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ANALYSIS OF CATHODIC PROTECTION STATION WITH THE FUNCTION OF SEARCHING FOR THE MAXIMUM POWER POINT OF A PHOTOVOLTAIC MODULE

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Abstract

Solar energy can be effectively used in the construction of power supply systems for cathodic protection installations. A properly designed photovoltaic system will avoid costly expansion of the electrical grid, or the use of hydrocarbon-fueled generators, which have high maintenance costs due to the need for maintenance and refueling. The article discusses the characteristics of photoelectric converters as power sources for cathodic protection stations, and proposes and analyzes options for circuit implementation.

Keywords: *cathode potential, photovoltaic modules, reducing power converter, point maximum power, charge-discharge controller*

Introduction

The formation of defects in the insulating coating of a metal pipeline and exposure of the pipe metal is protected against corrosion by an electrochemical protection system (ECP). This type of protection is called active. The essence of ECP protection is the artificial polarization of the pipeline (cathode) in such a way that its potential shifts to the negative side. As a result of a shift in the cathode potential to the negative side, the work of the corrosion couple stops. But it is necessary to take into account that this can only happen with a potential within certain limits and an appropriate strength of the protective current. Protective polarization of the cathode can be achieved by applying a protective potential from a direct current source or by using materials whose intrinsic potential is more negative than the cathode material as an additional anode.

Research method

The implementation of cathodic protection in areas remote from centralized power supply networks causes great difficulties due to the fact that its implementation requires the construction of power lines along the pipeline route.

During development conversion equipment based on power electronics, designing distributed generation facilities, creating and operation of power plants, operating on the basis of solar energy, it is necessary to take into account the existing general requirements for objects generation and international standards and rules taking into account the specifics functioning of distributed energy sources in power systems.

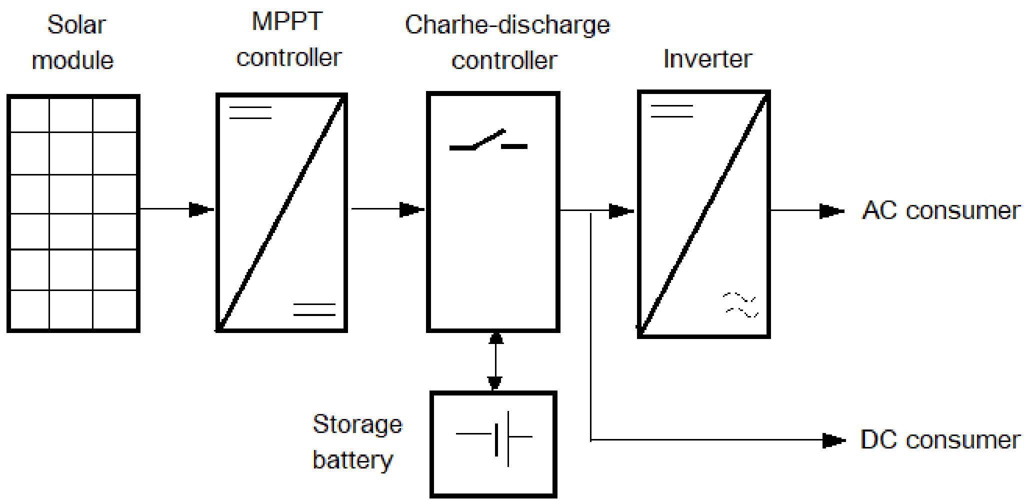
Depending on the type and scale of the distributed generation (DG) project, their conversion parts are divided into:

– autonomous (off-grid) installations with a power of up to hundreds of kilowatts, supplying single- or three-phase loads at remote sites in the absence of external power grids, including photovoltaic modules and a storage battery;

– grid-tie installations from units of kilowatts and power plants to hundreds of megawatts, and providing synchronous power delivery to distribution power grid, control of mode parameters, integration of renewable energy generating facilities and their monitoring, protection and management systems into the energy system;

– hybrid installations that combine the capabilities of the first two types and ensure parallel operation of several different types of sources of comparable power (SPP, WPP, micro-HPP, diesel generators and energy storage systems (ESS). Block diagram of an autonomous solar power plant is shown in Fig. 1.

Figure 1. *Block diagram of an autonomous solar power plant*



At remote sites or in isolated energy areas, the greatest interest is in autonomous hybrid installations (microgrid), including photovoltaic modules, wind turbines and backup diesel generators, which together provide reliable round-the-clock power supply to consumers, minimal fuel consumption (savings up to 90% compared to conventional diesel generator sets) and efficient use of battery life (charge/discharge cycles) and diesel generator sets.

