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The Program for Determining the Optimal Location for Installation of Symmetry Facilities in 0.4 Kv Power Supply Systems with a Motor-Drive Load

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Abstract. The article considers the issue for development of the computer-aided program designed for determining optimal location of installation of symmetry facilities in 0.4 kV power supply systems with the motor-drive load in conditions of imbalance of voltages. The program is aimed at making electrotechnical calculations during designing, modernization and operation of electrical grids with available motor drive load. It ensures plotting of schematic circuits for 0.4 kV power supply system sections with installed symmetry facilities. The software program provides for calculating different symmetry options and selecting the most economically feasible one. Using the program in motor-drive load power supply systems will enhance the asynchronous motor reliability and efficiency. The program is of interest during development of the power supply system projects for the regions with available non-linear loads.

Keywords: asynchronous motor, voltage asymmetry, reliability of asynchronous motor, object – oriented programming.

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Программа определения оптимального места установки средств симметрирования в системах электроснабжения 0,4 кВ с электродвигательной нагрузкой

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Аннотация. В статье рассматривается вопрос разработки компьютерной программы, предназначенной для определения оптимального места установки средств симметрирования в системах электроснабжения 0,4 кВ с электродвигательной нагрузкой в условиях несимметрии напряжений. Программа предназначена для выполнения электротехнических расчетов при проектировании, модернизации и эксплуатации электрических сетей с наличием электродвигательной нагрузки. Обеспечивает построение принципиальных схем участков систем электроснабжения 0,4 кВ с установленными средствами симметрирования. Программа предусматривает расчет различных вариантов симметрирования и выбор наиболее экономически целесообразного. Применение программы в системах электроснабжения с наличием электродвигательной нагрузки позволит повысить надежность и эффективность работы асинхронных двигателей. Программа представляет интерес при разработке проектов систем электроснабжения для регионов с наличием нелинейных нагрузок.

Ключевые слова: асинхронный электродвигатель, несимметрия напряжений, надежность работы асинхронного электродвигателя, объектно-ориентированное программирование.

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Introduction

Development of engineering and design solutions includes the system of research and development. At that, the use of software facilities allowing for solution of a large spectrum of tasks with different level of complexity, is the integral part of the design process, which, in its turn, allows to simplify the working process for the engineering and technical staff of the enterprises, and, in addition, to reduce the project deadlines.

As of today, the design solutions aimed at implementation of measures on normalization of the electrical power quality (EPQ), enhancement of the electrical equipment operational reliability and efficiency take up urgent need. As it is well known, under current conditions, the unified power quality indices (UPQI), such as imbalance of voltages and the non-sinusoidality, have become the inherent factors, which reduce materially the operation efficiency of the power supply system's themselves and of the connected consumers correspondingly [1-4]. The electrical equipment operating reliability and efficiency are directly related to EPQ in the power supply systems. Development of the software products contributing to these requirements satisfaction is the relevant and necessary task.

Within the framework of this publication, one of possible measures on EPQ increase is proposed due to implementation of symmetry facilities into power supply system (PSS) both at stage of designing and in conditions of the electrical networks actual operation.

The main objective of this research work is the development of the applied software program to determine the optimal installation location of symmetry facilities in 0.4 kV PSS with the motor-drive load.

Task description

Based on the data of experimental investigations of the main UPQI, the information on the power loss value in the elements of the power supply system under investigation, and besides, on the ground of consumers' allowable operation modes, it is possible to make selection of parameters for the symmetry facilities and determine optimal location of these devices in the power supply systems.

The calculation procedure for power supply system calculation algorithm with account of the symmetry facilities and their installation locations can be implemented according to the algorithm formulated in [5]. For Fig. 1 shows the block diagram of algorithm of calculation of system of power supply taking into account the costs of balancing and installation. The method of calculation of the electricity system to be the basis for implementation tasks to establish a program of optimal installation location of the means of balancing in 0.4 kV PSS with the electric motor and the load.

Program implementation

The software program is implemented by means of C# programing language in Microsoft Visual Studio 2012 programming environment using the embedded cross-platform data base SQLite [6-9].

Basic system requirements: 64-bit Windows 7 OS (w/SP1 service pack installed), RAM of at least 2 Gb (4 Gb recommended), processor clock speed shall be minimum 2.40 GHz.

The software program main functional capabilities:

1) input, editing of the initial parameters of the power supply system elements;

2) input, editing of the reference data of the power supply system elements;

3) input of additional data for calculation of option with installation the symmetry facilities;

4) plotting of power supply system section with the initial data entered into database;

5) calculation of options with installation of the power supply system symmetry facilities;

6) graphic presentation of schemes for options of calculations with particular location specification of the symmetry facilities in PSS.

The tasks solved by the software program:

1) accumulation and storage of the reference and initial data on PSS (PSS section) diagram;

2) designing of PSS (PSS section) diagram by means of the initial data input;

3) estimation of the optimal location for installation of symmetry facilities in PSS;

4) designing of PSS (PSS section) diagram with installed symmetry facilities following the estimation results;

5) output of the engineering and economic nature information following the estimation results.

