Analysis of DC Photovoltaic System Voltage Controller Based on Subregional Variable Duty Cycle

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Abstract

A modified MPPT control method which introduces the rapidity of the CVT method and the precision of the IncCond method, and combines the subregional variable duty cycle to optimize the photovoltaic array. To verify and analyze on basis of the setting up of the variable duty cycle ΔD and the time parameter of the power/hour T_a , and verify the method proposed in this paper on the experimental platform, In different areas of photovoltaic power generation using different duty cycle control method, Optimization of the target area using constant voltage method, Reached quickly determine the maximum power point (MPP) when light mutations.

Keywords: *subregional variable duty cycle; MPPT; Photovoltaic power generation; power curve*

1. Introduction

Photovoltaic power generation is an excellent clean energy, but there still exist some problems in the large-scale applications of photovoltaic power generation, such as that the input cost of photovoltaic power generation is high, while the utilization ratio is low. Thus to guarantee the maximum output of the photovoltaic system and to conduct maximum power point tracking on the photovoltaic system is of vital significance to the promotion of photovoltaic power generation. This paper focuses on the research of the MPPT control method of PV to guarantee that the photovoltaic system can quickly and effectively track its maximum power point. The goal of this MPPT control method research is to pursue the maximum electricity output according to the maximum power of the photovoltaic system. There are many MPPT control methods among which the Constant Voltage Tracking (CVT) method, the Perturbation and Observation (P & O) method, the Incremental Conductance (IncCond) method, and the Fuzzy Control method *etc.* are the most commonly used. However, each method has its advantages and disadvantages that the rapidity of the tracking method contradicts with its precision and that we should also consider the application conditions of different photovoltaic systems. Now some scholars proposed to combine the method of variable step length and P & O method or the IncCond method; this combination can accelerate the optimizing speed, but it possesses the disadvantages of large vibration near the maximum power point, and systematic dependency which means that the selection of parameters depends upon a particular system. Based on the above, this paper proposes a modified MPPT control method which introduces the rapidity of the CVT method and the precision of the IncCond method, and combines the subregional variable duty cycle to optimize the photovoltaic array. To verify and analyze on basis of the setting up of the variable duty cycle ΔD and the time parameter of the power/hour T_a , and verify the method proposed in this paper on the

experimental platform.

Currently recognized at home and abroad DC photovoltaic system is by solar panels and boost circuit, which are connected in parallel on the battery and the bidirectional converter constitute [3], most of the research and design is will photovoltaic systems as uncontrollable distributed power supply, the research on the maximum work rate tracking function, and the battery as a constant pressure control of main equipment [4], so when the photovoltaic power is greater than the load power battery appeared charging or over current, due to the latch up protection, so that the system loses the ability to direct pressure control. And traditional DC voltage control, the output side direct pressure and the reference DC voltage comparison by the PI controller feedback to switch sides [5], when used in photovoltaic boost circuit, because of the presence of inductance on the input side, the switch tube conduction period, only filter capacitor for the load to provide energy, electrical output Yajian small, the control to output transfer function exist right half plane zeros, cause ripple and control delay so the effect is not ideal [6]. Traditional straight on load intensity in response to weak conditions, the battery latch up protection. In this paper, the PV converter and load modeling and analysis of the direct pressure control characteristics, analysis of the traditional direct pressure control is used in the model, and then the direct pressure control is improved, the direct pressure power V2 control, its significance lies in through the detection of direct pressure and adjust the system output power to control the output pressure, to compensate for the boost pressure control circuit of the right half plane zeros caused by direct pressure shock, finally in the Simulink to establish the independent system and grid connected system, the improved direct pressure control effect in the simulation is validated.

2. Improvement of the MPPT of Photovoltaic Cells

2.1. Analysis of Direct Pressure Control Mechanism

Photovoltaic system is composed of photovoltaic power and the associated converter, in order to facilitate the analysis, in the bus voltage 500V direct network microgrid, the related converter is designed as boost boost circuit. Solar power and boost circuit constitute equivalent model of photovoltaic power generation system. The output end of a load connected P-U relationship equivalent impedance R . Due to the photovoltaic power inherent in the relationship of voltage and current, direct pressure controller is as the single voltage loop control, the overall structure as shown in Figure 1.

