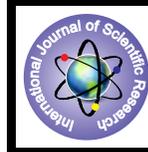


Particle Swarm Optimization based wind Turbine Location in Distribution System with Aiming Environmental protection



Engineering

KEYWORDS : environmental protection, particle swarm optimization, wind energy, wind turbine.

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ABSTRACT *This research focuses on the environmental protection by avoiding of CO₂ emissions using wind turbines (WT) placement in demand side of power distribution system. This paper proposes a particle swarm optimization algorithm based approach to analyze the long-term benefits of wind turbines (WTs) allocation at the demand side of a power distribution system. The benefits are evaluated based on the solar electricity generation and the avoidance of CO₂ emissions. The objective function has been considered as total emission minimizing with considering economical parameters for optimal location of WTs for installation in distribution system.*

1. Introduction-

The green house gas emission of electric power sectors around the world is about 1/3 of the total world emission, indicating the significance of electric power sectors in the global warming issue. In recent years, climate change due to greenhouse gas emissions has become a focus of international organizations and governments. In order to reduce green house gas emissions, the aim has been placed on finding more environmentally friendly alternatives for electricity power generation. Renewable energy technologies may include solar energy, wind, fuel cells, micro-turbines, etc. Due to advances in wind energy technologies, wind power is currently considered one of the most rapidly increasing resources. There is no doubt that the benefit of WTs is beginning to attract many utilities in the electricity market [1].

In the electricity market, WTs are like small Independent Power Producers (IPPs), which intend to sell power to utilities for profit [2]. WTs need to maximize profit instead of minimizing operating cost. This problem emphasizes the importance of the price signal in the electricity market. Electricity prices are very volatile, varying with the level of use at various times of day, thus affecting the profits received by the IPPs when selling the power to the distribution network [1-2]. In addition, as WTs reduce CO₂ emissions due to the use of wind generated electricity, the reduced emissions will turn into revenues in the carbon market. CO₂ emissions can be traded in the carbon market to gain further benefits [3]. This paper describes a benefit analysis when WTs are installed to meet load growth in a distribution system. A life time of 10 to 20 years is assumed for the solar-power installations. The benefits of WTs are evaluated by considering the power generation of WTs, electricity prices, and carbon trading prices. Distribution system planners must ensure the adequate capacity that meets the load growth within the planning horizon year. In general, WTs are mostly installed in a demand system, and connected directly to distribution networks.

2. Small wind turbines (WTs) modeling

Wind turbines have been improved in technology in recent years so that their efficiency has been increased from 15 % up to 50 %.

The wind turbine captures the wind's kinetic energy in rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on tall tower to enhance the energy capture. The output power of wind turbines is predicted by using the following equation [4]:

$$\begin{cases} P_w = 0 & v < v_{Cl} \\ P_w = a v^3 - b P_r & v_{Cl} < v < v_r \\ P_w = P_r & v_r < v < v_{Co} \\ P_w = 0 & v > v_{Co} \end{cases} \quad 1$$

That the parameters “a” and “b” calculated as:

$$\begin{cases} a = P_r / (v_r^3 - v_{Cl}^3) \\ b = v_{Cl}^3 / (v_r^3 - v_{Cl}^3) \end{cases} \quad 2$$

In these equations, P_w is the measurement power at the turbine, P_r is the nominal power of turbine, V_r is the speed related to nominal power, V is the speed of wind, V_{Cl} is the low cut speed and V_{Co} is the up cut speed.

The turbine power versus wind speed curve for Generic 10 kW is plotted in Figure 1.

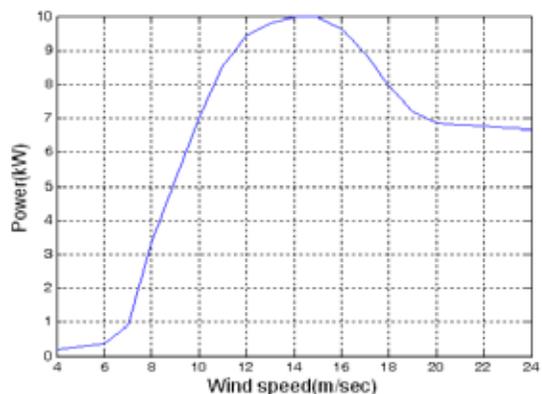


Figure 1 the 10kW generic wind turbine power generation curve

3. Problem formulation

The benefit of WTs installed is determined by the net change in the total cost of electricity generation before and after the installation. The costs include investment cost and maintenance cost, and the benefits include the profit of electricity sold, CO₂ emissions sold, and loss reduction.

