Web Application for an Information System for Diagnosing the Quality of Electricity Consumers Using Cloud Technologies

Nikolay Kiktev [a,b], Alexey Kutyrev [c], Dmitriy Khort [c] and Oleksii Kalivoshko [d]

[a] *National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony str., 15, Kyiv,03041, Ukraine*
[b] *Taras Shevchenko National Univercity of Kyiv, Volodymyrs'ka, 64/13, Kyiv, 01601, Ukraine*
[c] *Federal Scientific Agroengineering Center VIM, 1-st Institutsky proezd, 5, Moscow, 109428, Russia*
[d] *National Science Center "Institute of Agrarian Economics", Heroiv Oborony str., 10, Kyiv, 03041, Ukraine*

Abstract.
The work is devoted to the development of software for an automated system for diagnosing the quality of electricity consumers using cloud technologies. The WEB interface of the system is designed and developed for interactive interaction and visualization of indicators with the output of tables and graphs for analysis, graphical representation and display of the results of diagnostics of electricity quality. Data modeling was performed using the Google Colab service and implemented in the Phyton language. Dynamic database is designed in MySQL DBMS. The web interface is implemented using HTML, JS and PHP. The PhpStorm application and the local OpenServer server were used for the construction.

Keywords [1]
electricity, quality, vector measurements, dynamic database, algorithm, program, application, real time chart, web-interface

1. Introduction.

The relevance of scientific research and development, to which this work is devoted, is due to the unsolved problem of creating an automated system for diagnosing the quality of electricity of consumers using renewable sources of electricity. Currently, some customers of energy companies use devices for generating electricity (solar panels, windmills, etc.). And to save costs or to generate income, they also return energy to the grid. Since the electricity company is legally obliged to buy electricity produced by consumers, it wants to make sure that this will not damage the network. Now the network must be measured and monitored to ensure that the power coming into the network from other sources has the same quality and standards that the client equipment expects from it.

The quality of electricity is the quality of equipment that consumes this energy; it cannot guarantee its quality at the place of consumption.

The tasks of electricity quality management in enterprises (including agricultural) are an important task to improve the functioning of electrical equipment, computer equipment, especially servers, network equipment and other devices. Uninterrupted operation of electrical devices affects the quality of

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EMAIL: nkiktev@ukr.net (A.1); alexeykutyrev@gmail.com (A.2); dmitriyhort@mail.ru (A.3); alek-k@ukr.net (A.4)
ORCID: 0000-0001-7682-280X (A.1); 0000-0001-7643-775X (A.2); 0000-0001-6503-0065 (A.3); 0000-0003-0417-4529 (A.4)

production and the final product, as well as the service life of electrical equipment. These tasks should be based on:

- monitoring (continuous control) of electricity quality indicators at all levels of electricity consumption;
- information support of electricity supply to consumers;
- setting requirements for the consumer and the system;
- application of synchronized vector measurement technology for monitoring and quality management of electricity supply and electricity consumption (WAMS-technologies);
- developed, substantiated and timely applied measures to prevent reduction of electricity quality (NPP);
- assessment of the impact of nuclear power plants on the reliability of electricity supply, etc.

The article is devoted to the description of software development for the automated system of diagnostics of quality of consumers of the electric power with use of cloud technologies. The authors designed and developed a WEB-interface system for interactive interaction and visualization of indicators. The program should display tables and graphs for analysis, graphical representation and display of the results of diagnostics of electricity quality.

2. Literary review.

Many publications have been devoted to the study of the quality of electricity. Scientists from the National Technical University of Ukraine "Kyiv Polytechnic Institute" investigated a system for monitoring the quality of electrical energy in decentralized power supply systems [8]. Scientists of the Institute of Electrodynamics of the National Academy of Sciences of Ukraine have developed a recording device (SP) "Regina-CH", which in its technical and functional characteristics is not inferior to the best foreign analogues [9]. The device provides registration of instantaneous values of currents and voltages, storage and processing of measurement results; their reflection in the form most informative for personnel (text messages, graphs, tables, waveforms, etc.), as well as the transmission of information to any level of the control hierarchy with its binding to the signals of the exact time.

