order to evaluate the performance of both algorithm (HS) and algorithm (GA) and for non-constant variable limits of (WTS) [24]. We calculated the best solutions for each of them by means of re-sizing the cables and the Table 1 explains average performance values. Figure 4 shows the method of linking using the node so that the connections to the wind turbines are connected to a group of cables, and these cables [25], in order to reduce the cost, are connected and reached to a middle node from which the connection is made to the shore [26], [27]. Later researchers can find a way for a similar development process in order to find the most secure connection across the network (high voltage electricity network) and interconnect with the rest of the networks on the coast, and can test individual or multiple operating systems.

Table 1. Average performance values of both algorithm (HS) and algorithm (GA) and for non-constant variable limits of wind turbines (WTs)

Range of wind turbines (WTs)	GA algorithm (%)		HS algorithm (%)	
	Cable sizing method			
	Full	Partial	Full	Partial
Range of 18-22 WTs	84.9	91.5	97.6	94.8
Range of 37-43 WTs	73.3	84.6	91.3	88.6
Range of 58-65 WTs	57.1	72.4	83.7	76.8

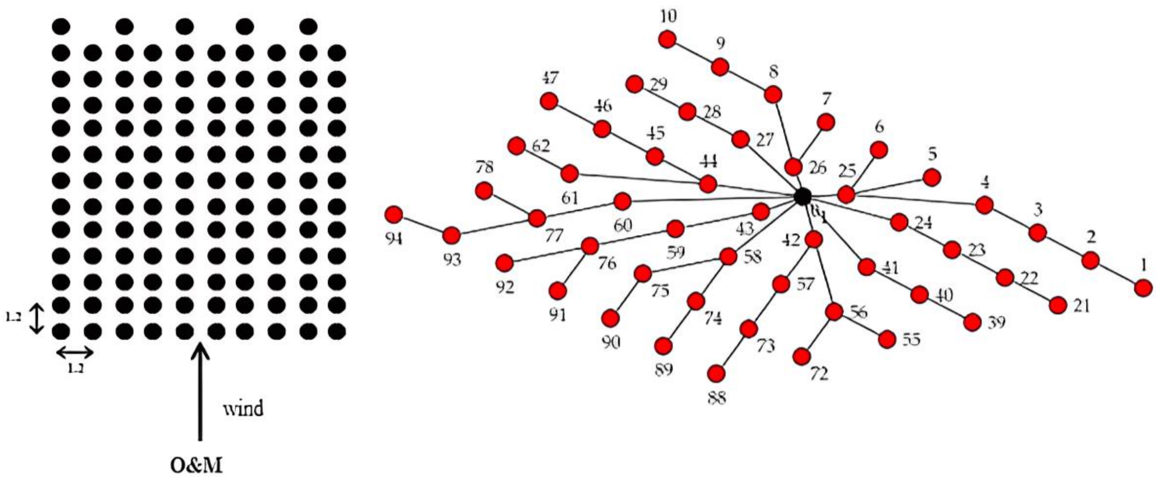

Figure 4. Middle knot for tying cables

5. CONCLUSION

In this paper, a method was studied in order to increase the efficiency and improve for the expenses and for the method of delivery in the system in order to make the designers more able to reach a balance between performance and cost at the same time. Its high-performance improvement and proposed formula can be easily adopted in wind farms. Later researchers can find a way for a similar development process in order to find the most secure connection across the network (high voltage electricity network) and interconnect with the rest of the networks on the coast, and can test individual or multiple operating systems. Later researchers can find a way for a similar development process in order to find the most secure connection across the network (high voltage electricity network) and interconnect with the rest of the networks on the coast, and can test individual or multiple operating systems.

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