A better planning method is to locate the minimum cost solu-

tion where the total benefits can be maximized. Therefore, costs and benefits of WT allocation in the network can be expressed as follows, with the cash flows presented below in Figure 2.

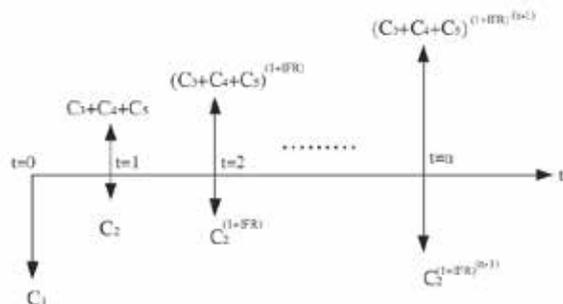


Figure 2 Cash flows of the WT project

3.1 Investment cost

The investment cost of WT units can be formulated as the following equation:

$$C_1 = \sum_{i=1}^m Fix_i \quad (3)$$

Where, Fix is the investment cost of WT units installed (NT\$ 5.2 × 10⁵ /unit) [5].

3.2 Maintenance cost

The maintenance cost can be evaluated by:

$$C_2 = \sum_{i=1}^m CM_i \quad (4)$$

CM is the maintenance cost of WT units (NT\$ 1.12 × 10⁷ /year) [3-5].

Present value of this is:

$$PW(C_2) = C_2 \sum_{i=1}^T \frac{(1+IFR)^{i-1}}{(1+INR)^i} \quad (5)$$

3.3 The Profit of CO₂ Sold

The main profit of WT installation is the profit of CO₂ sold which encourages engineering planners to employ the wind turbines in distribution systems.

The profit of CO₂ sold,

$$C_3 = 8760 \times CF \times \sum_{i=1}^m P_i \times \phi \times Cost_c \quad (6)$$

Where, φ is the Carbon exhaust coefficient (0.518 kg CO₂ e/kWh) [4], Cost_c is the carbon trading price (NT\$/ton) and CF is the capacity factor of WT units.

Of course the other annual profit of WT units installed includes the profit of line loss reduction, C₄, the profit of power generation, C₅. The formulation is calculated as follows:

The profit of line loss reduction:

$$C_4 = 8760 \times CF \times P_{loss} \times Cost_e \quad (7)$$

The profit of power generation:

$$C_5 = 8760 \times CF \times \sum_{i=1}^m P_i \times Cost_g \quad (8)$$

Where, Cost_e the electricity price (NT\$), P_{loss} the loss reduction after WT units are installed (kW).

Present value of this annual profit is calculated by:

$$BPW(B) = (C_4 + C_5) \sum_{i=1}^T \frac{(1+IFR)^{i-1}}{(1+INR)^i} \quad (9)$$

The benefits of WT units can be calculated as:

$$benefit = BPW(B) - C_1 - PW(C_2) \quad (10)$$

The benefits of WT units can be calculated as:

$$benefit = BPW(B) - C_1 - PW(C_2) \quad (11)$$

4. Particle Swarm Optimization

In a PSO system, Birds' (particles) flocking optimizes a certain objective function. Each particle knows its current optimal position (pbest), which is an analogy of personal experiences of each particle. Each particle also knows the current global optimal position (gbest) among all particles in the population. Through specific equations, each particle adjusts its position and determines the search direction according to its search memory and those of others.

