THREE-COMPONENT FLUXGATE MAGNETOVARITION STATION


Abstract. The work is devoted to the description of the design of the magnetovariation station, created on the basis of a three-component fluxgate sensor. This station is designed for geomagnetic work in stationary observation points, as well as for field expeditionary work.

Keywords: Magnetic field, magnetic measurements, component measurements, fluxgate magnetometers, magnetovariation station, digital inclinometers.

INTRODUCTION

Fluxgate devices are characterized by small size and compactness, low power consumption, high sensitivity and accuracy. Modern fluxgate sensors (FS) and devices based on them have low own noise, which allows you to work with high reliability in very weak magnetic fields (MF) and in a wide range of temperatures. The use of devices (magnetometers) based on FS in geomagnetic studies, allows you to realize the possibility of direct measurement of the magnetic induction vector (MIV) components, which provides complete information about the structure of the field and its sources, both at stationary measuring points of observations and in motion - during various kinds of expeditionary and search operations.

Currently, both in our country and abroad, there are already many developments of magnetic measuring converters (MMC) based on FS, which have an analog or digital output of the measured information. Along with certain advantages of all known component FS (and MMC based on them) such as compactness and low power consumption, these devices have some disadvantages. These disadvantages include: changing and increasing the measurement error due to changes in the external temperature of the environment (temperature drift), as well as measurement error due to uncontrolled changes in their orientation in space during prolonged operation. These parameters of the FS must be controlled and taken into account, especially when conducting long-term stationary measurements, both in the conditions of a magnetic observatory (MO) and during expeditionary work.

The paper describes the design of a new device - magnetovariation station (MVS), which is created on the basis of a measuring module (MM). And MM made on the basis of a three-component FS [1]. The modern equipment and technologies made it possible in this development to implement not only the control of the FS parameters, the accumulation, processing and correction of the data received from the MVS and their transmission through communication channels over a distance, but also to have the binding and synchronization of the obtained data during field work using the GPS system.

MEASURING MODULE

Fig.1 shows the functional diagram (a), the general view of the structure (b) and photo (c) of the measuring module. The MM is a universal converter of analog geophysical data and includes three different independent converters analog-to-digital: three-channel magnetometric converter (MMC), three-channel converter of inclination angles - digital inclinometer (DI) and temperature sensor (TS). The use of component FSs in MM and other devices that complement them (DI and TS) - allows you to compensate for distortions of the MF that arise due to various factors, which allows you to get rid of part of the additional measurement error, for example, when changing of the sensor angle inclination or the influence of ambient temperature.
As a result of the sensors characteristics analysis for the scheme of the MMC device, FS type FLC3-70 was selected [2]. These sensors implement a 1 nT accuracy in the range from 0 to ±70 μT and a field-voltage conversion factor of 35 μT/V for each of measuring channels (MC). At the same time, the own noise of each FS does not exceed the level of 0,1 ... 0,15 nT. The main criterion for choosing this option of FS was a higher accuracy of measurements and low consumption (6 mA) of energy from a single-polar power supply (PS). Low consumption (low value of compensation current in the measuring windings of the FS) was important for reducing (or eliminating) the effect of the interaction of the measuring channels on each other in the design of a three-component small-sized FS.

Analog voltage (±2 V) from the output of each of the three measuring channels (MC) of MMC (D, H and Z) enters the inputs of the ADC, which is located on the microcontroller board (MCB), where there are also microcontroller (MCC) circuits with a serial data channel interface (RS-232) and a power supply (PSU). From the output of the ADC, data from the MCC is received to the input of the MCC and then through the serial port RS-232 in digital form to the MM output. Through this RS-232 serial port, the MMC operating modes are also controlled from the outside and the incoming data correction is also carried out.

To control the spatial orientation of the FS, a three-component inclinometer is used, which is based on the ADIS16209 chip [3] and contains two devices (two chips) for measuring angles of inclination. The choice of this chip for DI was due to its compactness, high measurement accuracy, unipolar PS and low power consumption, which is very important when installing DI near the sensors. The main advantage of this DI is the presence of built-in TS in it, which allows correction of the measured data of both DI and FS.

Inclinometers X, Y measure deviations in the horizontal plane, and inclinometer R measures the angle of inclination of the FS in the vertical plane. The DIs are rigidly fixed relative to the FS on the inclinometer board (IB) and removed from them at a distance of 55 mm (to exclude the effect on the FS results measurements), as shown in Fig. 1b. With the help of inclinometers (simultaneously and synchronously with the measurement of the components of the MIV), three angles of deviation of the FS measuring axes are controlled, and the accuracy of these measurements is ± 0,1 °.

