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Physical and electronic model of studying infrared radiator for drying wending insulation

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Physical and electronic model of studying infrared radiator for drying winding insulation

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Abstract. During a long shutdown of the motors, the insulation quality of the windings of asynchronous motors deteriorates due to moisture. This requires additional costs for drying the insulation of electrical machines. The signs and possible causes of malfunctions of electrical machines, as well as methods of drying insulation, are studied: Drying by external heating, Drying by heating from an external source, Convective drying, Drying by induction loss, drying using light emitters. Drying using infrared radiation is the mildest method and helps to maintain the quality of the insulation. The movement of moisture in the layers of insulating windings occurs according to the laws of heat-mass exchange, that is, heat and moisture are simultaneously transferred. In this case, heat is transferred from more heated layers to less heated layers and at the same time promotes moisture transfer. A physical and electronic model was developed to study the effect of infrared radiation on the drying process of insulation of electrical machines. The main factors influencing the process under consideration are the power of the radiation sources and the supply voltage, that is, the temperature changes in the layers of the insulated windings were studied depending on the change in the power of the emitters and the supply voltage. The created model was investigated according to the main features corresponding to the real process (even the geometrical dimensions coincide). An indispensable condition for physical modeling is the strict geometric similarity of the model and nature, as well as the equality of the corresponding similarity criteria in them.

1. Introduction

To date, in order to provide water resources for the existing 4.3 million hectares of irrigated land in the Republic of Uzbekistan, irrigation networks with a length of 180 thousand km, more than 800 large hydraulic structures, about 20 thousand gauging stations and water distribution structures, 55 reservoirs with a total volume of 19,2 billion m³, 1614 pumping stations, 4124 vertical irrigation wells with a total annual electricity consumption of 8.2 billion kWh.

Irrigation works on the above-mentioned irrigation networks are often carried out seasonally. At the same time, the nominal operation of the electric motors of the pumping units is about three months, and the remaining nine months they stop. During a long stop of the motors, the quality of the insulation of the stator windings of asynchronous motors deteriorates due to moisture. This condition requires additional costs for drying the insulation of electrical machines. The textile industry itself is complex and diverse. One of its largest sectors is yarn production.

The subject of research is: analysis of the principles of heat and mass transfer processes in the layers of the windings of electrical machines; quality of functioning of technological processes;



development of methods for measuring the electrical characteristics of electrical insulating materials and their mathematical models; analysis of the main characteristics of the emitters; development of their calculation.

During operation, transportation and storage, the insulating structures of electrical machines are exposed to the environment. At the same time, they are moistened. The ingress of moisture into the winding leads to a deterioration in the dielectric characteristics of the insulation and premature failure of the electrical machine.

In practice, the insulation resistance of windings of electric machines with voltage up to 500 V should be at least 0.5 megohm. If before starting the insulation resistance of the windings is lower than the standardized, then the machine should be dried. There are several drying methods: convective (in drying cabinets), an electric current, losses in stator steel and etc.

2. Methods

Methods for drying insulation of electrical machines. Drying of insulation is carried out: by external heating, heating from a current of an external source, induction method, short-circuit current in generator mode, at "creeping speed" (for DC motors) and ventilation losses. In the event that one of the listed methods does not create the temperature required for drying or heating occurs unevenly, combined drying is used. In this case, not one, but any two methods are used simultaneously.

Table 1. Signs and possible causes of malfunctions in induction motors[2].

Malfunction symptoms	Possible reason
The electric motor does not reach its rated speed and is humming.	Unilateral attraction of the rotor due to bearing wear, misaligned end shields or shaft bent.
The electric motor hums, the rotor rotates slowly, the current in all three phases is different and even at idle exceeds the nominal.	Breakage of one or more rotor winding rods; incorrect connection of the beginning and the end of the stator winding phase (phase "inverted").
The rotor does not rotate or rotates slowly, the motor hums and heats up. The motor heats up at rated load.	Loss of phase of the stator winding. Turning fault in the stator winding; deterioration of ventilation conditions due to contamination of ventilation ducts.
Inadmissibly low insulation resistance of the stator winding of the electric motor.	Moisture or severe contamination of the stator winding insulation; aging or damage to the insulation.
The electric motor vibrates during operation, and after shutdown at a rotor speed close to the nominal. The electric motor vibrates strongly, but the vibration stops after disconnecting it from the network, the motor hums strongly, the current in the phases is not the same, one of the sections of the stator heats up quickly.	Shaft misalignment; rotor imbalance (imbalance). Short circuit in the stator winding of the electric motor.

Drying with external heating. For external heating of machines, cast iron resistances or boxes of resistances are used, as well as specially made heaters, which are located under the machine in such a way as to exclude the possibility of local overheating from direct heat radiation or excessively close placement of the heater.

