2016 International Siberian Conference on Control and Communications (SIBCON)

The Algorithm for Battery Charge Control of Renewable Energy Sources - Wind Turbine and Solar Panel

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***Abstract*—In this paper the algorithm for battery charge control of renewable energy sources - wind turbine and solar panel. Every operating block is also described with specifying the dependencies.The principle of the charging current limitation that prevents battery failure as a result of a strong internal resistance increase while preliminary deep discharge is considered.**

Keywords–algorithm, battery charge, charging current limitation, threshold voltage, renewable energy sources

I. INTRODUCTION

The modern solar power plants to transmit electricity generated by operating battery (rechargeable battery) are used to connect different circuits of current sources.Devices that control current source and, therefore, the battery charge are so-called charge controllers. How do the charge controllers operate?

The energy generated by the solar battery can be transmitted to accumulative battery:

- directly, without the use of switchgear and adjusting(controlling) devices;
- through the charge controller (see Fig. 1).

Fig. 1. Battery charge controller.

In the first method, an electrical source current flows to the batteries and will increase the voltage at their terminals. First, it comes to certain, limiting value, depending on the design (type) battery and ambient temperature. Then, overcome the recommended level.

Circuit is functioning normally during the initial charging. But then an extremely undesirable processes begin: Continued charging current increases voltage values to over permissible (approx. 14V), recharging with a sharp increase in the electrolyte temperature arises and leads to its boiling with intensive release of distilled water vapor from the elements. Sometimes up to complete drying of the containers. Naturally, the battery life is significantly reduced.

This problem is solved by controlling the charging current with the use of controller or manually. The method of constant controlling of the voltage value and commuting switches exists only in theory.

Solar battery charge controller is the main part of an autonomous system, as batteries are afraid of a deep discharge and overcharge. In the case of overcharge, battery life decreases dramatically. If the battery is charged, but the charging current continues to leak through the battery, that leads to electrolyte boiling or swelling. Therefore, the controllers must be included in an autonomous system, which cut off the load from the battery if they inadmissible discharged, and disconnect the power source (solar panel) if the batteries are fully charged.

There is no use to save the controllers because of their cost, relative to the entire system is about 5-10%, and the quality importance of this product is the basis for the correct entire system operation.

At the moment, there are several most common operation algorithms of charge controller battery from renewable energy

978-1-4673-8383-7/16/$31.00 ©2016 IEEE

sources (solar panel, wind turbine), which in total can be divided into three types:

1. Disconnection/ connection. This algorithm is the easiest and also the most reliable one. The principle disadvantage is that by increasing the voltage across the battery terminals to a certain maximum level of full charge capacity occurs. The system is configured so that in mentioned case the battery charge comes to approximately 90 percent of the nominal level. As a result is a permanent energy shortage in turn significantly reduces the operating life.

2. Pulse-width modulation (PWM) control. Certain power block control algorithm, often built on a modern thyristor or IGBT modules, regulates the voltage at the output of the charge controller within a predetermined range by feedback signals.

In addition, this algorithm allows ensure the temperature compensated battery charge, as well as the ability to configure the system for a certain type of battery with different indices of a voltage graph at the same points. However, increasing the PWM controller functions leads to significant cost in comparison with the first type, which severely limits their scope.

3. Maximum power point scanning. Controllers operate according to the method of pulse-width converters and are very accurate. They consider the greatest power level of solar battery. Tracking it, they are able to charge the battery to its maximum level at 10-15% increased capacity solar battery output. Except high cost there is one another principal drawback. To align the different levels of the solar panel and the battery voltages it is necessary to use transformer-semiconductor down converter DC-DC, which greatly increase the weight and size dimensions of the device, and if solar intensity (cloudy, twilight) is low then all its advantages compared with the second type are reduced to nothing.

II. BATTERY CHARGING ALGORITHM

Mentioned above various types of charge controllers operating algorithms are basically used in for medium-power units from tens of watts to tens of kilowatts. In the range of low capacity (up watt units) the most common type is the first as the simplest and cheapest one. The algorithm is justified while the system is usedwithout rigid reliability requirements, but there are special reliability requirements in industry, that means a necessity of a new type algorithm to ensure high level of operation reliability with sufficient performance characteristics.

