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Investigation the Effects of Electricity Price Variation under Power Market on Optimal Selection of Wind Turbines with Purpose of Co2 Emission Reduction

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ABSTRACT

It is a universal problem that the investments of solar power and wind power technologies as renewable energy resources (RES) require support and incentives in most economies as long as prices for fossil fuels fail to reflect the negative externalities on the environment. The characteristics of solar and wind power include high capacity cost, and low CO2 emissions as compared to fossil-fuel plants. If CO2 emissions could be charged in the future electricity market, the environmental benefits of solar and wind power can be increased significantly. Wind Turbines (WTs) are small plants that are properly located to provide an incremental capacity to power systems. The integration of WTs into an existing distribution system, depending on the allocation of them can result in several advantages, such as line loss reduction, peak shaving, emission reduction, and increased system voltage profile.

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INTRODUCTION

The green house gas (GHG) emission of electric power sectors around the world is about 1/3 of the total world GHG emission, indicating the significance of electric power sectors in the global warming issue. In recent years, climate change due to greenhouse gas (GHG) emissions has become a focus of international organizations and governments [1]. In order to reduce GHG emissions, the aim has been placed on finding more environmentally friendly alternatives for electricity power generation. Renewable Energy (RE) is required for local energy markets, as an important alternative energy production option in the near future [2]. RE technologies may include solar energy, wind, fuel cells, micro-turbines, etc. Due to advances in solar energy technologies, solar power is currently considered one of the most rapidly increasing resources [3-4].

1. Wind energy:

As shown in figure 1, the application of wind turbine for electricity production with aim of the lesser utilization of fossil-fuel plants for meet customers is presented.

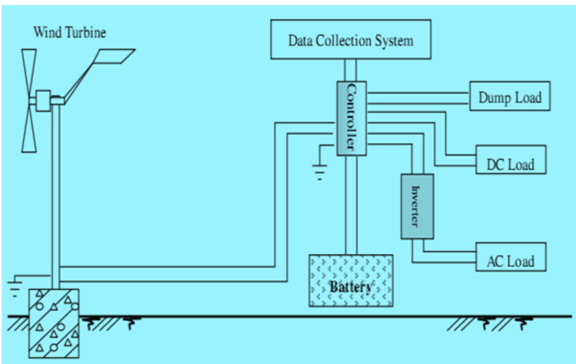

Fig.1: wind turbine for electricity production instead of fossil-fuel plants.

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To assess the operating performance of a wind turbine at a given location, its energy production is first expressed in terms of wind speed. Among the many mathematical models used in studies of wind power, the cumulative Weibull statistical distribution is most appropriate to describe the variations in wind speed. It is given by [5]:

$$f(v) = \frac{K}{C}\left(\frac{V}{C}\right)^{K-1} \exp\left(-\left(\frac{V}{C}\right)^{K}\right) \quad (1)$$

Where **f(v)** is the Weibull probability density function; **K** is the dimensionless shape factor which describes the distribution of the wind; **C** is the scale factor (m/s) which characterizes the wind speed, **V** is the average wind speed (m/s).

K and **C** are determined using iteration method as follows:

$$K = \left(\frac{\sum_{i=1}^{n} V_i^K \ln(V_i)}{\sum_{i=1}^{n} V_i^K} - \frac{\ln(V_i)}{n}\right)^{-1} \quad (2)$$

$$C = \left(\frac{1}{n}\sum_{i=1}^{n} V_i^K\right)^{\frac{1}{K}} \quad (3)$$

The power delivered by wind turbines is determined by following equation:

$$P_W = \frac{1}{2}\rho_{air} \times A_{ref} \times \overline{V}^3 \quad (4)$$

Where $\mathbf{P_W}$ is the power in the wind (W), $\mathbf{A_{ref}}$ the reference area of WT which is normally the swept area of the rotor blade (m^2), ρ_{air} the air density (kg/m^3), and $\overline{V}$ is the mean wind speed during certain time interval (m/s) and is calculated as follows:

$$\overline{V}^3 = \sum_{i=1}^{N} f_i V_i^3 \quad (5)$$

Where **N** is the number of measurements, **Vi** is the wind speed.

$$\overline{P}_d = \frac{1}{2}\rho_{air}\sum_{i=1}^{N} f_i V_i^3 \quad (6)$$

As wind speed increases with altitude, an empirical relationship is applied to extrapolate these data to the hub height. Its basic form is [6]:

$$V = V_{ref}\left(\frac{h}{h_r}\right)^{\alpha} \quad (7)$$

where V_{ref} is the wind speed recorded at anemometer height h_r, V is the wind speed to be determined for the desired heights h, α is the ground surface friction coefficient. A typical value of 1/7 for low roughness surfaces and well-exposed sites is used in this study.

