Information System for Predicting the Technical Condition of Electrical Equipment Devices

D. A. Ermakova*, and *V. A.* Fateev

Samara State Transport University, 1st Nameless lane, 18, 443066, Samara, Russia

Abstract. The information system for predicting the technical condition of electrical equipment devices was described, which allows to analyze the data obtained and predict the residual life at the output in the form of regulatory documents. A new database using the open-source relational database management system MySQL (hereinafter – RDBMS MySQL) was designed. An analysis of the subject area and an analysis of the operation of electrical equipment devices was carried out. The developed information system allows to analyze the data obtained and predict the residual life in the form of regulatory documents.

1 Introduction

The existence of a huge fleet of various electrical machines and other electrical equipment devices in the railway infrastructure requires significant costs for maintenance, service and replacement. In general, operation and performance of works is carried out according to schedules developed in accordance with the regulatory requirements of the governing documents. Thus, the maintenance activities of electrical equipment devices practically do not take into account the operating conditions. At the same time, working under different conditions, the life of the same devices will not be run out in the same way. This can lead to the case when some devices of electrical equipment can be written off only because of the regulatory end of life, while still having a sufficient life reserve. In addition, consideration of the influence of operating conditions on the state of operating life of electrical equipment devices will identify those of them, which due to complex operating conditions may fail before its due time. Thus, monitoring the operating parameters of electrical equipment will allow to react flexibly to the service life of this equipment, which will make it possible to obtain savings by extending the service life of individual devices, as well as to prevent timely emergencies with devices operating under adverse conditions.

The idea of monitoring the electrical parameters of electrical equipment of the railway infrastructure, in particular transformers of traction substations in order to regulate the timing of maintenance has already been expressed in various sources, such as [1] and [2]. The key point is to monitor peak values such as the current flowing through the transformer windings and the oil temperature inside the transformer during operation. To implement the collection of sensor readings and further processing of the data obtained, it is assumed to

*Corresponding author: ermakova_44@mail.ru

build an information system that includes a database and a software module that implements the necessary calculations.

2 Materials and Methods

2.1 Purpose of Paper and Research Methods Used

The purpose of the paper is to expand the capabilities of such an information system for more effective use of the data obtained in the course of the measurement. Data collection and pre-processing is supposed to be done with a controller located in the immediate vicinity of the device and connected to the sensors. Data should be collected in accordance with the physical parameters of the controlled process. For example, the current in the transformer windings can have sharp jumps in readings in relatively short intervals of time, while the ambient temperature has a significant inertia. Consequently, the time intervals between receiving the next batch of data should be different for each process. This will reduce the amount of data transmitted. Data pre-processing also reduces the load on the communication channels, through which the data will be transmitted to the server. The pre-processing algorithms will depend on the method used. The results of pre-processing will be accumulated in the local database, and then transferred to the main database of the information system. This will help to transmit data over relatively slow communication channels, and it is advisable to use two buffers for data accumulation. While data are being transferred to the server from one memory buffer, data are collected in another.

Since the process of operation of electrical equipment devices is rather long, the accumulation of data during the life cycle of the device will lead to a huge array of readings, the processing of which will provide additional opportunities, in particular, prediction of technical condition in order to prevent accidents. Diagnostic methods for industrial electrical equipment to prevent accidents are used in different ways. For example, the article [3] gives an example of the use of spectral analysis in the diagnostics of electric motors. At the same time, it is suggested to monitor the current spectrum of the electric machine and make timely conclusions about the nature of a failure. Thus, the obtained spectrograms allow to draw conclusions about the current technical state of the equipment and make short-term predictions.

In the case of collecting large amounts of data using the information system, it is possible to use both statistical methods and various intelligent methods of data analysis for their processing. The most common statistical methods of predicting are such methods as extrapolation by moving average and predicting by linear regression [4].

