THE SIMULATION OF PHOTOVOLTAIC POWER GENERATION AND WIND POWER GENERATION ON THE HYDRID ELECTRICITY SUPPLY SYSTEM OF A BUILDING

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ABSTRACT

Solar energy and wind energy are one of renewable energies, and they are inexhaustible energy source which are available anywhere. Photovoltaic power generation and wind power generation are inexhaustible energy system, and they are cleanly safe, because of their no discharge of CO_2 (one of the major causes of global warming), NOx and SOx (the major atmosphere pollutants).

In designing of the energy supply system of a building, these are one of the efficient power generating installations. For assessment analysis of the hybrid natural energy power generating system plan on photovoltaic power generation and wind power generation, an annual simulation program was developed.

INTRODUCTION

The annual simulation program about a hybrid system on photovoltaic power generation and wind power generation estimates the electric power demand of a building in every time for 24 hours in typical 1-day in each month. It simulates electric power generation of photovoltaic power generation and wind power generation, power purchase quantity of commercial electric power, and electric power selling quantity.

A building application is chosen from detached house, group houses, office building, hotel, hospital, and large store. In simulation, data of solar radiation and wind velocity is used within meteorological data of Meteorological Agency annual report announced.

Two application analysis case studies of photovoltaic power generation and wind power generation are shown. The one's building application is detached house and the other's is large store. Analysis and evaluation on 3E (energy saving, environment, economical efficiency) are carried out.

SIMULATION

The simulation is carried out by the following procedure. (1) Input of meteorological data, (2) Assuming the building, (3) Setting of photovoltaic power generation, (4) Setting of the wind power generation, (5) Annual simulation, and (6) 3E analysis evaluation.

(1) Input of meteorological data
Meteorological data, the data of global solar radiation and wind velocity of the meteorological station in the region vicinity simulated are input from CDROM of the Meteorological Agency annual report announced. The global solar radiation is divided into the direct normal solar radiation and the horizontal surface diffuse solar radiation.

(2) Assuming a building
A building application of a simulating building is chosen, and the architectural area is input. A building application is chosen from detached house, group houses, office building, hotel, hospital, and large store. On a detached house, setting of annual income and family make-up is necessary. By the Primary Unit Method, the annual electric power demand quantity is estimated using primary unit/year shown at Table-1, with the building application and the architectural area.

Table-1 primary unit/year of the annual electric power demand quantity

Building application	Primary unit/year	Reference
Office building	156 kWh/ m^2・a	1)
Large store	226 kWh/ m^2・a	1)
Hotel	200 kWh/ m^2・a	1)
Hospital	170 kWh/ m^2・a	1)
Group houses	21 kWh/ m^2・a	1)
Detached house *1	3,564 kWh/family・a	2)

*1 Family 4 persons, ¥ 10,000,000 annual yields

Using monthly loading rate and monthly number of workdays and loading rate according to the time, the electric power demand/year of the building are assigned to electric power demand quantity in the every time for 24 hours of typical 1-day in each month.

(3) Setting photovoltaic power generation
In setting of photovoltaic power generation, azimuth angle and tilt angle, photovoltaic power generation capacity, generating efficiency, power generation correction factor, and latitude and longitude of simulating region are input. Power generation correction factor considers temperature correction coefficient, fouling correction factor, direct current circuit loss correction factor, and output correction factor.

Based on global solar radiation, which separated into normal direct radiation and horizontal diffuse radiation, the program calculates solar irradiation on inclined surface of the solar panel and photovoltaic power generation, which are incident on the solar panel.

(4) Setting wind power generation
In setting of the wind power generation, height of the windmill, wind power generation capacity, cut-in wind speed, cut-out wind speed, rated wind speed is input. Based on approximate curve of wind power generation characteristic curve and meteorological data correct with height correct coefficient, wind power generation electric energy is calculated.