During drying, make sure that the temperature of the hot air entering the machine does not exceed 90 °C, and the temperature of the windings in the most heated part is 70 °C. The temperature is measured with thermometers installed on the blower nozzle and in the hottest part of the winding, and in large electrical machines - with built-in temperature indicators (thermocouples). This method is used for drying highly damp machines.

Drying by heating from the current of an external source. A number of schemes are used to dry machines in this way. Only the most common ones are discussed below. Synchronous machines are dried by connecting all three phases and the rotor in series (at close values of the rotor and stator currents) to a direct current source. Drying current should be $0.5 \div 0.7 I_{nom}$ of the rotor. Asynchronous motors are dried with three-phase current in short circuit mode. To do this, the rotor is braked, and its winding is short-circuited on the rings with a special jumper (to avoid burning the rings).

The convective drying method is carried out in special drying ovens. Steam, electricity or gas can be used as heat sources. In all cases, the heat carrier is heated air. With this drying method, heat is transferred from the stator to the winding, so its outer layers dry out faster than the inner ones. For a more uniform removal of moisture from the insulation, the temperature in the drying cabinet should be raised gradually.

The current drying method consists in passing through the windings an electric current of reduced voltage (15–20%) of the nominal voltage value. In this case, heat is generated directly in the winding conductors and moisture is initially removed from the center of the insulating structure. Drying can be done on an assembled machine or one stator. The power supply can be either DC or AC. In the case of AC drying, heat is additionally generated in the stator steel by dissipation fluxes.

Drying by induction loss. In this method, the heating of the machine is carried out by induction currents arising from the passage of alternating current through a special magnetizing winding wound on the stator. The magnetizing winding is performed with an insulated wire. To control the heating temperature of the unit, the magnetizing winding is sectioned.

Electric machines are dried when the insulation of windings and other live parts is moistened, for example, during transportation, storage, installation and repair, as well as during prolonged shutdown of the unit. Drying the insulation of the windings of electrical machines unnecessarily causes additional unjustified costs, and if the drying regime is not properly maintained, in addition, damage to the winding occurs.

The purpose of drying is to remove moisture from the insulation of the windings and increase the resistance to a value at which the electric machine can be energized. The absolute resistance, $M\Omega$, of insulation for electrical machines that have undergone major overhaul must be at least $0.5 M\Omega$ at a temperature of 10 - 30 °C.

Moisture movement occurs due to the difference in moisture in different layers of insulation, from layers with higher moisture content moisture moves to layers with lower moisture. The drop in humidity is in turn created by the drop in temperature. The greater the temperature difference, the more intensive the drying of the insulation takes place. For example, by heating the inner parts of the winding with current, it is possible to create a temperature difference between the inner and outer layers of insulation and thus speed up the drying process.

To accelerate drying, windings heated to the limiting temperature should be periodically cooled to ambient temperature. In this case, the efficiency of thermal diffusion is the greater, the faster the surface layers of the insulation are cooled.

3. Results and Discussion

Having studied the above methods, taking into account their shortcomings, we put forward a hypothesis for creating a physical and electronic model for drying the insulation of electrical machines.

The model of an object should reflect its most important qualities, neglecting the secondary ones, and the following goals are pursued during modeling: 1) cognition of the essence of the object under study, the reasons for its behavior, “structure” and the mechanism of interaction of elements; 2)

an explanation of the already known results of empirical studies, verification of model parameters using experimental data; 3) predicting the behavior of systems in new conditions under various external influences and control methods; 4) optimization of the functioning of the systems under study, the search for the correct control of the object in accordance with the selected criterion of optimality and etc [1,2,3,4,5,6,7,8].

In the above sources, models are also classified into the following types: a) cybernetic or functional models; b) structural models - these are models, the structure of which corresponds to the structure of the simulated object (Examples: They are command post exercises, self-government day, electronic circuit model in Electronics Workbench (EWB) and etc.); c) information models, which are a set of specially selected quantities and their specific values that characterize the object under study.

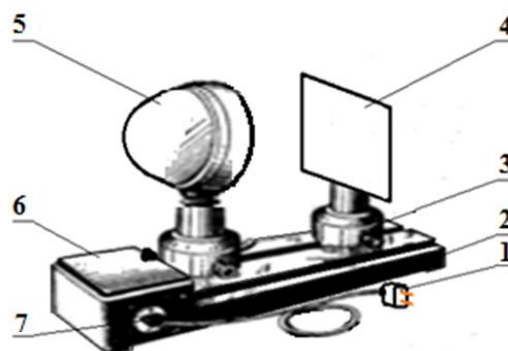
Physical modeling is widely used in experimental research in the field of electrical engineering and electrical technology. Modeling is based on the creation of a model that has the same physical nature as the processes occurring in nature. The obtained results of experiments on a physical bench are processed and generalized with the aim of transferring them to nature. Electrophysical modeling is based on the laws of conservation of energy.