The moving average extrapolation is most often used for short-term predicting purposes. As a rule, it is used in the case when the obtained data do not allow revealing the development trend of the controlled process, i.e. building a trend. The linear regression method is more widely used for predicting. Its advantage is a sufficient simplicity of computational algorithms and clarity and interpretability of the result characteristic for the linear model. The disadvantage is the low accuracy. To check the possibility of using this or that method in the tasks of predicting the technical condition of electrical equipment devices, it is necessary to conduct modelling.

Application of models using fuzzy sets and neural networks in prediction tasks requires verification as well. These models are the most promising in terms of obtaining a positive result [5]. Their use is based on modelling and time series estimation. Thus, a further development of the information system for collecting data on the technical condition of electrical equipment devices can be a software module that implements prediction algorithms built on statistical models or models that use various intelligent methods of data processing. The use of such methods in the future may make it possible to build different operating profiles of electrical equipment devices. This will allow a more rational use of this or that equipment depending on the operating conditions.

The result of the work is an information system for predicting the technical condition of electrical equipment devices.

3 Development of an Algorithm for Monitoring the State of Objects

In the case of building a model that generates input data for monitoring and predicting the condition of electrical equipment objects (for example, an oil transformer), the general algorithm of the model will be as follows.

The main loop of the software performs the following actions:

1. Check of the current generation conditions of the monitored parameters.
2. Sequential parameter generation (according to the list set by the user).
3. Recording of the obtained parameters to the database indicating the time segment.
4. Check of the necessity of changing the current generation conditions of the monitored parameters and introduction of these changes if the result of the check is positive.
5. Checking the termination of the main loop. If the loop is terminated, exit from it, otherwise, entails the transfer to the next iteration.

Thus, the model algorithm can be represented as follows (Figure 1):

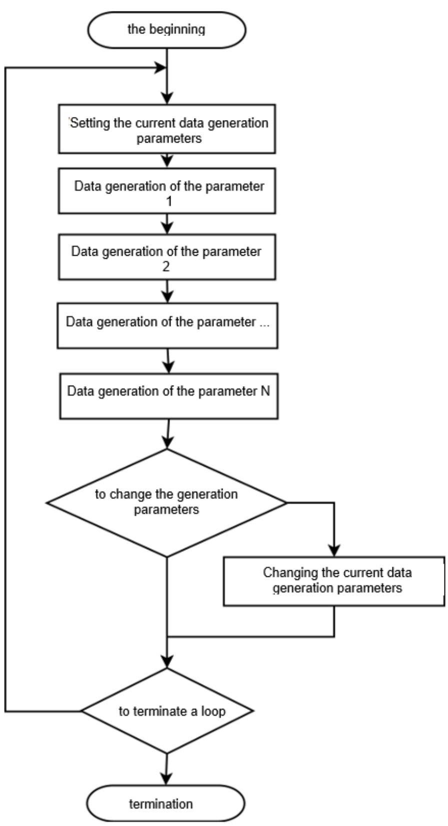

Fig. 1. Simulation model algorithm

Input data for use in prediction algorithms will be obtained as a result of this algorithm. They are a series of totals of indicators combined under one time segment. It is advisable to arrange the storage of such indicators using a database. This will allow quick and easy access from the user or other software.

Thus, using this algorithm, you can get the necessary amount of input data to test any prediction algorithm. Practical implementation of this algorithm can be done using any software language. In addition, this algorithm can be easily extended by connecting any additional software modules of the model under study.

3.1 Information System Design

Possible options for a technician are presented in the precedent diagram (Figure 2) [5]. The main activities are as follows:

- Selecting the data to view.
- Revising the phase voltage readings.
- Revising the phase current readings.
- Revising the temperature of the top layer of oil.
- Revising the temperature of the maximum heated section of the transformer.
- Revising the ambient temperature.
- Development of the trend.

Thus, the technician's activity covers the control of parameters such as voltage, current and temperature. In addition, they can initialize the trending of these parameters.

