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INFORMATION SYSTEM FOR CURRENT STATE DIAGNOSTICS OF INDUCTION MOTORS

МОБІЛЬНА ІНФОРМАЦІЙНА СИСТЕМА ДІАГНОСТИКИ ПОТОЧНОГО СТАНУ АСИНХРОННИХ ДВИГУНІВ

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Abstract. *Purpose*. The paper addresses the urgent scientific and technical problem of non-contact real-time diagnostics and condition monitoring of industrial induction motors without disrupting continuous technological processes. The primary objective is to develop and evaluate a mobile information-diagnostic system capable of assessing the current operational state and predicting the remaining useful life (RUL) of induction motors. *Method*. The proposed methodology utilizes measured stator currents to evaluate the parametric electromagnetic asymmetry of stator phases. Functional analysis and system decomposition were performed in accordance with the IDEF0 modeling standard. The software architecture was developed using a client-server paradigm, implementing asynchronous background data processing via Kotlin coroutines, REST API network interaction over HTTPS, and centralized data management based on a distributed MySQL database. *Results*. A mobile diagnostic application operating on Android OS was developed and integrated as a client node in a distributed diagnostic environment. Industrial field testing was conducted at PrJSC «Poltava Mining and Processing Plant» on a 320 kW AKZ-12-39-6UKHL4 induction motor driving a heavy-duty belt conveyor. The system successfully detected low-frequency acoustic vibrations (0.5–1 Hz) and current amplitude oscillations (5–10 %), identifying their root cause as contact degradation in the rotor rheostat. The application calculated the motor's RUL trend with an average coefficient of 0.908. *Scientific novelty*. The scientific novelty lies in the advancement of diagnostic system design principles through the synergy of stator current asymmetry identification algorithms, parallel thread execution, real-time data visualization, and automated client-server database

synchronization. *Practical importance*. The implementation enables early fault detection, reduces unscheduled downtime, lowers maintenance expenditures, and supports predictive maintenance strategies for fleets of industrial electrical machinery.
Key words: induction motor; condition monitoring; non-contact diagnostics; remaining useful life; Android OS; client-server architecture; REST API; parallel processing; fault detection.

Анотація. *Мета*. Робота присвячена вирішенню актуальної науково-технічної проблеми безконтактної діагностики та моніторингу поточного стану промислових асинхронних двигунів у режимі реального часу без зупинки безперервного технологічного процесу. Головною метою є розробка та дослідження мобільної інформаційно-діагностичної системи, здатної оцінювати технічний стан та прогнозувати залишковий ресурс електродвигунів. *Методика*. Запропонований підхід базується на вимірюванні струмів статора для виявлення параметричної електромагнітної несиметрії фаз. Функціональний аналіз та декомпозиція системних процесів виконані відповідно до стандарту IDEF0. Архітектура програмного забезпечення реалізована за клієнт-серверною технологією з використанням асинхронної фонової обробки даних корутини Kotlin, мережевої взаємодії через REST API за протоколом HTTPS та централізованого збереження інформації в БД MySQL. *Результати*. Створено мобільний діагностичний додаток під управлінням ОС Android, що виступає клієнтським компонентом розподіленої системи. Промислові випробування проведено в умовах ПрАТ «Полтавський ГЗК» на асинхронному двигуні АКЗ-12-39-6УХЛ4 потужністю 320 кВт приводу стрічкового конвеєра. Система успішно ідентифікувала низькочастотні коливання (0,5–1 Гц) та пульсації струму (5–10 %), встановивши їхню причину – погіршення контакту в пусковому реостаті ротора. Додаток розрахував тренд залишкового ресурсу двигуна із середнім значенням 0,908. *Наукова новизна*. Набули подальшого розвитку принципи побудови діагностичних систем завдяки інтеграції розрахункових алгоритмів несиметрії, засобів паралельних обчислень, візуалізації часових рядів та автоматизованого синхронного обміну даними з розподіленою БД. *Практична значимість*. Впровадження системи дозволяє своєчасно виявляти аварійні режими, зменшити ризик позапланових зупинок обладнання, оптимізувати витрати на ремонт та забезпечити перехід до обслуговування за фактичним станом.
Ключові слова: асинхронний двигун; моніторинг стану; безконтактна діагностика; залишковий ресурс; ОС Android; клієнт-серверна архітектура; REST API; паралельна обробка даних.