(5) Annual simulation
Photovoltaic power generation electric energy and wind power generation electric energy are calculated in every 365th and 24 hours. By averaging on the time, this data is arranged at the generated energy in every time for 24 hours in average 1-day in each month.

Supply-demand relationship of electric power is simulated in comparison with electric power demand quantity of the building and the generated energy of photovoltaic power generation and wind power generation on the time with each month.

The surpassed electric power generates reverse tide to the system electric power, when the generated energy is bigger than the electric power demand quantity. Surpassed electric power is sold to the system electric power. In reverse, the insufficient electric power is purchased from system electric power, when generated energy is smaller than the electric power demand quantity. It is assumed that photovoltaic power generation electric energy is prior supplied from wind power generation electric energy.

(6) 3E analysis
The program carries out the analysis evaluation on energy saving, environ-ment, economical efficiency, after supply-demand relationship of generated electric power and system electric power are clarified. The energy saving is compared with conventional system, having no natural energy power generating installation, on first energy amount. The environment is compared with the conventional system on the CO_2 emission reduction rate. The economical efficiency is compared with the conventional system on recovery years, which divides initial cost by reduced running cost.

First energy conversion factor, CO_2 discharge rate, cost of equipment unit price, and electricity rate unit price are shown at Table-2.

Table-2 Parameter of evaluation

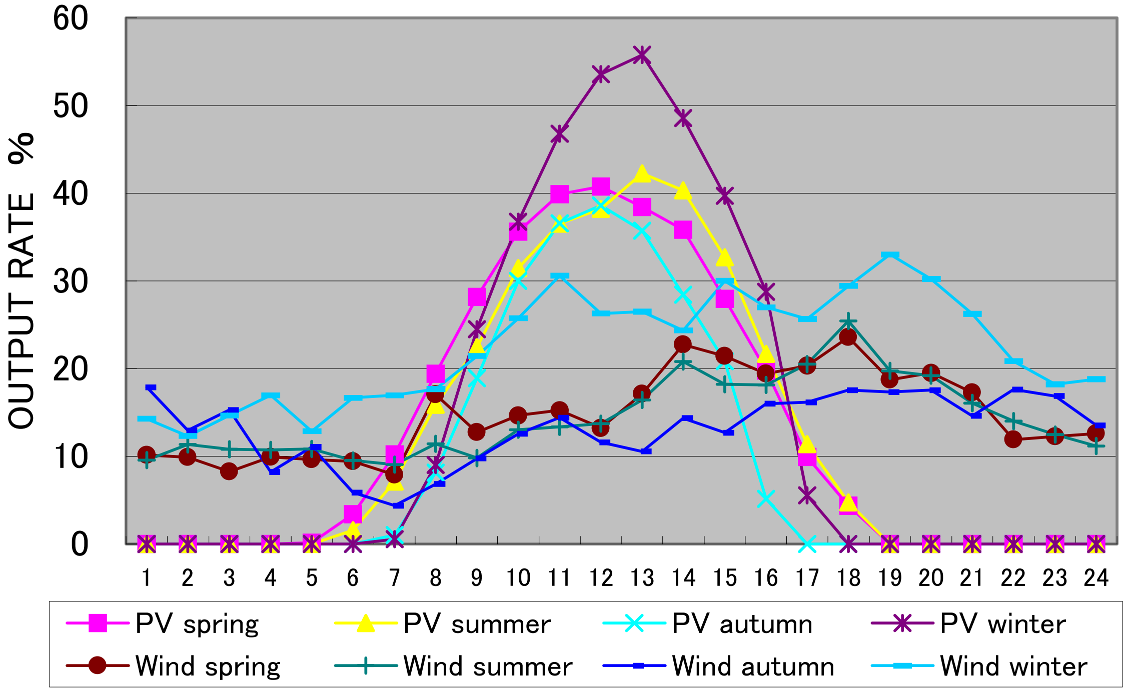
First energy conversion factor	2450	Kcal/kWh
Second energy conversion factor	860	Kcal/kWh
CO_2 discharge rate	0.165	Kg-C/kWh
Cost of equipment unit price of photovoltaic power generation	1,000,000	Yen/kW
Cost of equipment unit price of wind power generation	400,000	Yen/kW
Electricity rate unit price(day) for purchase	25	Yen/kWh
Electricity rate unit price(night) for purchase	8	Yen/kWh
Electricity rate unit price(day) for sell	25	Yen/kWh
Electricity rate unit price(night) for sell	8	Yen/kWh

