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Photovoltaics System for Maximum Output Control

Moon-Taek Cho[1], Young-Choon Kim[2*], Chung-Sik Lee[1] and Ok-Hwan Kim[2]

[1] *Dept. of Electrical & Electronic Engineering, Daewon University College, 316 Daehak Road, Jecheon, Chungbuk, 27135, Korea*
[2] *Dept. of Mechanical & Automotive Engineering, Kongju National University, 275 Budae-dong, Seobuk-gu, Cheonam-si, Chungnam, 31080, Korea*
{mtcho,cslee}@mail.daewon.ac.kr, {yckim59,owkim}@kongju.ac.kr,

Abstract

In this thesis, a boost chopper using PV (Photovoltaics) system and PWM (Pulse Width Modulation) voltage type power converter were constructed to provide a pleasant environment to the patients in the hospital wards by controlling temperature, humidity and air-conditioning & heating. For the stable modulation of solar cell, synchronizing signal and control signal were processed using one chip microprocessor. Power converter system was constructed with booster chopper and voltage source inverter and test was carried out for both devices. Constant voltage control method was used to track a maximum power point at boost converter control. For the inverter control, synchronizing signal and control signal were processed by microprocessor for the stable modulation according to the switching theory of SPWM (Sinusoidal Pulse Width Modulation) and directions to each sector. Test was carried out for inverter control using SPWM control method. In addition, grid voltage was detected and this grid voltage and inverter output were operated at the same phase for the phase locking with PWM voltage source inverter so that surplus power could be linked to grid. This characteristic was applied on the temperature and humidity sensors in the general buildings and buildings having specific purposes such as hospitals. The good dynamic characteristic of inverter could be obtained by these applications. Also, PWM voltage inverter maintains a high power factor and low-frequency harmonic output so that power can be supplied in the load as well as system.

Keywords*: PV, PWM, Power converter, SPWM, Power factor*

1. Introduction

Output of solar cell with the photovoltaics system is a dc voltage. Therefore, if solar cell has to be linked to grid, it is needed to convert this output into ac. and the sinusoidal current having unity power factor and voltage have to be supplied into solar cell. Also, PWM modulator should perform a stable modulation even if disturbance such as distortion or noise in grid source voltage waveform which is synchronizing signal is included. Besides, when synchronizing signal and control signal are processed by microprocessor, time difference is existed between sampling timing and carrier wave, thus compensation method is required for this time difference.

Photovoltaics system is categorized into two types according to linking method with utility line. A parallel connection system refers to a system wherein photon is always electrically connected. Whereas, a grid change-over system refers to a system which enables reverse power transmission of surplus power which is generated by photovoltaics. It is always electrically separated and is connected only when generated output is in shortage. In this system, reverse power transmission is not possible and it supplies power only on the load.

In the grid-connected type, if output of solar cell is shorter as compared with the demand of load, the shortage is received from electric power system. While, if surplus

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output is available, it is supplied to grid side. With these mechanisms, PV system and electric power system have close relationship. Therefore, when PV system is connected to grid, countermeasures are required for output changes of grid system and grid power quality which is hampered by high frequency wave generation, voltage disturbance, and individual drive. Since output characteristic of solar cell is greatly changed according to insolation and load, it is required to always track maximum output point regardless of insolation and load. Also, in case PV system is constructed as a stand-alone type, output voltage of voltage source inverter has to be maintained as constant. When PV system is applied in the houses and small-scale loads, these systems are largely relied on the area and weather. Therefore, in the present study, it was intended to develop an energy saving type source combined power supply unit to obtain power saving effect by around 10~20[%] by linking it with utility line to overcome shortcomings of not generating power continuously and independently.

In this thesis, we intended to control boost chopper so that maximum output point can be always tracked regardless of insolation and temperature changes by changing time ratio based on the power comparison after constructing a grid connected photovoltaics system as voltage type inverter. Also, inverter was controlled as phase driving the grid voltage and inverter output by detecting grid voltage in order to synchronize phase so that power of high power factor and low-frequency harmonic were supplied to the load and system.

Besides, supplied power was not used for maintaining temperature and humidity control in the wards and general chambers in the hospital. Instead, photovoltaics system was used so that grid voltage and inverter output were to be driven at the same phase for the separate PWM voltage type inverter and phase locking.

Further, surplus voltage was linked with grid system by control of power converter to control room temperature and humidity in the room in the hospital by using photovoltaics system so that high power factor and low-frequency wave output were maintained enough to supply power stably to load and grid system.

