Electrical equipment maintenance system with elements of augmented reality technology

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Abstract. Any industrial enterprise serves a significant fleet of electrical equipment. Equipment servicing takes place in various ways: according to the schedule and without it, by direct and indirect methods, in manual and automated mode, with or without the involvement of specialists, etc. Timely maintenance prolongs the life of electrical equipment. So technical maintenance is indirectly related to the efficiency of production. Today there are many different technologies that simplify the process of maintenance of electrical equipment. One of these technologies is augmented reality technology. The existing practice of application of augmented reality technology shows that the one of the main difficulty faced by the enterprise is the lack of unified solutions and software modules. As a rule, the electrical equipment maintenance system is developed specifically for each type of equipment; its software modules and components are unique. This article describes the approach of developing a unified module of augmented reality technology for servicing electrical equipment.

1. The maintenance of electrical equipment

Electrical equipment maintenance is a list of operations that allows to maintain equipment in working condition [1]. In addition, maintenance can solve a number of other problems, for example, reduce the factor of wear of equipment, proactively detect equipment defects, etc [2].

A modern industrial enterprise usually uses three methods of maintenance: by schedule, by operating time and by actual state [3, 4]. During the maintenance by schedule, a special developed maintenance schedule is used. This schedule shows which type of equipment and in which time will be maintenance [5]. The advantage of this method of maintenance is the presence of a previously known work plan and the calculation of the cost of performing maintenance. The disadvantage of this method is strictly fixed interval between repairs [6, 7]. Carrying out maintenance in strictly prescribed periods, not based on actual condition can lead to the situation when equipment repairs, but it does not need it, and contrariwise, equipment that needs repair is not repaired, it is waiting for its repair period [8-10].

During the maintenance, according to operating time, equipment characteristics such as machine-hours, volume of processed products, mileage, etc. are taken into account. During maintenance, according to the actual state certain electrical parameters monitors [11, 12]. Maintenance is carried out only at the moment when these parameters reach exactly defined values. Maintenance of electrical equipment according to its actual condition is most preferable, since in this case maintenance is carried out only as needed [13, 14]. However, if the list of parameters by which the decision on the need for maintenance is made is not complete, the electrical equipment may fail abruptly. This can be reason of...
major accidents. Another problem with this method of maintenance is the correct estimate of time, from the moment of detection of overflowing some parameters to the moment of equipment repair. Failure to perform maintenance in a short time can lead to accidental breakdown of electrical equipment, even in the case of the availability of information about the defect being developed [16, 17].

The possibility of timely repairing a defect in the operation of electrical equipment may be related to some problems: the lack of spare parts, the lack of competent personnel who can repair the defect, and the errors that were made during maintenance [18,19]. These problems will help solve the introduction of a special system of maintenance of electrical equipment based on augmented reality. The technology of augmented reality will allow to visually demonstrate the stages of work during maintenance, indicate the method and place of fastening the main parts, give the specialist additional information about the equipment. This significantly reduces the time and quality of electrical equipment maintenance.

2. Theoretical aspects of the use of augmented reality technology for the maintenance of electrical equipment

Augmented reality is an extended version of reality. There are the image of the real environment is complemented by elements created using a computer. Augmented reality is a “mixed reality”, as it combines the resources of the real world and the virtual world [20].

AR applications can be either conventional push notifications in text form or full-length instructions on how to start and stop the technological unit in production. The key point is that the information provided is up-to-date and relevant for what you want to do [21].

There are several categories of augmented reality, which differ in the method of reproduction, goals and applications.

- Marker Based Augmented Reality
  This category of applications uses the camera to recognize markers, which can be QR codes or any 2D images.
- Markerless type of augmented reality
  In this case, the implementation of the technology is based on the binding of elements of augmented reality to the labels on the real world map. GPS, digital compass, accelerometer, device speed sensor are used to determine the position. This type is most often used for mapping, routes, determining the proximity of any enterprise.
- Augmented reality based on projections
  This category is realized by projection of artificial light on objects of the real world. Human interaction occurs through the processing of actions that are reproduced by the person to the projected light. For example, it could be a phone keyboard or a sheet of a book. Detection of user interaction is carried out by differentiating the expected (or known) projection and modified projection (caused by the user interaction). Another application based on predictions of reality uses laser plasma technology for three-dimensional (3D) interactive hologram in the air.
- Augmented Reality Based on Superpositions
  The superposition-based reality partially or completely replaces the original appearance of the object with a new extended representation of the same object. In augmented reality based on superposition, object recognition plays a vital role, because the application cannot replace the original representation with an extended one if it cannot determine what the object is.

