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The Application of Ant Colonies Algorithm in Optimal Positioning Wind Turbine Farms

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Abstract

Reduction of fossil fuel resources has made wind energy as one of the most prolific alternative energies in the world. Therefore, the design and operation of the wind turbine farms in many countries has become a priority. The place of installation of the wind turbines is one of the most important issues related to the design of these farms. Therefore, the characteristics of the relevant environmental and other restrictions that are usually linked to a couple of variables in the design of these sites are being considered. In this paper a new method based on Ant Colony algorithm for optimal positioning installation of wind turbine farms in the electrical distribution networks is provided. And the performance of the proposed method is tested and reviewed.

Keywords: positioning, wind turbine farms, the optimal positioning, smart electric networks, Ant algorithm

Introduction

Wind energy is one of the most prolific alternative energies in the world. Because it is available and fossil fuel resources are reducing. One of the most important issues on the use of these turbines is discussion of how to choose the optimal installation location. The intelligent systems-based approach to this issue is provided in the country of Saudi Arabia (Baldick, 2012). Also, in the other method for wind farms has been raised in Iran as well (Bevrani and Daneshmand, 2012). In the industry for this issue software are provided, but these applications require the presence of human to guide the system in determining the optimum location (Baldick, 2012). Hence, smart practices would be suitable for the above guidelines, especially by increasing the properties of the system and the needs of users, it is a very complicated issue which has turned to be NP-hard problem.

Evolutionary search methods including the Ant algorithm is one of the suitable methods for solving NP-hard problems (Bookman, 2005; Dorigo, and Gambardella, 1997). With respect to the particular characteristics of Ant Colony Algorithm in resolving graph issues, the purpose of this article is to convert the issue of the optimal positioning to graph issues and then using Ant Colony algorithm to solve it (Dorigo, 1996). We will later, in part two will have a review on the smart electrical networks and the importance of the wind farms. Then, in the third part Ant algorithm would be provided and in part four, the proposed method will be described completely. In the fifth part the results of simulation will be provided and finally, in part sixth the conclusion will be drawn.

A review on smart electric networks and the importance of wind farms

Since concerns about climate change, rising fossil fuel prices, and increase energy security is growing, field of renewable energy sources is a favorite subject around the world. Hence determining the installation location of the turbines has become a challenging issue (Ghaderi, et al, 2012; Gonz´alez-Longatt, et al, 2012).

One of the platforms that smart electric networks provide is a managed efficiency of renewable sources of energy as pure energies in order to exclude human beings in the nature. For example, wind energy is considered as one of the most important and most accessible energy (Mishra et al, 2012; Parvania and Fotuhi-Firuzabad, 2012). So that in the United States in the fourth quarter of 2011 wind energy production has been multiplied (Salehinejad and Talebi, 2010; Salman and Sha_qur Rehman, 1892) and a lot of techniques for the design of wind turbine network has provided (Slootweg, and Kling, 2013). The importance of smart electric network would be fully understood when its users can both use the energy for their own consumption as well as selling it. Figure 1 is an example of injecting electrical energy obtained from wind farms.

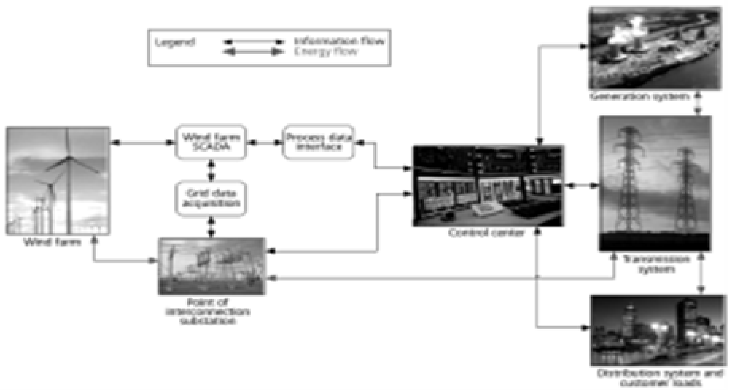

Figure 1: Structure of the Electric Energy from Wind Farms Are Injected Into the Power Network