STATEMENT OF THE PROBLEM

Induction motors are used in drives in virtually all areas of engineering and production equipment. Their unscheduled shutdown or sudden failure is accompanied by significant economic losses. Losses are especially high at large power plants and facilities, so technical diagnostics in this area is quite developed and is mandatory for failure prevention and timely repair. Much less attention is paid to the diagnostics of medium- and low-power power plants, but their importance is constantly growing, given the development of autonomous drives and the mass of the latter. Diagnostics is mainly carried out by thermal, electrical and vibroacoustic methods, which in certain situations, such as low temperatures, vibroacoustic interference, etc., are not applicable or do not provide the required reliability of information.

The solution of modern problems of monitoring and diagnostics of induction motors requires the involvement of fundamentally new methods and tools, including diagnostics based on the pattern of the external magnetic field, acoustic and even organoleptic diagnostic methods that involve the use of human senses. At the same time, the measurement of diagnostic parameters is carried out by a non-contact method and, importantly, in the operating mode. This makes it possible to identify damage in motors more quickly, efficiently, and without the help of additional equipment, as well as the possibility of using express methods to monitor and analyze the current state of electric motors during their operation without interrupting the technological process.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Novel non-contact methods for real-time monitoring and diagnostics of induction motors (IMs) have been developed and implemented. These methods enable prompt and cost-effective detection of motor faults and condition monitoring during operation without disrupting the technological process. This will lead to a significant reduction in operating costs compared to traditional preventive maintenance methods (PM) [1]. Current research in IM diagnostics is focused on developing non-contact methods that do not require stopping the technological process. Advances in diagnostic theory and information technology have made it possible to assess motor condition and resource in real time as well as remotely.

A non-contact IM monitoring method based on stator magnetic field measurement and signal extraction is presented in [2, 16, 17]. This signal carries information about changes in motor parameters for predicting its condition, remaining life, and further operation. «Step-detection» algorithms make it possible to determine the moment of parameter change, which allows for quantitative assessment of the motor's condition.

Works [3–6] are devoted to mathematical modeling of processes in IMs, development of sensorless identification methods, and calculation of electromagnetic parameters. Some authors propose methods for sensorless calculation of stator and rotor active resistances, which greatly simplifies the diagnostic process and reduces its cost.

Works [7–10], [18] describe statistical and analytical methods for online calculation of IM electromagnetic parameters. The calculated parameters are used in monitoring systems to assess motor performance and timely detection of faults.

Mobile applications for non-contact IM diagnostics are considered in [12]. Vibration sensors are connected to smartphones, and based on the measurement data, a conclusion is made about the motor's condition. [13, 15] The applications also allow calculating operating parameters: rotor resistance, rotor reactance, shaft torque and IM efficiency based on the data in the machine's nameplate. The application can also model and visualize the torque and slip characteristics of the IM. [11, 14] – virtual stands and mobile applications for use in the educational process, which allow to study the behavior of IMs, including those with parametric asymmetry.

However, most mobile solutions focus primarily on local parameter calculation. For enterprises operating a large number of motors, it is preferable to use a networked information and diagnostic system. Such a system can provide not only the assessment of the current state of an individual motor but also the accumulation of statistics for a group of electric motors, the comparison of results across different production areas, and decision support for maintenance.

Studies [18–23] consider the design principles of networked information systems, the organisation of client-server exchange, data transmission, and information storage in mobile applications. Such solutions can be utilised to transmit measurement and calculation results to the server side and a centralised database.

