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태양광의 세기와 셀 온도가 최대전력 추종을 하는 태양광 발전의 동특성에 미치는 영향 분석

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Analysis of the Effects of the Irradiation and Cell-Temperature on the Dynamic Responses of PV System with MPPT

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Abstract - As well known, the maximum power point tracking (MPPT) is an important role in photovoltaic (PV) power systems. MPPT finds and maintains the operation of PV at the maximum power point when the irradiation and cell-temperature change.

In this paper, the studied system includes a PV array, a Buck-Boost DC/DC converter, a DC/AC inverter and it is connected to the three phase power system. The solar array operates as a non-linear voltage source. The P&O algorithm with power feed-back is used to control the operating point of PV array at the maximum power point. The effects of irradiation and cell-temperature on the dynamic responses are also considered.

1. Introduction

Nowadays the worldwide installed Photovoltaic power capacity is rapidly increased. Normally, the photovoltaic power systems use a maximum power point tracking to deliver the highest power to loads.

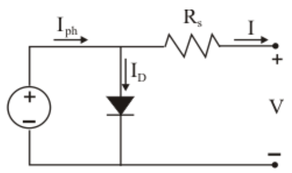
Many MPPT algorithms have been proposed in the literatures, however, the Perturbation and Observation method has been widely used because of its simple feedback structure and fewer measured parameters.

The maximum power delivered to the system depends on the weather conditions. It also depends on the cell-temperature. The changes in solar irradiation and cell-temperature affect to the MPPT process and thus, the operation of PV system are varied. The change of these parameters can be large or small, fast or slow. They also affect to the system stability and to the power quality. Therefore, the analysis of the effect of solar irradiation and cell-temperature is very necessary. In this paper these effects can be observed through the simulation results.

2. Photovoltaic model and MPPT Algorithm

2.1 Photovoltaic Model

The single diode model [1], as shown in Fig. 1, is used:



<Fig. 1> The Single-diode PV cell model

The mathematical model is as follows

$$I = I_{ph} - I_{sat}\left(e^{\frac{V+IR_s}{V_t}} - 1\right) \qquad (1)$$

Where I_{ph} is the photo current, I_{sat} is the dark saturation current. Both of I_{ph} and I_{sat} are depended on solar irradiation and cell-temperature and can be mathematically express as follows:

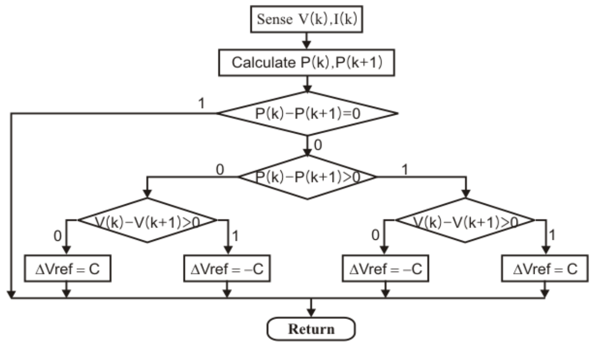
$$I_{ph}(G_a, T) = I_{scs}\frac{G_a}{G_{as}}\left[1 + \Delta I_{sc}(T - T_s)\right] \qquad (2)$$

$$I_{sat}(G_a, T) = \frac{I_{ph}(G_a, T)}{e^{\left(\frac{V_{oc}(T)}{V_t(T)}\right)} - 1} \qquad (3)$$

In the above, I_{sc} is short circuit, DI_{sc} is temperature coefficient, V_t is thermal voltage, V_{op} is open circuit voltage, G_a is irradiation (W/m^2), G_{as} is standard irradiation (1000W/m^2), T is cell-temperature in Kelvin, T_s is standard temperature (298K), R_s is series resistor.

2.2 The MPPT Algorithm

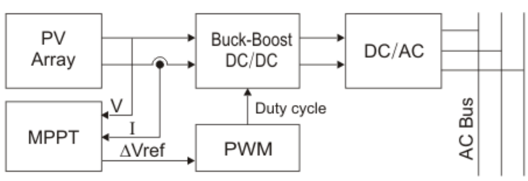
Fig.2 shows the MPPT process using power feedback control [2]. As PV voltage and current are determined, the power is calculated. At the maximum power point, the derivative (dP/dV) equal to zero. The maximum power point can be achieved by changing the reference voltage (DV_{ref}).