Autonomous solar power plants (SPP) include:

– energy source — a group of low-power solar panels;

– MPPT controller (DC-DC converter), which controls the operating mode of the source to select its power at the maximum point (Maximum Power Point Tracking), providing a normalized output voltage;

– matching charger for storage batteries with voltage DC12/24/48 V (domestic and small commercial installations) or 96 V and higher (industrial installations);

– a group of series-parallel connected storage batteries of the required voltage and capacity;

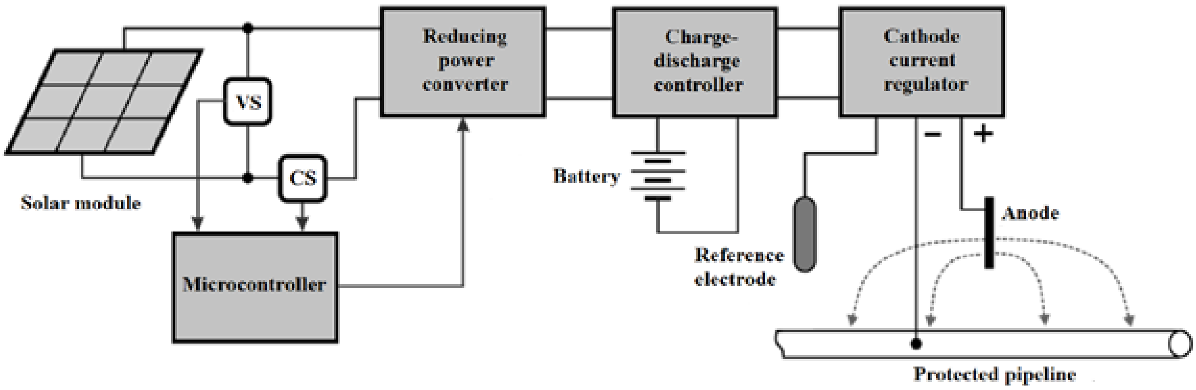
– an autonomous inverter that converts the battery voltage together with the isolation transformer to a standard level to power the AC load.

Results analysis

As part of photovoltaic power plants, they are assembled into serial chains or, if necessary, in parallel, several strings with a maximum voltage of DC24–250 V (domestic installations) or 600/1000/1500 V (industrial), which are connected to the input of the MPPT controller. The number of PV modules in the chain is limited by the open circuit voltage (Voc) under conditions of a combination of maximum instantaneous insolation and minimum temperatures in the area where the solar power plant is located, taking into account the negative temperature coefficients characteristic of PV modules (on average –0.45%/°C in power and –0.35%/°C at open circuit voltage.

In order to increase the efficiency of the cathodic protection (CP) station, in a photovoltaic power supply system it is necessary to monitor the maximum power point of the photovoltaic module. The principle of construction and operation of the cathodic protection (CP) station, which ensures the selection of maximum power, is illustrated by the diagram in Fig. 2.

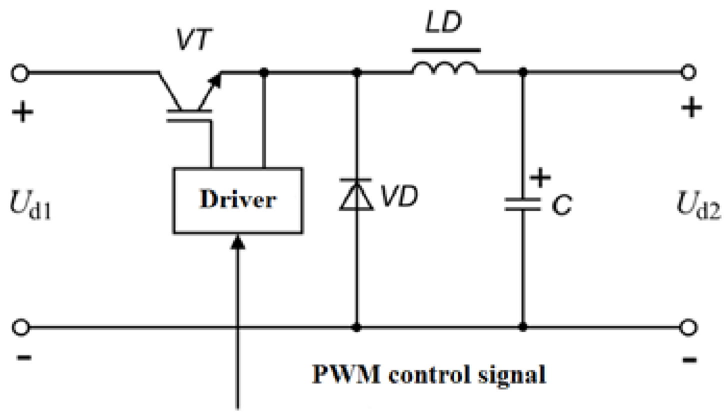
Figure 2. *Installation diagram of cathodic protection with the function of tracking the maximum power point of solar panels*



The power section of the circuit, in addition to the PV module, includes a reducing power converter, a cathode current regulator, and a battery with a charge-discharge controller.

The reducing power converter is made according to the circuit shown in Fig. 3. The VT power switch is controlled through the driver by a signal that comes from a microcontroller with a search function for the maximum power point.