2. Electrical Characteristics of Solar Module

Voltage of a solar battery is about 0.5V, it is extremely low voltage in actual use. Thus, arrangement of some cells, which supply 12V, consists of around 30~40 cells connected in serial. The solar Battery is very sensitive in damages and humidity. Thus, manufactures generally connect numerous cells in mechanically and electrically. They form in Solar battery module. (It is called Solar battery panel or PV panel.) Life of a Solar battery should be over than 30 years. Material of module's case should stand permanently against maximum solar light, humidity, air pollution, and so on. Upper cover usually consists of high translucent special glasses which have tolerant about storm or hail.

Solar battery cells under case have tolerance against light and temperature. They are completely insulated. They have built-in 2-ply plastic films compensating of variation temperature in length of cells, which has enough elasticity. The back of this module is covered with glass or metal applied plastic.

Installation of high photovoltaic (PV) system consists of various modules connected to serial or parallel.

3. MPPT (Maximum Power Point Tracking) Control

Voltage and current of Solar battery are changed by characteristics of total irradiance and temperature, and the point of maximum power output of voltage and current is called Maximum Power Point (MPP). Grid-connected invertor only operates on MPP of solar generation allay, and maximum power supplies power systems. MPPT of grid-connected invertor should be adjusted to MPP.

According to weather condition voltage and current of module changes a lot, grid-connected invertor needs to move for optimal operation. Electric circuits of control voltage uses for this, circuits makes that grid-connected invertor operates when solar generating allay gets MPP.

Maximum possible power to be supplied is a MPP tracker. Essentially, the MPP tracker consists of electric control DC convertors. A Grid-connected invertor should have PV inverters operating point of the module maximum power point (MPP) for the ability to adjust (maximum power point (MPP) tracking).

Figure 1 shows that differences between V-I output characteristics in uniform light source and generating power of Solar battery by different operating points. V-I characteristic curve in the figure that appears on the solar cells is called the operating point.

Solar battery has a property that current is determined by voltage of connected load. In Figure 1, if voltage operating point set up low like V1, large current can be produced, if voltage operating point set up high like V2, large current cannot be produced.

Look at Figure 1 where the operating point voltage is set to V_p, output voltage and current balance is the most good and the area of the dotted rectangle is the maximum. This means generating power is set to the maximum and solar cell operating point (PA) is called the optimal operating point.

When Solar battery generates in the optimum operating point, the maximum power can be output.

When Solar battery generates in this voltage, nominal maximum output voltage will get. However, because this is commentary value under certain conditions, optimum operating point always changes according to intensity or angle of solar light in actual generation.

Voltage convertor chases optimum operating point. Input voltage of voltage convertor and operating point of Solar battery change for chasing optimum operating point. If charge current and output voltage control, input voltage can be controlled.

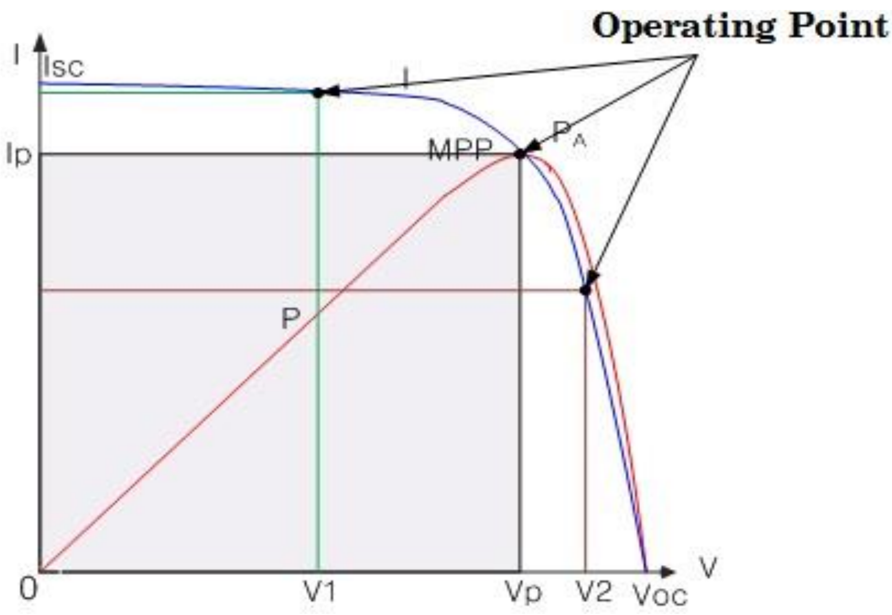

Figure 1. V-I Output Characteristic in Uniform Light Source

If output voltage of voltage convertor intentionally set to highly and set to high voltage difference between storage battery, charge current of charge current increases. Because of input current of voltage convertor increases simultaneously, input voltage of voltage convertor can be decreased. If output voltage sets to low, due to charge current and input current decrease, input voltage of voltage convertor can be increased.

