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A study on the development of high-efficiency solar electric cart applied with MPPT

Sun-yeobKim
Dept. of Information Communication Eng., Namseoul University
Cheonan, Korea

Abstract- The load in the solar power system requires a constant voltage. However, the photovoltaic panel can have a different voltage depending on the solar radiation and temperature. Therefore, the technology of matching the energy waveform characteristics with the requirements of energy supply unit is most important. A variety of studies are being reported for the maximum power point tracking algorithm(MPPT) and its control methods but the development of customized application that fits the characteristics of electric cart and its effectiveness is nonexistent. In this study, the maximum power point was maintained using the MPPT algorithm to check whether the main grid voltage and the frequency was in the normal value. The energy generated from the solar power was converted into a proper format and the analysis on the MPPT control algorithm was conducted in order to constantly maintain the maximum value of the power being delivered to the load in the solar power system. The results were applied to the electric cart

Keywords- Solar cell, MPPT, middleware, data fusion, database, adaptability

1. Introduction

Solar vehicles and electric vehicles are being spotlighted in terms of being environmentally friendly and it is expected to rise as an important means of transportation in the future. Both the United States and Europe is mandating the deployment of non-polluting and low-emission automobiles by establishing the Atmospheric Conservation Act. These trends are spreading to the entire United States and the interest is increasing around the world. In addition, the market size of solar vehicles and electric vehicles going forward is expected to increase very rapidly. In the case of solar vehicles, when the power generated by the solar light is less than the power consumed, it uses the energy stored in the battery. But since the energy stored in the battery is limited, a study on the methods to maximize the use of photovoltaic power is essential [1-2].

In addition, although the development of solar power systems are being actively promoted in order to achieve high efficiency of eco-friendly vehicles and industrial equipments, the energy density of the solar energy is low and the output characteristics are dependent on the natural conditions such as the amount of solar radiation and temperature, etc. Therefore, a study on the minimization of the energy loss, maximum output control to obtain the maximum power from the solar cell array and the development of related applications are imperatively emerging.

2.Maximum Power Point Tracking Algorithm

Since the maximum voltage of a solar cell ray changes moment to moment by the solar radiation and temperature as well as the changes occurring to the condition of the load, even if there are no changes to the characteristics of the solar cell, the operating point will change thus it cannot be the same as the load where the maximum output is obtained. In other words, due to inherent nonlinear characteristic of the solar cell, a control measure is needed to always operate at the maximum power point of the solar cell. Such control is carried out by the electric power conversion systems such as DC/DC converter or DC/AC inverter, etc[3-4].

Power variation in the solar cell array according to the amount of solar light fluctuation is shown in Figure 1.

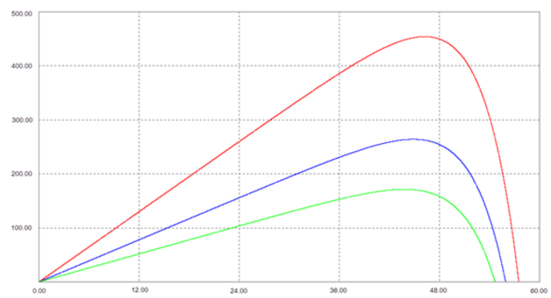

Fig. 1. The Characteristic of the PV array dueto the changed irradiance

As shown in the power-voltage curve characteristics of solar cell array according to the changes in solar radiation, it can be seen that the solar cells have electrically non-linear characteristics. And as seen in the power-voltage characteristics, the maximum power point is determined according to the solar radiation, and this point becomes the operating point of maximum power which the solar cell array can have. Even if this maximum power point changes due to external solar radiation and temperature, being able to obtain the maximum output of the solar cell array through the use of solar inverter is called the maximum power point tracking control(MPPT)[5]. Most of the MPPT control methods are typically applied to the mass solar systems by performing complex operations such as multiplication or division using an expensive DSP digital control method.

3. Solar electric cart applied with MPPT

The Figure 3 represents the low voltage charging device using MPPT method applied with DC/DC booster converter developed through this study. In the previous MPPT control methods, the voltage and power is directly proportional in the power-voltage graph when the maximum power point in the solar cell characteristic curve is below the solar cell array voltage, whereas the slope is inversely proportional when the solar cell array voltage is above the MPP. In the digital control, a separated current value of the power value and the slight fluctuations of the previous value is measured using these characteristics to determine the switching operation. Since these methods require many operations when applying such algorithm, it has a problem of the system and the control becoming complicated [6-7].

Therefore, in the case of the MPPT method applied with the booster converter developed through this study, it has an advantage of having a simple system implementation and control since it does not use such expensive processor. The Figure 4 represents the block diagram of MPT algorithm applied with boost converter and the operation is shown in Figure 5.