Figure 1. Direct Voltage Control Model of Photovoltaic System

In Figure 1, the U_i and U_o respectively represent photovoltaic power input voltage and PV power generation system output voltage, I_i and I_o respectively represent photovoltaic power input current and photovoltaic power generation system output current, L represents a boost voltage booster circuit inductance, C represents the output end of the

voltage stabilizing capacitance, proportion integral parameters are $K1 + K2/S$.

Analysis of the conditions for the establishment of photovoltaic direct pressure control. Since the boost circuit input and output power is consistent, therefore, the direct pressure control is established, the condition is that the photovoltaic system needs the output power of the photovoltaic power supply P-U curve has at least one solution. The maximum output power of a photovoltaic power is P_m , when the load power is greater than P_m P_L , photovoltaic power supply can not meet the demand of power, so the direct pressure control can not be achieved, need to send the energy storage battery auxiliary current to maintain the voltage; when the load power is P_L equal to P_m , just meet the demand of photovoltaic power supply power, so the direct pressure control point the only and is equal to the maximum power point; when the load power is P_L less than P_m , photovoltaic power in two control points to meet the needs of power, 1 control points in a current source region, 2 control points in voltage source area, then the maximum power point of PV power by reducing the load power point to the desired, so in the photovoltaic DC voltage control, microgrid power balance problems have been fundamentally improved. Due to the stability of PV cell in the voltage source working area is better than the current source, this paper discusses the direct voltage control of the system, the photovoltaic cells are set to work in the voltage source working area [8].

2.2. The Principle of Photovoltaic MPPT

The photovoltaic array is in nature a power generation unit controlled by natural conditions, which means that the quantity of the electricity power it generates is limited by the natural conditions. Thus to control its generation output requires us to control the output voltage and output current to guarantee the maximum output. The power curve of the simulation model of photovoltaic output built by the simulation software PSCAD is as shown in Figure 2.

The (a) and (b) curve in Figure 2 are the P-V and I-V curve of the photovoltaic array within same temperature range but different illuminations (500w/m^2 , 800w/m^2 , 1000w/m^2)

The PV system diagram (including BOOST Circuit Diagram) is as shown in Figure 3. In Figure 3, U_s refers to Photovoltaic Power, R_s refers Equivalent Resistance and the part in the dashed box marked 2 represents the BOOST Circuit Load Structure which is an equivalence to the R_0 in Figure 4.

Figure 2. The P-V and I-V Curves In Different Illuminations

Figure 3. PV System Diagram

Figure 4. PV System Diagram

As we all know, the output power of the photovoltaic system can reach the maximum point in case of impedance matching. Therefore, the process of tracking the MPP of the photovoltaic array is, in effect, the process of constantly changing the Duty Cycle D to match R_o and R_i . The photovoltaic array connects the BOOST circuit structure to output power and analyze small signal model, we can get the conclusion that the variation (ΔP) of the Output Power of the photovoltaic array (P_{pv}), and the duty cycle variation (ΔD) of the BOOST circuit satisfy the following approximate relationship:

$$\Delta P = -\frac{\Delta U_{pv}^2}{R_{MPP}} \approx -\frac{\mu^2 \Delta D^2}{R_{MPP}} f(T_a) \quad (2)$$

$f(T_a)$ is the function of the sampling time T_a , and μ is the opposite number of the output power (U_o) of the Boost circuit.

Analyzing from the above, we can conclude that we can dynamically change R_o through dynamically changing ΔD to achieve impedance matching, and thus to achieve the maximum dynamic output power. Compared with the traditional method, this method saves the process of voltage/current control loop, thus

greatly simplifying the control process. MPPT is in essence the dynamic process of real-time comparison, real-time computing and real-time output.

2.3. Improving Method of the MPPT of the Variable Duty Cycle

Among the existing methods, there exist a contradiction between the rapidity and the vibration output loss in the MPPT of PV. A greater duty cycle with better rapidity means inability to work at a stable power point, while a smaller duty cycle means lower rapidity, poor dynamic effect and unsatisfactory function in acute illumination change which is very common in field application.

