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변압기 없는 태양광 PCS에서의 최대전력추종제어기법 분석

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Analysis and study for MPPT algorithms in transformerless PV PCS

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ABSTRACT

Maximum power point tracking(MPPT) is usually used for a solar power system. Many maximum power tracking techniques have been considered in the past. The microprocessors with appropriate MPPT algorithms are favored because of their flexibility and compatibility with different solar arrays. In this paper, four MPPT algorithms are analyzed and studied. Perturbation and Observation(P&O), Incremental Conductance(IncCond), which are used from the past. Improved P&O and Two-mode , which are developed P&O and IncCond algorithms. Also, the author introduces grid-connected transformerless PV PCS to apply MPPT control. MPPT efficiency is measured by changing irradiance from 0.1kW/m^2 to 1kW/m^2 and simulation was performed for each MPPT algorithm.

1. Introduction

Solar energy has become a promising alternative source due to its advantages: abundance, pollution free and renewability. The main drawbacks are that the initial installation cost is considerably high, and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used : (1) increase the efficiency of conversion for the solar array, and (2) maximize the output power from the solar array.[2]

In the system view, maximum power should be produced from the solar array for MPPT efficiency. Therefore, many MPPT algorithms are performed from the past. In this paper, four algorithms are introduced and analyzed to get high efficiency. P&O and IncCond, which are used from the past. Improved P&O and Two-mode, which are advanced P&O and IncCond MPPT algorithms. Also, many MPPT algorithm are used in the DC-DC converter from the past. However, single grid-connected transformerless PV PCS is applied for MPPT control in this paper.

P&O algorithm has simple structure and only needs two measuring parameters. However, the array voltage is perturbing every MPPT cycle; therefore, array output power has a loss at the maximum power point(MPP) because of oscillation.[1]

IncCond algorithm offers good performance under rapidly changing atmospheric conditions, the more time is needed for calculating dI/dV than P&O due to two divisions.[3]

The Improved P&O algorithm is to stop perturbation of PV output and to play an important role in an absorber for P&O and calculation time takes less than IncCond.

The advantage of Two-mode algorithm is performed well under low irradiance(in this paper 0.25kW/m^2).[4]

2. MPPT algorithm

2.1 I-V-P characteristic curve of solar cell

The electric power generated by a solar array swings depending on the solar irradiance and

temperature. Fig. 1 shows the characteristic of I-V-P curve due to changing irradiance from 0.2kW/m^2 to 1.0kW/m^2.

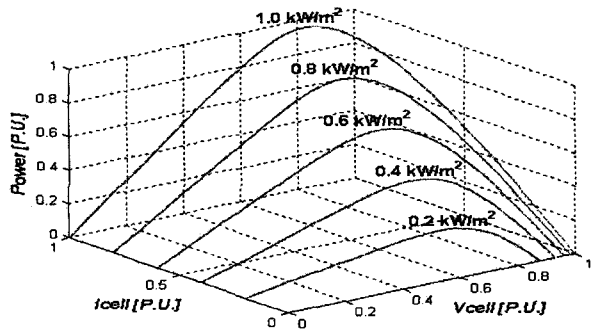

Fig. 1. The characteristic of I-V-P curve in solar array due to changing irradiance

The solar array is a nonlinear device and can be represented as a current source model. Mathematical I-V curve of the solar array is important in order to use in the simulation. Equation (1) shows the mathematical characteristic model of the solar array.

$$I_{OUT} = I_{SC} - [\frac{I_{MAX}}{\exp(39 \times K) - 1}] \times [\exp(39 \times \frac{V_{OUT}}{V_{OP}} \times K) - 1] \quad (1)$$

I_{SC} : Current short circuit due to irradiance
I_{MAX} : Maximum current when irradiance is 1kW/m^2
V_{OP} : Open voltage when irradiance is 1kW/m^2
K : Factor (diode positive voltage V_D)

2.2 MPPT algorithms

The variable reference voltage control method changes the reference voltage of the PV array to achieve maximum power tracking when the irradiance or temperature changes significantly. In this method, the array voltage measurement is important because the MPPT operation relies on the array voltage.[2]

2.2.1 Perturbation and Observation(P&O) method

P&O algorithms are widely used in MPPT control because of their simple structure and the few measuring paramters are required. They operate by periodically perturbing(i.e. incrementing and decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. When the the power reached to MPP, the P&O algorithm will oscillate around it resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions.