Figure 3. *Reducing power converter circuit voltage*



The clock frequency f_0 of the pulse converter depends on the dynamic properties of the power switches on which the converter is made.

Voltage U_{d1} is supplied from the output PV module. Adjustment of output voltage U_{d2} and change in equivalent resistance load for the solar panel occurs due to the Pulse Width Modulation (PWM).

Average voltage U_{d2} at output of the pulse converter depends on the input voltage U_{d1} and parameter D, which is equal to pulse duration ratio voltage at the pulse output converter to cycle duration T_0, i.e.

$$D = \frac{\tau}{T_0} = \tau \cdot f_0 \qquad (1)$$

Thus, the adjustment pulse characteristic DC/DC converter can be represented in the following form:

$$U_{d2} = \psi(D) \cdot U_{d1} \qquad (2)$$

For a converter made according to diagram in Fig. 3, adjustment characteristic has the form:

$$U_{d2} = D \cdot U_{d1} \qquad (3)$$

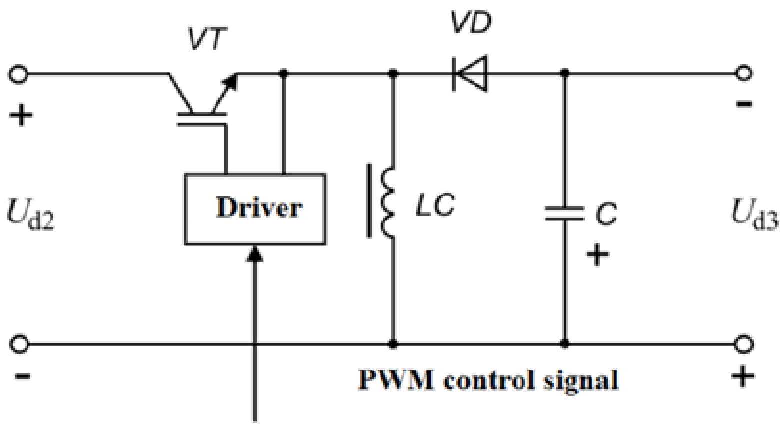
Information from voltage sensors VS and the CS current of the solar panel is supplied to microcontroller that implements PWM signal D controlling reducing power converter At every stroke of work power $P_k = U_k \cdot I_k$ is calculated, selected from the PV module. Then it is produced comparison of the obtained P_k value with the value of P_{k-1} at the previous cycle. In addition, the signal is compared control D_k at a given control cycle with signal D_{k-1} at the previous step. Depending on the signs received differences are adjusted control signal to high or the smaller side with a given discreteness ΔD_{k-1}. Thus, on every cycle of system operation the maximum point is searched for power taken from the PV module.

Simultaneously with searching for a point maximum power in the system power supply, the condition of the battery is monitored. When the battery is full charged, the controller disconnects it from solar panel, thereby preventing overcharging and premature failure.

Voltage U_{d2} is supplied to the cathode current regulator. The battery is also connected to pulse converter output voltage through the charge-discharge controller.

The cathode current regulator is designed as pulse buck-boost converter according to the diagram presented in Fig. 4. A feature of the circuit is that it allows, through PWM, not only to regulate the output voltage U_{d3}, but also to invert its polarity.

Figure 4. *Cathode current regulator circuit*



The control characteristic (2) for this converter has the form:

$$U_{d3} = \frac{D}{1-D} \cdot U_2 \qquad (4)$$

From expression (4) it follows that when D = 0,5 the output voltage is equal to the input voltage, but has the opposite polarity.

If D < 0.5, then the output voltage is value less than the input voltage. And, conversely, when D > 0.5, the output voltage greater than the input voltage converter Thus, by changing parameter D of the cathode current regulator, can provide the specified value potential on the protected pipeline.

Discussions

Each cathodic protection station, depending on the corrosive properties of the soil, the quality of insulation, and the power of the station itself, can protect the pipeline over a section of a certain length. Within this length, the protective potential created by the cathodic protection station ensures the absence of electrochemical corrosion on the cathode (pipeline). At the same time, the anode (grounding) is intensively destroyed due to the activation of the anodic process. The highest value of the potential difference within the length of the section is usually recorded opposite the anode, i.e. grounding.

Conclusion

This article analyzes the composition of the power part of the circuit of a cathodic protection station with power supply from renewable energy sources and, in particular, from solar panels. We have proven that by changing parameter D of the cathode current regulator, can provide the specified value potential on the protected pipeline.

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