Therefore, this paper proposes a MPPT control method based on subregional variable duty cycle. On basis of the rapid algorithm of the variable duty cycle, this control method adopts variable ΔD through taking the extension area of the CVT as its regional boundary to achieve MPPT. The subregional schematic diagram is as shown in Figure 5.

Figure 5. PV Output Characteristic Curve

Set a targeted region: U_1-U_2 , and the point in this region is marked as U_0 . U_0 in this region represents the corresponding voltage of the maximum power point P_m set in the CVT method. On basis of our field measuring data, we set the length of U_1-U_0 and U_2-U_0 as $20\% U_k$, U_k representing the Open-circuit Voltage. ΔD in $0-U_1$, U_2-U_k is the great duty cycle and in U_1-U_2 is small duty cycle.

The influence of the value of ΔD on the MPPT will be firstly analyzed through simulation, selecting proper value for ΔD and T_a . Figure 6 shows the two duty cycle curves ($D=0.05$ and $D=0.005$) for simulated analysis under the PSCAD. From this diagram we can see that when $D=0.05$, the optimizing speed is high, but the vibration is comparatively great; when $D=0.005$, the optimizing effect is just the other way around. This paper proposes to respectively carry out MPPT under the circumstance of the two variable ΔD values.

Figure 6. Different Duty Cycles Comparison Chart

Similar to set of the duty cycle D , the problem of rapidity and precision also exists in the set of the time constant T_a . So synthetically consider, we set the time constant $T_a=0.001$.

When the illumination suddenly changes, the MPPT should have sound dynamic properties. Measure the illumination of a region and get the different MPPT curve of different illumination conditions, and then save them in the memory of the system. We can judge the working curve of the photovoltaic array in circumstance of sudden illumination change. When the illumination condition suddenly changes, set a power change value P_{th} and adjust the corresponding voltage value of the existing P_m to do MPPT of the small duty cycle ΔD near this value to reduce power vibration.

The control flow chart of the subreional variable duty cycle is as shown in Figure 7.

Figure 7. Control Flow Chart

3. Experiment

Power judgment and region judgment process, which have shortened the tracking time and can optimizing more quickly in circumstance of sudden illumination change condition. The method proposed in this paper is conducted in DSP-based experiment platform. The model of the control chip is 32-digit DSP28035 and LCD 12864 display module should be adopted to display the parameters of the photovoltaic cell such as voltage, current and power *etc.* in real time.

The experimental system chart is as shown in Figure 8.

Figure 8. Experimental System

Assuming that the following experimental conditions have been satisfied: the illumination condition of the photovoltaic array is good, the MPPT of the photovoltaic array is valid, the illumination condition is 1000W/m^2 the climate temperature is 25°C , then the photovoltaic output curve can satisfy the P-V curve. Set the view time 3s and adopt the P & O method we can see that the tracking speed is high. Respectively conduct two experiments in which the first one adopts the MPPT control method based traditional fixed duty cycle while the second one adopts the MPPT control method based on subregional variable duty cycle proposed in this paper to verify the dynamic properties of the proposed methods and observe the curve change of the output power under the circumstance that the outdoor illumination suddenly changes to 800W/m^2 in the time point t_2 . The output power curves of the experiments are as shown in Figure 9.

Table 1. Experimental Circuit Parameters

Name of Parameter	Value
PV	100W
C1	100 μF
C2	500Mf
L	2mH
I_{mpp}	2.5A
V_{mpp}	24V
Open-circuit Voltage	30V
Short-circuit Current	4A

Figure 9. PSCAD Simulation Figure

4. Conclusion

From the above analysis we can conclude that compared with the traditional tracking method, the MPPT control method based on subregional variable duty cycle has the advantage of rapid optimization and small vibration. The photovoltaic array can rapidly determine its optimizing point even in circumstances that the external abrupt illumination change has gone beyond the set value. Conducting MPPT near this point overcomes the problems of output misjudgment and great vibration near the maximum power point. Simple and precise and without extra investment for hardware, the method proposed in this paper is of great guiding significance to the promotion and application of photovoltaic popularization.

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