Papers [24–28] discuss the means of organising network exchange, as well as the issues of parallel and asynchronous data processing in mobile and embedded systems. Their application is expedient for diagnostic applications that simultaneously perform data input, parameter calculation, plotting, database writing, and information transmission over a computer network.

An analysis of methods for estimating the parameters of electric drive motors indicates the need to develop new scientific and technical solutions that differ from existing ones in their simplicity and feasibility of automation within the electromechanical system. A solution to this problem may involve equipping the electric drive with a monitoring system that controls changes in characteristics and decides on the decommissioning of electric motors if the parameters of the electromechanical system change so rapidly that an emergency failure is likely to occur before the scheduled shutdown for technical inspection.

Therefore, the development of a mobile application for a system to diagnose and predict the remaining resource of induction motors based on smartphones and tablets, along with its investigation, determines the relevance of this study and constitutes the aim of this paper.

OBJECTIVES AND PURPOSES OF THE STUDY

The purpose of the paper is to develop and investigate a mobile application for diagnosing and predicting the current life of induction motors. To achieve this goal, it is necessary to solve the following tasks:

– to analyse existing methods and tools for motor diagnostics;

– to develop algorithms and a mobile application for the induction motor diagnostic system;

– to determine the principles of interaction between the mobile application, the server side, and the database;

– to propose an approach for the asynchronous processing of diagnostic data within the mobile application;

– to distribute the functions of the mobile application among separate processes;

– to evaluate the scalability of the information system;

– to conduct experimental investigations.

MAIN MATERIAL

I. DEVELOPMENT OF THE MOBILE APPLICATION

The development of information technologies has led to the realistic possibility of utilising mobile devices and companion applications for gadgets as measurement and diagnostic systems.

Depending on the tasks at hand, the requirements for the software of such mobile applications are formulated as follows:

– it must function with the OS of the mobile device and allow the user to work with a MySQL database;

– it must automatically calculate parameters and other diagnostic motor data using the values of the monitored parameters;

– it must provide the capability to view plots of monitored parameters and changes in the remaining resource over time;

– it must ensure data exchange with the server side via a local network or mobile Internet;

– it must support synchronisation with the database;

– it must ensure the execution of complex computational operations in the background without blocking the user interface.

To display the functional relationships, a context diagram was created in accordance with the IDEF0 standard, describing data analysis in Android technology for studying the state of an induction motor using stator current measurement values as the monitored parameter (Fig. 1).

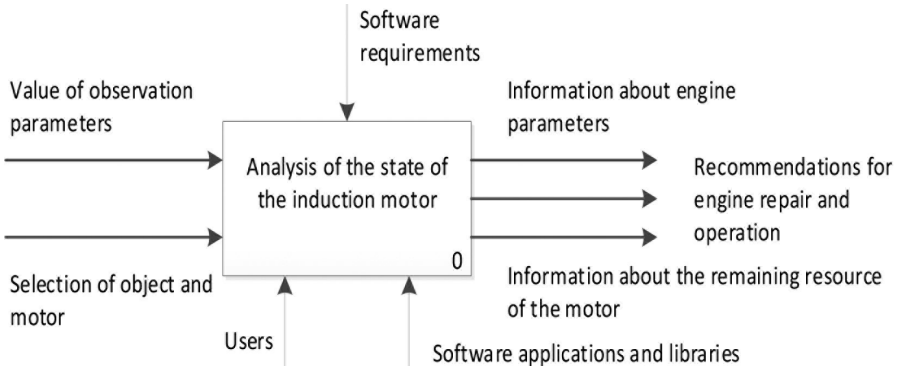


Fig. 1. The diagram for analyzing the process of monitoring the induction motor's condition based on observation parameter measurements

