การหาสถานที่ตั้งและขนาดที่เหมาะสมของโซล่าฟาร์มในระบบไฟฟ้ากำลังโดยใช้วิธีการหาค่าที่เหมาะสมของฝูงผึ้ง โดยพิจารณาการแผ่รังสีดวงอาทิตย์

Optimal Location and Size of Solar Farm on Power System Using Bees Algorithm with Consideration of Solar Radiation

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บทคัดย่อ

พลังงานแสงอาทิตย์เป็นแหล่งพลังงานทดแทนที่ได้รับความนิยมเป็นอย่างมากซึ่งสามารถลดการใช้น้ำมันเชื้อเพลิงและลดผลกระทบต่อสิ่งแวดล้อม พลังงานแสงอาทิตย์เป็นแหล่งพลังงานสะอาดและยั่งยืน ในบทความนี้นำเสนอวิธีการหาตำแหน่งและขนาดที่เหมาะสมของโซล่าฟาร์มในระบบไฟฟ้ากำลังที่มีการใช้เชื้อเพลิงน้อยที่สุดโดยมีการพิจารณาการแผ่รังสีแสงอาทิตย์ในแต่ละตำแหน่งของโซล่าฟาร์ม วิธีการหาค่าที่เหมาะสมของฝูงผึ้งจึงถูกนำมาใช้ในการลดปริมาณเชื้อเพลิงของอุปกรณ์ความร้อนโดยการเปลี่ยนตำแหน่งและเปลี่ยนขนาดของโซล่าฟาร์มด้วยการพิจารณาถึงความปลอดภัยของระบบไฟฟ้ากำลังและปริมาณการแผ่รังสีแสงอาทิตย์ ระบบทดสอบแบบ IEEE 30 บัส จึงถูกนำมาใช้ในการทดสอบและพิสูจน์วิธีการที่นำเสนอ จากผลที่ได้แสดงให้เห็นว่าวิธีการที่นำเสนอนี้พบตำแหน่งที่เหมาะสมของโซล่าฟาร์มโดยมีต้นทุนทางเศรษฐศาสตร์ที่ต่ำที่สุด

Abstract

A solar energy is most popular renewable energy source which can reduce usage of fuel in thermal generation and impact on environment. The solar energy is a clean and sustainable source. This paper proposed method of finding optimal locating and sizing of PV solar farm on the power system with minimize fuel costs by considering solar radiation in each location of solar farm. The bees algorithm (BA) is used to minimize fuel cost of thermal units by changing location and varying sizes of solar farm with security constraints of power system and solar radiation. IEEE 30 bus test system is used to verify the proposed method. The results show that the proposed method found the optimal position of solar farm with minimum economic cost

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Keywords : Solar Farm, Power System, Bees algorithm, Solar Radiation

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1. INTRODUCTION

Pv solar farm is a system which uses many solar modules to convert sunlight into electricity. It consists of multiple components, including the photovoltaic modules, mechanical and electrical connections. Solar power has become popular renewable energy due to reducing of investment cost The advantage of solar power is very low maintenance and operation. One of the main advantages of a solar power system is the lack of pollution given off by solar panels when generating during daytime. Moreover; solar energy system operations do not generate air or water emissions pollutant and do not produce hazardous waste like coal, oil, or gas .

Integration of solar energy in power system is studied to find utilization of an existing solar farm. But the result of solar farm in economic benefit with considering solar radiation is not still developed. The goal of this paper is to find best location and sizing of solar farm in IEEE 30 bus test system with minimum fuel cost with many real constraints and considering solar radiation of each location of solar farm. The multiobjective bees algorithm is developed to find minimum fuel cost when the solar farm varies in its location and sizing on IEEE 30 bus power system. The result show that the best location and sizing of solar farm with minimum fuel cost in system.

2. PROBLEM FORMULATION

The objective of economic power dispatch with varying location and sizing of solar farm is to minimize the economic cost function of power system while satisfying various equality and inequality constrains with considering solar radiation. The total fuel cost can be expressed as

$$f(P)=\left(\sum_{d=1}^{N} a_d + b_d P_{G_d} + c_d P_{G_d}^2\right) + dP_S \quad (1)$$

Where a_i, b_i, c_i and d are the cost coefficients of the i^{th} generator units and Solar farm, and P_{Gi} and P_S are the real power output of the i^{th} generator units and Solar farm. N and N_S is the number of generators and solar farm respectively.