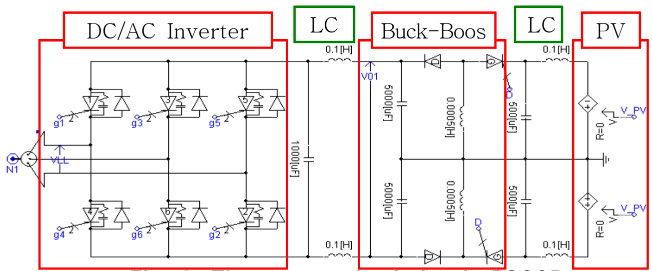
<Fig. 2> The MPPT algorithm diagram

3. Simulation result and Analysis of the Effects of the Irradiation and Cell-Temperature

The examining PV system is shown in Fig.3. The proposed system consists of a Photovoltaic array as a non-linear voltage source, a Buck-Boost DC/DC converter, a DC/AC inverter and the 3 phase power grid. The system modeling is simulated in PSCAD software as shown in Fig.4.

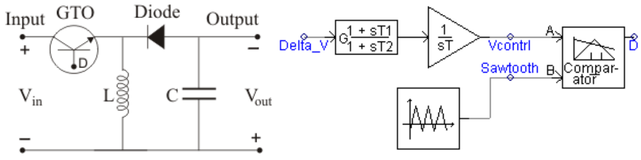


<Fig. 3> Photovoltaic system configuration



<Fig. 4> The system simulation in PSCAD

In order to track the maximum power point, a Buck-Boost DC/DC converter is used as depicted in Fig.5(a).



(a) (b)

<Fig. 5> (a)Buck-Boost topology (b)PWM circuit

The parameters L and C must satisfy as following conditions [3]:

$$L > \frac{(1-D)^2 R}{2f} \quad (4) \qquad C > \frac{D}{Rf(\Delta V/V_0)} \quad (5)$$

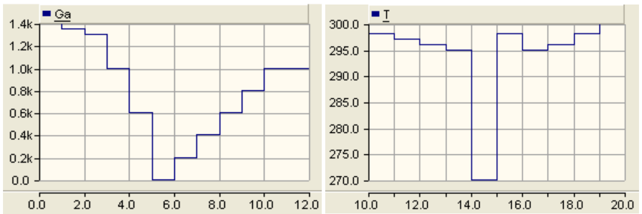
(D: duty cycle; f: switching frequency; DV/V_0: voltage ripple)

The Buck-Boost converter consists of one switching device (GTO) which enables to turn on and off depending on the applied gate signal (D). The gate signal for the GTO can be obtained by comparing the sawtooth waveform with a control voltage[3] as shown in Fig.5(b). The change of the reference voltage (DV_{ref}) obtained by the MPPT algorithm becomes the input of Pulse-Width-Modulation (PWM). The PWM generate the gate signal to control Buck-Boost converter and thus, the maximum power is tracked and delivered to the three phase power grid through the DC/AC inverter.

The two following cases are considered to analyse the effects of the irradiation and cell-temperature:

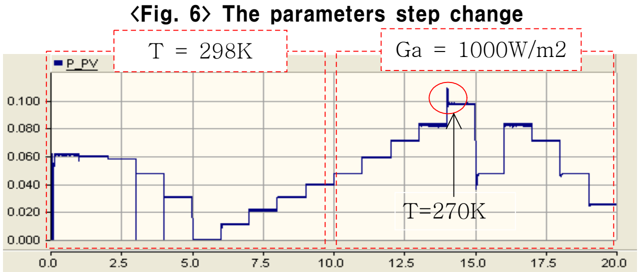
Case 1: The Irradiation and Cell-Temperature step change:

From 0s to 10s, the irradiation is step change and the cell-temperature is 298K. From 10s to 20s, the temperature is step change and the irradiation is 1000W/m^2, as shown in Fig.6.