These devices are an integral part of the transient mode monitoring system (SMPR), integrated into a local area network that combines measuring transducers or other lower-level monitoring devices and a data acquisition server (Fast Ethernet 100 Mbit/s, TCP/IP). A top-level remote computer is installed in the dispatch center (DC) of the united energy system of the UES (NEC "Ukrenergo") and the corresponding electrical system to receive information from the switching server [9].

Intelligent electronic devices ENIP-2 manufactured by eNergoservice Engineering Center LLC (Arkhangelsk, Russia) [10] measure synchronized vectors (synchrophasors) of currents and voltages (PMU, Phasor Measurement Unit), as well as synchronized measurements of the parameters of the power system mode according to the current values of current and voltage and the main harmonic and transfer of parameters to automated technological control systems via digitally galvanically isolated Ethernet interfaces.

These devices are intended for use in transient monitoring systems (WAMS) and in automated process control systems of a new generation of WACS, in substation automated control systems and automated dispatch control systems, in automatic process control systems of active adaptive networks, mode automation. ENIP-2 devices can directly transmit data when connected to the local network of a substation or power plant, or through devices for collecting and transmitting data of synchronized PDC measurements or through similar devices for collecting and transmitting technological information.

SMPR is a multi-level distributed automated system for collecting, processing and storing data of synchronized vector measurements of parameters of electromechanical transients and steady-state modes. In the EU countries, this class of systems is called Wide Area Measurement System (WAMS) [11]. One of these systems was developed by the company "Parma" (St. Petersburg, Russia). Digital process recorders PARMA RP4.11 and PARMA RP4.12 - microprocessor devices combining the functionality of autonomous emergency event recorders, synchronized vector measurement devices are used as the main element of the lower level of the SMPR (the level of energy facilities). At the upper level of the SMPR, a specialized software package WAProtector is used - this is a specialized SCADA, which is focused on working in real time with large volumes of synchronized vector measurements obtained using the IEEEC37.118.2-2011 protocol. The program allows you to create custom algorithms designed to solve problems of monitoring and ensuring the stability of the power system in real time. Other devices for measuring the quality of electricity, including synchronized vector measurements, are presented in the catalog [7].

The issues of the efficiency of the use of energy resources and their impact on production technologies, as well as environmental safety were studied by scientists from China, the European Union, Brazil [2-4], etc. Justification of the effectiveness of the use of renewable energy sources is actively engaged in the European Union. In the work of American researchers [5], a microfaser (PMU) is described - a device using intelligent inverters that support the Internet of Things (IoT). The automation of vector measurement systems was also carried out by Croatian researchers, who developed an algorithm for detecting and protecting distributed generation of a microgrid [12].

Ukrainian researchers were engaged in the development of methods for effective management of electricity quality, including the use of renewable energy sources. In the dissertation work of L.A. Kopylova (Ukraine) [1], an intelligent automated control system for power consumption and power supply of an industrial enterprise was developed. Intelligent control methods are represented by fuzzy logic. I.S. Goncharenko's dissertation research is devoted to determining the optimal options for connecting renewable energy sources to electric grids [6]. The work determines the optimal connection points, capacity and type of renewable energy sources.

The development of software tools for statistical analysis in systems using restorative energy is described in the works of Ukrainian researchers N. Kiktev, V. Osipenko et al. [14, 17]. The use of cloud technologies and the Internet of Things in automation systems was carried out by researchers at the National University of Biological and Environmental Sciences of Ukraine [15]. Students of Taras Shevchenko National University of Kyiv took part in the development of software applications for the diagnosis of electricity quality [13].

The objective of the study is to create a distributed information management control system and a web application for diagnosing the quality of electricity using renewable sources.

