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RESEARCH ON THE POSSIBILITIES OF SOLUTION OF THE MONITORING PROJECTS OF THE RAILWAY POWER SUPPLY SYSTEM

Об'єктом дослідження є параметри моніторингу системи електропостачання залізничного транспорту. Пристрої реєстрації параметрів роботи об'єктів системи постачання електроенергії PMUs складають основу системи моніторингу перехідних режимів WAMS. Важливим аспектом елементів WAMS є синхронізація даних, яка технологічно забезпечується за допомогою супутникових систем орієнтації.

В ході дослідження використовувалися системний аналіз, системний підхід до проблеми, а також способи синхронізації та систематизації даних.

Досліджено методи розв'язування задач процесів моніторингу системи електропостачання залізничного транспорту. Функції діагностики, що в даний час реалізуються за допомогою PMUs, WAMS, фактично зосереджені та обмежені на ділянках електропостачання, і включають в себе моніторинг низькочастотних коливань системних параметрів. А також ідентифікацію аварійного режиму та визначення місця пошкодження в об'єктах системи електропостачання. Крім того, для використання цих функцій, разом з тим, вже при сучасному розвитку систем, необхідним є забезпечення діагностичних функцій в масштабі енергосистем, з мінімізацією участі та впливу людини у формуванні результатів оцінювання режимів. Це пов'язано з тим, що є необхідність розширення діагностичних функцій щодо параметрів об'єктів системи електропостачання, використовуваних систем моніторингу, які дозволять розв'язувати задачі оперативно-диспетчерського управління цих об'єктів.

Завдяки цьому забезпечується можливість розв'язання оперативно-диспетчерських задач, оцінювання та прогнозування стану при обробці інформації, її синхронізації та систематизації. А також спостереження і синхронізації вимірів за часом, що значно підвищує рівень оперативно-диспетчерського управління режимами роботи об'єктів системи електропостачання. У порівнянні з аналогічними технологіями, нові, засновані на використанні пристроїв PMU для збору даних, мають перевагу перед традиційними технологіями SCADA, які проводили вимірювання об'єктів системи без синхронізації за часом.

Ключові слова: *система електропостачання, залізничний транспорт, синхронізація даних, комп'ютерні засоби, налаштування інтерфейсу людина-машина.*

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1. Introduction

The solution to the problems of operational management, ensuring reliable, flexible and efficient operation of the power supply system can be achieved when moving to a new level of information support. The functions of time synchronization of data in distributed monitoring systems are most often implemented on the basis of existing

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satellite-based orientation technologies – GPS satellite global positioning system and GLONASS (global navigation satellite system). They are solved by the tasks of monitoring transients, which provides for the creation of appropriate means of collecting information and software systems for its processing, which must meet a number of requirements [1]. And to ensure the necessary level of reliability and safety of the system, it is necessary to solve the problem of monitoring the frequency, power, current, voltage and their angular parameters. This is possible due to the development of a new technology for vector measurement of the operational parameters of these systems, which provides synchronization of measurements using GPS, provides operational personnel with qualitatively new information in the form of voltage vectors [2].

The synchronized PMU voltage vector measurement devices form the object level of WAMS mode monitoring systems. They also open up the possibility of solving the problems of operational dispatch control of electric networks, based on the information exchange protocol that is used in the data collection system with PMU.

The experience of scientists in works [3, 4] shows that monitoring systems are designed for continuous monitoring of the parameters of the modes of electric power systems, assessing and forecasting the development of current operating modes. As well as the issuance of the received information in digital form to control systems and information systems.

Therefore, the urgent need is the combination of parameters from various registrars and other monitoring devices for the possibility of solving operational dispatch problems, assessing and predicting the state of information processing. At the same time, *the object of research* is the monitoring parameters of the railway transport power supply system. And *the aim of research* is studying the solution of problems of monitoring the railway power supply system by processing significant amounts of information due to its synchronization and systematization.

2. Methods of research

In order to continuously diagnose and predict the state of electrical equipment, of the «Regina-F» type controllers (Ukraine) are used to register emergency modes of traction substations of Ukrainian railways. Based on these registrars, a transient the wide area monitoring systems (WAMS) monitoring system (TMS) is created, which is designed for continuous monitoring of the parameters of the electric network modes, assessment and forecast of the development of current operating modes. As well as transmitting the received information in digital form to control systems and information systems, it provides functional capabilities for diagnosing the power supply system, in particular, assessing the condition, monitoring transient conditions and low-frequency oscillations [4]. With the help of the «Regina-F» controllers, it is possible to obtain research results for modeling the modes of electric networks and, in particular, for solving the problems of state assessment.