CASE STUDY

Region for case study is made to be Tokyo. Meteorological data of the Meteorological Agency annual report are used in 1997. The solar panel is installed at 0 degree azimuth angle, 30 degree tilt angle, and it is assumed with the 12% generating efficiency. The windmill is made to be cut-in wind speed 3m/sec, cut-out wind speed 20m/sec, rated wind speed 8m/sec.

The output rate of the generated electric power for rated power of photovoltaic power generation and wind power generation of each season is shown in Figure-1. Power generation data in spring is shown on May, summer on August, autumn on November, winter on February.

On winter output rate of photovoltaic power generation increases most, and it reaches 55% at the peak. The peak is around 40% on the other season,



Fig–1 The output rate of the generated electric power for rated power

and on autumn it is the smallest. The wind power generation can be generated throughout 24 hours, and output rate is the most largely exceeds 30% at the peak on winter. By averaging with each season, the output rate over 10% is obtained.

Full load equivalent hour of photovoltaic power generation and that of wind power generation are shown in Figure-2. The left axis is for the full load equivalent hour of month, and the right axis is for the annual full load equivalent hour.

Full load equivalent hour of month of photovoltaic power generation is also around 120h each month, when September, November, December is small with 70h-95h, and the annual full load equivalent hour is 1305h.