3. Materials and methods

3.1. Power quality diagnostics technology using synchronized vector measurements

Generally, the process of diagnosing the quality of electricity by the method of synchronized vector measurements can be represented in the form of a block diagram (Fig. 1).

The standards set the following indicators of the quality of electrical energy [1, 2]:

- steady-state voltage deviation δUy;
- the scope of the voltage change δUt;
- flicker dose Pt;
- the distortion coefficient of the sinusoidal voltage curve K_U;
- the coefficient of the harmonic component of the voltage $K_U\ (n)$
- the coefficient of stress asymmetry in the reverse sequence K_{2U};
- the coefficient of stress asymmetry in the zero sequence K_{0U};

- frequency deviations Δf;
- duration of voltage failure Δtn;
- pulse voltage U;
- temporary overvoltage coefficient $K\ U$.

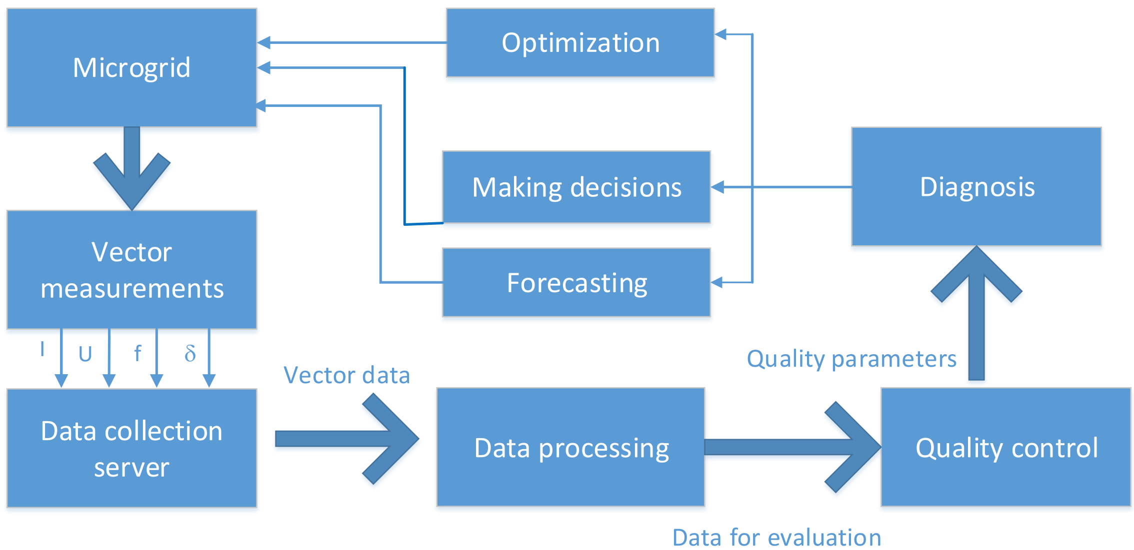

Figure 1: Block diagram of the power quality diagnostics technology using synchronized vector measurements

3.2. Formation of input information.

The input information is represented by the readings of 4 recorders of electricity indicators (PMU devices), which are located in 4 different locations:

- Central PMU (Kiev region);
- West PMU (Lviv region);
- East PMU (city of Slavyansk);
- South PMU (city of Kherson).

Data modeling was performed using the Google Colab service and implemented in the Phyton language. Four program codes generate real-time indicators in parallel and are written to the MySQL database. According to these indicators, the voltage and frequency deviation is calculated. This web interface should provide an opportunity to view indicators from measuring devices connected to the electricity network in different places. These indicators should be presented both in tabular form and in a more user-friendly form - graphical.