The system equality constraints $g(x,u)$ include: Power flow equations are:
Power flow equations are:

$$P_{Gi} + \text{«}_i P_{Si} - P_{Di} = V_i \sum_{j=1}^{NB} V_j \left[G_{ij}\cos(\text{¢}_i - \text{¢}_j) + B_{ij}\sin(\text{¢}_i - \text{¢}_j)\right] \quad (2)$$

$$Q_{Gi} - Q_{Di} = V_i \sum_{j=1}^{NB} V_j \left[G_{ij}\sin(\text{¢}_i - \text{¢}_j) - B_{ij}\cos(\text{¢}_i - \text{¢}_j)\right] \quad (3)$$

where NB is the number of buses. P_{Gi}, Q_{Gi} are real and reactive power generated at the i^{th} bus. V_i and V_j are the voltage magnitudes at bus i and j. ¢_i and ¢_j are the voltage angles at bus i and j. «_i is Solar radiation utilization factor of solar farm at bus i.

Power balance constraints: Power balance is an equality constraint. The total power generation must cover the total demand P_D. Hence,

$$\sum_{i=1}^{N} P_{Gi} + \sum_{i=1}^{N_S} «_i P_{Si} - P_D - P_L = 0 \tag{4}$$

Then, power loss in transmission lines can be calculated as

$$P_{loss} = \sum_{k=1}^{NL} g_k \left[V_i^2 + V_j^2 - 2V_i V_j \cos(¢_i - ¢_j) \right] \tag{5}$$

where V_i and V_j are the voltage magnitudes at bus i and j. $¢_i$ and $¢_j$ are the voltage angles at bus i and j.

The system operating constraints $h(x,u)$ include:

(1) Generation constraints:

For stable operation, generator voltages, real power outputs and reactive power outputs and reactive power outputs are restricted by the lower and upper limits as follows:

$$V_{Gi}^{\min} \le V_{Gi} \le V_{Gi}^{\max}, i \in N \tag{6}$$

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max}, i \in N \tag{7}$$

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max}, i \in N \tag{8}$$

$$P_S^{\min} \le P_S \le P_S^{\max} \tag{9}$$

where V_{Gi} and Q_{Gi} is voltage magnitude and reactive power at bus i of generator

(2) Security constraints:

Theses incorporate the constraints of voltage magnitudes of load buses as well as transmission line loadings as follows:

$$V_{Li}^{\min} \le V_{Li} \le V_{Li}^{\max}, i \in NB \tag{10}$$

$$S_{Li} \le S_{Li}^{\max}, i \in NL \tag{11}$$

where S_l and N_L are transmission line loading and the number of transmission lines.

3. Bees Algorithm

Bees algorithm (BA) was developed by Pham D.T which was used for optimizing numerical problems in 2006. The algorithm mimics the food foraging behavior of swarms of honey bees. Honey bees use several mechanisms such as waggle dance to optimally locate food sources and to search new one. This makes them one of candidate for developing Meta heuristic search algorithms. It is a simple, robust and population based stochastic optimization algorithm.

The colony of artificial bees is divided to two groups of bees namely scout and employed bees. The responsibility of scout bees is to find a new food source. The responsibility of employed bees is to determine a food source within the neighborhood of the food source in their memory and share their information with other bees within the hive.

3.1 COMPUTATION FLOW

The population has n_s scout bees and each bee is an *m*-dimensional vector, where *m* is the number of optimized parameters. The computation flow of the proposed BA technique is briefly stated and defined as follows:

Step 1: set $P = \left[P_{G_2},..,P_{G_N},P_S\right]^T$ is control vector bees.

Generate randomly the initial populations of P_i scout bees as following equation.

$$P_i = l + rand(0,1)\times(u-l) \quad ,i = 1....n_s \tag{12}$$

where u and l are upper and lower bound of control vector. These initial populations must be feasible candidate solutions that satisfy the constraints. Set $NC = 0$.

Step 2: Evaluate the fuel cost fitness value of the initial populations by using Newton power flow.

Step 3: Separate the m best solutions to two groups, the first group are e best solutions by using random selection and another group is other selected $m-e$ solutions.

Step 4: Determine the size of neighborhood search of each best solutions (ngh).

Step 5: Generate neighborhood solution (P_{ngh}) around the selected solutions within neighborhood size as following equations. For best solutions and

$$P_{ngh,e} = P_e + rand(0,1)\times ngh\times(u-l) \tag{13}$$

For other selected solutions.

$$P_{ngh,m-e} = P_{m-e} + rand(0,1)\times ngh\times(u-l) \tag{14}$$

Step 6: Evaluate the fuel cost fitness value of the generated solution by using Newton power flow and then select best solution.

Step 7: Check the stopping criterion. If satisfied, terminate the search, else $NC = NC+1$.

Step 8: Assign the $n-m$ population to generate new solutions and add it with last best solution. Go to Step 2.