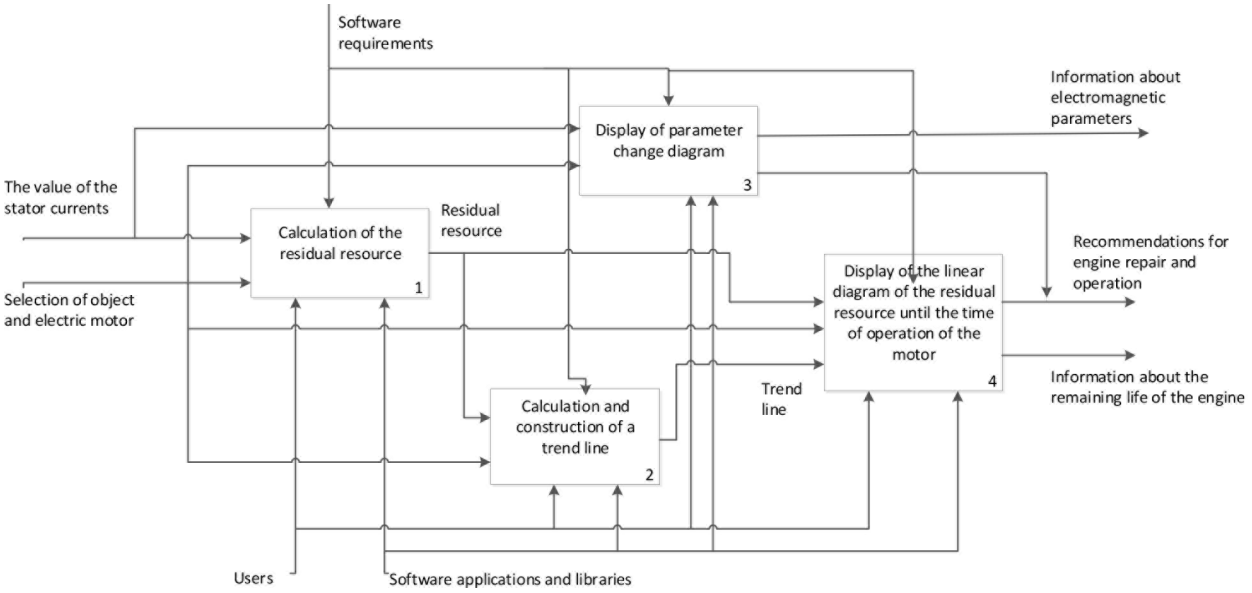


Fig. 2. The decomposition diagram of the process for monitoring an induction motor based on stator current observations

As a result of the functional analysis of the main process, the decomposition diagram shown in Fig. 2 was obtained. The decomposition diagram details the primary function of the system.

The monitoring system software allows for storing calculated diagnostic information. This information includes the asymmetry coefficient of active resistances and other indicators. All data is stored in specialized databases. Based on this information, automatic calculations of the current motor state are performed.

The monitoring system provides:

– reduced downtime and increased productivity. automatically calculate the current motor status based on the entered data;

– perform calculations of the current motor state based on observation parameters;

– maintain other observation objects in the database and allow their viewing;

– store information about other motors in the database and provide access to view them;

– create new records;

– edit data for existing objects and motors;

– view graphs generated from monitoring data;

– calculate and view trend lines and short-term forecasts for the motor.

All data is automatically stored in the database. Figures 3, *a–d* and 7 show the windows of the mobile application.

The obtained results from monitoring and calculated current remaining useful life (Fig. 6) indicate a high dispersion value. This is attributed to load fluctuations on different days of the week.

Since the developed mobile application functions not only as a standalone tool for data input and display but as a client component of a distributed information and diagnostic system, the generalised interaction structure of its main components is presented (Fig. 4).

The mobile application provides diagnostic data input, initial validation, calculation of diagnostic parameters, and visualisation of the obtained results.

Data transmission between mobile clients and the server side is carried out via a network interface using either the enterprise local area network or mobile Internet.