3.3. Choice of system development technology.

To create the database itself, the HeidiSQL software environment is used - this is free software, the purpose of which is ease of learning. "Heidi" allows you to view and edit data and structures from computers running in one of the MariaDB, MySQL, Microsoft SQL, PostgreSQL and SQLite database systems. MySQL was chosen as the system, which is the most popular database management system (DBMS). In order for parameters with PMU to be entered into the database, the Python language was used. It generates different values of frequency, voltage and current. One of the main requirements for web interfaces is their identical appearance and the same functionality when working in different browsers. The classic and most popular method of creating web interfaces is using HTML with CSS and

JavaScript, usually using server-side scripting languages.

3.4. Architecture of synchrophasor technology.

Synchrophasor technology (CT) is usually the use of input data from a PMU synchrophasor for monitoring. It includes a large variety of sensitive tools for transferring data from the PMU to the rest of the network, as well as for sending this data for processing by various applications. ST is presented in the form of a three-level structure [16].

1) <u>Measurement level</u>

The measuring layer (level) includes current and voltage transformers, analog units and PMUs, which have a built-in GPS for data timestamp. They are used at substations and are designed to collect analog data from transformers.

2) <u>Data collection level</u>

After data collection, PMU units send data to vector data concentrators (PDCs), which are devices that combine data from a certain number of measuring instruments. They receive phase measurements from individual remote PMUs through the communication medium and store this data in the DBMS. The PDC function is data processing, synchronization and storage, through its monitoring system it also provides information about system performance parameters such as latency, data quality, frame rate, etc.

In the standard configuration, PMU units connect the main substations in transmission systems and transmit measurements in real time viaInternet or other means of communication, in particular, fiber-optic. This data is collected by a local PDC, where it is aggregated into a DBMS. Local PDCs belonging to various enterprises can also be connected to a centralized PDC.

<u>3) Application Layer / Energy management layer of the Global Measurement System (WAMS)</u>

This layer is part of the CT, through which the PDC sends data to the control stations via communication channels. Since the data is provided in real time (that is, without taking into account the transmission delay), they provide a real-time network scenario. Applications are being developed to use this data to provide better visibility of the system. The architecture of the system software is shown in Fig. 2.

