Analysis on the Operation Characteristic of the Combined Electric Power Generation System by Photovoltaic and Wind Energy with Power Storage Apparatus

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1. Instruction

Currently there are very limited amounts of resources and serious amounts pollution. Because of the damage pollution is causing, we are trying to find a different way to substitute and develop and new way to create energy. Therefore advanced nations are developing and accelerating wind power, photovoltaic, tidal power, wave power, natural resource, methane, bio gas, which are affinity to the nature. Wind power and photovoltaic will be one of the best resources as energy in future.

Photovoltaic and wind power generation have an advantage of unlimited and unpolluted amount of energy resource. Since there is such an advantage in these energies, they are being studied and developed consistently. Currently they have developed MW Class wind power generation system so that it may work, but they have such a disadvantage because of the weather condition, which includes the velocity of wind, temperature, uncertain of heat radiant. Because of these conditions the power is unstable. At this time the combined electric power generation system is being used by the wind power and photovoltaic resource. The electric power generation is dependent on these sources but it is impossible to produce consistent energy because of the weather condition.

So the solution would be to develop power storage apparatus that would continually generate energy without any bad weather condition.

In this paper, because combining wind energy and photovoltaic, wish to add and compose power storage apparatus to combined electric power generation system that have repletion effect mutually and analyze actual operation characteristic of system.

2. Characteristic of energy

2.1 Characteristic of wind energy

Size of Wind power has a close affinity with the speed of wind. Total amount of energy of wind that pass area by speed is as following.

$$P_w = \frac{1}{2}\rho C_P v^3 A \qquad (1)$$

Here, P_w : Total amount of energy of wind [W], v : Wind speed [m/sec], C_P : Output coefficient of wind power system, A : Passing area [m²], ρ : Air density [kg/m³]

Figure 1 shows output characteristic model of general wind power generation system.

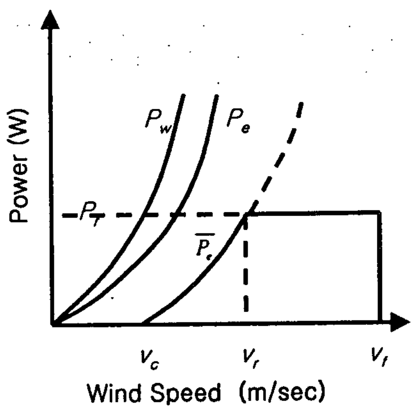

Fig. 1 Output characteristic model of wind generation system

Wind power generation system's actuality average wind energy $\overline{P}$ are as following by figure 1.

$$\overline{P}_e = \frac{1}{2}\rho A \int_{vc}^{vR} C_P \eta_m \eta_g v^3 P(v) dv + \frac{1}{2}\rho A C_p \eta_m \eta_g v_R^3 \int_{vR}^{vF} P(v) dv \quad (2)$$

In other words, from starting wind speed v_c to regularity wind speed v_R, increasing by v^3, value is decided because power coefficient and each efficiency relate wind speed v and in number of rotations of rotor. But, from regularity wind speed v_R to religious wind speed v_F, because wind energy are kept changelessly with model which appear in figure 1, $C_p \eta_m \eta_g v_R^3$'s value has fixed value regardless of wind speed.

2.2 characteristic of solar cell

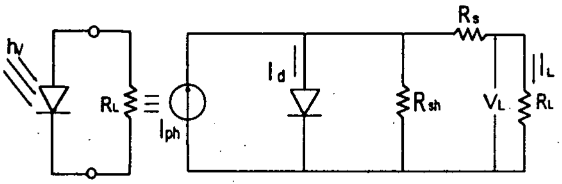

Fig. 2 Equivalent circuit of solar cell

Figure 2 shows the equivalent circuit of solar cell using photovoltaic effect. In ideal case, the characteristic of voltage-current, as radiated, Is

$$I = I_{Ph} - I_o \left[\exp\left(\frac{qV}{nKT} \right) - 1 \right] \quad (3)$$

But in actual case, the resistor in series Rs and the parallel resistor RSh are added. The equation (3) is rewritten as the equation (4).

$$I = I_{Ph} - I_o \left[\exp\left(\frac{q(V + IRs)}{nKT} \right) - 1 \right] - \frac{V + IRs}{2} \quad (4)$$

where, I is output current, IPh photo current, I0 saturation current of the diode, n diode constant, K boltzmann constant and q is a electric charge. Figure 3 is shown the characteristic of maximum output voltage and maximum power point of solar cell.

