Ways to improve safety in the power industry: automated hardware system for pre-shift inspection of personnel of power enterprises

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Abstract. This article considers the possibility for application of the automated medical system at power engineering enterprises, ensuring monitoring the physiological state of personnel of enterprises. The considered complex includes separate functional units with new technical characteristics, providing high accuracy of the recorded physiological parameters of the surveyed workers before working shift and, consequently, reliability of health monitoring.

1 Introduction

Works related to the operation and repair of energy objects and equipment may be hazardous to health. Personnel who have access to sensitive and especially dangerous energy objects as well as electrical and high-altitude work, may be subject to various psychophysical influences that affect the overall physiological state of the worker. In the Russian Federation there are sectoral documents regulating measures to ensure the reliability of production activities and preserve the health of workers "Provision on psychophysiological ensuring the reliability of professional activity and preserving the health of personnel of RAO UES of Russia energy enterprises» dated 18.06.2000. [1]. This document defines the legal framework of physiological ensuring the reliability of professional activity and preserving the health of the personnel. The tasks of the psychophysical support are realized according to the results of the conducted examinations, including pre-shift inspection.

Except Provision mentioned above there is Order of the Ministry of Energy of the Russian Federation of August, 31 2011 N 390 "About approval of the Procedure for conducting medical examinations (surveys) of employees directly involved in the work related to the maintenance of energy objects» [2], in accordance with part 3 article 28 of the Federal law of March, 6, 2003 N 35 «About power industry» [3], which defines the procedure for conducting medical examinations (surveys) of employees directly involved in the work related to the maintenance of energy objects. In accordance with this Order at the request of the employer, the pre-shift medical examinations may be conducted to establish the fact of alcohol use, drugs or psychotropic substances and physiological state of personnel, where there are mandatory items as measurement of blood pressure, pulse, body temperature.

A similar Order exists in the Ministry of Health and Social Development of Russia 12.04.2011 № 302n «On approval of the lists of harmful and/or hazardous production factors and work, during which the preliminary and periodic medical examinations are carried out, and of the Procedure for conducting mandatory preliminary and periodic medical examinations (surveys) of employees, involved in hard works and works with harmful and/or hazardous working conditions» [4].

In the Order of the Ministry of Health of Russia dated November, 8, 2012 "On approval of the Procedure for conducting of pre-shift (pre-trip) and post-shift (post-trip) medical inspections [5] in accordance with it. 7 article of the Federal law dated 21.11.2011 № 323 "About the basics of public health in Russian Federation" [6], there is a procedure of pre-shift (pre-trip) medical inspections, in the first item of which is said: «Pre-shift (pre-trip) medical inspections are carried out before working shift (trip) in order to establish signs of exposure of harmful and dangerous production factors, conditions and diseases that impede the performance of employment duties, including alcohol, drug or other intoxication and residual effects of such intoxication».

To fulfill these orders, it is necessary to provide medical and technical support sufficient to carry out a pre-shift examination no earlier than 30 minutes before shift beginning [3,4]. It is necessary to determine quickly and accurately the state of health of a certain number of personnel in a short period of time.

2 Solution of the actual problem and practical implementation

To help doctors who monitor the physical condition of people allowed to work, an automated medical system

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has been developed for pre-shift examinations of workers at power enterprises. This computerized hardware complex (Fig. 1) consists of the following main functional parts: a medical precision thermometer, a two-channel photoplethysmograph, and will be equipped with a three-channel pulse-oximeter.

Fig. 1. Computerized hardware complex.

The main task of the developed automated medical complex for pre-shift inspection (survey) is to identify with high confidence the psychophysical state of the employee, as well as the predictability of his condition for the period of the work shift. Also the medical worker must quickly and accurately make a decision on the admission of the employee to work and additional post-shift inspection of the employee. All data for each survey are recorded in a database of pre-shift surveys stored in electronic form.

As already noted above in the regulatory documents, the mandatory procedures for examination are takings of body temperature, blood pressure, pulse. In the developed automated complex, the measurement of temperature, pressure, pulse can be carried out simultaneously, which reduces the time of an examination.

In medicine, body temperature is an important physiological parameter, closely related to the physiological processes occurring in the body. Therefore, temperature measurement in medical diagnostics is a mandatory procedure.

The temperature range of measurement of the developed medical digital precision thermometer (TMCP) is: $+5 \dots +50^{\circ}\text{C}$, the accuracy is within $0.05 \dots 0.1^{\circ}\text{C}$. For a high-quality visual presentation of temperature measurements, and for relative measurements, as well as for a graphical display of temperature changes, it is important to have high linearity and resolution of the measuring technical system. Temperature resolution should not exceed 0.01°C .