This is called control using output characteristics of Solar battery. And a voltage convertor is called a MPPT device to chase optimum operating point of solar battery through changing input voltage, according to generate condition of Solar battery.

4. Electrical Characteristics of Slope and Distance

4.1. Affections of Slope and Distance

When light transmits 90° on the surface of module, power is supplied by Solar battery module. Since incidence angle of photovoltaic changes in every day and year, it can't be attained by fixed Solar battery module.

4.2. Output Current Characteristics Depends on Incidence Angle

The below figure 2 shows Output current characteristic curves mart Grid Photovoltaic Generation Trainer depends on incidence angle of light source and Solar battery module.

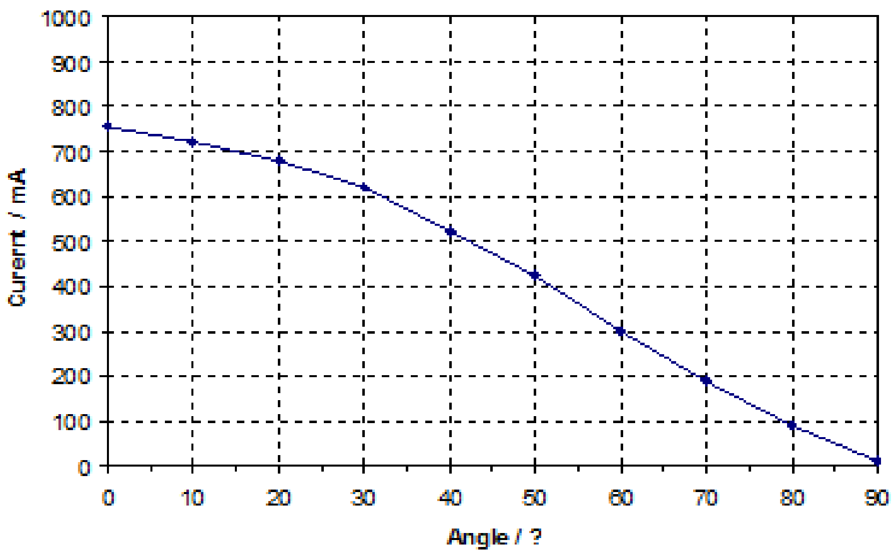

Figure 2. Current Characteristic 1 Depends on Incidence Angle

Photocurrent of Solar battery module is proportional to the value of cosine of incidence angle. ($I \propto \cos\alpha$) (Figure 3)

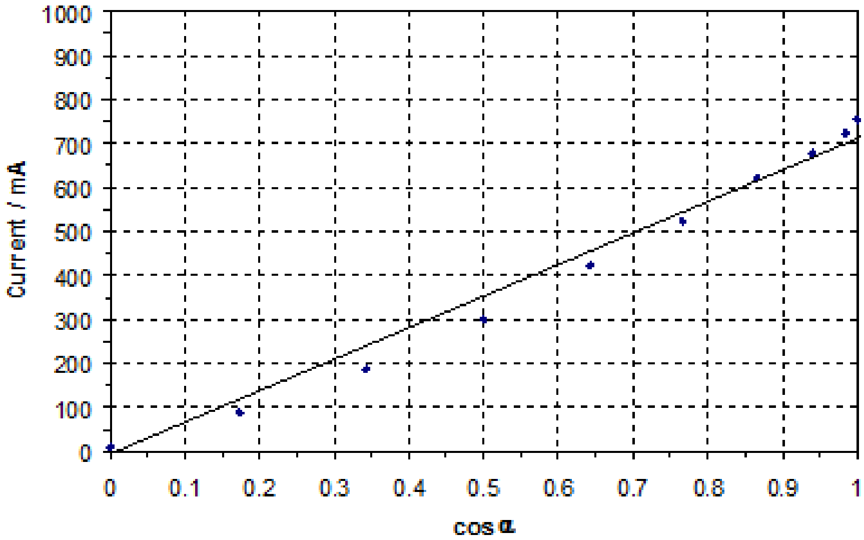

Figure 3. Current Characteristic 2 Depends on Incidence Angle

Current of Solar battery module decrease, when it gets far from light source. (Figure 4, 5)