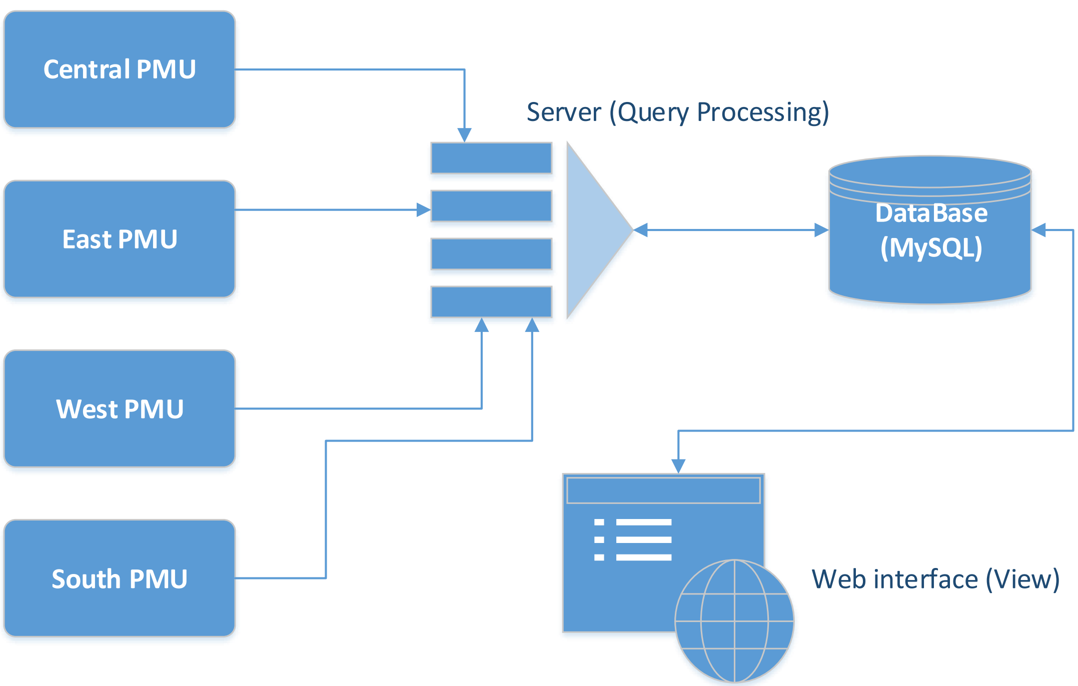

Figure 2: Information system software architecture

3.5. Database structure. Data to be processed.

The system uses the following tables: locations, pmus, indicators, quality. The following indicators were used as input data for building the interface:

- date and time;
- frequency indicator;
- voltage indicator;
- amperage indicator;
- voltage deviations;
- frequency deviations.

3.6. Stages of creating an information system.

Stage 1. Construction of a simulation model of four devices for generating electricity indicators. The simulation model is implemented using the Google Colab service in Python with the MySQL library [13].

Stage 2. Designing and creating a database for storing indicator values. The database is hosted on a remote server and runs on MySQL. The program works as a server providing "multi-user access" to database objects. The HeidiSQL application shown in Fig. 3 was used to build the database.

Stage 3. Construction of an analytical system for determining the quality of electricity using a mathematical apparatus (Fig. 4). The analytical system is implemented using the Google Colab service in Python. A fragment of the code for calculating the quality of electricity is shown in Fig. 5.

Stage 4. Defining user requirements for the web interface.

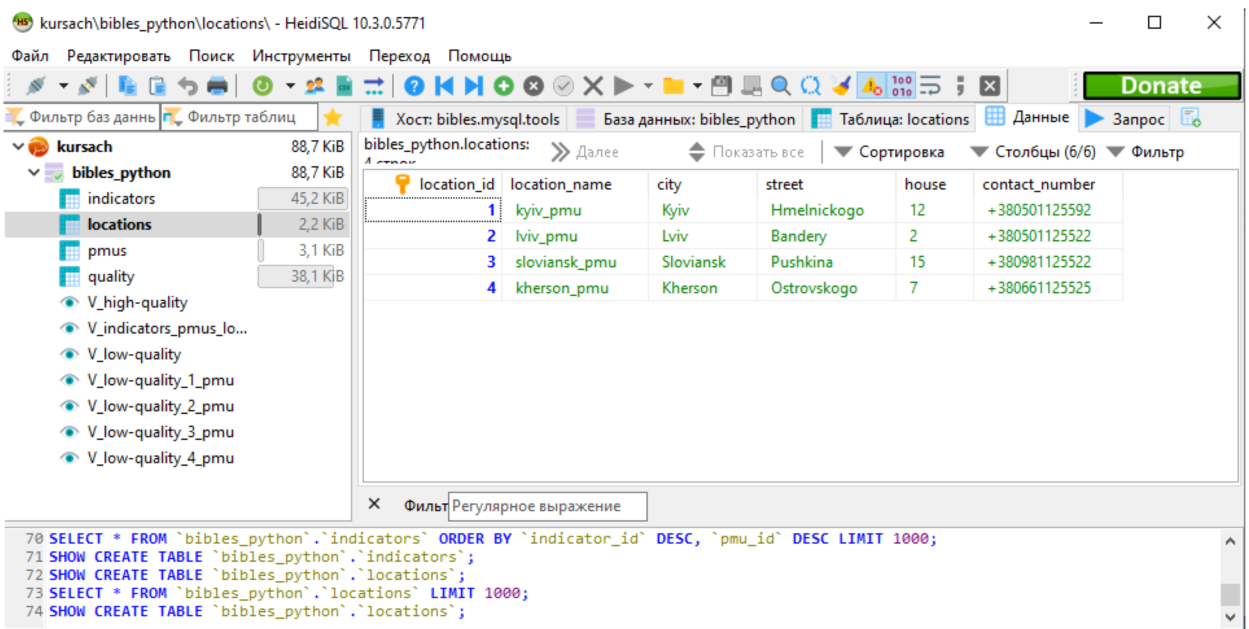

Figure 3: Designing a dynamic database in a HeidiSQL application

Stage 5. Designing and building a web interface of an information system for the diagnosis of electricity quality. The web interface is implemented using HTML, JS and PHP (a scripting programming language, was created to generate HTML pages on the web server side). The PhpStorm application and the local OpenServer server were used for the construction.

