A Three-stage Charging Method for Battery in Photovoltaic Power System

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Abstract. The battery is important storage device in the photovoltaic power system. To reduce the investment cost and to prolong the service life of battery, a three-stage charging methord for battery in photovoltaic power system is presented in this paper. The simulation model of the battery charging system has been set up by the Matlab/Simulink tool. Its battery model is based on the Thevenin's equivalent circuit. The buck circuit is controlled by switching three PID loops. The following works have been done in the study: the principle of three-stage charging for battery, the implementation of three-stage charging method, the simulation. Simulation results show that the proposed battery charge control method can be successfully applied to the battery charging of the photovoltaic power system. It can improve the stability and effectiveness of the battery charging system.

Introduction

With the increasingly serious environment problems, the utilization and management of the clean energy, such as solar energy, is becoming especially important. The battery has been widely used as an energy storage device in the photovoltaic power system. It is characterized by the low cost and repeated use [1, 2]. However, the output power of the photovoltaic power system is influenced by some factors, such as the natural resources, the lighting and environment temperature [3]. These factors result in the battery charged frequently.

The traditional charging methods include constant current charging, constant voltage charging and the piecewise charging [4], etc. The traditional battery charging circuit is simple. Its implement is easy. At present, the two-stage charging mode has been applied widely. The two stages are constant current charging and constant voltage charging. The quick charge can be ensured by the two-stage charging mode, but the outgoing gas is still increased at the end of the charging. It influences the service life of battery. Therefore, a three-stage charging methord for battery in the photovoltaic power system is presented in this paper. The following works have been done in the study: the principle of three-stage charging for battery, the implementation of three-stage charging method, the simulation.

Principle of three-stage charging for battery

In Fig.1, the charging curve can be divided into three sections.

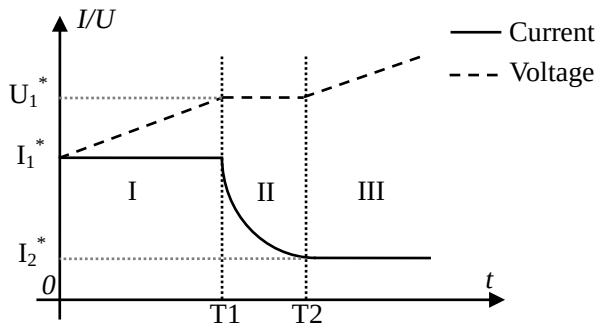

Fig.1. Three-stage charging curves

Section I (constant current stage): the capacity of battery is low at the beginning of the charging, the battery voltage of the gradually rises by using the constant current I1*.

Section II (constant voltage stage): the battery is charged under the constant voltage U1* (switching voltage), and at the same time, the charging current of battery decreases gradually.

Section III (small constant current stage): at the end of charging stage, battery is charged by the small constant current I2*.

Implementation of three-stage charging method

According to the method of three-stage charging for battery, the implementation can be divided into three steps as follow:

Step 1: when the voltage of the battery is less than U1*, the state of battery is in the section I. At the beginning of charging, the constant current changing with PID controller is adopted.

Step 2: when the voltage of the battery reaches U1*, the state of the battery goes into the section II. The switching voltage is the constant voltage U1*. The second PID controller is used to stabilize the volatge of battery at U1*. At the same time, the current of the battery gradually decreases from I1* to I2*.

Step 3: when the current decreases to the values of I2*, the state of the battery goes into the section III. The third PID controller is used to adjust the current of battery at I2*.

Simulation modeling of the battery charging

Battery modeling based on the Thevenin's equivalent circuit is shown in Fig.2.

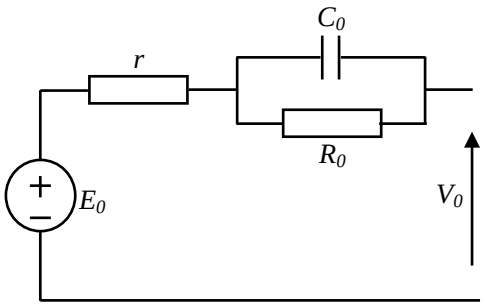

Fig.2. Battery modeling based on the Thevenin's equivalent circuit

This modeling consists in ideal power source E_0, internal resistance r, voltage resistance R_0 and capacitor C_0. R_0 is the nonlinear contact resistance between pole plate and electrolyte of battery, the voltage U_{c0} between two end of the capacitor C_0 is status variable, according to the Kirchhoff Voltage Law (KVL), the battery modeling can be described by a differential equation which is given by Eq.1.

$$r \cdot C_0 \frac{du_{c0}}{dt} + (1 + \frac{r}{R_0}) u_{c0} = V_0 - E_0 \quad (1)$$

In Fig.2, all the parameters of battery can be set as constant for simulation [5]. Based on the battery modeling, the simulation circuit can be set up. And the battery charging simulation circuit is shown in Fig.3.