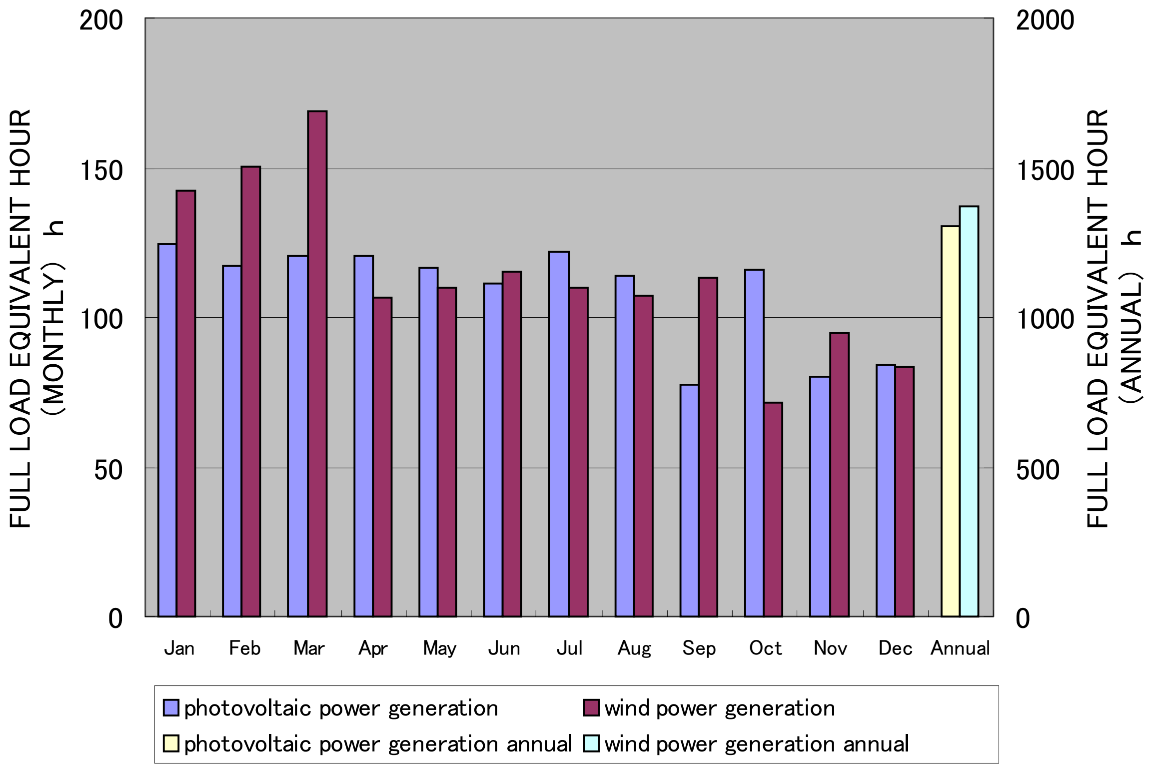


Fig-2 The full load equivalent hour

Full load equivalent hour of month of the wind power generation is big in January, February, and March. Except for October, November, December, it exceeds 100h, and the annual is 1373h.

In this fact, the annual generated energy of the wind power generation is bigger than that of the photovoltaic power generation, if it is the equal generation capacity.

(1) Detached house

Architectural area of detached house is 120m^2, and families 4 persons, 10 million-yen annual yields are assumed. The electric power demand/year is 3564 kWh/year.

For evaluating the energy saving, annual first energy amount concerned with the generation capacity is shown at Figure-3. With the increase of generation capacity, annual first energy amount decreases rectilinearly on both photovoltaic power generation and wind power generation. In 3kW annual first energy amount becomes the negativity, because reverse tide quantity to system electric power exceeds the consumption.

The generation capacity in which annual first energy amount becomes 0 is in 2.60kW by photovoltaic power generation, in 2.73kW by wind power generation. This is equal to the value, which is divided the annual electric power demand by the annual full load equivalent hour.

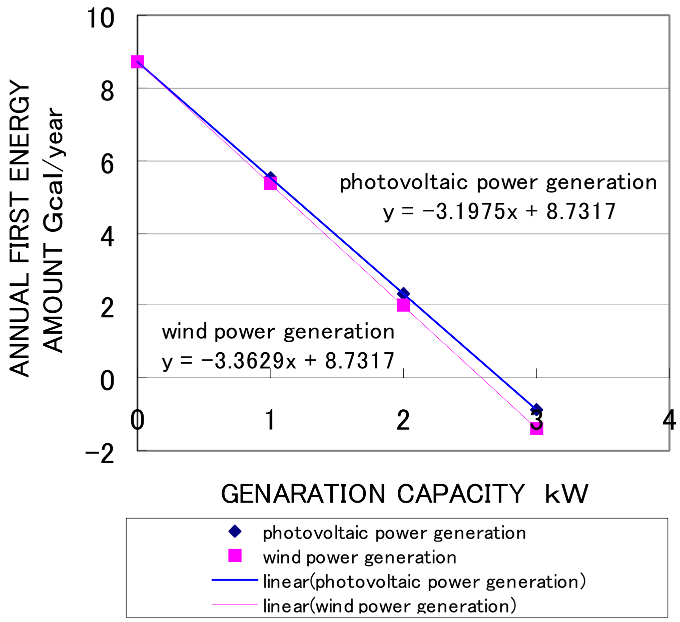


Fig-3 Annual first energy amount for the generation capacity

It can cover electric power demand/year of the detached house here in solar panel area of 30 m^2 (12% generating efficiency, power generation correction factor of 0.75) or facility of windmill diameter 4.7m (0.47 output coefficients).