Stage 6. Buying a domain for hosting on the web and configuring web hosting.

Stage 7. The deployment of the program code to the web server. The developed application is hosted on a web server using the FileZilla application.

indicator_id	pmu_id	datatime	frequency	voltage	amperage
10 000	1	2020-12-06 13:03:43	50,646	212	18
30 000	3	2020-12-06 13:03:45	49,015	228	22
20 000	2	2020-12-06 13:03:45	51,399	211	21
10 001	1	2020-12-06 13:03:46	49,485	241	21
40 000	4	2020-12-06 13:03:46	51,161	200	24
30 001	3	2020-12-06 13:03:47	48,926	229	22
20 001	2	2020-12-06 13:03:48	49,211	214	17
40 001	4	2020-12-06 13:03:49	49,114	203	16
10 002	1	2020-12-06 13:03:49	50,711	234	25
30 002	3	2020-12-06 13:03:49	51,051	236	19
20 002	2	2020-12-06 13:03:51	50,107	241	18
40 002	4	2020-12-06 13:03:51	50,523	241	18
10 003	1	2020-12-06 13:03:52	51,301	231	22
30 003	3	2020-12-06 13:03:52	48,969	239	19
40 003	4	2020-12-06 13:03:53	50,062	205	24
20 003	2	2020-12-06 13:03:53	48,798	202	15
30 004	3	2020-12-06 13:03:54	50,159	203	22
10 004	1	2020-12-06 13:03:54	50,366	240	11
40 004	4	2020-12-06 13:03:56	50,707	203	10
20 004	2	2020-12-06 13:03:56	50,283	218	26

Figure 4: Dynamic data in the indicators table

```python
if connection.is_connected():
    mycursor = connection.cursor()
    i = 10000
    while (i < 19000):
      now = datetime.now()
      current_time = now.strftime("%Y-%m-%d %H:%M:%S")
      print("Current Time =", current_time)
      freq = round(random.uniform(47.95, 52.05), 3)
      volt = random.randint(197, 241)
      amp = random.randint(10, 26)
      volt_nom = 220
      volt_dev = (volt - volt_nom) / volt_nom * 100
      freq_nom = 50
      freq_dev = (freq - freq_nom) / freq_nom * 100
      if volt_dev < -10 or volt_dev > 10 or freq_dev < -4 or freq_dev > 4:
        concl = 'low-quality'
      else: concl = 'high-quality'

      sql = "INSERT INTO indicators (indicator_id, pmu_id, datatime, frequency, voltage, amperage) VALUES (%s, %s, %s, %s, %s, %s)"
      val = (i, '1', current_time, freq, volt, amp)
      mycursor.execute(sql, val)

      sql = "INSERT INTO quality (indicator_id, voltage_deviation, frequency_deviation, conclusion) VALUES (%s, %s, %s, %s)"
      val = (i, volt_dev, freq_dev, concl)
      mycursor.execute(sql, val)
      connection.commit()
      print(mycursor.rowcount, i , " record inserted.")

      #### Delay for 2 seconds ####
      time.sleep(2)
      i = i + 1
```

Figure 5: A fragment of the program code for calculating the quality of electricity indicators

4. Results

Demonstration of the application. The main page of the web interface is shown in Figure 6. On the main page, you can view the power grid indicators from 4 different recorders by selecting the appropriate tab shown in Fig. 6. The constructed frequency graph from the first recorder is shown in Fig. 7. Similarly to the user, graphs of voltage indicators are displayed on the screen and Amperage is shown. The next block of the web interface consists of a tabular representation of electricity quality indicators.