At the beginning, we carried precursive experiments to establish the distance from the object of light emission to the screen. For this, an electric medical household reflector was used as a source of IR (infrared radiation) according to TU-205r of the Ukrainian SSR 236-82 [9].

On the basis of the experiment carried out, the temperature on the screen surface was measured. In this case, the radiation source had a power of 60 W. And the distance from the emitter to the screen is within 3-5 cm. For the physical model, we took the parameters with a 10-fold increase (emitter power within 600-1200 W) (see Figure. 1). The distance from the emitter to the screen was increased accordingly (30-50 cm). The latter, in practice, corresponds to the installation distance of the IR emitter from the stator windings of electrical machines to be dried during their repair.

In our case, the model is investigated according to the main features corresponding to the real process (even the geometric dimensions are the same). An indispensable condition for physical modeling is the strict geometric similarity of the model and nature, as well as the equality of the corresponding similarity criteria in them.

The resistance was determined with a multimeter, and then the circuit was tested and the microcircuit was tested. A thermal imager was used to measure the thermal radiation power of the measurement object in the infrared range. For electronic modeling, we used Automation Studio B & R™ - an integrated programming environment that includes tools for all phases of an automation project, being the basis for applications of any scale and application, as well as SolidWorks® 2014 featuring many improvements[10,11].



a

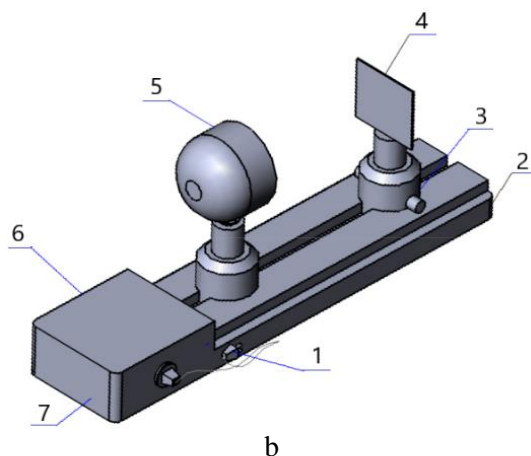


Figure 1. General view of the physical model for studying the characteristics of an infrared emitter. a - physical model; b - electronic model:
 1 - electric plug; 2 – body (base); 3 - movable part (for setting the distance between the radiator and the working screen); 4 – work screen; 5 – infrared emitter reflector; 6 – box for intelligent control; 7 – electrical socket for a detachable connector.

Figure 2 shows the emission spectrum of MEMS IR emitter under different electrical power consumption. It is found from Figure 2 that the radiation intensity increases with increasing the input power (or temperature). The radiative peak-value-wavelengths can be calculated with Wien’s displacement law(Figure 3):

$$\lambda_m \cdot T = 2897.79 \mu\text{m} \cdot K \tag{1}$$

Any information can be measured in bits and therefore, no matter on what physical principles and in what number system the digital computer operates (binary, ternary, decimal, etc.), numbers, text information, images, sound, video and etc. Other types of data can be represented by sequences of bit strings or binary numbers. This allows the computer to manipulate data, provided there is sufficient storage capacity. By now, many devices have been created for storing data based on the use of a variety of physical effects. There is no one-size-fits-all solution, each has its own advantages and disadvantages, therefore computer systems are usually equipped with several types of storage systems, the main properties of which determine their use and purpose.

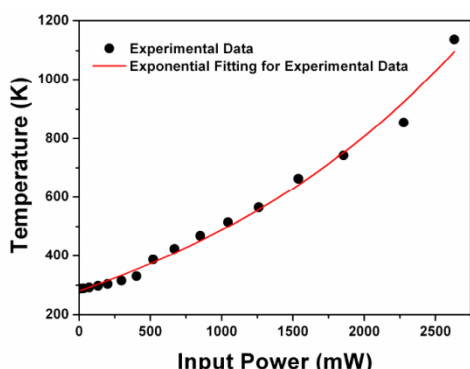


Figure 2. Dependence of electrical power consumption on membrane temperature in the range of 8~12μm[13].

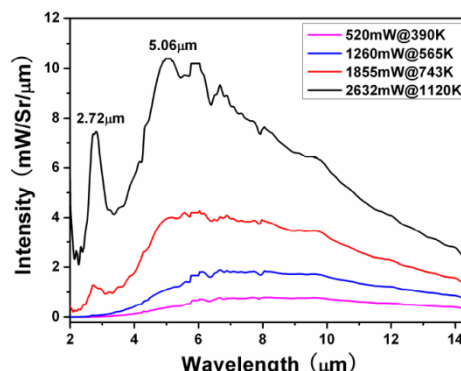


Figure 3. Emission spectrum of MEMS IR emitter under different electrical power consumption[13].

