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Analysis and Synthesis of distributed photovoltaic micro-grid System

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Abstract. The solar radiation conditions and environmental factors on the shadow of the power generation resulted in loss of efficiency. In this paper, a simple structure with interleaved isolation converter according to the characteristics of the hardware circuit is proposed in order to improve the conversion efficiency of photovoltaic grid system. First, the hot spot effect and discretization of solar panels according to the characteristics of the micro-inverter with a lot of promotion is analyzed. The least action recursive method is involved, which has high computing precision, and therefore is more suitable for distributed micro-inverter system.

Keywords: PV grid, the least action, modeling, photovoltaic panels, inverter.

1 Introduction

At present, photovoltaic generation system are not widely used because of low efficiency and high cost. Maximum power point tracking technology could make full use of photovoltaic cells to convert energy and further improve working efficiency of the solar cells, which should be an important link of PV grid connected generation. The commonly methods can be divided into three categories. First, perturbation incremental method; second, intelligent incremental method; third, differential method. Perturbation incremental method [1] is gradually closing to the maximum power through continuous sampling. The advantage of this method lies on the simple algorithm, however, the selection of initial value and step have a great influence on tracking accuracy and tracking speed, thus, it cannot adapt to drastic changing of sunshine per day. And it has a possibility of occurring oscillation near maximum power point which will cause power loss. Sometimes a program control disorder may occur in the proceeding, which will cause erroneous judgment. Intelligent incremental methods including fuzzy control [2] and neural network control [3]. Fuzzy control establishes fuzzy rules between sunshine changing and conduction rate, improving the influence of sunshine at the same time.

The advantage of fuzzy control is that maximum power point can also be found when sunshine changes dramatically every day, which also causes oscillation through

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continuous sampling. Neural network control need to extract a large number of samples but cannot reach the actual application process. Differential method[4] is more commonly used nowadays. When opening or closing the derivative of the power and voltage by calculating, the relationship of all pipe parameters adjust to the size of conduction rate. It will reach the maximum power when the derivative of the power and voltage is zero. The advantages of this method are the less volatile near the maximum power point, so it can have a higher precision, but this method is complex, it needs a lot of parameters to be made sure parameter values are also difficult to determine.

The recursive algorithm is proposed to use the duty cycle of the voltage and current changes combined with the principle of least action and calculation process, where the minimum amount is determined by the action of the maximum power point. This method avoids much fuzzy calculation process and improves the accuracy of the calculation.

2 Recursive solution method of least action for Maximum power point tracking

2.1 The judgment of maximum power point Volt-ampere conditions

The characteristics of solar cell can be expressed as:

$$i_s = I_{ph} - I_0 (e^{\frac{q}{KT} e_s} - 1) \tag{1}$$

where is is the current of the solar cell, es is the panel voltage, Iph is the short-circuit current of the solar cell, I0 is the reverse saturation current of the diode, q is the electron charge, K is the Boltzmann constant, T is the absolute temperature.

Denote $\phi = \frac{q}{K}$, and we can derive:

$$i_s = I_{ph} - I_0 (e^{\frac{\varphi}{T} e_s} - 1) \tag{2}$$

If ps is the power of panels, which is equal to the product of current and voltage, therefore:

$$p_s = i_s e_s = [I_{ph} - I_0 (e^{\frac{\phi}{T} e_s} - 1)] e_s \tag{3}$$

Based on the principle of least action, it can be drawn:

$$\frac{dp_s}{de_s} = i_s - \frac{e_s I_0 \varphi}{T} e^{\frac{\varphi}{T} e_s} \tag{4}$$

When the formula is equal to 0, the point is the maximum power point, then:

$$i_s = \frac{e_s I_0 \varphi}{T} e^{\frac{\varphi}{T} e_s} \tag{5}$$

Therefore, as long as we confirms the judge of these holds, the maximum power point can be derived.

2.2 Recurrence relations

IGBT is considered as an ideal switch according to Fig.2, on and off state of the two present in each cycle. When Tc is on, it can be drawn:

$$i_s = i_{Lc} + C_s \frac{d}{dt} e_s$$

$$e_s = L_c \frac{d}{dt} i_{Lc} \tag{6}$$

When tube Tc is off, that can be drawn:

$$i_s = i_{Lc} + C_s \frac{d}{dt} e_s$$

$$e_s = L_c \frac{d}{dt} i_{Lc} + e_d \tag{7}$$

where, iLc is the current flowing through Lc, ed is the output voltage of DC/DC. Denoting conduction rate α, the equation of state is:

$$\begin{cases} i_s = i_{Lc} + C_s \dfrac{d}{dt} e_s \\ e_s = L_c \dfrac{d}{dt} i_{Lc} + (1-\alpha) e_d \end{cases} \tag{8}$$

Denoting $e_{Tc} = (1-\alpha) e_d$, the above equation can be arranged:

$$\begin{cases} \dfrac{d}{dt} e_s = -\dfrac{1}{C_s} i_{Lc} + \dfrac{1}{C_s} i_s \\ \dfrac{d}{dt} i_{Lc} = \dfrac{1}{L_c} e_s - \dfrac{1}{L_c} e_{Tc} \end{cases} \tag{9}$$