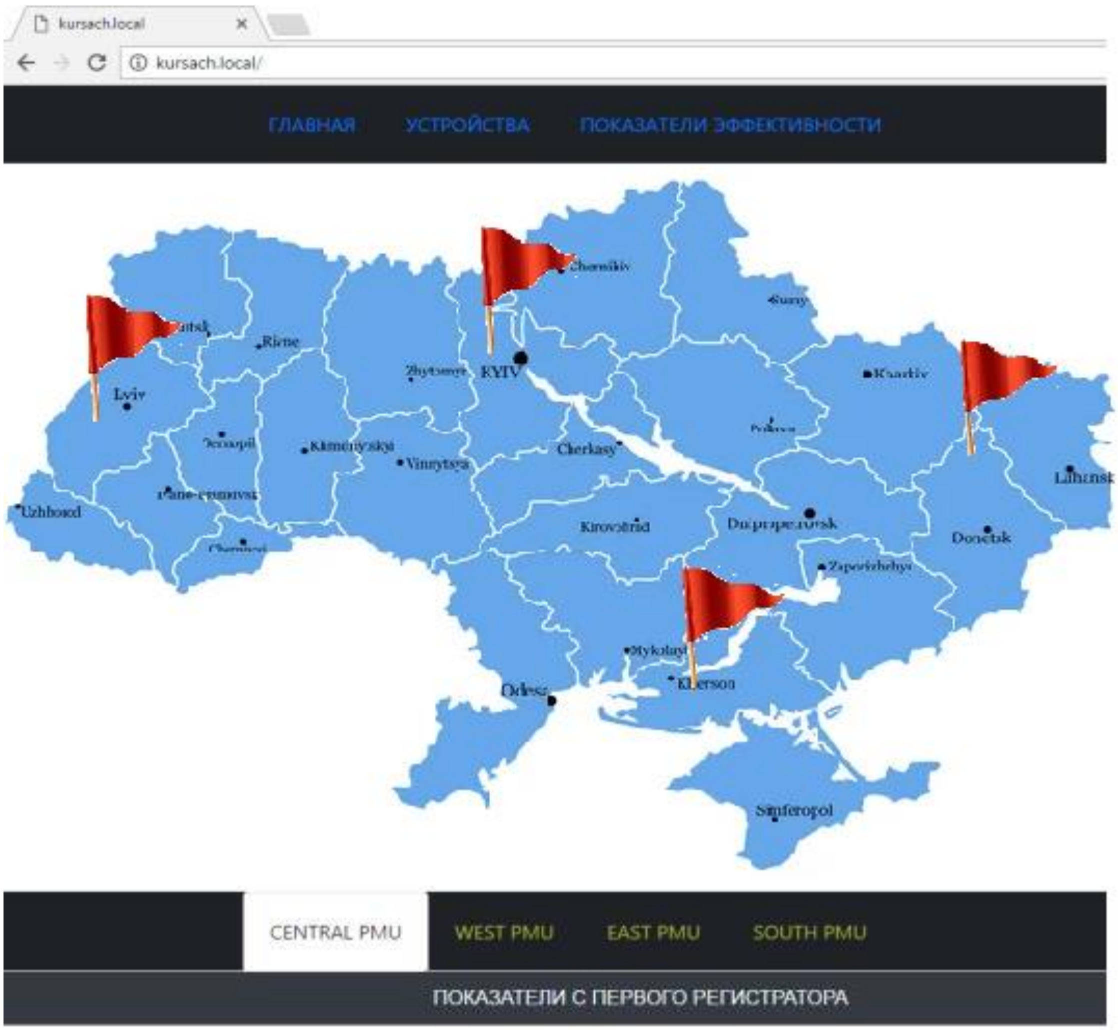

Figure 6: The main page of the web interface

This page contains information about working measuring devices. Four tabs of input indicators for quality assessment are shown in Fig. 7. And the last section is graphs, where information about the quality of electricity is presented.