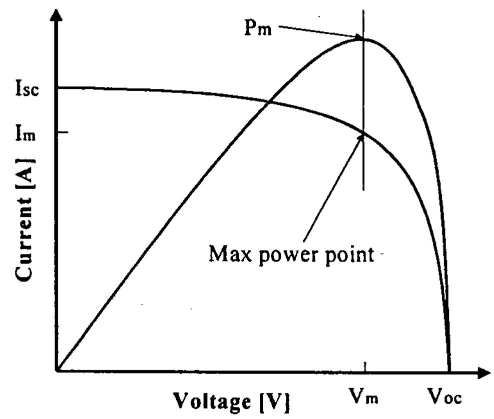

Fig. 3 Maximum output voltage and maximum power point of cell

The 3 variables of Figure 2, open voltage VOC, short current ISC, and Fill Factor FF, are the parameters related to the transformation efficiency of energy.

$$V_{oc} = \frac{nKT}{q} \ln\left(\frac{I_{Ph}}{I_o} + 1 \right) \quad (5)$$

First, the open voltage is the equation (5) and the short current is the equation (6).

$$I_{sc} = I_{Ph} - I_o \left[\exp\left(\frac{qIRs}{nKT} \right) - 1 \right] \quad (6)$$

The fill factor is defined as the equation (7).

$$FF = (V_m \times I_m)/(V_{oc} \times I_{sc}) \quad (7)$$

where, Vm is the maximum output voltage and Im is the maximum output current. The energy transformation efficiency of the solar cell is the value of dividing the maximum electric energy obtained from the solar cell by radiation energy. Its value is as follows.

$$\eta = \frac{V_m \times I_m}{P_{in}} = \frac{V_{oc} \times I_{sc}}{P_{in}} \times FF \quad (8)$$

where, Pin is the photovoltaic energy radiated.

3. Hybrid system

In case can not use photovoltaic or wind power by change of the weather, even if output voltage of combined electric power generation system is small while combined electric power generation system by power storage apparatus that install power storage apparatus additionally to existent combined electric power generation system composed voltage that is charged to battery as is available continuously . Figure 4 is displaying B schematic diagram that install D in addition.

Power storage apparatus that use spiral spring was consisted of small scale generator that voltage are developed acting in 12 [V] lows.

Battery is charged by small size generator, and does to supply continuous electric power to load.

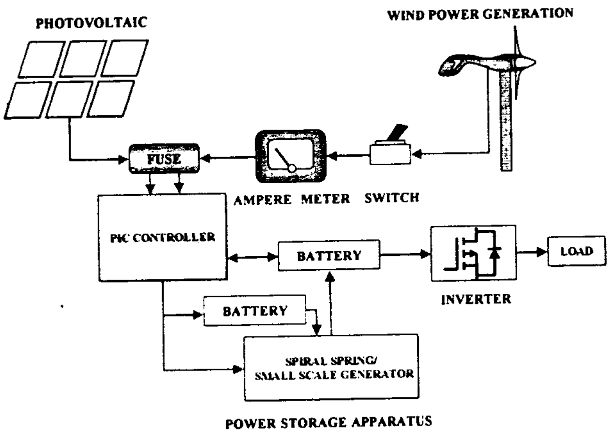

Fig. 4 Combined electric power generation system by power stroage Apparatus

If input voltage v_i ecomes more than DC 12 [V] sensing voltage in comparator in PIC, running DC motor that is v_M at the same time charge to battery that is v_B close s and run load through inverter.