The study developed the algorithm (Figure 2) of controller charge battery operation, built on the basis of the first - the simplest and cheapest - like, however, in addition to the voltage at the battery of constant charging current is controlled when under certain conditions the charging current becomes zero, it will mean that the charge is completed

This algorithm is quite versatile, that allows its use with different types of batteries: lithium-ion, lead-acid and others.

The first step of algorithm is to measure ongoing battery voltage Ubat and charging current Ich (block 1). Next step is to compare measured voltage to the maximum permissible voltage for this battery type Ubatmax (block 2). The voltage level depends on the type of battery used and installed in strict compliance with the manufacturer's recommendations (table 1).

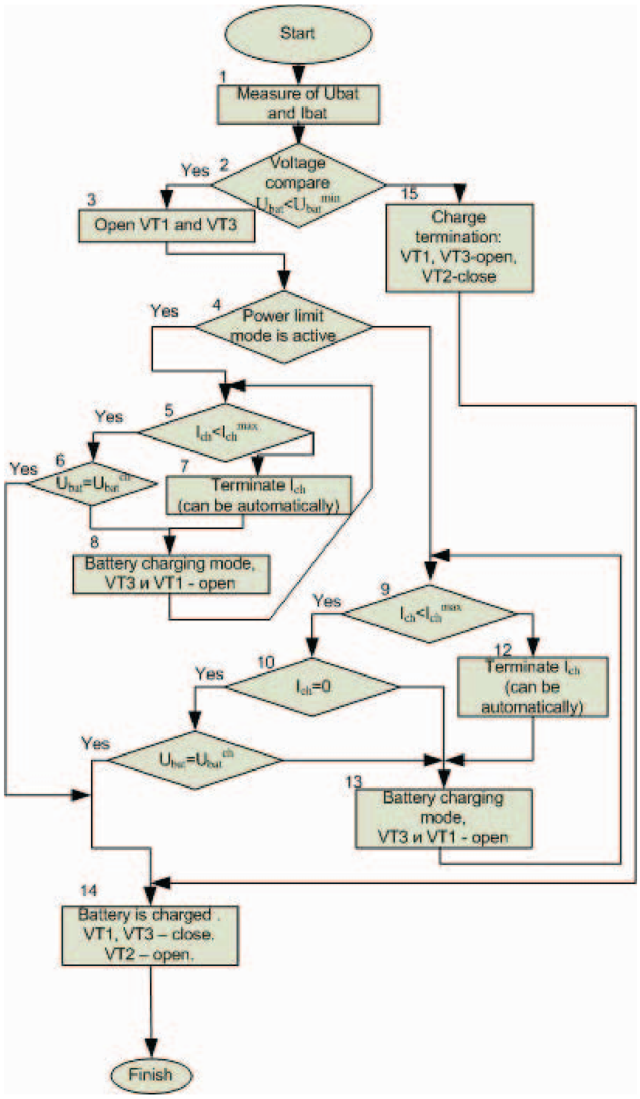

Fig. 2. Battery charge algorithm

If measured voltage is less than a predetermined threshold level, the outputs driven keys connect wind turbine and the solar panel to the battery, and the charging process begins (block 3, Figure 2). If the current power available from the power sources (wind turbine and solar panel) is below a sufficient level, and thus demand limit mode acts, then the algorithm proceeds to block 5 (Figure 2); if the available power is sufficient, then the process proceeds to block 9 (Figure 2).

The main difference between the block 5 and 9 processes (Figure 2) is that in the second charge end condition is not only to achieve a certain level of voltage, but to approach a zero value of the charging current.

Blocks 5 and 9 (Figure 2) compares the measured current value of the battery charging current Ich to the permissible maximum for this type of battery - Ichmax.

When power consumption limit modeand the ongoing charging current is less than permissible maximum, then charge stops as the battery voltage reaches level limit (unit 6, Figure 2). The battery considered to be completely charged.