5. Discussion and perspective

Directions for further research. In the future, it is planned to develop this project as follows:

- connection of several types of PMU devices (purchased as part of a research project), their integration into the system and collection of information in various facilities;

- application of optimization and decision-making methods for quality management at the points of connection of sources of restored generation (an example of solving the problem of multicriteria optimization is given in the work of a Ukrainian researcher H. Hnatiienko [18]);

- statistical processing and analysis of the data obtained for forecasting electricity quality indicators.

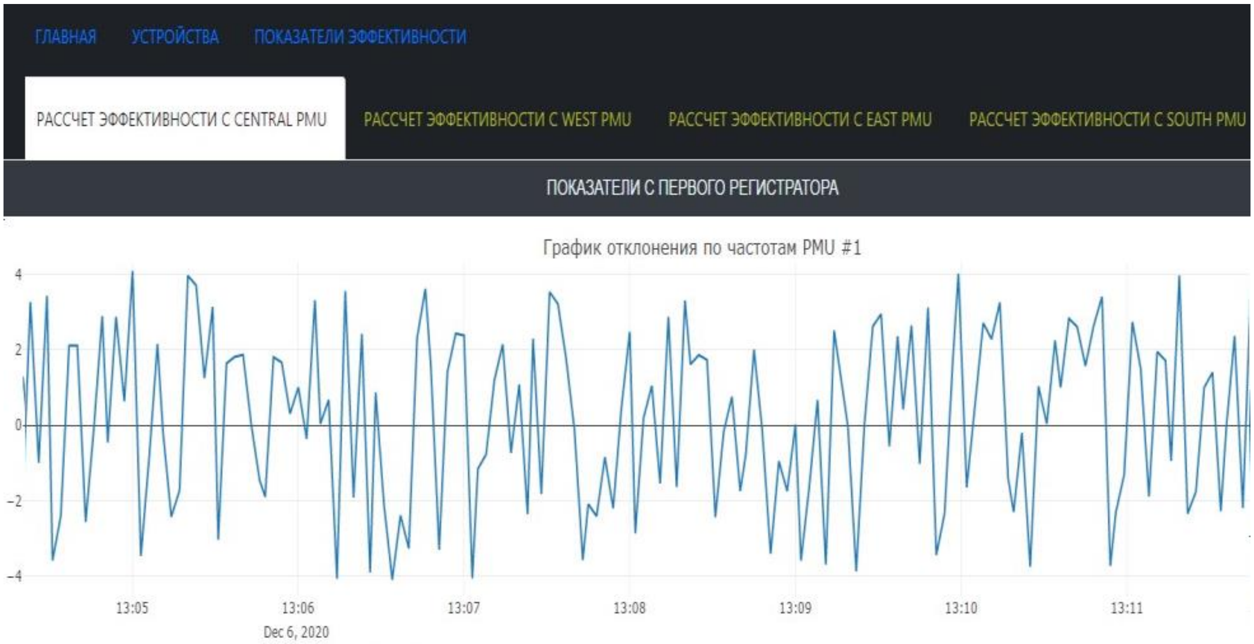

Figure 7: Frequency deviation graph

6. Conclusions.

The paper considers the urgent task of diagnosing the quality of electricity consumers on the basis of modern synchrophasor technologies, as well as building a convenient interface for visual representation of electricity quality indicators. To determine the quality of electricity, some of the following parameters are presented: frequency, voltage and amperage, according to which the diagnostics of the quality of electricity is tested. Designed and developed a web interface for interactive interaction and visualization of indicators with tables and graphs. This information is input for subsequent analysis, graphical representation and output of electricity quality results. The developed software can help to quickly analyze the quality of electrical energy, as well as learn about power failures at an early stage.

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