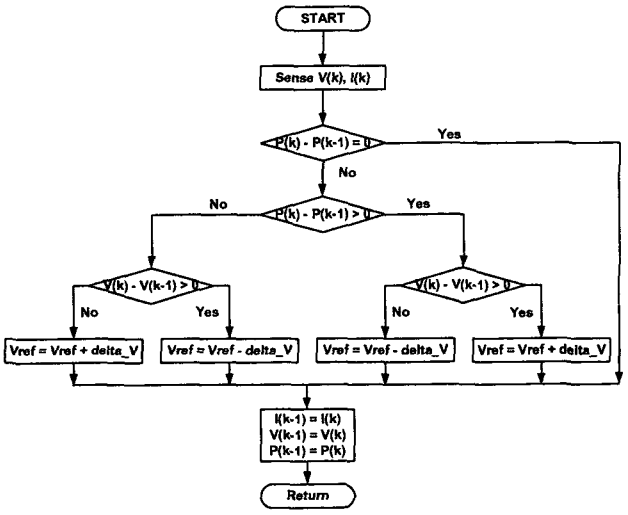

Fig. 2. The flowchart of the P&O method

2.2.2 Incremental Conductance method

IncCond method tracks MPP by using incremental conductance of PV array output power. The basic idea is that at the MPP the derivative of the power with respect to the voltage vanishes because the MPP is the maximum of the I-V-P curve, as shown in Fig. 1. Also, to the left of the MPP means the power is increasing with the voltage, i.e. dP/dV > 0, and it is decreasing to the right of the MPP, i.e. dP/dV < 0. This relationship represents following equation (2).[1]

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

multiplying 1/V to the both sides,

$$\frac{1}{V}\frac{dP}{dV} = \frac{I}{V} + \frac{dI}{dV} \quad (3)$$

Here, define PV conductance and incremental conductance,

$$G = \frac{I}{V} \quad (4)$$

$$\Delta G = \frac{dI}{dV} \quad (5)$$

From the Fig. 1,

$G > \Delta G$(to the left of the MPP), dP/dV>0 (6)

$G = \Delta G$(at the MPP), dP/dV=0 (7)

$G < \Delta G$(to the right of the MPP), dP/dV<0 (8)

In the end, this method makes PV output voltage

tracks to PV MPP voltage as PV conductance equals to incremental conductance.