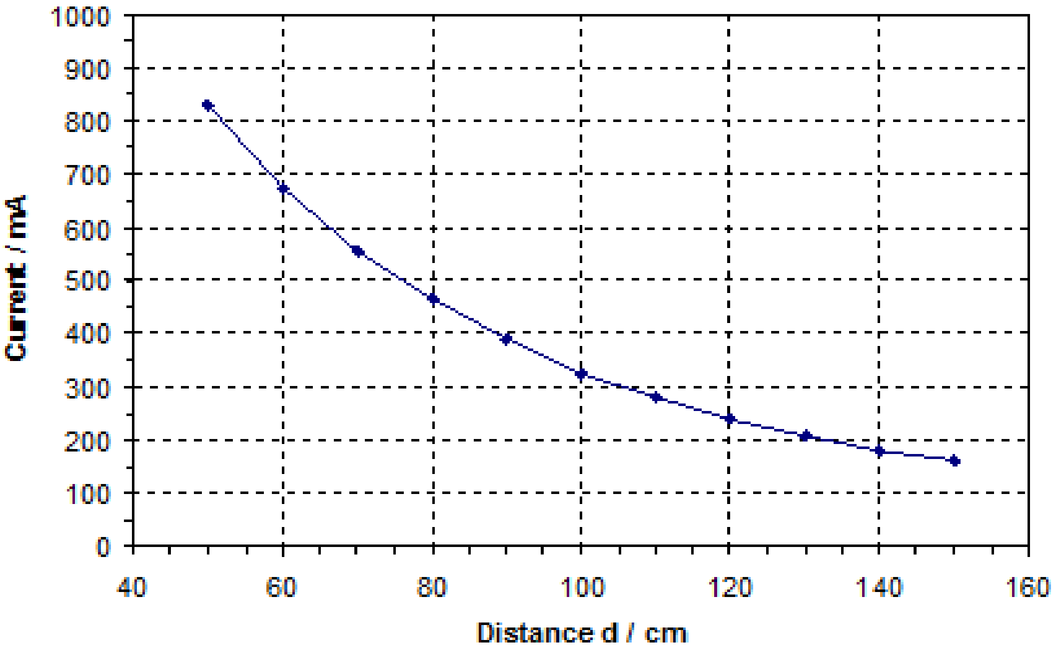

Figure 4. Current Characteristic 1 Depends on Distance

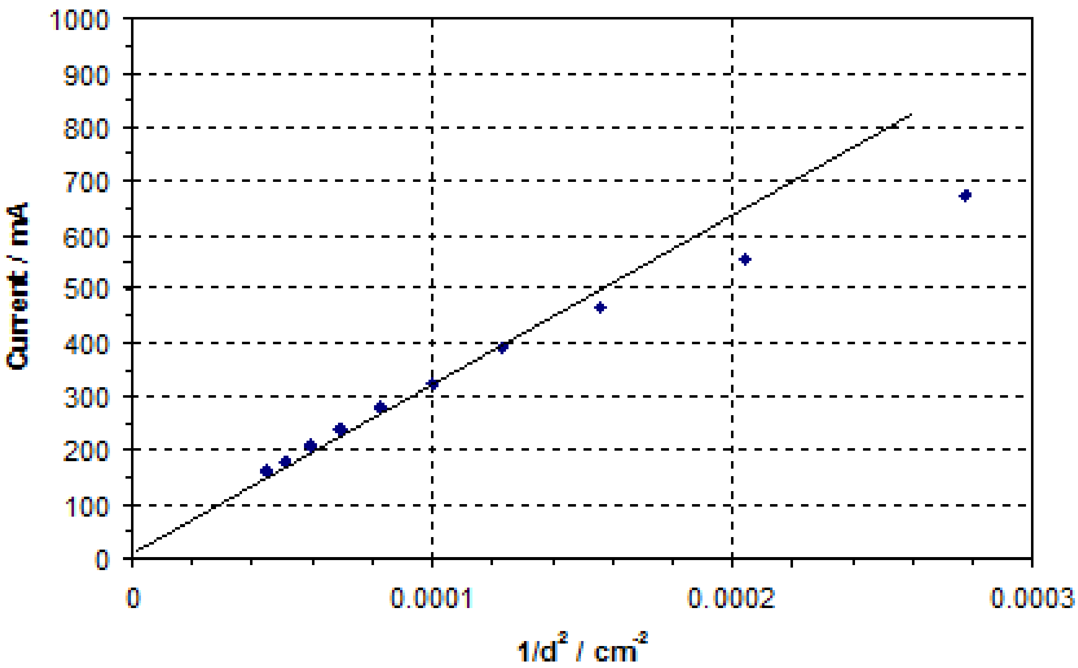

Figure 5. Current Characteristic 2 Depends on Distance

Photocurrent of Solar battery module is reciprocal proportion with square of distance from source of light.

$$I \infty \frac{1}{d^2}$$

Thus,

The relationship between incidence angle and photocurrent is very important, when Solar battery module installs (for example, elevation angle of solar)

Therefore, when high Solar battery module installs, it adjusts on path of elevation angle of solar.