And if voltage of battery that is v_B are and drop less than 12 [V] or ws is small, spiral spring untying, output current that DC Generator that is v_G is flowing acting is supplied in load at the same time charge to battery that is v_B. This system has spiral spring as a power storage apparatus. Figure 6 is the composition of power storage apparatus part for the combined electric power generation system. Spiral spring is wound up and down by the operation of DC motor (TD8025G-12, 12 [V], 2.5 [A], 25 [W], 300[rpm]) and gear Motor (S8KA60B, 50 [rpm]) according to the control signal. When the output voltage of the combined electric power generator increases over 12 [V], control unit perceives it and then it makes a battery charged. The charged battery supplies power to loads through an invertor.

Control unit was fabricated with a PIC(Peripheral Interface Controller). Output state of w or p uses good generation system by a control program. If weather condition does not use these two generation systems becoming changefully, use power storage apparatus. Also, do watch of charge and discharge control circuit. When the voltage of less than 12[V] outputs from wind power generator control unit recognizes it and the small scale generator(15 [V], 2 [A]) is driven by the wound-down of the spiral spring. Output voltage generated from small scale generator charges the battery. After the spiral spring is completely wound down it is rewound up by the control signal.

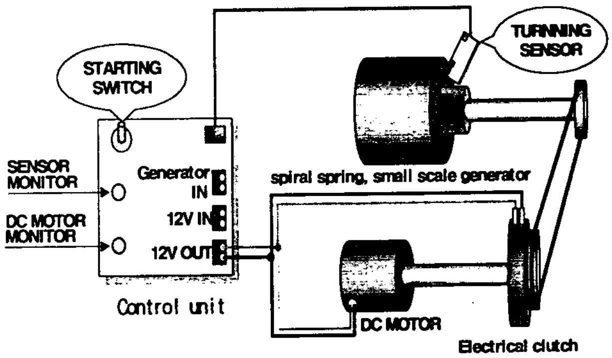

Fig. 6 Conventional generation system by power storage apparatus

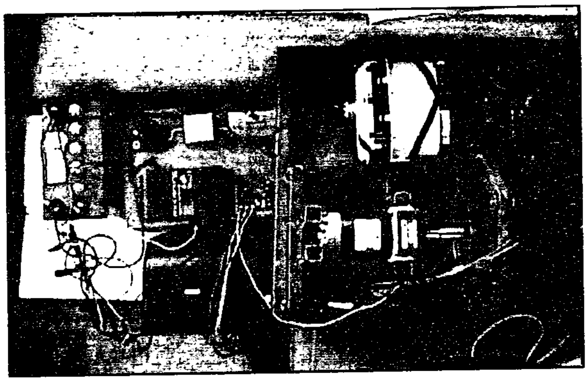

Fig. 7 Photography of conventional generation system by power storage apparatus

4. Experiment

Figure 8 represents simulation wave that the characteristics of maximum output power. When temperature is increasing, the maximum output power deceased linearly and the large value of insolation has steep slope characteristic.

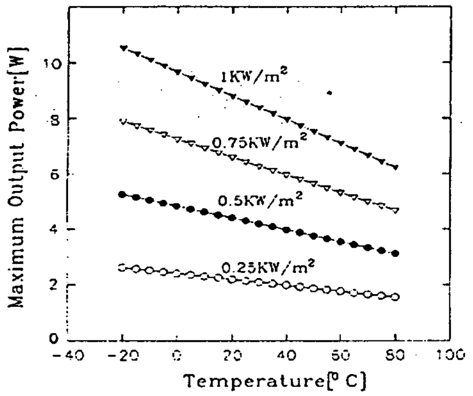

Fig. 8 The characteristics of maximum output power according to the solar insolation

Figure 9 represents simulation wave that the power's characteristics of wind power generation. When wind speed is increasing, the power increased linearly and the rated power is 400W at 12.5 m/s.