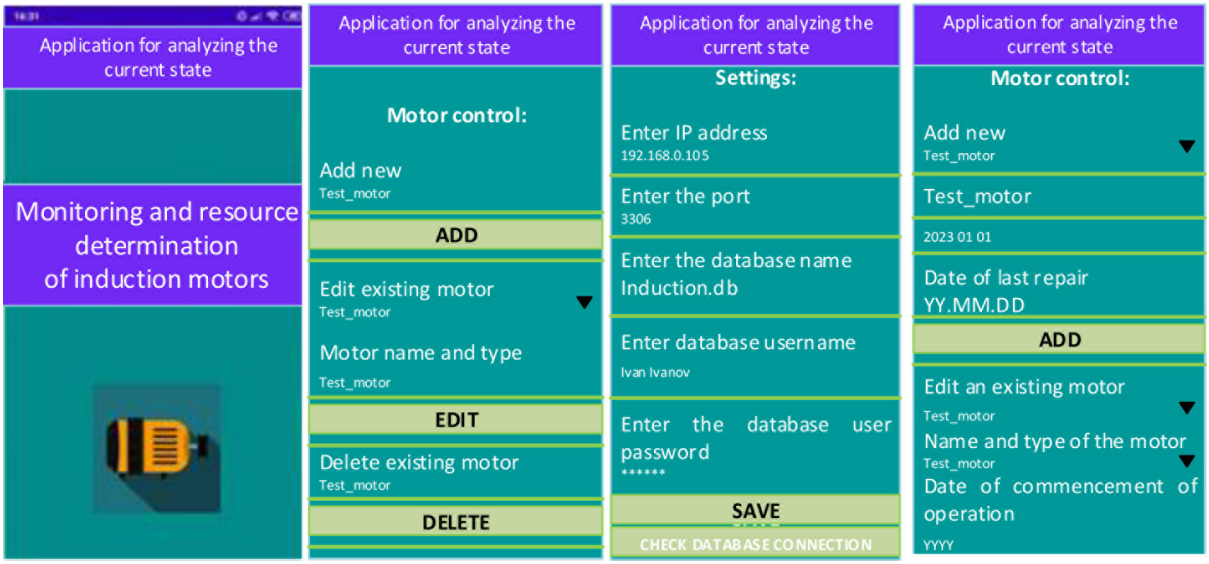


Fig. 3. Graphical user interface of the mobile application: a – Main window; b – Object management menu; c – Settings menu; d – Setting the data of the diagnosed motor