Figure 2 shows the wind speed distribution. By studying the distribution of this speed, we can notice that:

- 20.5% of wind speeds are less than or equal to 4 m/s,
- 62.5% of wind speeds between 5 and 9 m/s (representing the right speed for low power turbines),
- 17% of wind speeds above 10 m/s (nominal speed of most wind turbines of average power).

In view of these surveys to measure wind speed, we can notice that this region, could be a region favorable to the exploitation of wind energy small systems.

2 *Problem formulation:*

The benefit of RES over its life time is calculated when the WTs are allocated based on the load growth. The benefit of RES 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. To better techno-economic analysis of renewable energy resources implementation in distribution system, the costs and benefits of RES allocation in the network can be expressed as follows [7-8], with the cash flows presented below in Figure 3.

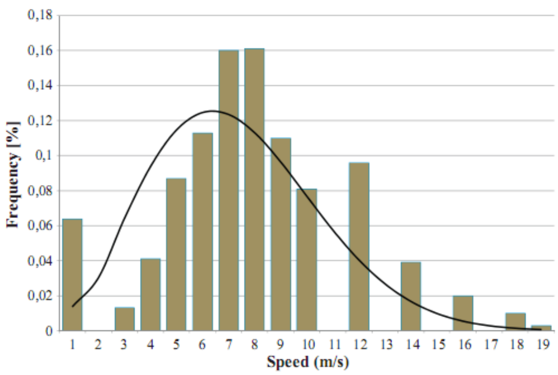

Fig. 2: Distribution of wind speed.

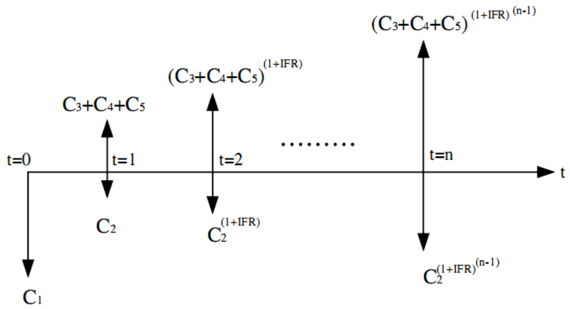

Fig. 3: Cash flows of the renewable energy resources project.

2.1 Investment cost:

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

$$C_1 = \sum_{i=1}^{m} Fix_i \quad (8)$$

Where, Fix is the investment cost of RES technologies includes WTs installed

2.3 Maintenance cost:

The maintenance cost can be evaluated by:

$$C_2 = \sum_{i=1}^{m} CM_i \quad (9)$$

CM is the maintenance cost of RES ($NT\$ \ 1.35\times10^7 /year$) [9].

Present value of this annual cost considering inflation rate and interest rate in the life time is calculated by:

$$PW(C_2) = C_2 \sum_{t=1}^{T} \frac{(1+IFR)^{t-1}}{(1+INR)^t} \quad (10)$$

Where, T is the life time of RES (20 years), *IFR* the annual inflation rate, *INR* the annual interest rate.

2.4 The Profit of CO_2 Sold:

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

The profit of CO2 sold,

$$C_3 = 8760 \times CF \times \sum_{i=1}^{m} P_i \times \phi \times Cost_c \quad (11)$$

Where, m is the number of RES installed, Pi is the rated real power output of each RES technology (kW), ¢ is the Carbon exhaust coefficient (0.612 kg CO2 e/kWh) , Costc is the carbon trading price (NT$/ton) and CF is the capacity factor of RES.