The outputs of all DI are connected to the MCC (see the diagram in Fig. 1a), to which the output of the digital TS (type LM35D), which has a plastic housing, is also connected. The TS consumes a current of no more than 60 μA and is installed near the FS, which allows you to control the temperature next to the FS with an accuracy of 0,1 °C.

The proposed design of the MM involves two main options for its use, which are shown in Fig. 1b:
- when working in the conditions of the MO or a stationary observation point, the installation of MM on a non-magnetic pedestal equipped with three alignment
legs-screws for leveling the container with MMC in the horizontal plane is implemented; when working in the field, the option of installing a container with MM in a hole dug in the ground, and located below ground level, is provided.

To ensure a favorable temperature regime of the FS, the entire MM scheme is placed in a non-magnetic housing, which is made of duralumin or plastic with dimensions of Ø150x300 mm. Inside the case there is a insulation insert made of foam plastic with a thickness of 20 mm (not shown in Fig. 1b), behind which there is a screen made of foil double-sided fiberglass (1 mm thick), which is also an electrostatic screen for FS. Inside this screen is fixed (soldered) heating element (HE), which is made on the basis of a small-sized ceramic self-regulating posistor heater (PH) type ST6-1B-1 [4]. The PN is powered by a voltage of direct or alternating (exceeding by about an order of magnitude the FS frequency excitation) current from the PSU circuit. At the same time, temperature control is carried out by TS and regulated with the help of MCC. The peculiarity of PN is that when the Curie point (switching point) is reached, its internal resistance increases sharply and it goes into the mode of self-regulation of the current, that is, into the mode of economical operation, while maintaining the specified temperature of heating the surface.

THE FUNCTIONAL SCHEME

The functional diagram of the MVS (built on the basis of MM) is shown in Fig. 2. The MVS circuit includes: MM and measuring unit (MU), which are interconnected by a cable, for data exchange and control signals between the units according to the RS-232 standard at a distance of up to 25 m.

![Fig.2. Functional scheme of MVS and general view of the MM and MU units included in it, as well as an example of recording the received data on the PC display during measurements of the components of IMI and inclinometers.]

The structure of the information security includes the following functional nodes: MCC, control circuit (CC), graphic indicator (GI), battery (AB), power supply (PS), as well as a GPS receiver and Bluetooth (BT) and GPRS data transmission modules with antennas A2, A1 and A3, respectively. The GPS module is equipped with a temporary strobe upon exit. The Bluetooth module has data transmission range options: class 2 module – up to 30 m, class 1 module – up to 100 ... 200 m, and the module of the 1st class with a remote antenna - up to 300 ... 400 m. The design of the GSM module is made using a removable SIM-card.

The MU also includes a real-time clock (with non-volatile power) and buffer non-volatile memory (NVM) - an internal data storage (IDS) with a volume of 8 MB.

Before starting the work, the cycle of measurements of the MVS is installed programmatically using an external personal computer (PC) and special software. The general view of the data received by the MVS in digital form on the PC display is shown in Fig. 2. The software also allows you to obtain data in graphical form, to calculate and visualize the module (Br) according to the measured components of the MIV, as well as to correct the obtained magnetometric data on the basis of DI and built-in TS.

As an external removable digital file data storage (RDS), a drive on the NVM with a volume of up to 4 GB is used, which connects to the MU and allows you to accumulate the measured data in offline mode, without connecting a PC. MVS allows you to accumulate and store data in the process of work in the internal NVM, as well as transfer the accumulated data...
through the existing GPRS and BT channels to a remote receiving point (PC).

The total consumption of the MM circuit (without HE) is not more than 20 mA, and the total consumption of the entire device in the data transmission mode through the communication channel is 250 mA. Power MVS can be carried out as from AB voltage of 7 ... 24 V, and from AC 220V (50 Hz) using a network adapter (NA) with a voltage of 12 V.

CONCLUSION

On the basis of MM, a new magnetometric device was created - fluxgate MVS, which allows for measurements and scientific research, both in the MO conditions and in the conditions of the expedition. At the same time, the use of DI allows you to set in the process of research FS arbitrarily, measure the components of the MIV and calculate its module ($B_t$).

The created MM on the basis of a three-component FS has sufficiently high accuracy characteristics and low power consumption, which allows it to be used as a universal element for many geophysical measuring systems. For example, the scheme and design of the MM was used in the development of marine magnetometers and gradientometers [5-7], as well as a search field device [8-10]. The results of full-scale tests of these devices in the process of conducting scientific expeditions and prospecting operations showed satisfactory results.

LITERATURE