If the ongoing charging current is greater than or equal to the permissible maximum or the voltage has not reached the ceiling Ubatch, then battery charging continues (block 8) with a mandatory limitation of the charging current (block 9) as long as the condition is not fulfilled the block 6.

TABLE I. THE VALUES OF THE THRESHOLD VOLTAGES FOR DIFFERENT BATTERY TYPES.

Battery type	U_{bat}^{max}, B	U_{bat}^{min}, B	U_{bat}^{nom}, B
NiCd	1.9	0.9	1.25
NiMH	1.9	0.9	1.25
Acid	2.4	1.65	2
Li-ion	4.25	2.8	3.6
Li-Ion polymer	4.25	2.8	3.6

In case the power consumption limit mode is inactive, then charge stops (the battery considered to be completely charged) only when all the following conditions are met:

- $I_{ch}<I_{ch}^{max}$ (block 9, Figure.2);
- I_{ch}tends to zero (block 10, Figure.2);
- $U_{bat}=U_{bat}^{ch}$ (block 11, Figure.2).

If at least one of the conditions is not satisfied, the battery charge continues (block 13, Figure 2) with a mandatory limitation of the charging current (block 12, Figure 2)

III. LIMITATIONOFCHARGINGCURRENT

Current limitation is most relevant when the battery charge occurs after a full charge. As in this case the battery has a lower resistance increasing at a constant current charging voltage:

$$I_{ch} = (I_{wg} + I_{sp}) = \frac{U_{ch}}{(R_c + r_{in})} \le I_{ch}^{max}$$
$$P_{ch} = P_{wg} + P_{sp} \qquad , \qquad (1)$$
$$I_{ch} = \frac{P_{ch}}{U_{ch}} = \frac{(P_{wg} + P_{sp})}{U_{ch}} \le I_{ch}^{max}$$

where I_{ch} - charge current, U_{ch} - chargevoltage,

$R_c + r_{in}$ - sum of the total resistance of the charging circuit and thebattery internal resistance.

Too high charge current can cause overheating of the charger and the battery cells, that leads to significantly acceleration their degradation and reduction the service life.

There are many different circuit solutions to limit the charging current, but always they are constructed with a feedback link that allows depending on the current value of the current change during the open state of the control transistor, thereby changing the charging current. The above principle is implemented below (Figure 3).

The operating principle of such a scheme is as follows. Input voltage from the battery charge controller U_{ch} via the resistor R1 is supplied to the base of the transistor VT1 and opens it, the transistor becomes saturated, and the bulk of the input voltage proceeds to charge the battery.

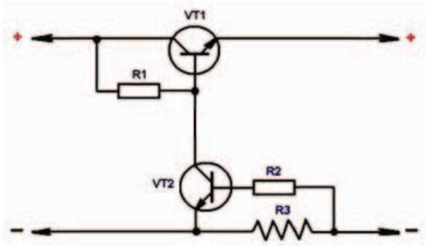

Fig. 3. Scheme of charging current limitation.

If the current is lower than threshold, then transistor VT2 is closed. Resistor R3 is a current sensor. As voltage drop across it exceeds the threshold of transistor VT2 opening, it will be opened, and the transistor VT1, on the contrary, partially will be closed, and the charging current will be limited.

To limit the charging current I_{ch}^{max} by upper maximum value, which level depends on a type and parameters of chosen battery. The current will subside as the battery charge and restore dielectric resistance. Thus, the condition is:

$$I_{ch} = (I_{wg} + I_{sp}) = \frac{U_{ch}}{(R_c + r_{in})} \le I_{ch}^{max} , \qquad (2)$$

or in the other form:

$$I_{ch} = \frac{P_{ch}}{U_{ch}} = \frac{(P_{wg} + P_{sp})}{U_{ch}} \le I_{ch}^{max} , \qquad (3)$$

IV. CONSUMPTION

Thus, the proposed algorithm of battery charge control of renewable energy sources (wind turbine and solar panel) is prevented such undesirable and dangerous consequences of poorly controlled or uncontrolled charge as deep discharge or overcharge the battery. And in some types of batteries (lithium-based and ions) it is a prerequisite for their use. A charging and discharging current limitation prevents premature battery failure associated with overheating, boiling, etc.

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