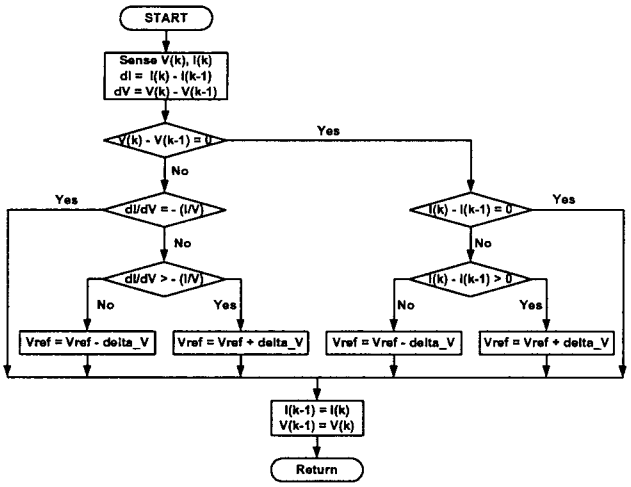

Fig. 3. The flowchart of the IncCond method

2.2.3 Improved P&O method

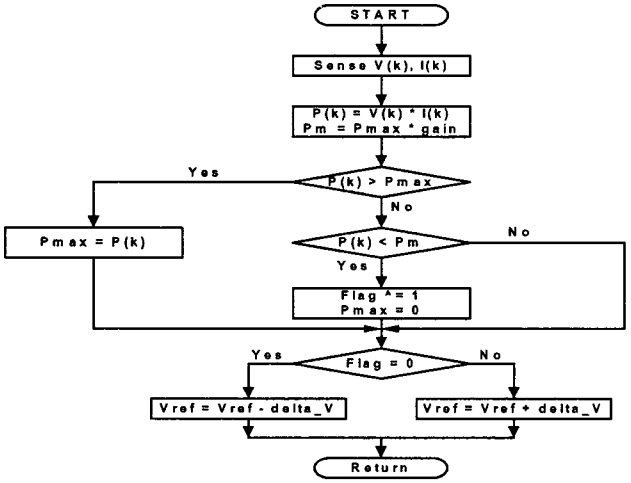

Fig. 4. The flowchart of the Improved P&O method

Avoiding the drawback of P&O, the control method of the Improved P&O algorithm renews maximum power by increasing or decreasing the reference of PV output voltage unitl the output power of PV array reaches to MPP. If the present array power is less than MPP as it comes to the MPP, it compares with the minimum power value(Pm), which can turn over PV output power. By simulating many results, the author suggests following equation for Pm.[3]

$$Pm = Pmax \times 0.98 \quad (9)$$

2.2.4 Two-mode method

Two-mode MPPT control algorithm which combines the constant voltage control at less than 0.25kW/m^2 normalized irradiance intensity with the IncCond method at more than 0.25kW/m^2 normalized irradiance intensity. Fig. 5 shows the flowchart of the Two-mode MPPT method. The advantage of this method is that when the irradiance is under 0.25kW/m2, the MPPT efficiency is high because of the constant voltage control.[4]

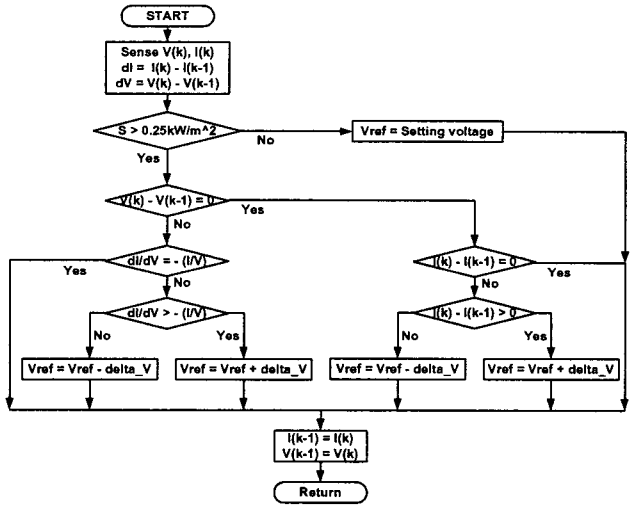

Fig. 5. The flowchart of the Two-mode method

3. Simulation

Fig. 6 shows transformerless type grid-connected PV PCS. By using PSIM program, PV array and converter with inverter pwm control are programed. The program code are included to DLL(Dynamic Link Library) blocks. The system consists of 3kW range PV array and the MPP voltage in the maximum irradiation is 280V. PV output voltage is step-up 380V through boost converter. Converter controls MPPT and inverter controls DClink voltage with grid connection.