The useful of facing south of Solar battery module is proved, because of the light in daytime and nighttime can be collected. (For example, installation on the roof of building)

5. Characteristics of Temperature and Irradiance

5.1. Characteristics of Irradiation

When a Solar battery has any light due to P-N junction, it works generally as passive element like a semiconductor diode. When it has light, the solar battery changes to active battery. A Diode characteristic curve is changed by Short-circuit current. The shape of V-I characteristic remains equally without consideration of illumination.

PV system works very rarely under standard test condition (STC). Electric output and I-V curve of PV module depend on temperature and irradiance. Irradiance within a day changes larger than temperature. Irradiance variations affect badly to current in module and affect directly to current or irradiance. When irradiance reduces half, generation of electricity reduces half. (Figure 6)

MPP voltage compared with variation of irradiance has a relatively constant state. Like Figure 6, maximum variation of MPP voltage resulted from irradiance variation is insignificant. (For example, polycrystalline 150W standard module has about 4V of MPP voltage variation)

However, variations of MPP voltage resulted from irradiance variations are up to 40V at high PV system connected numerous PV modules in serial.

Low irradiance of W/m2 value causes Breaks Down of voltage.

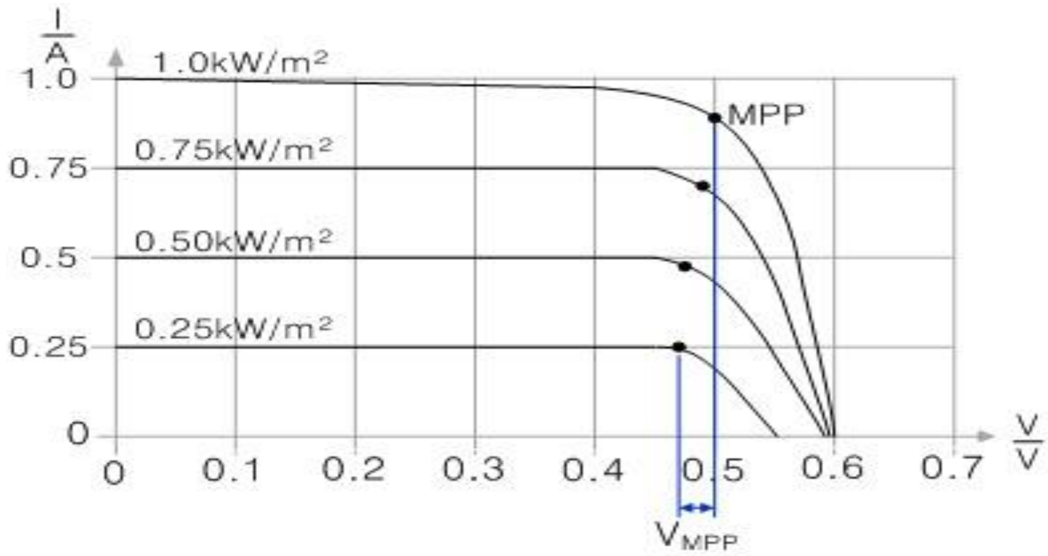

Figure 6. MPP Curves of Irradiance

5.2. Temperature Characteristics

When temperature increases, an active barrier layer gets thinner, thus open circuit voltage of Solar battery decreases about 2 ㎷/K, this means 0.4%/K. If current is supplied by Solar battery, voltage is determined by photoelectric current. Therefore short circuit current increases about 0.06%/k and battery power decreases about 0.5%/k. When temperature increases, efficiency of Solar battery decreases.

Module voltage is affected by almost temperature of module. PV system should install perfectly, because of system voltage is determined by voltage variation of module. Especially, it should be installed for increasing voltage in low temperature. Because of high temperature in summer, output power of module reduces about 35% than STC.