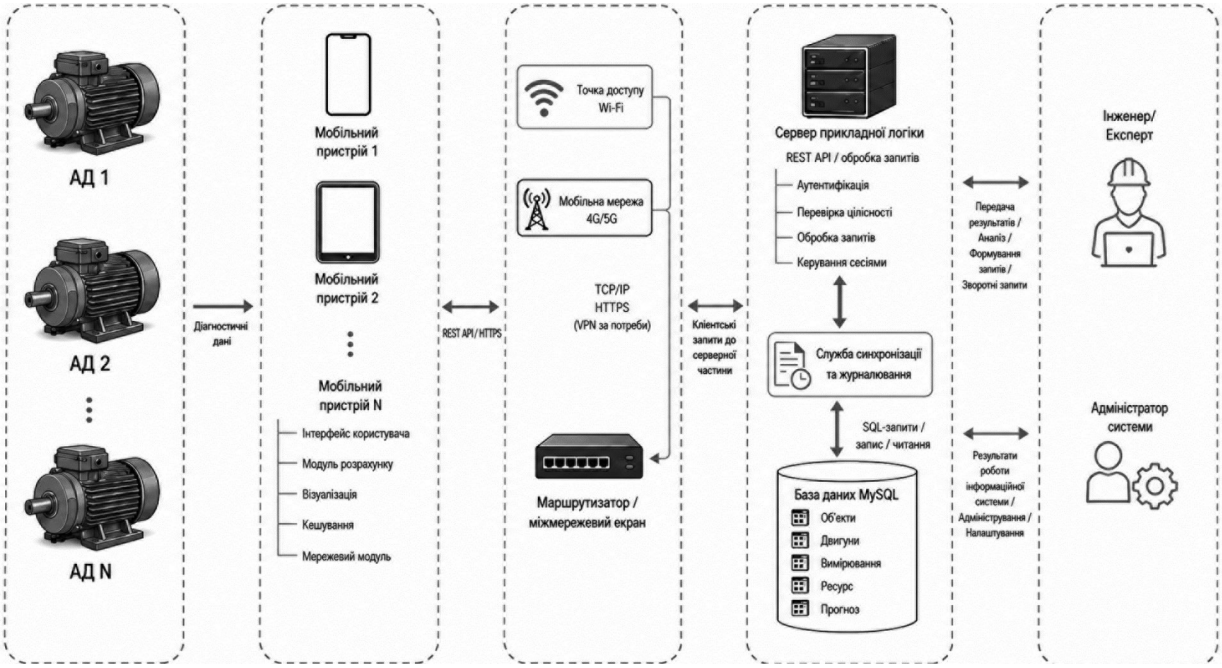


Fig. 4. Client-server architecture of network interaction for the mobile induction motor diagnostic system

Information exchange is implemented using TCP/IP stack protocols, while application-level interaction between the mobile application and the server is executed via a REST API using a secure HTTPS connection.

The application logic server receives requests from mobile clients, processes them, handles user authentication, verifies data integrity, and manages sessions. The synchronisation and logging service ensures consistency between locally stored data and the server, records exchange events, and monitors the correctness of data transmission.

A MySQL database is used for the centralised storage of information regarding technological assets. This structure enables each diagnostic result to be linked to a specific motor, facility, and point in time. Consequently, this allows for the accumulation of a history of changes in the technical condition of the motor, the analysis of its degradation indicators, and the planning of maintenance schedules.

An engineer or expert can view the induction motor diagnostic results, analyse changes in diagnostic parameters over time, evaluate the remaining resource,

and generate conclusions regarding the current technical condition of the equipment.

The system administrator is responsible for maintaining the operational capacity of the information and diagnostic system. Their functions include managing user accounts, configuring access permissions, monitoring the operational correctness of the server side, checking the database status, analysing event logs, and supporting synchronisation processes.

Since records may simultaneously arrive at the system from different mobile devices, the server side of the system must ensure the parallel handling of client requests. Before saving data into the database, the system must verify the correctness and uniqueness of the records.

Within the mobile application, parallel data processing is implemented by separating main operations into independent asynchronous tasks. The main thread of the application must exclusively serve the user interface. Operations that require significant computational resources or are potentially long-running are preferably moved to the background. Such operations include the calculation of diagnostic parameters, the determination of the remaining resource, local storage of records, and data transmission to the server.

Calculation of diagnostic parameters in a background computational thread:

```
val r = withContext(Dispatchers.Default)
{
     calc.run(d)
}
```

where *d* represents the input diagnostic data, *calc* is the calculation module, and *r* is the obtained diagnostic result.

Network transmission of results in the background mode:

```
withContext(Dispatchers.IO) {
     net.send(r)
}
```

where *net* is the network exchange module, and *r* is the result transmitted to the server side.

This avoids blocking the user interface and ensures the stable operation of the mobile application during the processing of diagnostic information.

II. EXPERIMENTAL RESEARCH

Experimental investigations of the diagnostic system were conducted under production conditions at the iron ore mining and processing plant of Private Joint Stock Company (PrJSC) “Poltava Mining and Processing Plant”, Horishni Plavni. The mobile application of the diagnostic system was installed on a Redmi 5 Plus smartphone running Android OS version 8.1.0. An AKZ-12-39-6UKHL4 induction motor with a rated power of 320 kW was selected as the investigated induction motor. This motor is part of the drive system for belt conveyor No. 82 at the SMS-2 section of the crushing and beneficiation plant. Conveyor No. 82 has a length of 182 m and a capacity of 3000 t/h. It transports ore from Barmac crushers and wet drum magnetic separators.

The appearance of the induction motor is shown in Fig. 5.