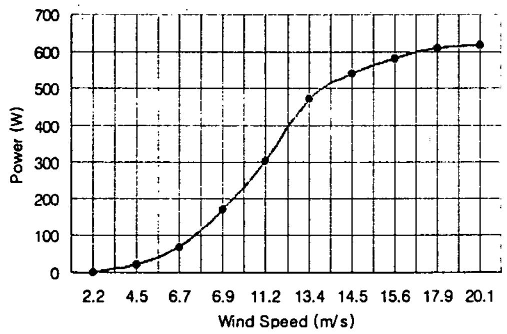

Fig. 9 The power's characteristics of wind power generation according to the wind speed.

Figure 10 is displaying wind generation's output waveform by wind speed' change.

We can see variableness voltage and current according to wind speed is variableness.

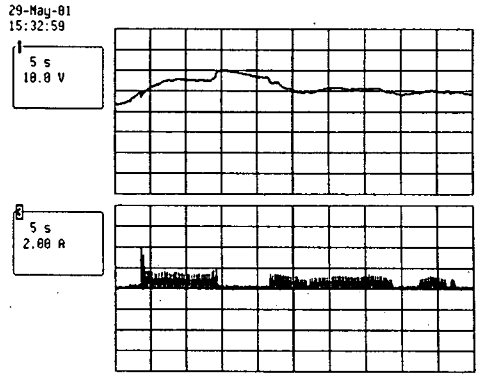

Fig. 10 Operating voltage and current wave of wind power generator

Figure 11 shows the locus of output voltage and current under a good weather condition of no wind of PV system. It illustrates more statable characteristics compared to other weather conditions of wind power generation.

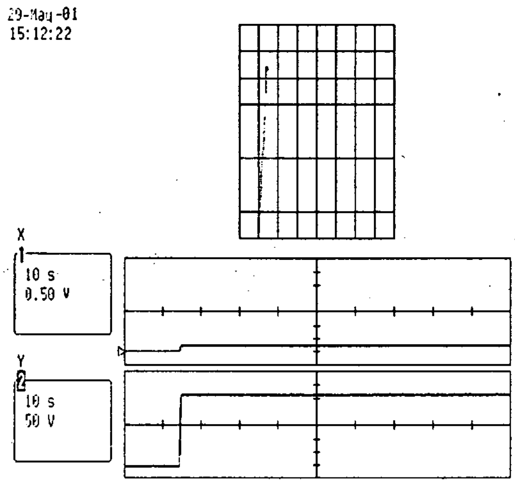

Fig. 11 Operating voltage photovoltaic system

Figure 12 shows combined electric power generation system starting voltage, current waveform.

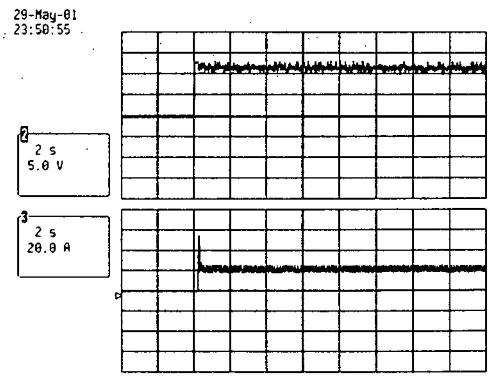

Fig. 12 Starting voltage, current of conventional generation system

Figure 13 shows voltage, current waveform and electric power trajectory of inverter on load state. Here, inverter input is 12 [V], and load is 220 [V], 200 [W].

Figure 14 shows output voltage of no load state of small scale generator that use to power storage apparatus.