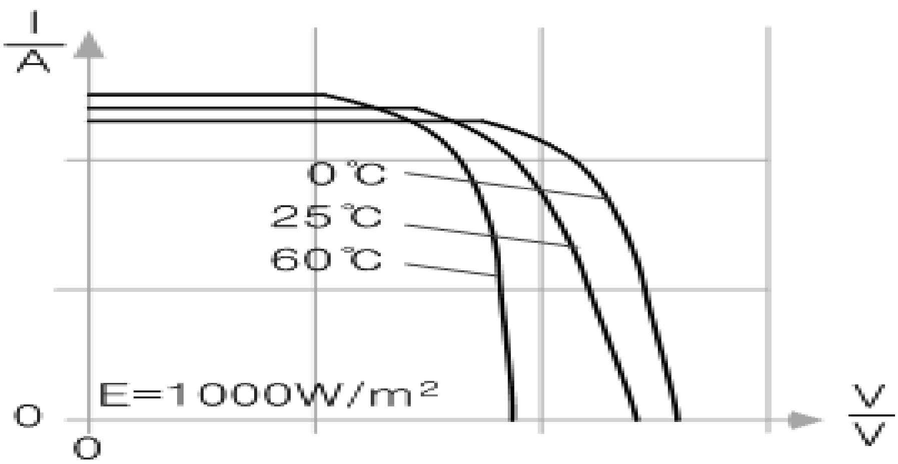

Figure 7. Temperature Characteristics

Figure 7 is a simulation circuit of temperature characteristic, output voltage of used cell is about 0.6V, output current based on standard solar cell (width x height = 10cmx10cm) is about 3A. Based on temperature 25℃ of STC, Characteristic curve and power characteristic curve in 50℃, 75℃, 100℃, and 125℃ simulate and shows in Figure 8 and 9.

It is shown in figure 8, when the temperatures are (4)=25℃, (3)=5 0℃, (2)= 75℃, (1)=100℃,and (0)=120℃, it represents voltage and current characteristics. The right line(red) of two characteristics curves is a standard model(Single-diode) which has good precision, and the left line(light blue) of two characteristics curves is a two-diode model which has very good precision.

It is shown in figure 9, when the temperatures are (4) =25℃, (3)=5 0℃, (2)= 75℃, (1)=100℃,and (0)=120℃, it represents power characteristic. It is a standard model (Single-diode) which has good precision.

The result is known from Figure 8 and 9, voltage, current, and power are decreased as temperature goes up.