Off course the other annual profit of RES 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:

$$C_4 = 8760 \times CF \times P_{loss}^{r} \times Cost_e \tag{12}$$

The profit of power generation:

$$C_5 = 8760 \times CF \times \sum_{i=1}^{m} P_i \times Cost_e \tag{13}$$

Where, $Cost_e$ the electricity price (NT$), P_{loss}^{r} the loss reduction after RES are installed (kW).
Present value of this annual profit is calculated by [10]:

$$BPW(B) = (C_3 + C_4 + C_5)\sum_{t=1}^{T} \frac{(1+IFR)^{t-1}}{(1+INR)^{t}} \tag{14}$$

The benefits of RES can be calculated as:

$$benefit = BPW(B) - C_1 - PW(C_2) \tag{15}$$

3 Technical analysis and discussion:

In this paper, to investigate the profits of utilization of renewable energy resources in electrical distribution system with aim of green house gas emission, a 34-bus test system as shown in figure 4 is considered. At first in first case, in order to investigate the effects of implantation of wind turbines, 8 WTs at buses 4, 16, 9, 20, 12, 34, 23 and 27 according to decision of planner is employed. In this case the profit evaluation of photovoltaic employment in distribution system three parameters including the variation of electricity price and the variation of generation output of WTs as presented further are analyzed. The line data of test system in listed in Table 1.

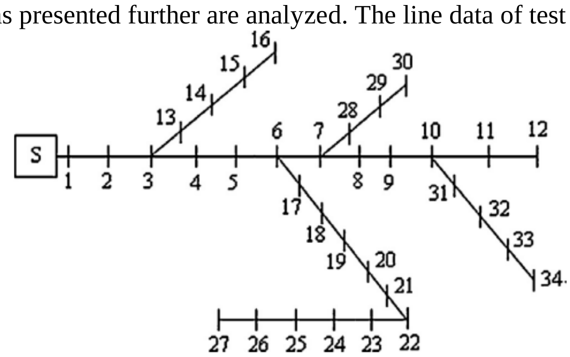

Fig. 4: The 34-bus test system.

3.1 *Profit evaluation based electricity price:*

In order to investigate the profit of renewable energy employment, the electricity price varied from 4.5 NT$/ kWh to 10 NT$/kWh and the carbon price and power generation of WTs were maintained at 800NT$/ton and 140kW/unit, respectively. In this study, the return time of RES was 20 years. Based on different horizon years, the benefits of RES installed were evaluated based on different electricity prices.

Figure 5 shows the profits of WTs installed with electricity price variation as second case study to investigate the system profit variation with electricity price when wind turbine are used in system for the horizon years were set at 10, 20 and 30 years.

At second case, in order to make a compression, the PVs are employed in proposed system and the discussion presented before are analyzed again.

The result of this study for photovoltaic cells is shown in Fig.6.

3.2 *Profit evaluation based power generation.*

In third study, to investigate the profit of renewable energy employment, the electricity price and carbon price were maintained constant and the effect of power generation variation of system profit has been analyzed. The simulation result of this study when photovoltaic are located in system is presented in Fig.7. The simulation result of this study when wind turbines are located in system is presented in Fig.8.

The power output for each WT ranged from 2500kW to 300kW, while all network bus voltage magnitudes remained within 0.95-1.05/unit.

Table 1: Line data in 34-bus test system.

From Bus	To Bus	R (p.u)	X (p.u)	From Bus	To Bus	R (p.u)	X (p.u)
1	2	0.03076	0.01567	18	19	0.09385	0.08457
2	3	0.02284	0.01163	19	20	0.02555	0.02985
3	4	0.02378	0.01211	20	21	0.04423	0.05848
4	5	0.05114	0.04411	21	22	0.02815	0.01924
5	6	0.01168	0.03861	22	23	0.05603	0.04424
6	7	0.04439	0.01467	23	24	0.05591	0.04374
7	8	0.06514	0.04617	24	25	0.01267	0.00645
8	9	0.01227	0.00406	25	26	0.01773	0.00903
9	10	0.02336	0.00772	26	27	0.06607	0.05826
10	11	0.09159	0.07206	7	28	0.05018	0.04371
11	12	0.03379	0.04448	28	29	0.03166	0.01613
3	13	0.03687	0.03282	29	30	0.06083	0.06008
13	14	0.04656	0.03410	10	31	0.01937	0.02258
14	15	0.08042	0.10738	31	32	0.02128	0.03319
15	16	0.04567	0.03581	32	33	0.00575	0.00293
6	17	0.01023	0.00976	33	34	0.02336	0.00772
17	18	0.08042	0.10738				