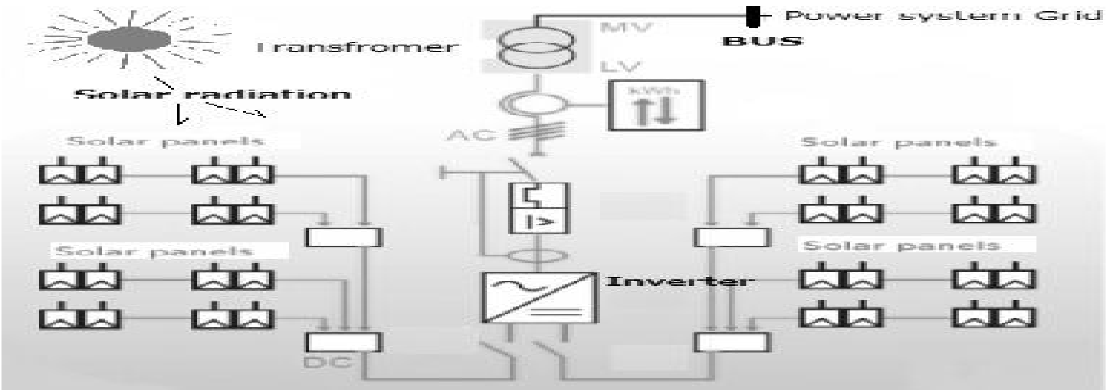


Figure.1: solar farm with inverter connect to bus of power system through power transformer

3.2 Solar farm

Solar farm consist of a large number of solar panel connected to bus of power system through power transformer. Solar farm uses inverter for converting dc power to 3 phase ac power into power system. Solar farm is shown in Fig.1

3.3 IMPLEMENTATION AND DATA OF SYSTEM

The parameter of BA can be set as follow. The population of bees is set to be 20. The number of selected sites and elite site is 3 and 1 respectively. Patch size is 0.1. Number of bees around elite site and Number of bees around other selected sites is 8 and 1 respectively. Maximum iteration = 100.The BA technique was tested on IEEE 30-bus 6-generator test system. The detail data and cost coefficient are given in. The BA is computed by Intel core i5 2.0 GHz processor 2 GB ram under MatLab program. The BA is tested to 30 runs to obtain best solution. The utilization factors depend on magnitude of solar radiation at each bus.

Table I. Solar radiation Utilization factor of bus location

Solar Radiation (MJ/m^2/day)	Bus Number	Utilization Factor
11	1,2,7,8,9,12, 14,15,18,19, 26, 28, ,30	0.7333
12	3,4,5,6,10,11	0.8
13	13,16,17,21,22,27	0.8667
14	20, 24	0.9333
15	23,25,29	1.0

3.4 RESULT AND DISCUSSION

Case 1: best fuel cost of power system without solar farm

Fuel cost is optimized to find the best solution by using BA Algorithm when solar farm is not penetrated into power system network. In order to confidence the accuracy of the result, the best solution in this case will be calculated by using Newton power flow of reference in IEEE 30 bus. Its result is shown in Table II. At the iteration of 10, the fuel cost of thermal generators is reduced to 802.38 $/h. This show that solar farm can supply some electric power replacing electric power from thermal generation

Case 2: best fuel cost of power system with solar farm penetration

Solar farm is penetrated into IEEE 30 bus test system. Its result can be shown in Table III and Fig 2. Table III shows the convergence graph of fuel cost when solar farm is penetrated into IEEE 30 bus systems. At the iteration of 60, the fuel cost of thermal generators is reduced to 474.13 $/h. This show that solar farm can supply some electric power replacing electric power from thermal generation

Table II. Results of best solution of the proposed approach without solar farm

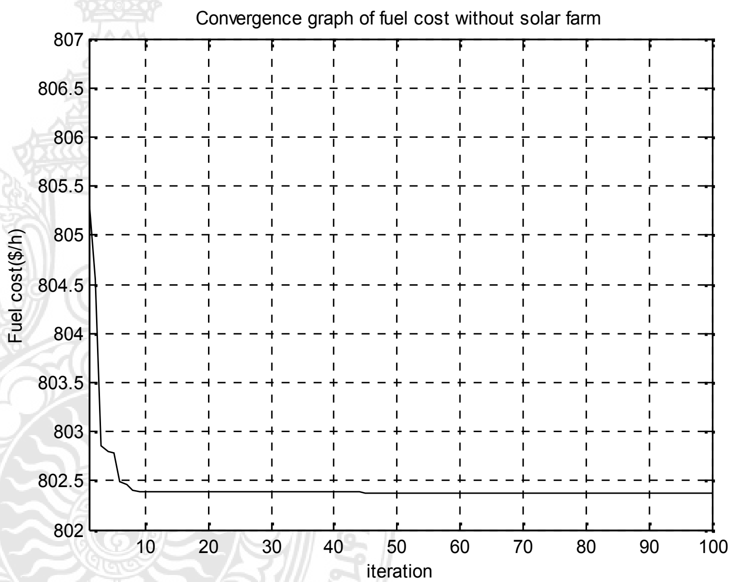
Unit (MW)	Best solution	Convergence graph of fuel cost without solar farm
P_{G1}	176.5317	
P_{G2}	48.9048	
P_{G3}	21.5192	
P_{G4}	21.8355	
P_{G5}	12.1108	
P_{G6}	12.0035	
Total of thermal units (MW)	292.9055	
Transmission loss	9.505	
Fuel Cost($/h)	802.38	