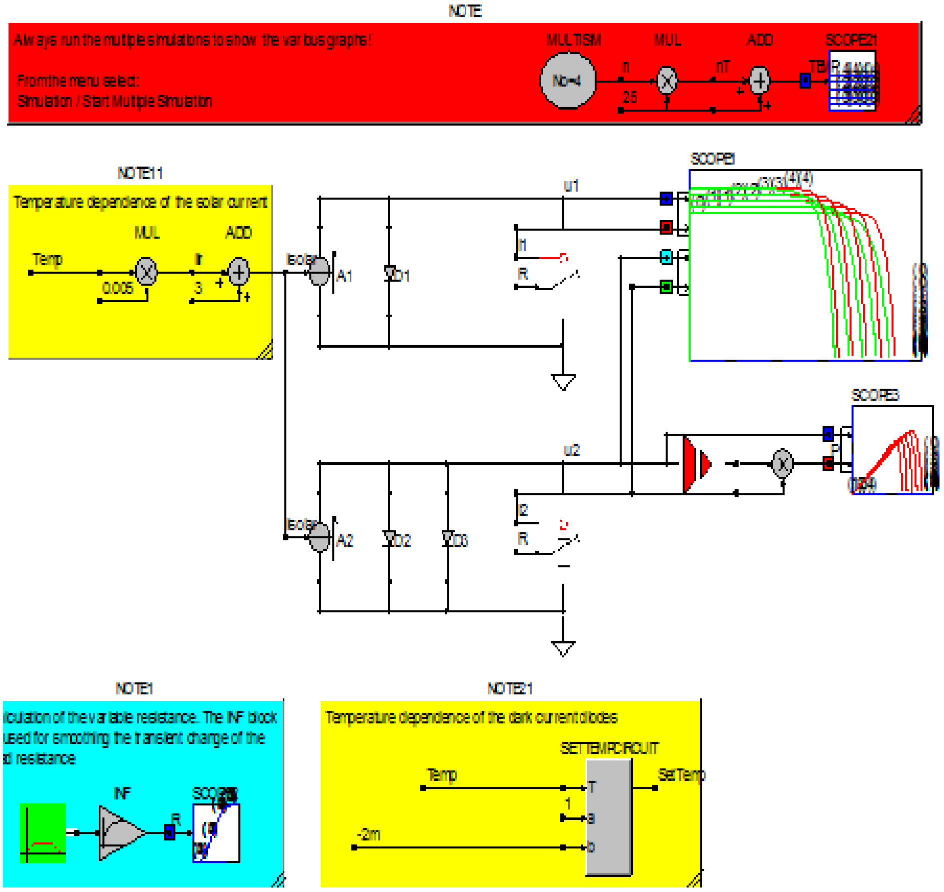

Figure 8. Temperature Characteristic Simulation Diagram

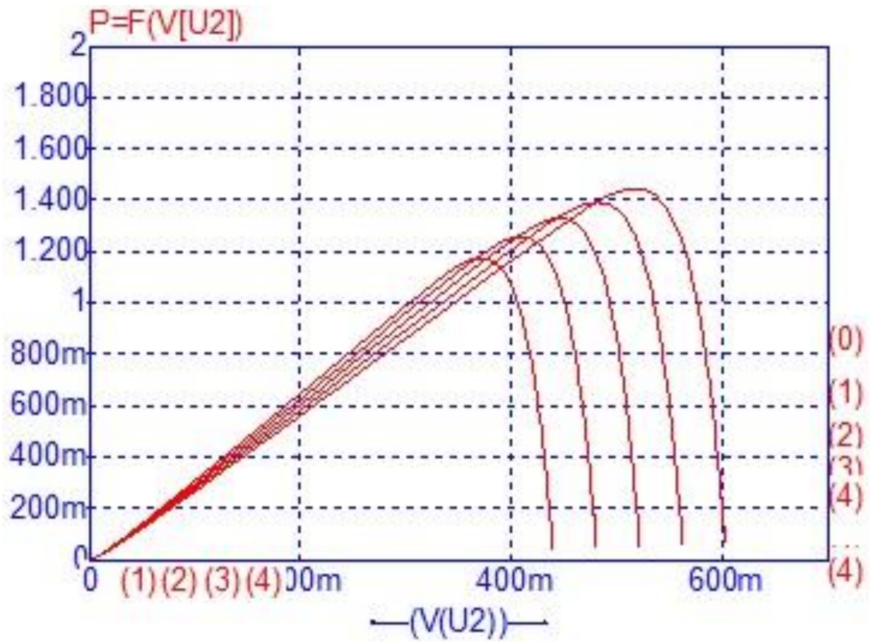

Figure 9. Power Characteristics Curve Depends on Temperature (Simulation)

6. PWM Power Converter Circuit

Figure 10 shows the system is capable of grid-connected solar cells as a single-phase voltage inverter, a structure that combines the power converter and the AC source to the reactance, as shown in Figure 11.

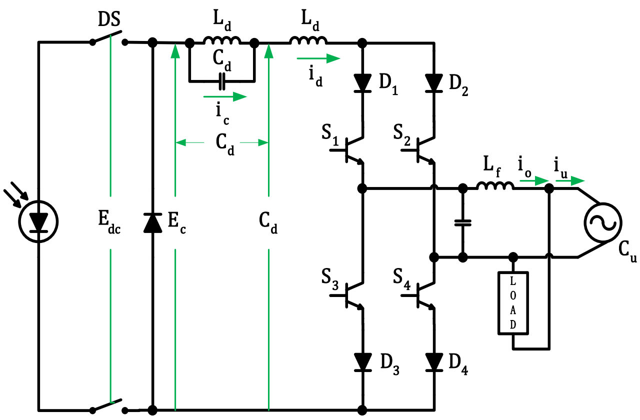

Figure 10. Single Phase PWM Inverter

The power converter is forced commutation method type with a structure of a voltage converter or with self-extinguishing capability of the device. Since the amplitude of the DC voltage is not defined, the function of controlling the DC voltage to be provided as necessary. Also can generate the reactive power because the power factor of the ac side, has a characteristic capable of controlling reactive power.

The power converter of the voltage type has a characteristic capable of controlling both the voltage and frequency and phase. Last of the power conversion technology is concentrated in technology for controlling the power converter and the voltage type of the development of power semiconductor device having self-extinguishing ability. Generally, the power converter of the voltage type is used, and is designed a method of PWM, in this paper was applied to the PWM sinusoidal wave modulation method.