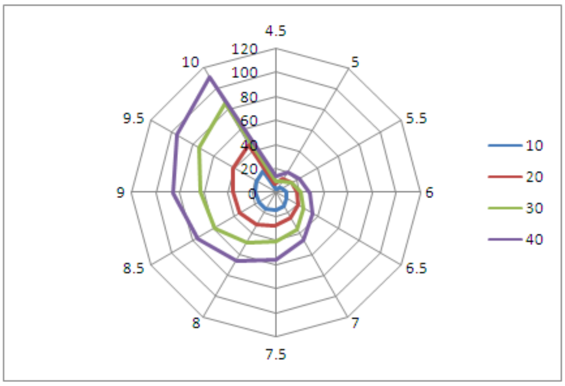

Fig. 5: System profits of WT utilization in terms of electricity price variation.

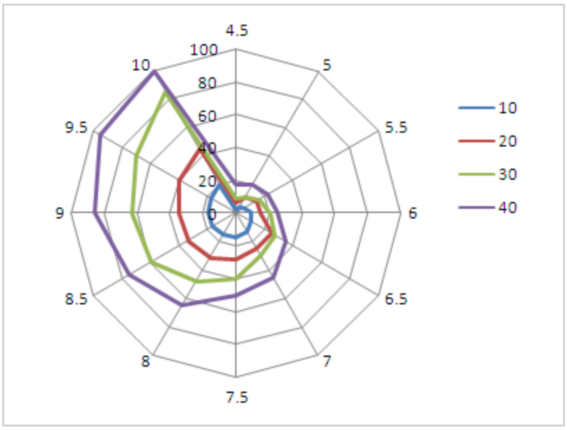

Fig. 6: System profits of PV utilization in terms of electricity price variation.

4. Conclusion:

This paper deals with environmental protection by avoiding CO_2 emission through renewable energy resources (RES) utilization in power generation sectors to reduce the green house gas emission of electric power sectors.

Renewable energy resources which have been employed in this research are solar and wind energies. The characteristics of solar and wind power include high capacity cost, and low CO_2 emissions as compared to fossil-fuel plants. If CO_2 emissions could be charged in the future electricity market, the environmental benefits of solar and wind power can be increased significantly.

In this research the profit evaluation of photovoltaic and wind turbine employment in distribution system under three parameters including, the variation of electricity price, the variation of carbon price, and the variation of generation output are analyzed.

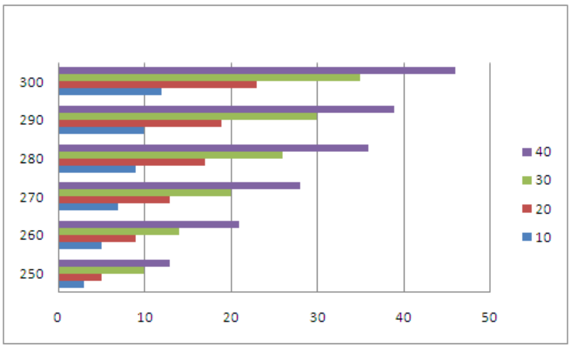

Fig.7: System profits of PV utilization in terms of generation output variation.

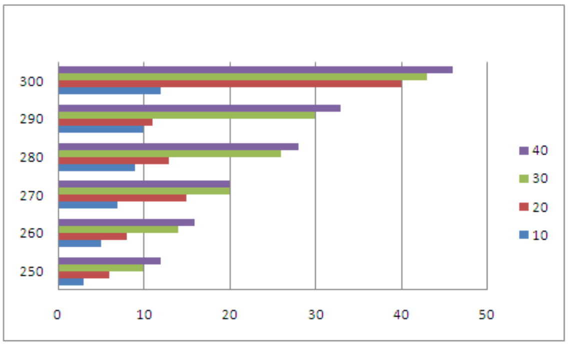

Fig. 8: System profits of WT utilization in terms of generation output variation.

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