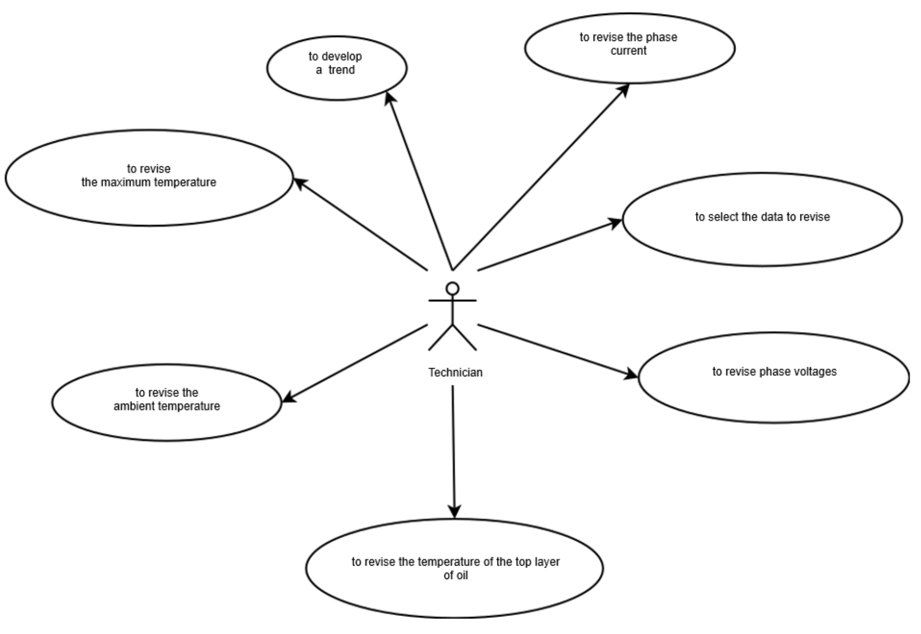

Fig. 2. Precedent diagram

3.2 Database Design

Selecting the data to revise means determining what to revise and how much data to revise. This will require a technician to be active in relation to the user interface. Exactly the same flurry of activity is required for trending and predicting. The other uses involve a rather passive interaction with the data, that is, simply revising the displayed data.

The data, with which a technician interacts, are presented in the following list:

- Transformer type.
- Power.
- Service life.
- Temperature of the maximum hot element of the transformer.
- Temperature of the top layer of oil.
- Ambient temperature.
- Name of transformer winding.
- Phase current value.
- Phase voltage value.

Figure 3 presents a database scheme of the designed information system.

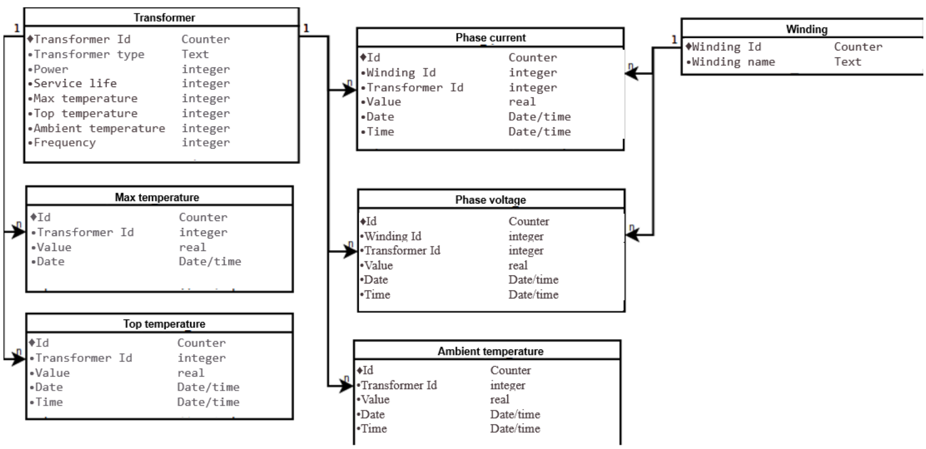

Fig. 3. Database scheme

All the data are grouped into entities in the diagram (Tables). There are a total of seven Tables in the database:

- Transformer.
- Winding.
- Phase current.
- Phase voltage.
- Maximum temperature.
- Temperature of top layers.
- Ambient temperature.