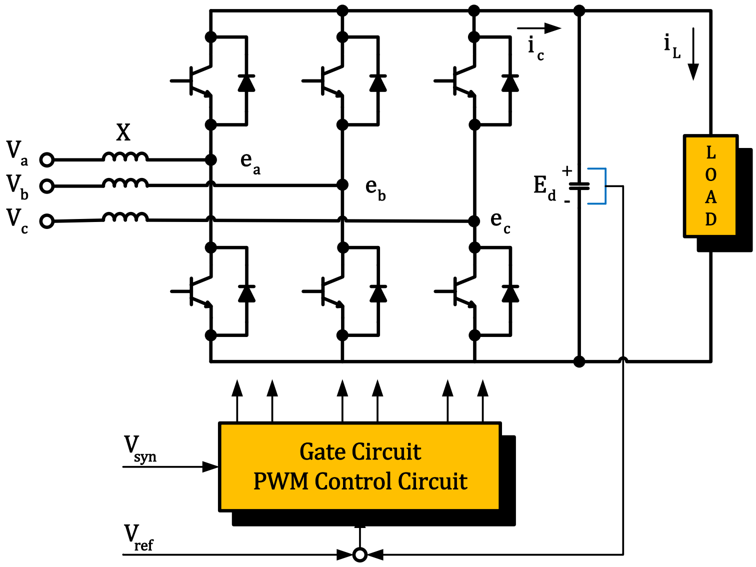

Figure 11. Three Phase PWM Inverter

7. Conclusion

In the present study, PV tracking system was constructed for air-conditioning & heating in the hospital wards. Since output of solar cell which is a dc source is relatively low, PWM voltage source inverter was constructed using a boost chopper having a low capacity dc voltage to operate all the loads inside of hospital including temperature sensor and humidity sensor. Experiment was performed using a microprocessor in the proposed system and conclusion was drawn as follows:

(1) With operation of PWM voltage inverter linking to boost chopper, voltage generated byconversion of dc-ac was applied on the temperature and humidity sensors and air-conditioning and heating load such as hospital. The applied devices showed a stable operation (applied on the temperature and humidity sensors and 15[W] and 53[W] electric fans, lamp load of 180[W], and air-conditioning & heating device(radiator) of 1[KW]).

(2) Voltage and current of solar cell were measured and the calculated optimum movement voltage was set as a reference of dc voltage. After that, the maximum voltage by boost was made to be operated at near maximum output point for solar cell.

(3) Location tracking device was designed using sensor and microprocessor for maximum power generation output in the solar energy power generation system. The location tracking type device showed a good performance in the power generation capacity by more than 5[%] as compared with fixed type.

(4) Boost converter was controlled using a constant voltage control method among maximum output point control methods to obtain maximum power considering the characteristics of solar cell. When actual experiment result was compared with simulation, almost same boost rate was obtained at error less than 2[%].

(5) The present system was applied in the temperature and humidity sensors in the hospitals and obtained a pleasant condition with reference temperature of 24~27[℃] and reference humidity 30~60[%]. Also, it provided a standardization possibility so that can be applied in all the loads within power capacity of hospital.

(6) Low-frequency harmonics Modulation delay compensation algorithm was used to remove high-frequency harmonics component in the inverter output voltage so that control

was possible to make the system close to sinusoidal wave. Also, size of dc reactor could be reduced by using a parallel resonance circuit between and chopper and inverter.

(7) Phase angle of grid voltage was detected and system was constructed with PLL circuit. Reference phase was tracked and it was synchronized to correctly control the current so that linking operation with unity power factor could be realized.

(8) Power conversion was achieved in a wider range in case of space vector modulation since ac voltage 61.2[%] of PV output dc voltage in sinusoidal modulation and 70.7% of PV output dc voltage were obtained in space vector modulation.

Acknowledgements

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Authors

Moon-Taek Cho, He was born in Korea on February 23, 1965. He received the B.S., M.Eng. and Ph.D. degrees from Myongji Univ. Korea in 1988, 1990 and 1999, respectively. Currently, he is a professor in the Daewon University College Division of Electrical & Electronic Engineering, Korea. His special field of interest includes power electric, electrical machine, new renewable energy, super-capacitor, PSPICE, CASPOC.

Young-Choon Kim, He was born in Korea on August 9, 1959. He received the Mechanical Engineering and Ph.D. degrees from Myongji University Korea in 1989 and 1997, respectively. Currently, he is a professor in the Kongju National Univ. Dept. of Mechanical & Automotive Eng., Korea. His special field of interest includes power electric, electrical machine, new renewable energy, PSPICE, Matlab, Fatigue and Fracture Mechanics.

Chung-Sik Lee, He was born in Korea on February 21, 1966. He received the B.S., ME.Eng. and Ph.D. degrees from Kyungnam Univ. Korea in 1991, 1993 and 2000, respectively. Currently, he is an professor in the Daewon Univ. College Division of Electrical & Electronic Engineering, Korea. His special field of interest includes

power system, fuel cells generation, new renewable energy, PSPICE, super-capacitor, UPS system.

Ok-Hwan Kim, He was born in Korea on January 3, 1960. He received the ME.Eng. and Ph.D. degrees from Yonsei Univ. in Korea in 1982 and 1996, respectively. Currently, he is a professor in the Kongju National Univ. Dept. of Mechanical & Automotive Eng. Korea. His special field of interest includes machine design, electrical machine, fatigue analysis and fracture mechanics.

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