In evaluating the environment the CO_2 discharge is dependent only on power purchase quantity of the system electric power. And the tendency of the environment (CO_2 discharge) is completely equal to

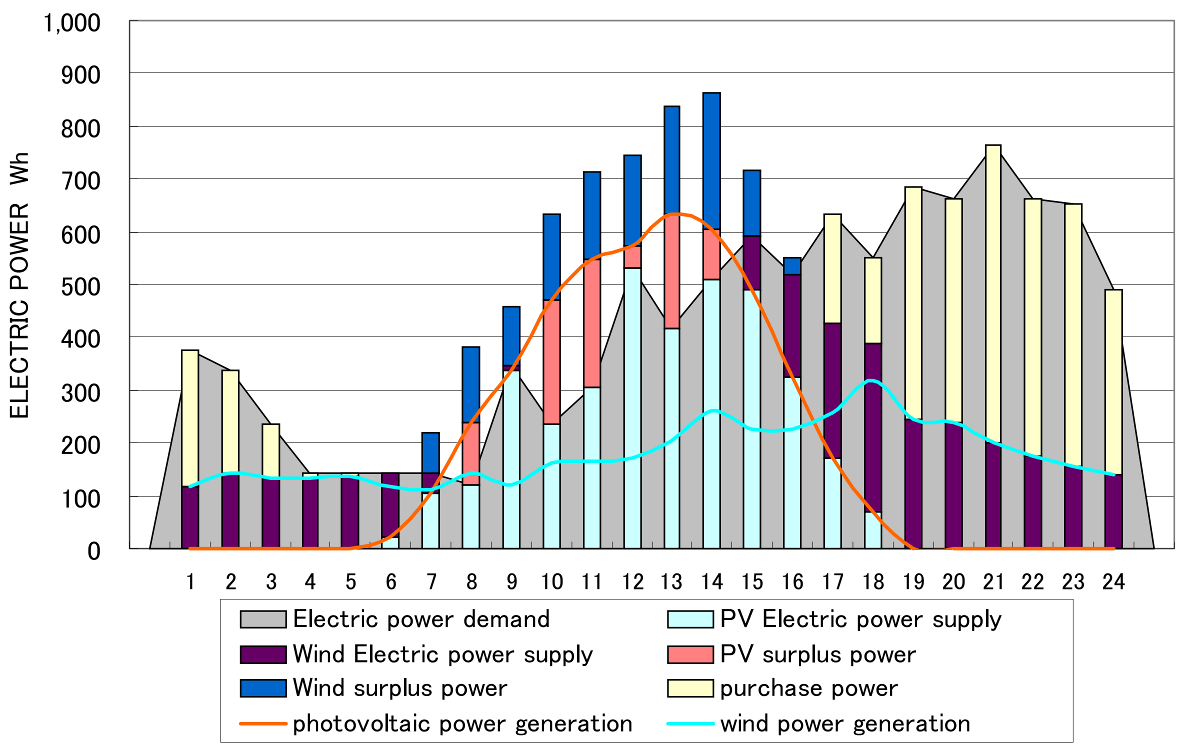


Fig.-4 Electric power supply and demand graph in 1 day in the summer, on hybrid power generating installation for the detached house that of the energy saving (the annual first energy amount), because the photovoltaic power generation and the wind power generation are the clean facilities which completely do not generate CO_2. Then the CO_2 discharge becomes 0 at photovoltaic power generation 2.73kW, wind power generation 2.60kW.

Wind power generation becomes in 10.6 years, photovoltaic power generation in 36.8 years, when economical efficiency is evaluated at the recovery years.

Electric power supply and demand graph in typical 1-day in the summer is shown at Figure-4, on the case hybrid power generating installation is introduced into the detached house. Photovoltaic power generation assumed 1.25kW, and the wind power generation assumed 1.25kW.

The electric power demand gradually increases from morning of 8 o'clock, and it becomes a maximum at 21 o'clock in the night, and it gradually decreases afterwards. There is the consumption of any electric power in midnight of 4 o'clock - 6 o'clock.

