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PSCAD/EMTDC를 이용한 PV Cell 및 MPPT 모델링에 관한 연구

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Simplified PV Cell and MPPT Modeling based on PSCAD/EMTDC

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Abstract – The power generated by a *Photovoltaic*(PV) cell depends on the operating voltage of the array, its voltage-current and voltage-power characteristic curves specify a unique operating point at which maximum possible power is delivered and the array is operated at its highest efficiency. PSCAD/EMTDC, which is a simulation tool for the transient analysis of an electric power system, was used to simulate the PV Cell system. So, in this paper, the PV cell components of the PSCAD/EMTDC were developed, and the *Maximum Power Point Tracking*(MPPT) modeling was used for the developed PV power system to find the maximum power.

1. Introduction

Solar power also known as solar energy is solar radiation emitted from our sun. Solar energy has been used in many traditional technologies for centuries, and has come into widespread use where other power supplies are absent, such as in remote locations and in place.

PV generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. The amount of power generated by a PV depends on the operating voltage of the array. A PV's *Maximum Power Point* (MPP) varies with solar insulation and temperature. Its V-I and V-P characteristic curves specify a unique operating point at which maximum possible power is delivered. At the MPP, the PV operates at its highest efficiency. Therefore, many methods have been developed to determine MPPT. But PV modules still have relatively low conversion efficiency, therefore, controlling MPPT for the solar array is essential in a PV system[1]. The equivalent circuit of PV, V-I characteristic and a power system connected PV cell modeling and MPPT control was developed in this paper.

2. Simplified PV Cell and MPPT Modeling

2.1 PV Equivalent Electrical Circuit

The complex physics of the PV cell can be represented by the equivalent electrical circuit shown in Fig.1.

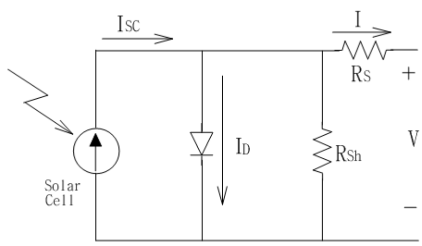

Figure.1 PV Cell Equivalent Electrical Circuit

The load current is therefore given by the expression:

$$\begin{aligned} I &= I_{SC} - I_d - I_{SH} \\ &= I_{SC} - I_o\left(exp\left[\frac{V+IR_S}{nV_T}\right]-1\right) - \frac{V+IR_S}{R_{SH}} \end{aligned} \tag{1}$$

where, I = output terminal current
I_{sc}= light-generated current
I_{SH}= ground-shunt current
V_T = KT/Q, absolute temperature per voltage
I_o = the reverse saturation current of the diode
V = output voltage
Q = electron charge=$1.6*10^{-19}$ Coulombs
A = curve fitting constant
K = Boltzmann constant=$1.38*10^{-23}$ Joule/$^\circ K$
T = temperature on absolute scale $^\circ K$
R_{SH}= shunt resistance of the cell
R_S = series resistance of the cell
n = diode quality factor

The electrical characteristic of the PV cell is generally represented by the current versus voltage(V-I) curve. Equation (1) was used in computer simulations to obtain the output characteristics of a solar cell, as shown in Figure 2. This curve clearly shows that the output characteristics of a solar cell are non-linear and are crucially influenced by solar radiation, temperature and load condition. Each curve has a MPP, at which the solar array operates most efficiently[2].

2.2 MPPT Control

The electric power supplied by a photovoltaic power generation system depends on the solar radiation and temperature. Designing efficient PV systems heavily emphasizes to track the maximum power operating point. Several techniques for tracking MPP have been proposed, as described in [3]. Two algorithms are commonly used to track the MPPT - the P&O method and *Incremental Conductance* (Inc-Cond) method. The P&O method has been broadly used because it is easy to implement. And Inc-Cond algorithm is based on differentiation of PV power to its voltage and on condition of zero slope of P-V curve

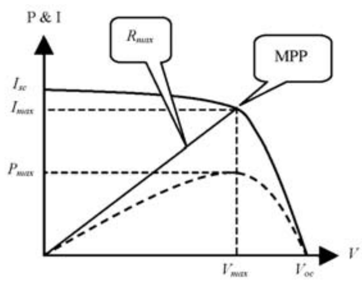

Figure.2 V-I characteristic of a solar cell

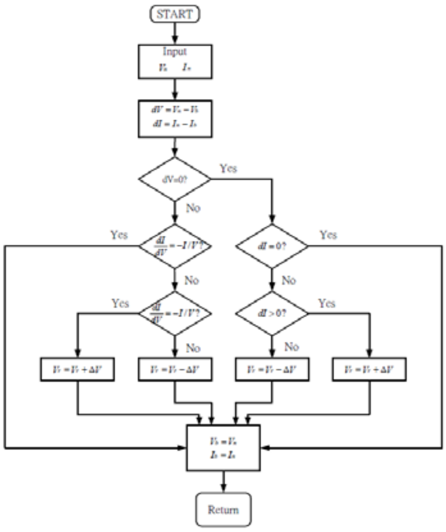

Figure.3 Inc-Cond Algorithm Control Flow Chart

in MPP. And Figure 3 presents the control flow chart of the Inc-Cond algorithm. Especially, Inc-Cond method differencing PV power and replacing power with P&O equation, arises equation (2).

