Battery Cyclization Automatic System

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***Abstract* - The project is dedicated to the development of the battery cyclization automatic system. The work is consisted of four main paragraphs: the description of the hardware structure; the software description; the principle of operation of the system and the clarification of the algorithm of wor; the requirements to the system in terms of safe running, exploitation and maintenance, concerning fire safety and necessary demands to the system in case of the installation on ships.**

Keywords – battery, cyclization, hardware, software.

I. Introduction

The main purpose of the battery cyclization automatic system is to maintain the readiness of the battery to substitute the main power source and provide the emergency power to a load when problems with the grid occur. Possible faults at the supply network are the voltage absence, the impulse and frequency transients. The mains supply the consumer with the power of 12-14 V. When the mains power fails, the fully charged battery starts supplying the power.

The time of switching between the sources of the power plays a crucial role, as the less is the delay the higher is the probability that the consumer will not be influenced by the main power interruption. Otherwise, the problems arisen can lead to the disconnection from the power grid with the following data loss, incorrect work etc. Ideally, the switching time tends to zero. This principle is implemented in the cyclization system, as at any moment one of the batteries is in a standby mode (aka buffer mode).

II. Hardware

In the system, two lead-acid 12V batteries are used, as one of them works in the buffer mode while another one is connected to either discharging or charging device. The main characteristics of the batteries used in the cyclization system are listed in the table I [1].

As the cyclization system is automatic, the presence of a microcontroller is essential. The microcontroller (MC) generates control signals for the devices mentioned below, synchronizing the work of the whole cyclization system, what ensures the constant readiness of the batteries to provide the consumer with the power. The schematic diagram is shown in the figure 1. The most suitable microcontroller for the system is ATmega16.

TABLE I. Main characteristics of GP-1272 battery

Index	Value
Operating voltage	12 V
Capacity	7.2 A*h
Maximum discharge current	130 A (5 sec)
Maximum charge current	2.16 A
Float voltage	13.6 V
Discharge temperature range	-20°C – 50°C
Charge temperature range	0°C – 40°C
Storage temperature range	-20°C – 40°C

The charging and discharging devices provide the cyclization process with the recurrent discharge of the batteries with the withdrawal of 80-100% of the capacity [2]. Such process ensures the correct functioning of the batteries, what allows to increase their resource and service time. The discharging device itself can be implemented by various techniques. However, in the cyclization system the most simple and cheapest one is used. Thus, the device comprises a 3-meter section of a nichrome (NiCr) cable. As the resistance of NiCr is quite high, the battery connected to the NiCr cable discharges. The temperature of the heated-up cable doesn`t exceed the stated limits. As a charging device, TOPSwitch family power sources are recommended.

Switching between the working modes of each battery is implemented by using the switching device. In general, the switching device comprises several relays, switching batteries to the alternation between the charging and discharging processes. The switching device is designed in a way that the first relay sets the battery connection either to the buffer or to the next relay, which connects the battery to the discharging or charging device.

The voltage sensor measures the level of the voltage remained in the battery with the following transmitting to the microcontroller. This sensor allows to discharge batteries in the specified ranges and avoid the overcharge. It is necessary to use two sensors as each is connected with only one battery. The structure of the voltage sensor is the following. To measure the battery voltage the analog-to-digit converter (ADC) of the microcontroller is used. The voltage is applied to the ADC input through the resistive voltage divider, as the low voltage input of the microcontroller can measure the voltage only

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within 0-5 V, but the measured values can reach 12 V [3]. For this reason, the voltage divider with the V_{out}/V_{in} voltage ratio of 3 is used.

The current sensor is used for the electric current measurement and transmission of the data to the microcontroller in the form of analog signals. This sensor makes possible to control the battery cyclization process. In the system, two current sensors are used, each connected to one battery. The electric current measurement is implemented by the evaluation of the voltage drop in the shunt (a device which allows electric current to pass around another point in the circuit by creating a low resistance path) [3]. The signal from the current measuring shunt is amplified by the operational amplifier. The gain value can be changed by the adjusting resistor connected to the non-inverting pin of the amplifier. Then, the amplified signal is applied to the input of the ADC, where it is converted to the digital form for the following processing.