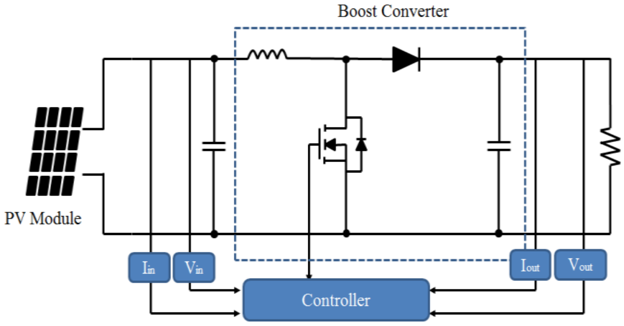

Fig. 3. The MPPT system with booster converter

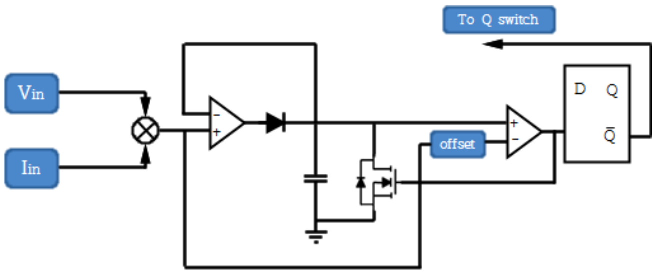

Fig. 4. The MPPT circuit with booster converter

Since the output voltage of the initial solar cell array is positioned on the right side than the MPP, when the Q switch of the Boost Converter is turned on in order to increase the duty ratio, the current and the output power of the solar cell array rises toward the maximum power point(MPP). At this time, when the power passes the MPP, there is a difference equal to the offset value and the Q switch for the Boost Converter will turn off leading to the decrease in the current of the solar cell array, thus the power will move to the voltage source area passing the MPP and again moving to the current source area heading for the MPP [8].

The simulation was performed by applying such MPP algorithm and the Table 1 represents the parameter used for performing the simulation.

A low-pass filtering was performed using a S/W for the average voltage and average current which becomes the basis of increase and decrease of the current reference value and the average value was calculated using the MPPT performing cycle of 0.2s. The Figure 6 represents the simulation results of I-V.

Table 1.A Parameter of I-V Curves

Parameter	curve 1	curve 2	Curve 3
V_{OC}	170[V]	170[V]	170[V]
I_{SC}	1.68[A]	2.45[A]	3.24[A]
Temperature	28[℃]	28[℃]	28[℃]
Maximum Power	210[W]	310[W]	393[W]
V_{MPP}	140[V]	140[V]	140[V]
I_{MPP}	1.5[A]	2.22[A]	2.81[A]

The Table 2 represents the current and voltage of the point that shows the maximum power in each of the I-V curve.

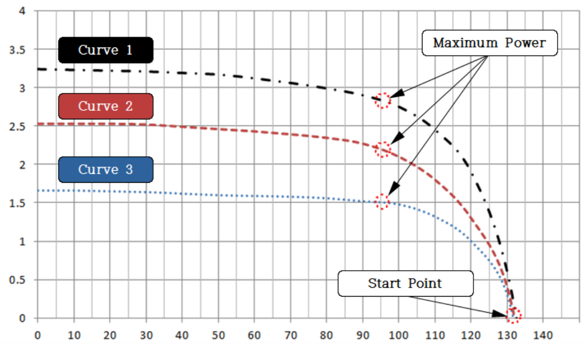

Fig. 6. The simulation result I-V

Table 2.The I-V values of maximum points

Parameter	curve 1	curve 2	Curve 3
Maximum Power	210[W]	310[W]	393[W]
V_{CAL}	139[V]	140[V]	140[V]
I_{CAL}	1.491[A]	2.19[A]	2.79[A]
MPP_{CAL}	207[W]	306[W]	390.6[W]
Efficiency	98.5	98.7	99.3

After completing the development of the control system, an electric cart propulsion system was developed in order to develop the application for the high-efficiency solar electric cart as seen in Figure 10.

The control section of high-efficiency electric cart motor was made to include the motor driver which generates the electric power, power management device, battery charging device, lamp control device, control device and a communication device, etc.

4. Conclusion

Recently, due to the depletion of fossil resources and environmental pollution, the solar power system using unlimited use of solar energy without pollution is being spotlighted as a new energy source. Solar vehicles and electric vehicles are being spotlighted in terms of environmental purification and it is expected to rise as an important means of transportation of the future. Both the United States and Europe is mandating the deployment of non-polluting and low-emission automobiles by establishing the Atmospheric Conservation Act. These trends are spreading to the entire United States and the interest is increasing around the world. In addition, the market size of solar vehicles and electric vehicles going forward is expected to increase very rapidly. Therefore in this study, the problems of previous MPPT algorithm were analyzed by reviewing the previous MPPT algorithm. Although a system having an expensive CPU was required in order to implement high-efficiency MPPT system, but in this study, it has shown that high-efficiency MPPT system can be implemented without an expensive CPU and such fact was proven by applying this to the high-efficient solar electric cart.

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