After experiment result, energy of so much so that can fill up battery with output voltage and current that is displayed in small scale generator was displayed By power storage apparatus acts

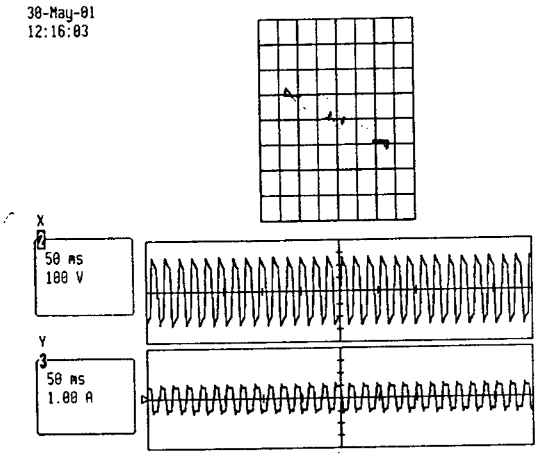

Fig. 13 Output wave for a load of inverter

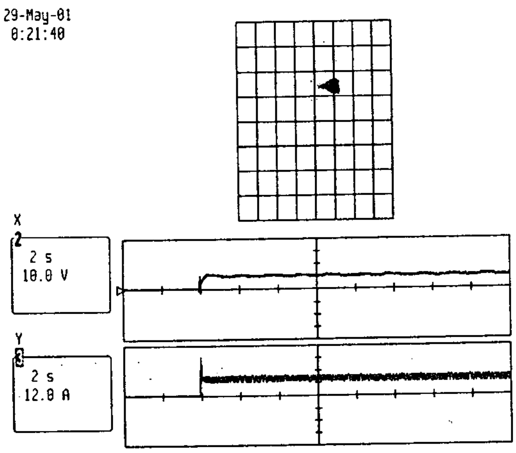

Fig. 14 Output wave for a unload of power storage device

The voltage waveform of drive characteristic under the operation of combined electric power generator and small scale generator is shown in Figure 15. Whenever output voltage of combined electric power generator decreases less than 12 [V] small scale generator operates.

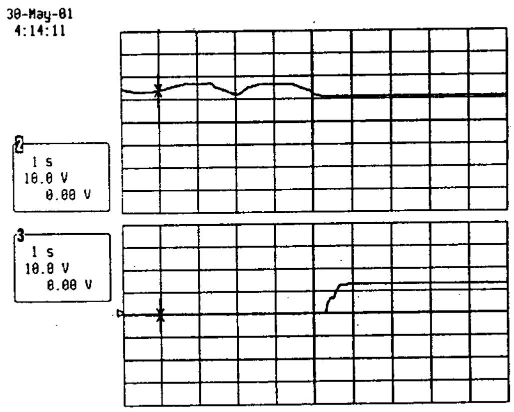

Fig. 15 Wave of output voltage from conventional system and small scale generator

If output voltage of combined electric power generation system becomes more than 12 [V], DC motor of small size generator of this system that see acts and close spiral spring that is linked to small size generator. And if output voltage is below 12 [V] and drops, at the same time, as spiral spring unties, small size generator is acted. This time, time that DC motor is acted is about 2 minutes and spiral spring pulley time about 2 hours be.

So, even if weather condition is bad, some measure can run load continually.

5. Result

In conventional wind generation systems, since the blade rotates at low speed when the velocity of wind decreases their operations are possible only under limited conditions. Therefore they are in trouble of self-generation without the help of auxiliary generation devices outside.

Similarly, because photovoltaic system reacts sensitively because of the weather of that change according to low conversion efficiency and the quantity of solar radiation or temperature and special quality is each different in solar cell manufacturer, if output decreases by decline of photovoltaic or wind velocity by can solve such usual problem and add power storage so that can use system without that is courted greatly area or topography, store energy to storage battery because do so that may act small size generator and supply electric power consecutively in load. Composition development compensation system that use power storage that is presented in this paper could supply energy that experiment result, wind velocity is continuous because power storage operates and does so that store energy that is displayed in small scale generator to storage battery in case fewer than 12 [V] in load.

For the application to real life, this system contributes efficient energy utilization over the places which need small-scale electric power such as residential buildings, isolated and undeveloped areas.

6. Reference

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