In the research work, such problems have been studied: acting factors for electromechanical systems for measuring and monitoring the insulation temperature of electrical machines, as well as the development of energy-efficient technical means for monitoring and measuring the temperature of the windings being dried, increasing the measurement accuracy and based on it, a mathematical model has been developed in terms of creating a measuring system Consisting of a large, intelligent sensor with low power consumption, simple and high-precision measurement in control, with a large measuring range.

Electric motors of various types and capacities are often used in practice. In this situation, for each individual type of engine, its own thermostat and a separate temperature sensor must be provided. Thanks to this, it is possible to ensure an optimal drying mode and avoid deterioration of the quality of the insulation of the windings. This requirement can be met using two power supply schemes: 1) current regulation with a change in the number of electric heaters (see Figure 3); 2) regulation of the supply voltage using a laboratory autotransformer (see Figure 4). This ensures the correct operating conditions.

Standard devices withstand electric heater power up to 3.5 kW. If the power of the system is higher, then you need to split the stator windings into three phases and connect each to a separate thermostat.

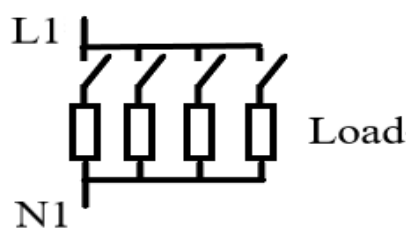


Figure 4. Current regulation with a change in the number of electric heaters.

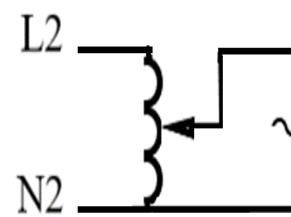


Figure 5. Regulation of the supply voltage using a laboratory autotransformer.

Thermostat installation requirements

It is always recommended to use the thermostat for layers of heated insulated conductors of windings of electrical machines. When carrying out installation work, it should be borne in mind that the equipment should not switch directly. Before connecting the thermostat, it is necessary to determine in advance the place where it will be located. In the process of work, the following requirements must be met:

- The heating temperature control system is connected according to the diagram(Figure 5). The thermostat must be near the outlet or the cable stretches to the switchboard;
- The whole connection process is carried out according to the developed scheme.

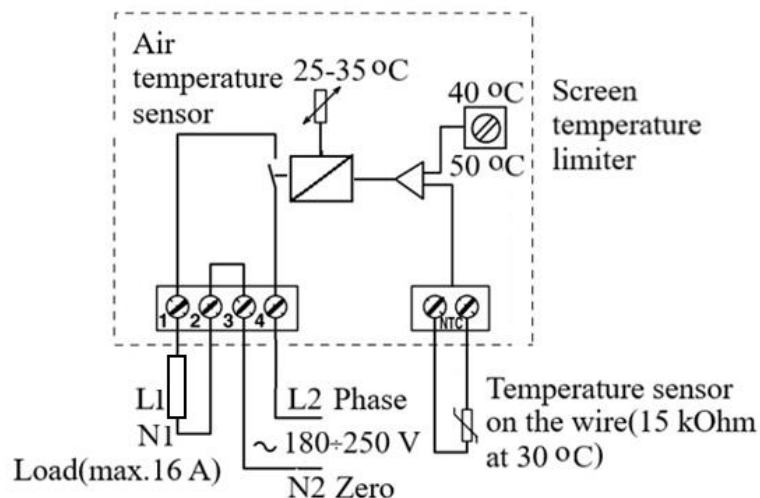


Figure 6. The heating temperature control system

The heating temperature control system contains air temperature sensor, screen temperature limiter, temperature sensor on the wire, Phase and Zero.

We have studied many journal scientific articles included in the Scopus database [14,15,16,17,18,19,20,21,22,23,24]. They study in detail infrared radiation with different wavelengths. However, in the above works, infrared radiation is mainly used in medicine and biology.

We have investigated the use of microprocessor-based relay protection and automation devices, distributed generation installations, including renewable energy sources and energy storage devices, as well as “smart” automated information and measurement systems capable of controlling electrical devices[25].

4. Conclusions

The results obtained in the electronic module are unreliable without verification by experiment. The measuring equipment during the experiment gave results indicating the quality and quantity of measurements, the correctness of conducting the electrotechnological process of heating using an infrared radiation source of the object for drying the insulation of stator windings of electrical machines. At the same time, intelligent electrophysical measurements due to low energy consumption, the possibility of transmitting and storing measured information and its transmission over a distance, high measurement speed, as well as high accuracy and sensitivity turned out to be the best.

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