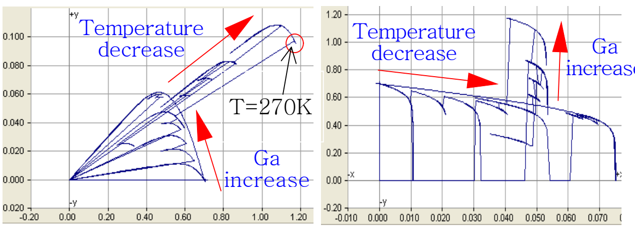


a) Cell - Temperature b) Solar irradiation

<Fig. 6> The parameters step change



<Fig. 7> Maximum output power of PV



a) P-V characteristic b) The V-I characteristic

<Fig. 8> MPPT process result

It is observed from Fig. 6 and Fig. 7 that, in the first 10 seconds, as the irradiation changes, the PV output power is directly proportional to irradiation. Every change in irradiation causes the change of output power. The detailed explanation for these changes is expressed as follows:

- From 0s to 3s, Ga slightly changes from 1400W/m2 down to 1300W/m2, the MPPT process as shown in Fig. 7 and Fig.8 works very well. But from 3s to 5s, the irradiation rapidly changes from 1300 W/m2 down to 0 W/m2 and thus, MPPT process is slower tracked.

At 5s, Ga is down to zero, corresponding to the shading effect, the MPPT process shows a very good performance.

It can be said that, when the irradiation rapidly changes with a large amount, so that, the MPPT process is slower. In the every conditions of the irradiation change, the MPPT process with power feed back control operates well with high performance.

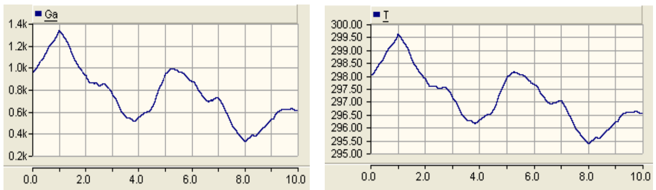
- For the time duration from 10s to 20s, as the cell-temperature changes, the PV output power is inversely proportional to the temperature. It can be also seen that, from 10s to 13s, the temperature changes from 298K down to 295K and the output power increase from 47.5kW to 71kW. It shows that, when temperature slightly decreases, the output power largely increases and vice versa. In other words, when the temperature is increased, the conversion efficient of solar cell is decreased.

At 14s the temperature rapidly changes from 295K down to 270K, the MPPT process get a wrong result. However, at 15s, it returns to 298K and the MPPT process get the true result, as shown in Fig.7 and Fig.8.

If the temperature rapidly changes, the MPPT process may get the wrong result. However, in this case, if the temperature is returned to normal conditions, the MPPT process can works well. In fact, it is impossible to rapidly change the cell-temperature in a large scale..

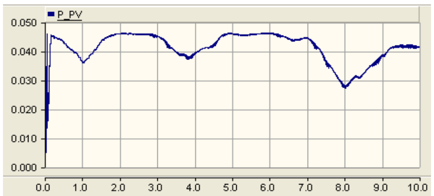
Case 2: The Irradiation and Temperature continuous change:

In this case, the parameters are continuously changed as shown in Fig.9 and the output power is shown in Fig.10. From the figures, it is seen that, when the parameters continuously change without a sharply change, the MPPT process works well with a high performance.



a) Solar Irradiation b) Cell - Temperature

<Fig. 9> The parameters continuous change



<Fig. 10> Maximum power point tracking

4. Conclusion

- In this paper, the proposed PV system is considered. The PV system with MPPT is connected to the AC grid. The analysis of the effects of Irradiation and Cell-Temperature on the PV system with MPPT is presented. Two cases of parameters change are considered: step and continuous change.
- The Buck-Boost converter and P&O MPPT algorithm with power control feed back is used for tracking the maximum power of PV.
- The MPPT algorithm with power feed back control co-ordinated with Buck-Boost converter works well with high performance when the parameters change.
- Every changes in the Irradiation and Cell-Temperature cause the change in PV output power. The output power is inversely proportional to the cell-temperature and directly proportional to the irradiation.
- The change of the cell-temperature strongly affects to the conversion performance of PV array.

[Reference]

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