Only the low-inertia system can provide qualitative registration of the temperature change in the body, i.e. one whose inertness is at least an order of magnitude less than the temperature inertness of the measured area of the organism. It follows from this that the temperature sensor should have as small overall dimensions and thermal inertia as possible.

As sensors that allow recording the temperature with an accuracy of 0.1°C and having the smallest dimensions with the highest temperature sensitivity in

the range of $+5 \dots +50^{\circ}\text{C}$, thermistors are most widely used in medicine [7].

The general technical requirements for medical thermometers [8-12] are fully met by the digital precision thermometer described in [13]:

- range of measured temperature $+5 \dots +50^{\circ}\text{C}$;
- the relative error of the device when measuring the temperature of 0.1% ;
- the type of temperature sensor used is a thermistor;
- the absolute error of temperature measurement with an uncalibrated thermistor in the range of $+25 \dots +50^{\circ}\text{C}$ is 0.1°C (additional calibration is possible);
- temp measurement - 15 values per second.

The developed thermometer medical digital precision (TMTSP) (Fig.2), included in the automated complex consists of two main parts: a temperature recording unit and a temperature sensor having a remote sensing element (temperature sensor) - thermistor. This sensor allows you to record the temperature with an accuracy of $\pm 0.1^{\circ}\text{C}$.

Fig. 2. Thermometer medical digital precision (TMTSP).

The length of the active part of the sensor is 450 mm, diameter is 1 mm, diameter of the thermistor head is 1.3 mm. The sensor is connected to the unit using a 6.35mm JACK connector. The total length of the sensor, including the supply cable and connector, is 1.5 m. The sensor can be sterilized with any common hospital disinfectant, such as ethanol, isopropyl, or chlorite compounds.

The registration unit processes the sensor signal and displays it on the display screen. As a power source of the main unit, either USB 2.0 interface or an external medical power supply (a special adapter with a constant voltage of $+7.5 \dots +12\text{V}$) can be used. When the unit is connected via USB 2.0, temperature data is transferred to a computer and displayed using real-time specialized

software on the monitor, stored in the computer's memory in the form of a simple text file.

The block diagram of the thermometer is shown in fig. 3 [14]. The temperature sensor signal is fed to an amplifier, then to an analog-to-digital converter (ADC), where it is digitized and converted into a digital code, which is transmitted to the microcontroller via galvanic isolation. The microcontroller processes the received data, calculating the temperature value, displays the received information on the display and transmits the temperature data in a digital code via a galvanically isolated USB 2.0 interface to the computer. Also included is a power selector.

The second device of the automated complex is a dual-channel photoplethysmograph, which operates on the basis of the finger photoplethysmography method.

The use of finger photoplethysmography has great diagnostic value in quick and accurate assessment of local capillary blood flow, measurement of arterial and venous pressure, volume pulse, blood flow velocity, vascular tone, heart rate, minute and systolic blood volume. One of the features of the diagnostic capabilities of photoplethysmography is the ability to prevent negative reactions as a result of exposure to physical factors at some energy production facilities (for example, nuclear energy, etc.), and to identify stress conditions. The fact that digital photoplethysmography provides for a short period of time accurate and objective information about changes in circulatory parameters when the body is exposed to various physical factors allows it to be effectively used in assessing the physiological state of technical staff and workers at energy production facilities, where there are pathogenic factors affecting on the human body. The diagnostic capabilities of photoplethysmography allow us to predict the permissible dose of a pathogenic physical influence factor and prevent negative reactions as a result of an overdose of this pathogenic factor affecting the body.

The photoplethysmographic signal is associated with the hemodynamics of the whole organism, since reflects the kind of pulse wave, and the connection with hemodynamics is not direct, i.e. The photoplethysmographic signal is the result of a "low pass filter" on a pulse wave. From this it follows that the analysis of the form of the variable component of the signal can provide information about both the local blood circulation and the hemodynamics of the organism as a whole. That is why photoplethysmographs recently are increasingly used in medical diagnostics.