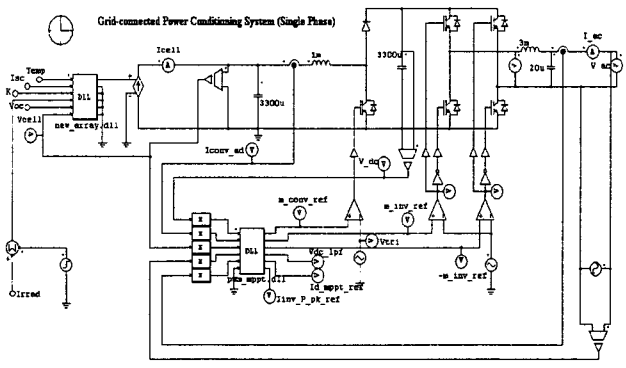

Fig. 6. Single transformerless grid-connected PV PCS

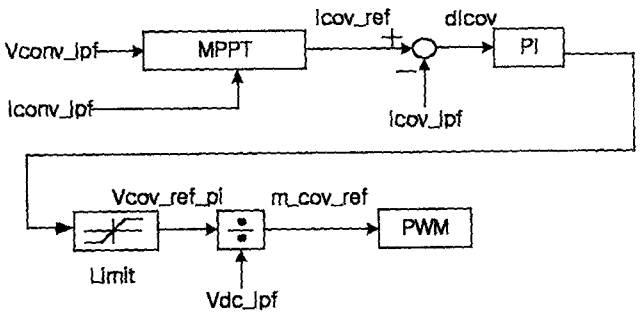

Fig. 7. Converter control block

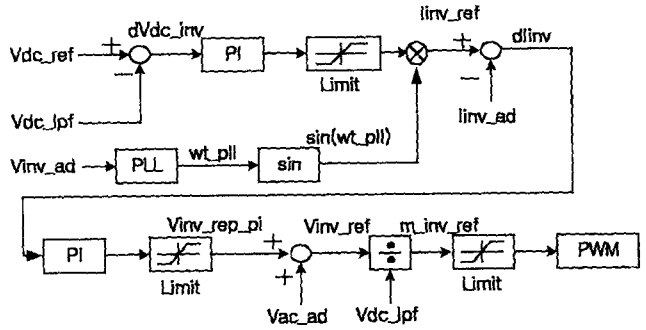

Fig. 8. Inverter control block

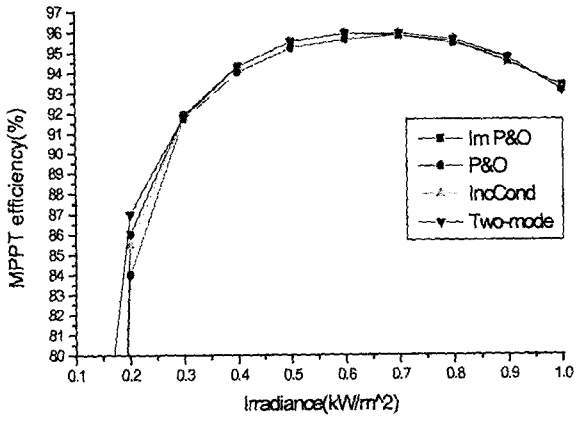

Fig. 9. The comparison of four MPPT efficiency under changing irradiance

Fig. 7 and 8 show control blocks of converter and inverter control. Converter forms current reference from the MPPT control and this reference is transformed to voltage reference and then this will result of final PWM waveform after comparing triangle waveform.

In inverter control, the error value from comparing DClink reference voltage(380V) with DClink sensing voltage goes through PI controller and then this is changed into magnitude of inverter control reference. The phase is made from the grid sensing voltage, which is then goes through PLL(Phase Lock Loop). In the end, inverter current reference is made multiplying magnitude by phase. This inverter current reference, finally, is to be PWM reference of inverter and then this compares to triangle waveform.

Fig. 9 shows the MPPT efficiency of four methods with changing irradiance. When irradiance is higher, the MPPT efficiency of four methods is higher. However, irradiance is lower than 0.3kW/m^2, the MPPT efficiency is less than 90%. Two-mode MPPT method is good performance at 0.2kW/m^2 because it works constant voltage control under 0.25kW/m^2. Three MPPT methods without Two-mode MPPT method do not work at 0.1kW/m^2. As a result, four algorithms have very similar MPPT efficiency from 0.3kW/m^2 to 1.0kW/m^2, but Two-mode algorithm is performing well under 0.3kW/m^2 in PV PCS.

4. Conclusion

The purpose of the maximum power point tracking is to transfer the maximum available power to the load from the PV array. In this paper, four MPPT algorithms : P&O, IncCond, Improved P&O and Two-mode, are introduced and analyzed their flowchart. To compare MPPT following efficiency, four MPPT algorithms are used under changing irradiance. As a result, four algorithms have very similiar MPPT efficiency from 0.3kW/m^2 to 1.0kW/m^2, but Two-mode algorithm is working well under 0.3kW/m^2.

Also, MPPT control is performed in the transformerless type grid-connected PV PCS. Converter controls MPPT and inverter controls DClink voltage, at the same time, connects with grid continuously.

Reference

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