3. Research results and discussion

Monitoring of the parameters of the modes of electric networks, evaluating and forecasting the development of current operating modes and issuing the received information in digital form, measuring the instantaneous values of phase currents and voltages and calculating electrical parameters is carried out using WAMS. The system consists of PMUs, data transmission channels between electric power facilities and dispatch centers, as well as means for processing the information received. The communication server provides the collection, registration and archiving of data from multifunction measuring transducers, the reception of accurate time signals from a GPS receiver, and the provision of data at the request of remote consumers in on-line and off-line modes [5].

In general, in assessing the reliability of WAMS, three risk categories are distinguished, which include information security, equipment reliability and the operability of the human operator. The focus is on research related to the elimination of WAMS vulnerabilities related to the dependence of the time stamp of synchronized measurements on GPS signals [6], the reliability of PMUs and software. As well as the resilience of servers and data concentrators with respect to concentrated cyber-attacks.

WAMS for monitoring the state of the objects of the power supply system of the railway transport is built on the basis of «Regina-F» devices [7]. This implements monitoring at the level of world power supply intellectualization programs and gives the potential for the implementation and development of analysis and control functions in accordance with the latest trends.

In connection with the transition to intelligent energy, including in traction substations, the number of monitoring devices is growing, in turn, they accumulate more available data to help operational dispatch personnel monitor the status of the power supply system in real time. However, more data does not necessarily mean more information. Only processing converts data into useful information. The next generation monitoring functions are designed to provide dispatchers with useful information, not primary data. Data forms the basis for decisions made by dispatchers [8].

It is especially important to observe not only the instantaneous values of currents and voltages, but also other quantities (parameters) and signals, since all these quantities can be indicators of monitoring. In the form of linear or nonlinear functions of input signals, the results of their operator transformations, including obtaining functionals, their harmonic analysis, etc. Obtaining these parameters and signals is the basis for performing calculations of various other parameters of current and voltage of electric networks, as well as other parameters.

The phase angles of voltages on substation busbar systems are the most «important» variables of the state vector, since they are related to the boundaries of static stability and the flow of power along the power line [9]. Therefore, for the active power transmitted along the line between the busbar (p) and (k), the actual expression:

$$P_{be} = \frac{U_b \cdot U_e}{X_{be}} \sin \delta_{be}, \quad (1)$$

where U_b – the voltage at the beginning of the line; U_e – the voltage at the end of the line; δ_{be} – the angle between them; X_{be} – the transmission reactance.

Permanent registration of synchronized state variables of the system allows verification and refinement of the design models of the network and the results of mathematical modeling. According to the expression for reactive power, let's write:

$$Q_{be} = \frac{U_b^2}{X_{be}} - \frac{U_b \cdot U_e}{X_{be}} \cos \delta_{be}, \quad (2)$$

hence the transfer reactance:

$$X_{be} = \frac{U_b^2 - U_b \cdot U_e \cos \delta_{be}}{Q_{be}}. \quad (3)$$

The analysis of archives of synchronized measurements of phase angles at the «key» points of the power system before and after emergency shutdowns also allowsto draw conclusions about the availability of reserves in the power system to respond to various violations of the regime [10].

The next generation monitoring and control functions offer advanced visualization methods and the ability to easily customize the man-machine interface for each dispatcher based on itspreferences in order to help quickly comprehend information. With the use of human-oriented monitoring functions, the effectiveness of operational dispatching personnel will increase in understanding the current working conditions, identifying abnormal operating conditions, and considering potential problems [11]. Moreover, the monitoring system should provide information in real time so as not to overload the dispatcher with messages, it may interfere with the work.

Information from sensors in traction substations and power lines, instead of being sent directly to dispatchers, can go through an intelligent data processing procedure to quickly determine the viability of equipment. Providing dispatchers with potential data on component malfunctions can help them anticipate problems in the operation of the traction power supply system and develop a plan to mitigate the consequences of an emergency condition [11, 12].

For example, a substation protection system can record incidents of malfunction (emergency condition). Instead of providing the dispatcher with the full amount of recorded data, he can be provided with information about specific types of faults and where they occurred. The provision of such information will allow operational and dispatching personnel to save a large amount of time. Information can be additionally used in an operational safety assessment to help dispatching personnel analyze system stability problems and develop optimal strategies for their correction.

4. Conclusions

It is revealed that new technologies based on the use of PMU devices for data collection have an advantage over traditional SCADA technologies, which performed network measurements every 2–4 seconds without time synchronization. Therefore, technologies with PMUs proposed in this work, due to synchronization with GPS, will ensure synchronization of time measurements of the modes of objects of the railway power supply system. This significantly increases the level of operational dispatch control of operating modes. The research results will allow the registration of the results of the monitoring measurement on-line, as well as in real time, which is especially important for their current use. It is proved that it is precisely PMU devices with time synchronization that allow real-time monitoring of network parameters and elimination of emergency situations, information operations of temporary and spatial synchronization, which is necessary for monitoring the railway power supply system.

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