In addition to the continuous registration of the photoplethysmogram as part of the survey, it is possible to perform an occlusive test. At the time of the development of a two-channel photoplethysmograph, there were publications on medical use of a single-channel finger LED ($\lambda = 940 \pm 20$ nm) photoplethysmography. The use of one photo sensor (one channel) with a wavelength of 920 ... 960 nm will inevitably lead to "physiological interference" when registering a FPG signal due to different amounts of light absorption by the main informative components of the blood flow - oxy- and deoxyhemoglobin. Therefore, it is impossible to obtain acceptable accuracy, repeatability

and adequacy of PPG signal. Therefore, a new laser ($\lambda = 805 \pm 0.75$ nm, $P = 0.1 \dots 0.2$ mW) dual-channel two-finger photo plethysmograph was developed. The radiation wavelength 804.25... 805.75 nm is the "isobestic point" for hydroxy and deoxyhemoglobin, that is, the wavelength at which the spectral characteristics of these two substances coincide. Consequently, "physiological disturbance" can be avoided when receiving a photoplethysmogram.

In the previously developed photoplethysmographs, the individual physiological state of the examined persons was ignored when exposed to an external "energy" load. Physical factors such as electromagnetic radiation, radioactive radiation, electrical, magnetic, mechanical, and other factors are susceptible to the human body and seriously affect the human physiological state. Therefore, it is important to take into account the individual physiology of the worker being examined, since the photoplethysmogram of different people may have a strong variation in the value of the constant component, which is associated with different optical densities of human tissues. In the developed two-channel photoplethysmograph, the individual physiological state of the worker being examined is taken into account, so the doctor receives a photoplethysmogram, which reflects reliable information about the worker being examined. The device also allows for artificial occlusion through an ordinary cuff. To do this, the device has a valve and a compressor with a pressure sensor. Occlusal photoplethysmography is widely used in the diagnosis of vascular tone.

The main technical characteristics of the device FPG-2KL [15]:

- registration, display and linear filtering of biomedical information in real time;
- support for standard (Nell-Cor-compatible) and laser photoplethysmographic sensors;
- synchronous registration of photoplethysmographic signal and pressure;
- the use of laser diodes for operating the instrument at an isobestic point (805 nm);
- wide dynamic range (photocurrent conversion coefficient varies in the range of $2 \cdot 10^5 \dots 2 \cdot 10^6$), as a result of which the device can be used for studies of peripheral blood flow;
- two-channel operation mode. Both channels operate in parallel with a sampling rate of 350 Hz per channel;
- the band of the useful signal 0.1 ... 40 Hz;
- automatic artificial occlusion using a compressor and an electronic valve;
- option to control the level of artificial occlusion in accordance with the measurement method;
- the bundled software is supplied for the automated processing and analysis of the registered information.

Appearance of the device is presented in fig. 4 (conditionally named FPG-2KL - two-channel laser photoplethysmograph).

Fig. 4. Appearance of dual channel two-finger laser photoplethysmograph.

The block diagram of a two-channel laser photoplethysmograph is shown in Fig.5.

Fig. 5. Block diagram of a two-channel two-finger laser photoplethysmograph.

3 Conclusions

The developed automated medical complex for pre-shift inspection (survey) of personnel of enterprises of the energy complex is an effective tool for medical workers, which can significantly reduce the time for pre-shift examinations (surveys), and, most importantly, reliably diagnose deviations of human physiological parameters, such as temperature, pressure, pulse and a number of other physiological parameters. The reliability of the instrument readings is based on the chosen methodology and principles for constructing instruments based on current knowledge of the interaction of laser radiation with the main components of the blood flow.

A medical digital precision thermometer measures an important diagnostic parameter — the temperature of the employee being examined and, together with the photoplethysmogram, provides a more complete and accurate assessment of the physiological state of the employee.

The features of the developed TMCP are temperature measurement with high accuracy and resolution of 0.01°C , which ensures registration of even insignificant temperature measurements for diagnostic purposes, and significantly expand the field of medical thermometry, has automatic registration and recording of indications on a computer.

The advantages of the method of photoplethysmography, implemented in the developed

photoplethysmograph FPG-2KL:

1. provides registration of reactions of the human body to the external physical effects of a pathogenic nature;

2. The use of a laser with a wavelength of 805 nm eliminates the possibility of "physiological interference" associated with a change in the ratio of hydroxy and deoxyhemoglobin, since the spectral characteristics of the optical absorption of both types of hemoglobin intersect at an "isobestic point" at a wavelength of 805 nm;

3. The use of a two-channel laser photoplethysmographic system for registering a photoplethysmogram allows you to: compare both signals; improve the quality of the overall FPG signal; expand the scope of photoplethysmographs.

4. the use of a two-channel laser photoplethysmograph as a recorder of changes in the state of the body, which is pathogenic external influence;

5. photoplethysmogram in this aspect reflects the dynamics of the blood supply in the body. By registering such changes, it is possible to evaluate the effect of external pathogenic influences and further control the amount of such effects in order to prevent negative consequences for the organism as a whole.

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