See the Tables for more information.

Table 1. Transformer

Field name	Field type	Description
Transformer_Id	counter	Key field
Transformer type	Text	Transformer grade
Power	integer	Transformer power
Service life	Integer	Guaranteed operation time
Max temperature	Real	Temperature of the maximum hot spot
Top temperature	Real	Temperature of the top layer

		of oil
Ambient temperature	Real	Ambient temperature

Table 2. Winding

Field name	Field type	Description
Winding_Id	counter	Key field
Winding name	Text	Winding grade

Table 3. Phase Current

Field name	Field type	Description
Id	counter	Key field
Winding_Id	integer	Source key
Transformer_Id	integer	Source key
Value	Real	Current value
Date	Date/time	Date of readings
Time	Date/time	Time of readings

Table 4. Phase Voltage

Field name	Field type	Description
Id	counter	Key field
Winding_Id	integer	Source key
Transformer_Id	integer	Source key
Value	Real	Voltage value
Date	Date/time	Date of readings
Time	Date/time	Time of readings

Table 5. Max Temperature

Field name	Field type	Description
Id	counter	Key field
Transformer_Id	integer	Source key
Value	Real	Temperature value
Date	Date/time	Date of readings
Time	Date/time	Time of readings

Table 6. Temperature of the top layers

Field name	Field type	Description
Id	counter	Key field
Transformer_Id	integer	Source key
Value	Real	Temperature value
Date	Date/time	Date of readings
Time	Date/time	Time of readings

Table 7. Ambient temperature

Field name	Field type	Description
Id	counter	Key field
Transformer_Id	integer	Source key
Value	Real	Temperature value
Date	Date/time	Date of readings
Time	Date/time	Time of readings

Thus, all actions with data will be performed within the created database, through SQL queries [7, 9].

The next step in designing an information system is to create a class diagram. Class diagrams allow creating a logical representation of a system, on the basis of which the source code of the described classes is created. A class is a named description of a set of objects with common attributes, operations, relations, and semantics. Diagram icons allow displaying a complex hierarchy of systems, class interrelations and interfaces.

It is especially important to have a class diagram in projects that use the concept of object-oriented software engineering. A class diagram created before the coding process can reveal design problems early on — before the software code is created.

In addition, there is a certain class of tool softwares (CASE tools) that not only allows building class diagrams, but also generating source code for the class based on these diagrams. In other words, CASE tool in this case is a class constructor with a possibility to get the source code [8]. The source code can be obtained in different software languages. Supplementing it with the contents of the methods and passing it to the compiler, we get an executable module in the output.

The class diagram is very important when using the concept of object-oriented software engineering, because the model built with its help fully reflects the physical structure of classes [6].

The class diagram of the information system is shown in Figure 4. As can be seen from the Figure, the designed information system contains three classes, namely: “Transformer”, “Winding” and “Data”.

The “Transformer” class contains data representing an individual transformer and methods that allow working with these data. All the data have the “private” access modifier and methods are “public”. The data are represented by the following fields:

- Transformer name — grade. Has a string type;
- Winding is an array of elements that represent objects of the “Winding” class;
- max_temperature — temperature of the hottest element of the transformer;
- top_temperature — temperature of the top layer of oil;
- ambient_temperature — ambient temperature.