An overview to the Ant Colony algorithm

An algorithm of Ant population for the first time was proposed by Doriko and his colleagues as a solution to solve a few issues like salesman optimization problem. An algorithm of Ant population is inspired by studies and observations on ants' population. These studies have shown that the ants are social insects which live in the population and they are more in the direction of the survival of the population rather than being toward the survival of one of its component. One of the most important and most interesting behaviors of ants is their behavior for finding food, particularly, in finding the shortest path between the nest and food sources. This kind of ants' behavior has a kind of smartness.

Modeling for the problem of salesman

In this section, an Ant system would be introduced as mathematical issue and with the help of a salesman issue it would be given as a standard. At issue of a salesman, a seller starts his trip from a definite city and after traveling to other cities comes back to the first spot, knowing that he enters each city once and passes them by. The goal is to find the shortest path for the trip.

In this issue *d* is the number of the cities. *d* (i,j) is the distance between cities and the distance between two cities *i,j* is :

$$d_{ij} = \left[(x_i - x_j)^2 + (y_i - y_j)^2 \right]^{0.5} \qquad (1)$$

$b_i(t)$, in which $i = 1, 2, 3,.., d$ is the number of the ants in city i at t time . The total population of ants are as follows:

$$m = \sum_{i=1}^{d} b_i(t). \qquad (2)$$

Each ant is a simple representative with following characteristic

• The Ant chooses a town to go to which is a function of the distance and the amount of effect on that path.

• In order to make ants to have logical trips, going to the cities which has been once the destination of a trip is forbidden.

• When an Ant is taken a full trip, it leaves some pheromone on each rout of i and j

τ_{ij} is the intensity of the pheromone on the routes i, j at time t. Each ant at time t chooses the next city and at time $t + 1$ would be in that city. Therefore, if a repeat of the Ant system algorithm is performed, in the interval time t and $t + 1$, after d (one cycle) every ant has done a full travel. The intensity of the effect can be calculated according to the following relationship pheromones:

$$\tau_{ij}(new) = \rho\tau_{ij}(old) + \Delta\tau_{ij}, \quad (3)$$

In the above relationship ρ is lasting factor. $(1-\rho)$ show the pheromone evaporation during $t,t+1$ time. $\Delta\tau_{ij}$ The amount of pheromone per unit length on (i, j) by ant K in the interval time of t, $t+1$. This value is equal to.

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{f_k} & \text{if route(i, j) be traversed by the } k^{th} \text{ ant (at the current cycle)} \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

In the above relationship Q is a random number and fk is the cost of found route by ant K. ρ coefficient has to be small in order to prevent unlimited stacking pheromone. In this report the severity of effectiveness in time 0 $\tau_{ij}(0)$ equals fixed amount of C. In order to satisfy this constraint which an ant has to pass all d cities, each ant is given a data structure called the attributed prohibited list. When a full travel is made a forbidden list is used in order to calculate the currents solutions (The length of the exceptionally long days that is done by the ants). The forbidden list, then is cleaned and ants are set free to choose. $tabu_k$ is a dynamic growth including the forbidden list of ant K . The probability of transition (transition) from i to j for ant k will be as follows

$$p_{ij}^{k} = \begin{cases} \frac{(\tau_{ij})^{\alpha}(\eta_{ij})^{\beta}}{\sum_{h \notin tabu_k}(\tau_{ih})^{\alpha}(\eta_{ih})^{\beta}} & \text{if } j \notin tabu_k \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

In the above relationship, there are the parameters which control relative importance of the footprint and vision.

The proposed approach

In this section we investigate the different parts of the proposed method. The proposed code is shown in Figure 2 and it is in the form of the following steps:

Initialization: At this point the initial information necessary to find location is read and stored such as data of the regions, the algorithm parameters, etc. Also in this stage the issue of optimization is prepared in a graph where each site is considered as a node site and each graph as a route between the two sites.