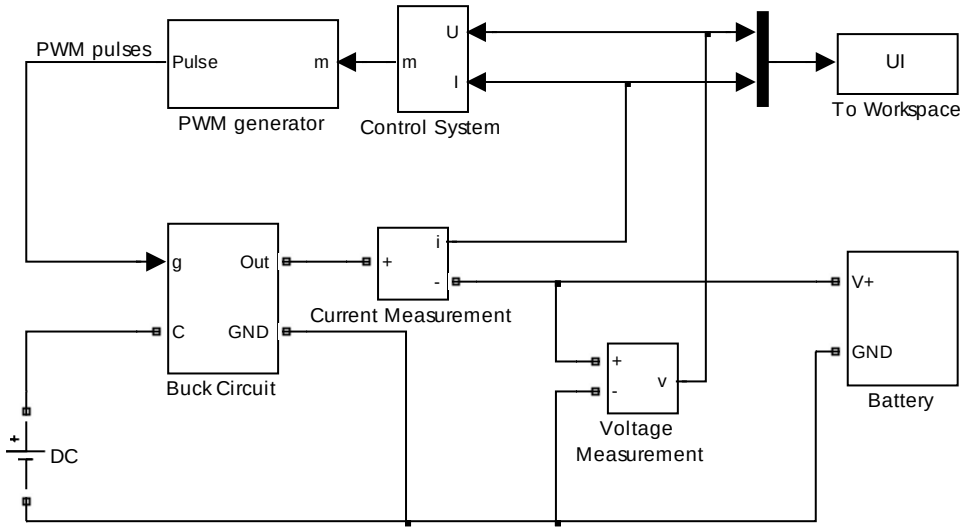

Fig.3. Battery charging simulation circuit

In Fig.3, the Buck Circuit is used as charging circuit. The Controll System contains three PID controllers. It adjusts the constant voltage charging value and the constant current charging value. The main simulation parameters are shown in table 1.

Table 1 Main simulation parameters

Parameters	Value	Unit
DC side voltage	37	V
PWM carrier frequency	1000	Hz
Ideal power source of battery E_0	20	V
Internal resistance of battery r	0.05	Ω
voltage resistance of battery R_0	2.6	Ω
Initial charging current	3	A
Switching voltage U1*	24	V

Simulation results

The curves of charging voltage and current in this simulation are shown in Fig.4 and Fig.5 respectively.

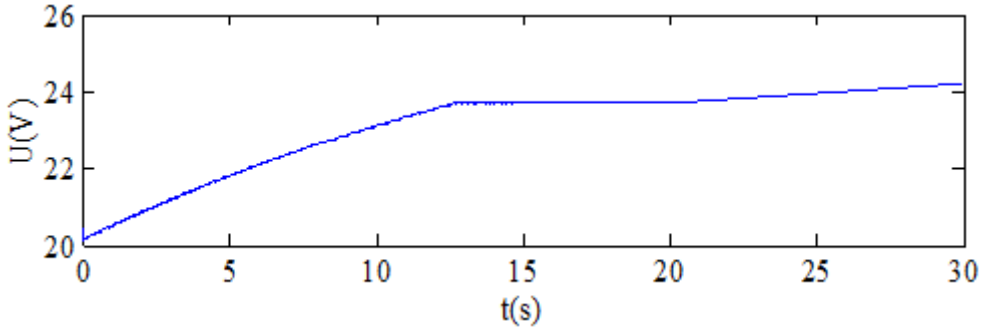

Fig.4. The curve of charging voltage

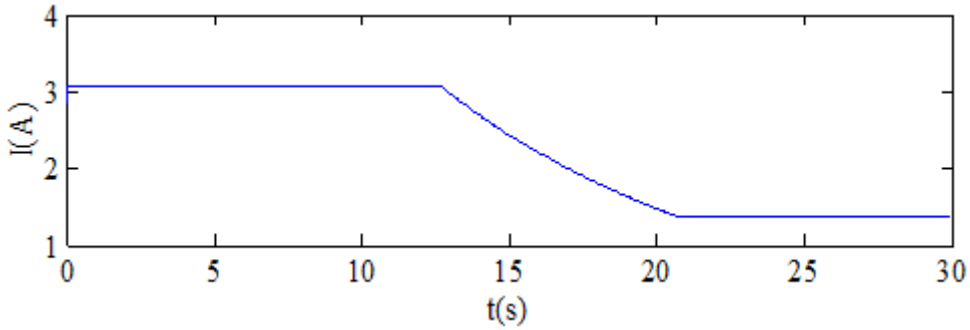

Fig.5. The curve of charging current

The simulation results show that battery can be charged smoothly and effectively using the proposed method.

Conclusions

A three-stage charging methord for battery in photovoltaic power system is presented in this paper. According to the battery model based on the Thevenin's equivalent circuit and the buck circuit controlled by switching three PID loops, the simulation model of the battery charging system has been set up.

The simulation results indicate that the proposed charging method can realize the fast, smooth and effective charging, it can be successfully applied to the battery charging of photovoltaic power system and prolong the service life of battery and reduce the investment cost.

Acknowledgement

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