Possible areas of application of augmented reality systems are very diverse. The system can provide access to maintenance instructions, historical data on the operation of the equipment, information on the predicted defects on different parts of the machines [22, 23]. At the same time there are two of the most important directions of use of augmented reality in industry:

- Assistance in complex assembly on the production line
  Not everything in our world is performed by robots, some things even on conveyor production are still performed manually by employees of the enterprise. At each stage of work, a specific instruction is
developed, which is often presented as a printed PDF file, with which it can be difficult to work. Also, these documents are static, which excludes the possibility of a quick update in case of a change of instructions. Augmented reality allows you to display the most relevant instructions right in front of the worker’s eyes, which frees his hands and reduces the time spent on performing actions in the workflow.

- Assistance in maintenance

In addition to assistance on the conveyor belt, augmented reality technology can also help with maintenance. For example, Mitsubishi Electric uses an augmented reality based on a three-dimensional model that allows users to confirm the test order on the AR display, and then enter the test results with their voice [24].

Regardless of the goals of the use of augmented reality, an important part of the augmented reality system is the script. Since augmented reality is a combination of real and virtual reality, the script is very similar to the virtual reality scenario, but there are some unique features.

3. Augmented reality technology for the maintenance of electrical equipment

The basis of maintenance of an electrical equipment unit is its maintenance service script. The development of a service script is the first step in creating an augmented reality system. Developing a service script means identifying a sequence of actions that collectively solve one of the tasks performed during equipment maintenance, predict the time that a specialist will spend on performing equipment maintenance. Figure 1 shows the flowchart of the service script development algorithm for the maintenance of electrical equipment.

![Flowchart of the service script development algorithm for the maintenance of electrical equipment](image-url)

**Figure 1.** The flowchart of the service script development algorithm for the maintenance of electrical equipment.
The first step in developing a maintenance service script is to define the task. When formulating a task, it is important to take into account a number of significant factors: the task must be specific, i.e. identifying specific parts of the equipment required for replacement, the type of defect for which it is directed, etc. (for example, replacing the motor shaft, replacing the insulating contacts, etc.), the task should not be voluminous, it should be solved in a number of actions not exceeding 20. In the case of more voluminous tasks, it should be divided into subtasks. After formulating the task, a description of the actions is given. The combination of these actions should fully solve the task. The next step is to check whether such actions already exist in the system, whether there is a template on them, whether they are unique or not. If an action template exists, then during the description of the action it is necessary to bind to the template. At the end of the description, the action is bound to real objects. At this stage, it is decided which type of binding will be used - marker or without marker. Both in the first and in the second case, the search for unique features of the object, which can become its identifier, is performed [25]. After successfully creating the list of actions and linking them to the objects, the system is tested for operability. With successful testing, the service script is recorded in a special service script database. In this database, the newly created service script is being tested for uniqueness. In the event that the base of the service script of the action just saved is additionally checked for the identity of the solutions. Additional identity checks will allow you to avoid redundant information in the service script database and additionally create patterns from frequently repeated actions. For example, when servicing the internal parts of electrical equipment, it is imperative to remove the protective cover [26]. The action for removing the cover will fall into the action templates. When writing the next service script, this action will be taken from the template, which will save resources on compiling the module of augmented reality. In addition, more complex analytical tasks can be implemented in the service script database. For example, the search for relationships between various repair operations. Related tasks may appear side by side in the repair schedule, there may be new dependencies between the occurrence of defects and performed repair work on the equipment.

When writing a service script, it is necessary to take into account that the maintenance service script is written for two cases - the case of equipment failure and the case of scheduled maintenance of electrical equipment.

4. The sample of augmented reality system for the maintenance of electrical equipment

In the specialized laboratory of the Mining University, an augmented reality system was developed for the maintenance of electrical equipment. As a control object, the device was used "Smart Shield" by Schneider Electric. "Smart Shield" - allows for: distribution of electricity and load management; technical accounting of electricity; operational service; power quality monitoring.

To test the algorithm presented in the previous section, a scenario was developed to connect a new device to SmartLink. This device is a meter of electrical energy. The figure 2 shows the object's appearance, the general system menu and the field with the main parameters of the counter connected to SmartLink.

Figure 2. The testing of the augmented reality system.
During testing, it was revealed that when connecting an electricity meter to the Smart Link bus, it is necessary to perform 10 template actions, examples of which are the following actions: mounting the meter on a DIN rail, connecting the data bus, connecting the power bus. The unique action that was recorded in the templates was the action of connecting the electric power meter to the local service. A script was written for this process, the script was transferred to a template and saved to a special database of script templates.

5. Conclusion
The augmented reality system significantly reduces the cost of electrical equipment maintenance. An important element of system development is the writing of a maintenance service script. A special approach to writing and implementing a script for servicing electrical equipment will reduce errors during service script development, more quickly adapt personnel to the new system functionality, perform additional analytical calculations to find dependencies between various tasks and system maintenance steps, and also facilitate the system development process.

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