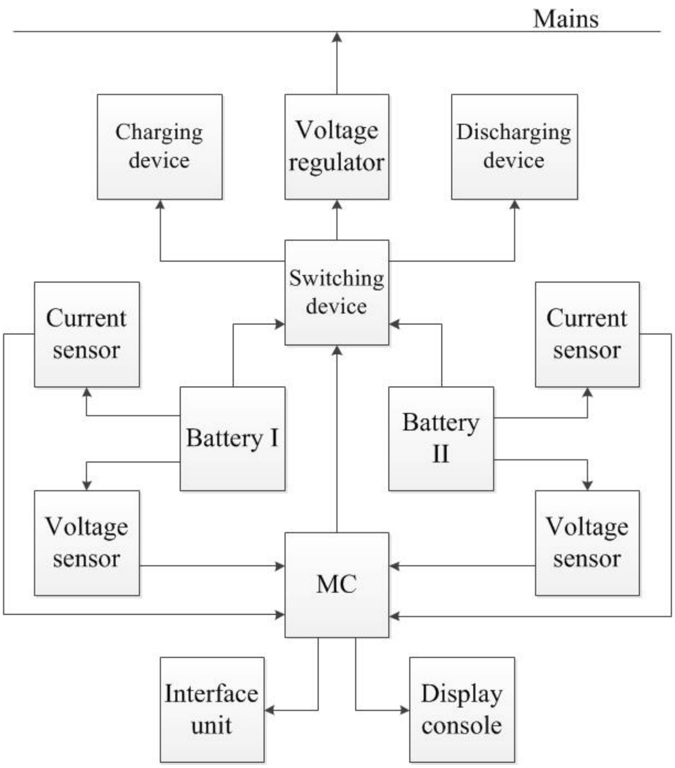

Fig. 1. Schematic diagram.

The display console indicates the main data of the device condition. The indicated information is each battery`s charge level remained as well as the values of the electrical current. In addition to this, a single LED displays the cyclization system status. As a console, a three-digit seven-segment display is recommended.

The interface unit is a device, used for the data exchange between the system and another top-level system, what allows using the battery cyclization automatic system as a part of more complicated devices. The interface unit makes the usage of the system more versatile. The RS-485 is recommended to be used as the interface unit, though it can be easily substituted with another similar devices.

In order to automatically maintain a constant voltage level, the linear voltage regulator is used. Its main objectives are ensuring the power transfer, the voltage waveform and value conversion, as well as the stabilization, protection and others. In the system, the regulator is used for the power leveling before it is applied to the microcontroller. The most suitable linear voltage regulator is LM7805, which is recommended to be used in the system.

III. SOFTWARE

The operating frequency of the microcontroller is set by the crystal oscillator. To convert analog values received from the sensors to the digital ones, the analog-to-digital converter (ADC) is used. The timer-counter is used to count the time elapsed since the moment of charging the battery. In order to connect the system with another top-level system, the Universal Asynchronous Receiver-Transmitter (UART) should be activated [4].

The input port of the ADC can be sensitive to various interferences. To avoid the interference occurrences and incorrect data processing, the low-pass filter is used. Thus, the low-pass filter, connected between the AVCC and VCC outputs, increases the accuracy of the current and voltage values processing without the loss of the ADC sensitivity.

The data displayed on the seven-segment indicator are the voltage and electric current of each battery as well as the remained capacity in percent estimated. The listed values are displayed with the minus sign during the discharging process and without it during the charging one. Since the only one indicator is used, the displayed data is changed every 5 seconds. In order to display the values on the seven-segment indicator, the principle of the dynamic indication is used.

IV. PRINCIPLE OF WORK

The algorithm based on the endless cycle represents one of the main requirements to the system – it should keep the operability throughout the service life. The end of the work is possible only in case of the complete discharge of two batteries. The block diagram of the algorithm is shown in the figure 2.

For clarity, the variable ‘n’ with the value range from 0 to 4 matches the different sources of the data. Thus, when the variable equals 1 (n=1) the ADC processes the data from the voltage sensor of the 1st battery; when n=2 the source of data is the voltage sensor of the 2nd battery; n=3 and n=4 corresponds to the modes processing the data from the current sensors of the 1st and 2nd batteries respectively. The variable ‘m’ matches the number of the battery, and can be set to either 1 or 2.

The main algorithm repeatedly calls the function, which implements the measurement of the batteries parameters via the sensors with the following processing in the ADC of the microcontroller and indication on the seven-segment display.