Using the PSO, the velocity can be represented under Eq. (14) in the PSO algorithm. Using Eq. (13), a certain velocity can be calculated as the position of individuals gradually moves closer to pbest and gbest. The current position can be modified by:

$$v_{i,d}^{j+1} = K \times [v_{i,d}^j + c_1 \times \text{rand}(0,1) \times (X_{i,d}^{j+1} - X_{i,d}^j)] + c_2 \times \text{rand}(0,1) \times (Gbest^j - x_{i,d}^j) \quad (12)$$

$$X_{i,d}^{j+1} = X_{i,d}^j + V_{i,d}^j \quad (13)$$

Where

$$K = \frac{2}{|2 - c - \sqrt{c^2 - 4c}|}, c = c_1 + c_2 > 4 \quad (14)$$

c₁, c₂ is the acceleration constant, in this paper, c₁ = c₂ = 4.05.

5. Simulation and Results

The proposed algorithm was applied to solve the 33-bus distribution system problem, as shown in Figure 3 [7]. The total real and reactive power demand of the 33 bus system were 1470 kW and 1012 KVAR, respectively. The maximal power generation of WT units is set to 300kW.

The PSO parameter used in this paper was listed in Table 1. The power output for each WT ranged from 200kW to 300kW, while all network bus voltage magnitudes remained within 0.95-1.05/ unit. The power factor for each WT was 0.75. The load growth rate was 3% in the distribution system, and the horizon years were set at 20, 30 and 40 years. Table 2 shows the summary of the simulation results.

Table 1 PSO parameters

Indices	Parameter value
Num. of particles (d)	500
C1,C2	5
No. of iteration	500
V _{gd} ^{max} , V _{gd} ^{min}	6q _d ^{max} - 0.5q _d

Due to the load growth, the number of WT units installed was 3, 5 and 9 at 20, 30 and 40 horizon years in order to meet the load

growth and operational constraints. The total power output of WT's was 408.45 kW, 705.30 kW and 1102.42 kW at the different horizon years. The results suggested that the WT's installed significantly improved on the system losses. Because the executed characteristics of PSO might converge at different solutions for each test, the problem was solved 50 times by the proposed method. The best and worst system losses were found from the 50 trial tests.

The best percentage of loss reduction ranged from 12.24% to 34.20% at the various horizon years. Figure 4 shows the voltage profiles before and after the WT's were installed at the 20-th horizon year.

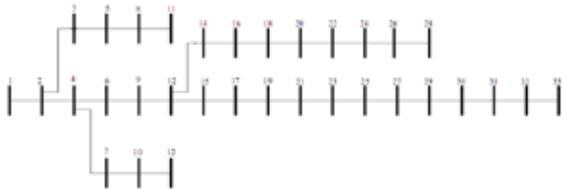


Figure 3 Single Line Diagram of the 33-Bus Radial Distribution System

Table 2 shows the summary of the simulation results.

Horizon year	20	30	40
Total real load demand (kW)	1705	1980	2290
Total reactive load demand (KVAR)	1210	1400	1650
The total power output of WT's(kW)	408.45	705.30	1102.42
The average percentage of loss reduction (%)	25.46	30.80	35.20
The number of WT's installed	3	5	9
The location of WT(no. of bus)	7,11,19	7,15,19,23,28	3,5,7,14,18,23,25,29,32

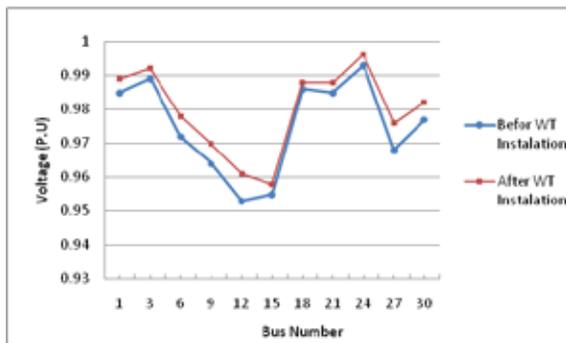


Figure 4 The voltage profiles before and after the WT's installation

The benefits sensitivity analysis of WT's contained two scenarios which varied with the electricity price, carbon price, and power generation after the WT's were installed. Table 3 shows the conditions of two scenarios in this study.