Locate ants: At this point, each ant randomly is being put in one of the nodes and its place is stored.

Probability: At this point, for any of the possible routes for the Ant, the amount of the cost according to the relationship:

$$Cost_{ij} = \prod_{g=1}^{G} parameter_{g,ij} \qquad (6)$$

It is calculated that G is the number of parameters to be considered which are set according to the issue. In this issue, the parameters have been set up in the form of a table.

Table 1: The Considered Parameters in Cost Calculation

	the considered parameters in cost calculation	
	Parameter	The parameter definition
1	$1/WS_{ij}$	Wind speed
2	T_{ij}	Temp
3	H_{ij}	Moisture
4	P_{ij}	Air pressure
5	R_{ij}	The Sun's radiation
6	SWS_{ij}	Parallel wind speed

After calculating the cost of each rout, the amount of probability is calculated according to the following relationship.

$$p_{ij}^{k} = \begin{cases} \dfrac{(\tau_{ij})^{\alpha}(Cost_{ij})^{\beta}}{\sum_{h \notin tabu_k}(\tau_{ih})^{\alpha}(Cost_{ih})^{\beta}} & if\ j \notin tabu_k \\ 0 & otherwise \end{cases} \qquad (7)$$

In which *q* is a random number between zero and one with a uniform statistical distribution and *j* is a chosen node.

Selection: At this point, after the calculation of the rout probabilities ahead of ant *k*, the target rout, in which *q* is a random number between zero and one, the following relationship can be selected by

$$j = \begin{cases} \arg\max\left(p_{ih}^{k}\right) & q > Q \\ \text{Roulette Wheel}\left(p_{ih}^{k}\right) & otherwise \end{cases} \qquad (8)$$

Where q is a random number between zero and one, with a uniform statistical distribution and the selected node j.

Local Pheromone Update: At this point, the Ant moves towards the selected node and on the way, according to the following relationship, pheromone spreading takes place.

$$\tau_{ij}(new) = \tau_{ij}(old) + \Delta\tau_{ij} \qquad (9)$$

$\Delta\tau_{ij}$ is incremental value of the pheromone for route i-j which is set through trial and error.

Global Pheromone Update: At this point, after a period movement of all ants, Evaporation of pheromone generally is done according to the following relationship

(10) $\tau_{ij}(new) = \rho\tau_{ij}(old)$

Result: Finally the nodes according to the amount of collected pheromone are arranged and offered.

The results of simulation

In this section, taking into account existing data, in [2] for the Iranian nation, system performance is evaluated. The considered parameters are shown in table 2. It should be noted that these parameters are set based on experience and trial and error.

Table 2: Simulation Parameters

	Topic	
	Parameter	amount
1	Number of the ants	30
2	Number of rings	20
3	Evaporation coefficient	0.9
4	The amount of incremental pheromone	1.5
5	Q	0.9
6	α	2
7	β	2
8	The height of the turbines	30m

Table 3: Output of the Turbine Installation Issue in Iran

	Topic	
	General pheromone	Site code
1	236.21	3
2	142.25	1
3	97.706	2
4	1.0942	5
5	0.72946	4
6	0.72946	6

Table 4: Data Related To Skip Iran Wind Areas

	Land cost in each square(5-20)Kmx1000 Rials X(5)	Geographical features X(4)	Geographical properties X(3)	Frequency of natural disasters X(2)	Average wind speed X(1)
Tehran	400	2898.4	27784.6	5.6	11
Yazd	100	11761.9	56358.9	3.6	8.8
Hamedan	100	274.5	14928.7	3	10.4
Kerman	100	3154.4	153426.3	12.9	9.6
Shiraz	200	5725.9	83693.9	24.3	6.4
Tabriz	200	1797.3	31271	7.8	8.6