Substituting the Eq. (1) into the equation (8), then:

$$\begin{cases} \dfrac{d}{dt} e_s = -\dfrac{1}{C_s} i_{Lc} + \dfrac{1}{C_s} (I_{ph} + I_0 - I_0 e^{\frac{\phi}{T} e_s}) \\ \dfrac{d}{dt} i_{Lc} = \dfrac{1}{L_c} e_s - \dfrac{1}{L_c} e_{Tc} \end{cases} \tag{10}$$

Let Δt take very small value, then:

$$\begin{cases} \dfrac{e_s(1) - e_s(0)}{\Delta t} = -\dfrac{1}{C_s} i_{Lc}(0) + \dfrac{1}{C_s}(I_{ph} + I_0 - I_0 e^{\frac{\phi}{T} e_s(0)}) \\ \dfrac{i_{Lc}(1) - i_{Lc}(0)}{\Delta t} = \dfrac{1}{L_c} e_s(0) - \dfrac{1}{L_c} e_{Tc}(0) \end{cases} \tag*{11)}$$

$$\begin{cases} e_s(1) = (-\dfrac{1}{C_s} i_{Lc}(0) + \dfrac{1}{C_s}(I_{ph} + I_0) - \dfrac{I_0}{C_s} e^{\frac{\phi}{T} e_s(0)})\Delta t + e_s(0) \\ i_{Lc}(1) = (\dfrac{1}{L_c} e_s(0) - \dfrac{1}{L_c} e_{Tc}(0))\Delta t + i_{Lc}(0) \end{cases} \tag{12}$$

2.3 Recursive algorithm for computing model

According to the judgment conditions in subsections 3.1 and 3.2 and recurrence relations, the recursive algorithm implementation process are shown in Fig.3, the calculation procedure can be illustrated as follows:

(1) Initial duty cycle is given, taking Δt is equal to a very small value, detect the initial value $e_s(0), i_{Lc}(0), e_d(0), T$.

(2) Calculate the initial value $e_{Tc}(0) = (1 - \alpha) e_d(0)$.

(3) If the value of $i_s(0) - e_s(0) I_0 \dfrac{q}{KT} e^{\frac{q}{KT} e_s(0)}$ is equal to 0, the procedure is ended; If not equal to 0, then turns to the next step.

(4) Eq. (11) can be derived into following recurrence relations:

$$\begin{cases} e_s(k+1) = (-\dfrac{1}{C_s} i_{Lc}(k) + \dfrac{1}{C_s}(I_{ph} + I_0) - \dfrac{I_0}{C_s} e^{\frac{\phi}{T} e_s(k)})\Delta t + e_s(k) \\ i_{Lc}(k+1) = (\dfrac{1}{L_c} e_s(k) - \dfrac{1}{L_c} e_{Tc}(k))\Delta t + i_{Lc}(k) \end{cases} \tag{13}$$

(5) According to the obtained values from $e_s(k+1)$, substituting it into the equation $i_s(k+1) = I_{ph} - I_0(e^{\frac{q}{KT} e_s(k+1)} - 1)$, we can calculate the values of $i_s(k+1)$

(6) If $i_s(k+1) - e_s(k+1) I_0 \dfrac{q}{KT} e^{\frac{q}{KT} e_s(k+1)}$ is equal to 0, the procedure is ended; if not, we change the value of $e_{Tc}(k)$, if $e_{Tc}(k+1) = e_{Tc}(k) \pm \Delta e_{Tc}(k)$, according to Eq. (8), continue to judge until the value is 0. This moment, calculate the value of

$e_s(k+1)$ as the voltage of the maximum power point while the value of $i_s(k+1)$ is the current of the maximum power point.

(7) According to the definition $e_{Tc} = (1-\alpha)e_d$, the duty cycle is equal to:

$$\alpha = 1 - \frac{e_{Tc}}{e_d} \tag{14}$$

Finally, we need assign the value of the duty cycle to the system.

2.4 Determination of parameter values

The two parameters I0, φ does not change with sunshine and temperature, when the solar panels and power systems is fixed.

Then, the formula is related to the following four changing values, the short-circuit current Isc, the temperature T, the voltage value e, the current i, then we can get:

$$i = I_{sc} - I_0(e^{\frac{\varphi}{T}e} - 1) \tag{15}$$

Then we can conclude:

$$I_{sc} = i - I_0(e^{\frac{\varphi}{T}e} - 1) \tag{16}$$

Thus, the voltage value e, the current value i, we can calculate the short-circuit current Isc by sampling the current temperature T.

2.5 A/D sampling parameters

The initial sampling of maximum power point tracking including: the temperature T, the voltage value of the panel e, the panel current i, the inductor current iLc, and the output voltage value ed.

3 Conclusion

The principle of distributed least action MPPT control method is proposed to overcome the difference between the electrical parameters of the solar cell and the actual difference in solar radiation. The energy loss caused by different solar module strings in the different direction is compared to the general application of the MPPT, which improves the power generation efficiency of the system. The proposed least action recursive method can be accurate when tracking the solar panels to the maximum power point when the sunlight intensity, ambient temperature and load resistance change a lot.

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