Fig. 5. Investigated induction motor

This motor was selected as the object of monitoring because the maintenance personnel detected the following deviations in the signs of normal operation:

1. At nominal load during motor operation, audible vibrations are detected. These vibrations exhibit periodic low-frequency changes in tonality. The sound oscillations occur at approximately 0.5–1 Hz.

2. Under nominal load, the conveyor motor exhibits a weakly pronounced irregular movement of the belt or minor jerks. This behavior is associated with uneven rotor rotation. The rotational frequency is slightly reduced.

3. At nominal load, the ammeter needle shows oscillations. The amplitude of these oscillations is approximately 5–10 % of the nominal current value. The average current remains at the nominal level.

Analysis of the observed indicators allowed us to determine the cause of this behavior of the induction motor. Deviations in normal operation were associated with poor contact in the rotor rheostat. The smartphone screen displays the dependence of the induction motor’s remaining resource (Fig. 6). Depending on the load, the current value of the resource may fluctuate. The average calculated value is 0.908 and tends to decrease.

DISCUSSION AND CONCLUSION

The paper develops and investigates a mobile information and diagnostic system for assessing the current state of induction motors without stopping the industrial process. The proposed approach is based on using diagnostic parameters obtained from stator current measurements, which enables rapid assessment of the motor condition.

The developed mobile application provides diagnostic data input, primary validation, calculation of the current state, determination of the remaining resource, construction of graphical dependencies, and generation of a short-term motor forecast. This allows the

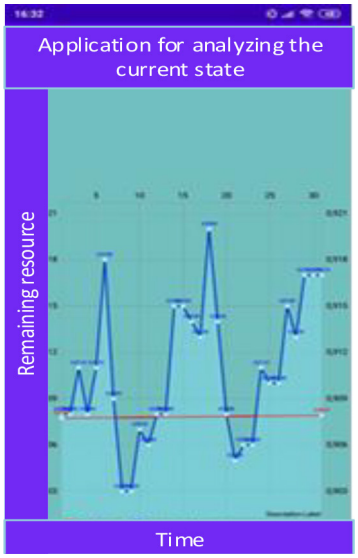


Fig. 6. The result of the application

mobile application to be used as a convenient software tool for the prompt analysis of the technical condition of induction motors without involving complex stationary equipment.

The study substantiates the feasibility of presenting the mobile application as a client component of a distributed information and diagnostic system. Data transmission to the server side via the enterprise local area network or mobile Internet, the use of a REST API, a secure HTTPS connection, and a centralised MySQL database enable the transition from the local analysis of an individual motor to the networked monitoring of a group of electric motors. Such a structure facilitates the accumulation of measurement history, the comparison of results for different assets, and decision support for maintenance.

The proposed organisation of asynchronous data processing within the mobile application enables the separation of user interaction operations, diagnostic parameter calculations, local storage, plotting, and network exchange. This reduces the risk of blocking the user interface and enhances the operational stability of the application during the processing of diagnostic information. At the server level, parallel handling of client requests is a prerequisite for system scalability in the case of simultaneous operations by multiple mobile devices.

Experimental testing of the system under industrial conditions confirmed the practical suitability of the proposed approach.

The practical value of the proposed system lies in the capability to timely detect hazardous states of induction motors, reduce the number of unscheduled downtimes, lower repair costs, and improve the efficiency of preventive maintenance planning. The centralised accumulation of results in the database allows for the generation of a history of the technical condition of each motor, the analysis of parameter changes over time, and the making of more informed engineering decisions.

Further development of the research should be directed towards extending the server side of the system, improving the mechanisms for synchronising locally stored data, implementing multi-user access, increasing the security of information exchange, and integrating the system with industrial networks for monitoring electromechanical equipment.

Information on the Use of Artificial Intelligence. While preparing this article, artificial intelligence tools were used exclusively for language editing, grammar checking, translation, or other auxiliary tasks, without using the content they generated as the results of academic work.

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