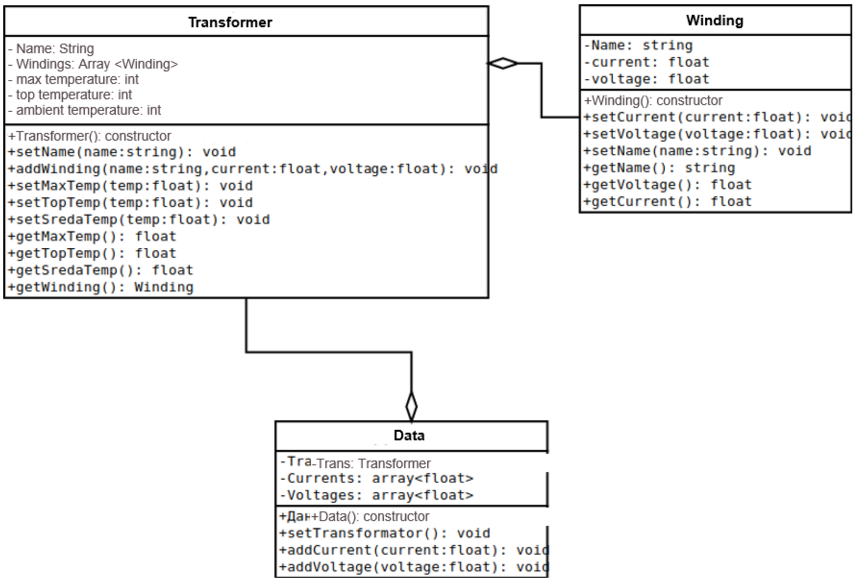

Fig. 4. Class diagram

"Winding" class contains the following fields:

- name — winding name (grade).
- Current — phase current value in the winding.
- Voltage — phase voltage value in the winding.

"Data" class contains the following fields:

- Trans — "Transformer" class object.
- Current — array containing current values.
- Voltage — array containing voltage values.

They all have private access rights and can only be used via public methods. All of these methods are implemented in the class as set and get methods. A method of "set" type sets the value of the private field. Such methods do not return anything, and the data to be transferred to the field are transferred as parameters.

Methods of the "get" type, on the contrary, return a value of the desired type, but do not transfer anything as parameters. Thus, there are usually two methods that can be used to write data into the field and to read data out of the class instance for each field.

In addition to the "set" and "get" methods, there are "add" methods that allow adding elements to arrays. Thus, these three classes allow fully organizing the work of the developed software of the automated workplace of students human resources specialist. Interacting with each other, they solve all the working points related to searching, editing, adding and deleting student records.

The classes are implemented in a separate module, which makes it possible to use them in other developments if necessary.

4 Main Conclusions

As part of the study, an information system for predicting the technical condition of electrical equipment devices was developed to ensure more effective maintenance of the monitored devices.

An analysis of the subject area was conducted and a choice of system architecture was made. For the successful operation of the automated workplace, the client-server architecture was selected. UML diagrams were developed in the design phase, as well as both logical and physical design of the database were made. In addition, the analysis and selection of RDBMS, software language and development environment were carried out. RDBMS MYSQL was selected as a RDBMS, java was selected as a software language, and Eclipse was selected as the design environment.

A software prototype for predicting the technical condition of electrical equipment devices was developed.

References

1. UML. Fundamentals, 192 (2002).
2. E. R. Alekseev, O. V. Chesnokova, T. V. Kucher, Free Pascal и Lazarus: programming textbook, 440 (2010).
3. L. Welling, L. Thomson, Developing Web Applications with the help of PHP and MySQL, 782-795 (2003).
4. GOST 34.320-96 Information Technologies. A system of database standards, Concepts and terminology for the conceptual framework and information base (2001), https://docs.cntd.ru/document/1200017661.

5. G. Butch, J. Rambo, I. Jacobson, The UML language. User's Guide, 2nd edition-DMK Press (2007).
6. J. Rambo, M. Blaha, UML 2.0. Object-oriented Modeling and Development (2007).
7. J. Robert, Muller: Databases and UML. Designing (2002).
8. S. A. Trofimov, CASE-technologies: practical work in Rational Rose, 288 (2002).
9. L. Ullmann, MySQL Manual for the study of language, 352 (2004).