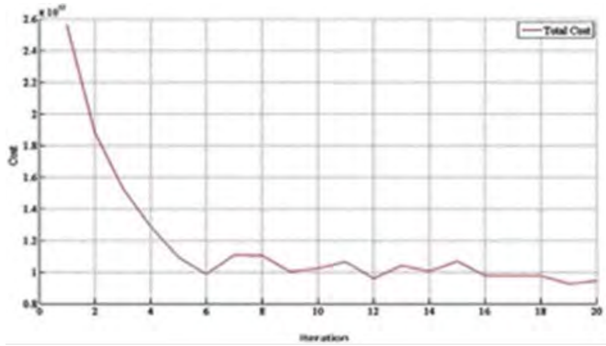

Figure 2: The Convergence of the Proposed Algorithm

In table 3, the output of algorithm for Iran's data mode, table 4, is shown. As it has been shown, Hamadan is the best place to install wind turbines due to climatic conditions and other parameters. In the second row of this table, the amount of pheromone on each case is presented.

In Figure 2 the rate of convergence of the proposed algorithm for a number of different circles have been shown. As seen in the primary loop, the system works with the high cost, but with an increase in the number of loop it can move to the lower cost. It can be said that the algorithm from the tenth loop till the end is relatively following a fixed routine and moving toward convergence.

Conclusion

Positioning wind turbines is an issues with high computational complexity which needs methods for optimal positioning regarding installation parameters. In this paper a method based on the Ant Colony algorithm was provided that can investigate the different options for construction of wind turbine sites and show their priorities. Simulation results show that the proposed approach shows a good performance with respect to the rate of convergence of algorithm and also positioning.

References

Baldick ,R., (2012). Wind and Energy Markets: A Case Study of Texas, *IEEE Systems Journal*, 6, 1, 27 – 34.

Bevrani ,H. & P. R. Daneshmand, (2012). Fuzzy Logic-Based Load Frequency Control Concerning High Penetration of Wind Turbines, *IEEE Systems Journal*, 6, 1, 173 – 180.

Bookman ,T., (2005). Wind energy's promise, offshore, IEEE Technology and Society Magazine, 24, 2, 9 – 15.

Dorigo, M. & Gambardella, L.M. (1997). Ant colony system: a cooperating learning approach to the traveling salesman problem, IEEE Trans. Evol. Compute 1(1), 1-24

Dorigo, M., Maniezz, V. & Colorni, A. (1996). The ant system: Optimization by a colony of cooperating agents' ‹IEEE Trans. on Systems. Man and Cybernetics, 26(1), 1-13.

Ghaderi, S.F., M.S.Zakerinia, E.Vaezi (2012). Optimal placement of wind turbine farms in Iran using new ranking method, Second Iranian Conference on Renewable Energy and Distributed Generation.134-135.

Gonz´alez-Longatt ,F. M., Wall, P., Regulski,P & V. Terzija, (2012). Optimal Electric Network Design for a Large Offshore Wind Farm Based on a Modified Genetic Algorithm Approach, *IEEE Systems Journal,* 6, 1, 164 – 172, Mishra ,Y., S. Mishra, & Li. Fangxing, (2012). Coordinated Tuning of DFIG-Based Wind Turbines and Batteries Using Bacteria Foraging Technique for Maintaining Constant Grid Power Output, *IEEE Systems Journal*, 6, 1, 16 – 26.

Parvania ,M. & M. Fotuhi-Firuzabad,(2012).Integrating Load Reduction into Wholesale Energy Market with Application to Wind Power Integration, *IEEE Systems Journal*, 6, 1, 35 – 45.

Salehinejad, H. and Talebi, S. (2010). Dynamic fuzzy logic-ant colony system based route selection system,, *Journal of Applied Computational Intelligence and Soft Computing*, 13 pages

Salman ,A. Khan & Sha_qur Rehman, (1892). Computational Intelligence Techniques for Placement of Wind Turbines: A Brief Plan of Research in Saudi Arabian Perspective, IEEE International Energy Conference, 2010... J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., 2. Oxford: Clarendon, 68-73.

Slootweg, G., & W.L. Kling,(2003). Is the answer blowing in the wind?, *IEEE Power and Energy Magazine,* 1 , 6, 26 – 33.