Photovoltaic power generation has similar sine curve, which made 13 o'clock to be a peak, and it begins at 6 o'clock and ends at 18 o'clock. The wind power generation is generated for 24 hours, and 18 o'clock are largest.

Photovoltaic power generation quantity surpasses the electric power demand in the daytime (8 o'clock - 14 o'clock) and it has generated the surplus power. The surplus power has been generated in 7 o'clock - 16 o'clock, because that photovoltaic power generation is prior supplied is assumed, though the wind power generation falls below electric power demand in most time.

(2) Large store

Architectural area assumed 1-floor on the large store in 2,000 m^2. The roof area is 2,000 m^2. The electric power demand/year is 452,000 kWh/year. The annual electric power demand quantity can be covered in 346kW only in photovoltaic power generation or 329kW only in wind power generation, when the electric power demand quantity/year is divided by the annual full load equivalent hour.

Here, the hybrid system of photovoltaic power generation and wind power generation is considered. The generation capacity is changed to 200kW at sum total of photovoltaic power generation and wind power generation because of the restriction of installation area of photovoltaic power generation.

The graph of the environment (the CO_2 reduction rate) and the economical efficiency (the recovery years) about hybrid system of photovoltaic power generation and wind power generation are shown in Figure-5.

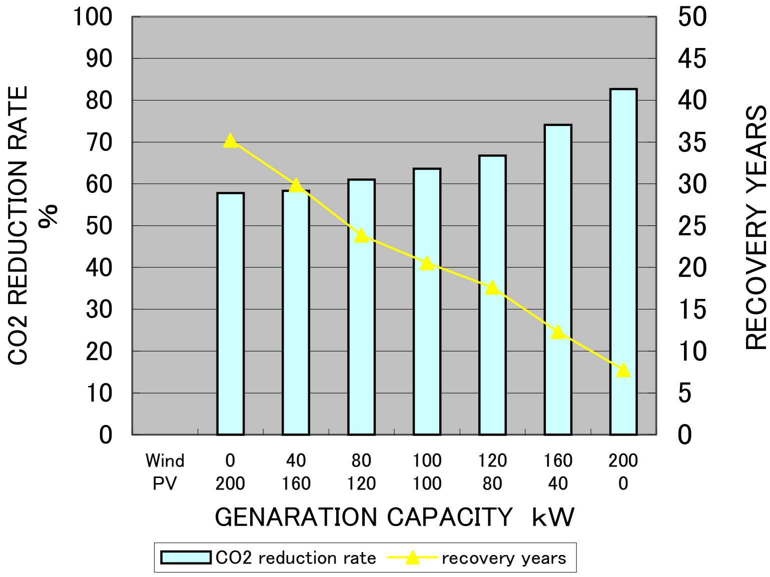


Fig.-5 Environment and Economical efficiency on large store

The CO_2 reduction rate is improved and the recovery years shorten, as the proportion of the wind power generation is bigger. Though only photovoltaic power generation is CO_2 reduction rate 57.8% and recovery years of 35.2 years on 200kW case, only wind power generation is CO_2 reduction rate 82.7% and recovery years of 7.8 years. That is to say, it is environmental excellent, moreover economically excellent of the wind power generation.

It becomes a hybrid facility of photovoltaic power generation 100kW (installation area 1,000 m^2) and wind power generation 100kW (the rotor diameter of the windmill is about 30m), when the half in the roof is regarded as the effective space where the installation of the solar panel was possible. That time CO_2 reduction is 63.6%, recovery years of 20.5 years.

Electric power supply and demand graph in typical 1-day in summer of this hybrid power generating installation is shown in Figure-6. The electric power demand is squarely near 9 o'clock - 18 o'clock, and there is seldom the night electric power demand.