Table 3 The conditions of three scenarios in this study.

	Carbon price (NT\$/ton)	Power generation (kW/unit)
Case 1	0-2000	140
Case 2	800	200-300

As shown in Figure 4, the voltage profile was clearly improved after the WT's were installed, almost satisfying the voltage limits along the feeder. Figure 5 shows the convergent characteristics of the proposed method at the 20-th horizon year. The convergent generation was about the 300-th generation

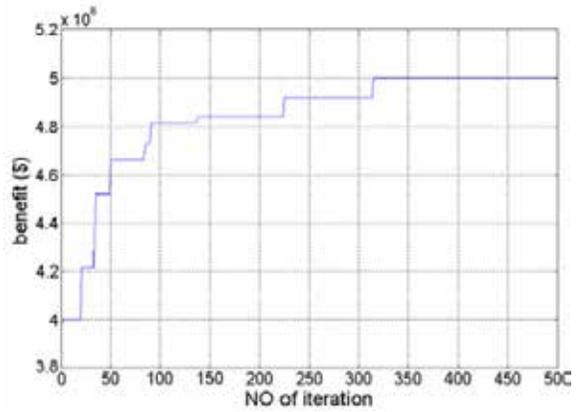


Figure 5 The convergent characteristics of the proposed method.

In Case-1, the carbon price varied from between 0-2000 NT\$/ton. In case 2 the power generation varied between 200-300 kW/unit. A lifetime of 20 years was assumed for the WT's installed.

Figure 6 shows the benefits analysis of WT's installed in Case 1. The largest positive contribution to the WT's benefit was from the reduction in CO₂ charges.

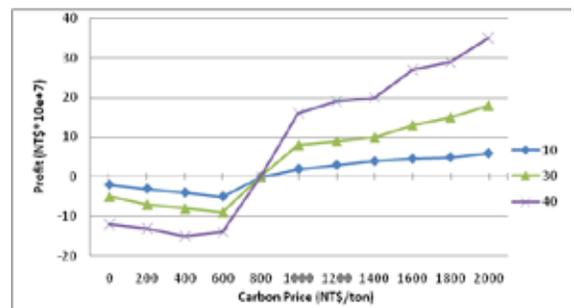


Figure 6 The benefits of WT's installed in Case-2 versus carbon price at the various horizon year

The investment in WT's arrived at economical equilibrium when the carbon prices were sold at 800 NT\$/ton in this case. When the carbon price was high, the benefits of the WT investment would increase.

Figure 7 shows the benefits of WT's installed in Case-2. As seen, when the power generation for each WT was about 140kW, the investment in WT's could arrive at economical equilibrium. When the power generation of WT's increased, the benefits of the WT investment were also higher.

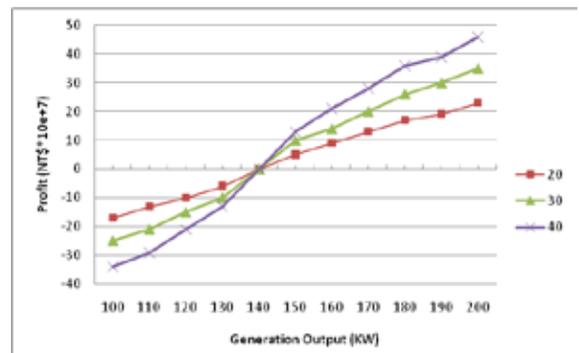


Figure 7 The benefits of WT's installed in Case-3 versus generation output at the various horizon year

6. Conclusion

This study successfully solved the photovoltaic allocation in distribution systems by aim of CO₂ emission reduction using PSO.

By considering electricity price and carbon price, the economical benefits of the installation of WTs were evaluated in three different scenarios. This study found that electricity price or carbon price is a key parameter in the development of WTs.

Simulation results also showed that optimal incorporating the WTs in the distribution system can reduce system losses, as well as improve the voltage profiles.

In addition, it is found that as WTs reduce CO₂ emissions due to the use of solar generated electricity, the reduced emissions will turn into revenues in the carbon market.

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