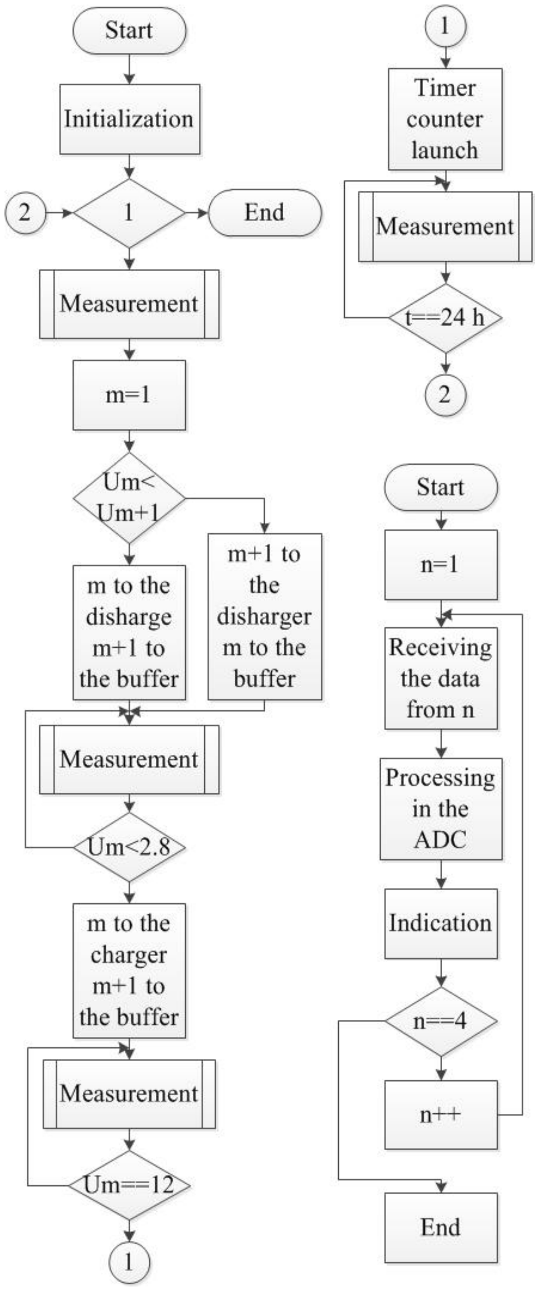

Fig. 2. Block diagram of algorithm

The block comparing the voltage values of the batteries allows to determine the battery with the lowest level of the remained charge with the following connection to the discharging device. Upon reaching the sufficient level of the charge remained, the battery is switched to the charging device. Reaching the maximum level of the battery charge signifies the cease of one charging-recharging cycle. At the same time the timer-counter is launched, which implements the delay, corresponding to the standby mode. After the time delay is over, the working modes of the batteries are changed.

V. Safe Running, Exploitation and Maintenance

In order to make the cyclization system safe to operate, a protection from the s/c and overloading is required. For this reason, thermistors are used.

In case of the installation on ships, the cyclization system should also meet the criteria of the Russian Maritime Register of Shipping (RMRS).

The lead-acid batteries used should have such a design, so that after 28 days in a standby mode at the temperature within (25±5) °C the capacity loss because of the self-discharge do not exceed 30% of the nominal capacity. As in the system two batteries are used, the charging time should not exceed 8 hours. The charger should have an ability to measure the voltage between the battery terminals as well as the charging and recharging currents.

VI. Conclusion

All the devices mentioned above could be substituted with the similar ones. It also concerns the batteries, which could be not exactly the lead-acid ones. However, the use of another types of batteries require extra research in the field of their resource, service time and terms of use, as the demands vary from the battery model and the sphere of the use of the cyclization system. The programme for the microcontroller should be amended as well if the applied changes concerns the algorithm of the work.

The prospect of development is the total synchronization of the system with the top-level systems. It can be implemented by elaborating the extended programme code for the microcontroller, allowing operating with the interface unit.

The battery cyclization automatic system can be considered as an uninterruptible power supply. The system provides emergency power to the consumer if the mains fails. The switching time between the sources is scarce, as one of the batteries is always ready to substitute the main power source, what reduces the risk of emergencies.

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References

[1] N.V. Korovin, A.M. Skundina, Chemical power sources. Moscow, 2003. (in Russian)

[2] A.A. Taganova, A.E. Semenov, Lead-acid batteries: stationary and portable. Saint Petersburg, 2004. (in Russian)

[3] Rudolf F. Graf. Modern dictionary of electronics. Newness, 1999.

[4] Atmel corporation, ATmega16 datasheet. 2010.