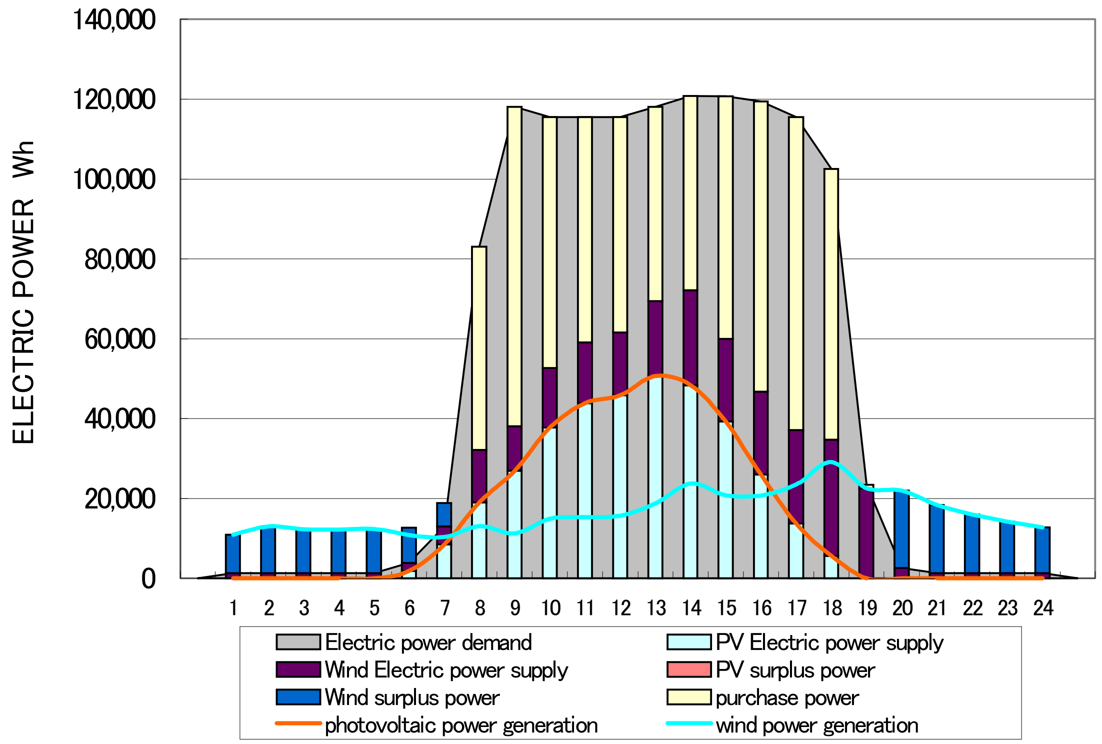


Fig.-6 Electric power supply and demand graph in 1 day in the summer, on hybrid power generating installation for the large store

The sum total of photovoltaic power generation and wind power generation covers electric power demand of the 40% weakness - 60% weakness in the daytime, and the generated output of wind power generation becomes surplus power in the night.

SUMMARY

The simulation program, which did the assessment of the hybrid natural energy power generating installation intro-duction plan of photovoltaic power generation and wind power generation in the building application independence, was developed. This program has following features.

1. The hybrid power generating installation of photovoltaic power generation and wind power generation is simulated.

2. Announced meteorological data are used.

3. The Primary Unit Method requires the electric power demand of the building.

4. Supply and demand simulation of the electric power is carried out in every time of the typical 1-day in each month, and power purchase from system electric power and electric power selling as the reverse tide electric power can be predicted.

5. It is possible to carry out the analysis evaluation of 3E (energy saving, environment, economical efficiency).

The case study of one detached house and one large store in Tokyo was carried out. In the detached house, it was proven that annual electric power demand could be covered at generation capacity of the 3kW weakness. In the large store, it was proven that the hybrid natural energy facility was excellent in energy saving and environment, though only the power generating installation could not cover an annual demand because of the restriction of installation area, when the roof was made to be an installation site.

REFERENCE

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2) "The Research on Amenity Evaluation Technique of the Indoor Environment" Indoor Environment Forum (1998.3)