Table III. Results of best solution of the proposed approach with solar farm on IEEE 30 bus test system

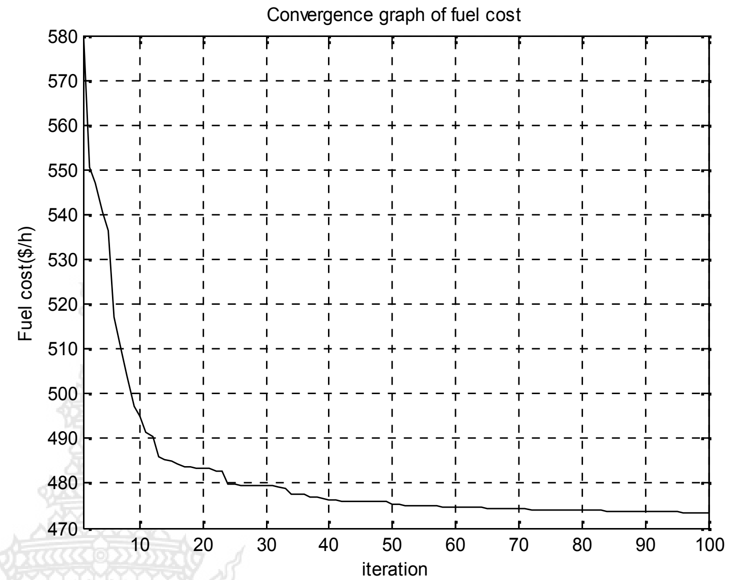
Unit (MW)	Best solution	Convergence graph of fuel cost with solar farm
P_{G1}	106.282	
P_{G2}	32.881	
P_{G3}	13.070	
P_{G4}	13.864	
P_{G5}	10.021	
P_{G6}	12.047	
Total of thermal units (MW)	188.167	
Transmission loss	4.739	
Fuel Cost($/h)	474.143	
Solar farm		
Location (Bus)	5	
Size (MW)	99.971	

Table III shows the power generation and solar farm position optimized by the BA technique. The result in this case has cost lower than previous case. Solar farm penetrated into IEEE 30 bus test system can reduce fuel cost as 328.23 $/hr and transmission loss as 4.766 MW respectively

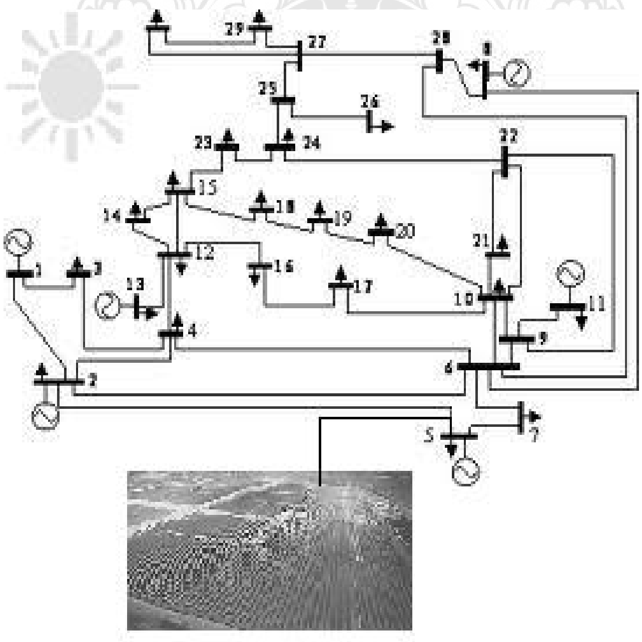


Figure.2: Location of solar farm in IEEE 30 bus tests system

4. CONCLUSION

BA algorithm has been proposed to find best location and sizing of solar farm on power system topology with minimum economic with considering solar radiation at location of solar farm. Solar farm is formulated as active power source to inject real electric power into power system network during daytime. The bees algorithm is used to search the optimum sizing and location of solar farm in power system. Then, the power from solar farm replaces some power from thermal generator in optimum location of solar farm by using the bees algorithm. Consequently, the solar farm can reduce usage of thermal generator in generating electric power for power system and fuel cost is reduced. The simulation result demonstrates that solar farm in optimum sizing and location can reduce fuel cost of generations with many real constrains of power system. In addition, the result indicated that proposed BA has effectiveness to search optimum point of solar farm on power system network with minimum fuel cost from thermal generator. Moreover, it will reduce emission from thermal generator.

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