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I + V\frac{dI}{dV} \qquad (2)$$

2.3 PSCAD/EMTDC Modeling

Figure 4 shows the control block diagram of PV array system connected with a equivalent 11kV system whose MPPT control method is the incremental conductance algorithm control which feedbacks I and V of PV array output in order to control MPPT. A DC-DC converter is used to match the PV system to the load and to operate solar array at maximum power point and an inverter is used connect to the AC system. The full-bridge converter is a very suitable topology for connecting multiple panels in series and sinusoidal PWM is employed to generate a sinusoidal terminal voltage and to control it's magnitude so that it can be interfaced with the AC system.

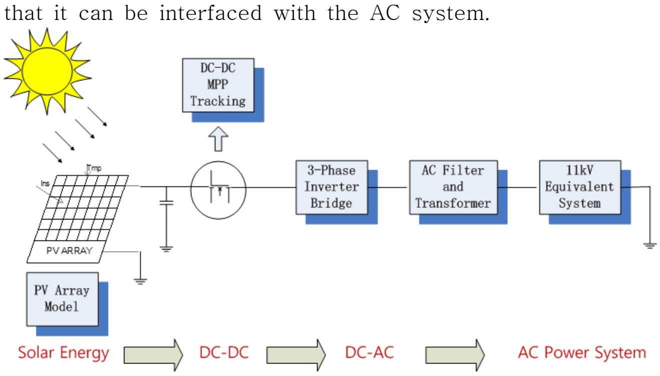

Figure.4 Control Block Diagram of a PV System

2.4 Case Study

Figure 5 shows the simulation result of the output power of PV array under a certain Solar Radiation(1000W/m^2) and Cell Temperature(25 ° C) condition. In this case, the mean value of PV array output power is approximately 37.4[W] without MPPT control, and up to 53.1[W] by using MPPT control starting from 3.0 Second. And figure 6 shows the simulation result of the output power of PV array when solar radiation changed form 1000W/m^2 to 800W/m^2 at 4.0 second with Cell Temperature of 25 ° C condition; also the MPPT contol starting time is 3.0 second.

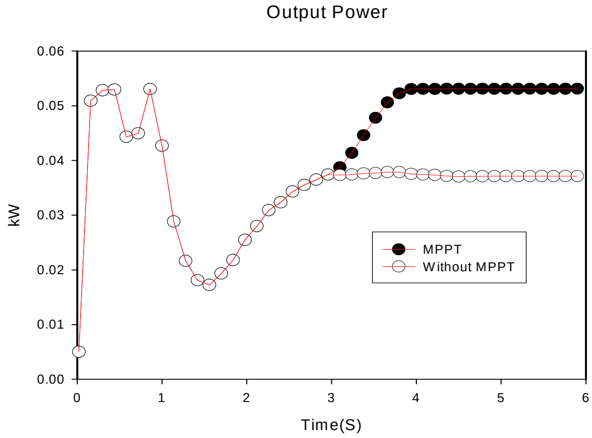

Figure.5 PSCAD/EMTDC Simulation Result

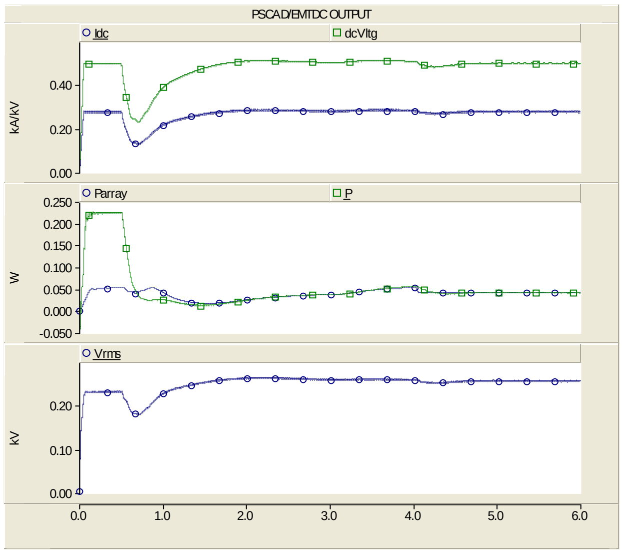

Figure.6 MPPT Control with Radiation Changed from 1000W/m^2 to 800W/m^2
(PV output DC Current and Voltage; MPP power and Inverter Output Real Power; Voltage RMS)

3. Conclusion

One of the problems in designing efficient PV systems is to track the maximum power operating point for varying solar irradiance levels and ambient conditions. So in this paper, the PV cell components of the PSCAD/EMTDC were developed, and the Maximum Power Point Tracking modeling was used for the developed PV power system to find the maximum PV power. The photovoltaic generator exhibits nonlinear V-I characteristics and maximum power point varies with solar insolation. The simulation results shows the PV generation efficiency was significantly improved by using the MPPT control. In addition to, more simulation should be done(Eg. changing the solar radiation and temperature, fault analysis and so on) to confirm the developed PV cell modeling and MPPT control.

[Reference]

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