The software program consists of the database storing all required information for calculation and designing of 0.4 kV power supply systems with the motor drive load; the computational calculation module with the algorithm for calculation of power capacity losses in the power supply system elements;

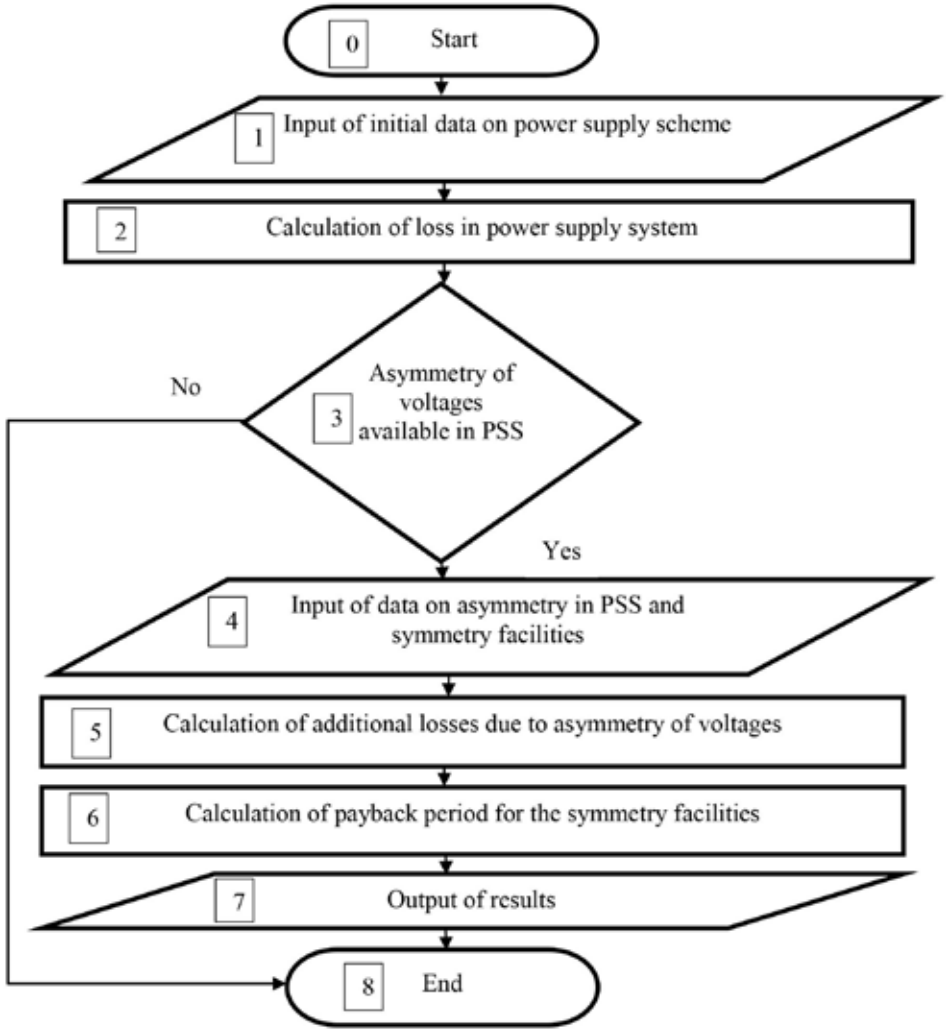

Fig. 1. Flow diagram for power supply system calculation algorithm with account of the symmetry facilities and their installation locations

the module for data input and output of 0.4 kV power supply system design calculation results. The software program carries out the required calculations automatically based on the set initial data. The initial data includes the data on 0.4 kV power supply system section with the motor drive load. The data is developed into data base (DB).

The data base includes the tables of the following nature: reference parameters of the power supply system elements, table the symmetry facilities, tables of the power supply system input data, tables of tables of the power supply system output calculations.

Symmetry facilities DB is updatable; the user can add, change and delete the parameters of symmetry facilities (of type, capacity and value) required for the project implementation. At the moment, DB table of symmetry facilities includes the following devices: balancing adjustment transformers, frequency converters, and filter-balancing adjustment devices [10-12]. First of all, selection of this or

that symmetry facilities are made depending on imbalance nature in the network, based on the critical analysis of the existing protective equipment for motors aimed at obtaining the maximum symmetry capability. Ultimately, the decision on using symmetry facilities is taken based on the engineering and economic estimates.

The proposed software essence consists in the fact, that, based on the obtained investigation results of K_{2U} permissible values for AM [13] entered in the software program algorithm, the data of K_{2U} power supply system calculation experimental investigation, selection of parameters for the symmetry facilities and the optimal location of these devices in the power supply system are determined. When changing the calculation scheme parameters (for example, replacing the symmetry facilities and their quantity), it is possible to match them in such way that the sustainable and fail-free operation of asynchronous motors is ensured in the whole power supply system.

Program testing

For the software program implementation and testing, let us consider the power supply system section of Taptugary village, Mogochinsky region of Trans-Baikal district.

The following initial information was used during this publication performance:

1) results of processing of data of main UPQI in 0.4 kV grid nodes in Mogochinsky region of Trans-Baikal district;

2) configuration of the power supply system of Taptugary village, description of electric power consumers.

Power supply system, where the software program was approbated, is given in Fig. 2. The scheme of power supply system section includes:

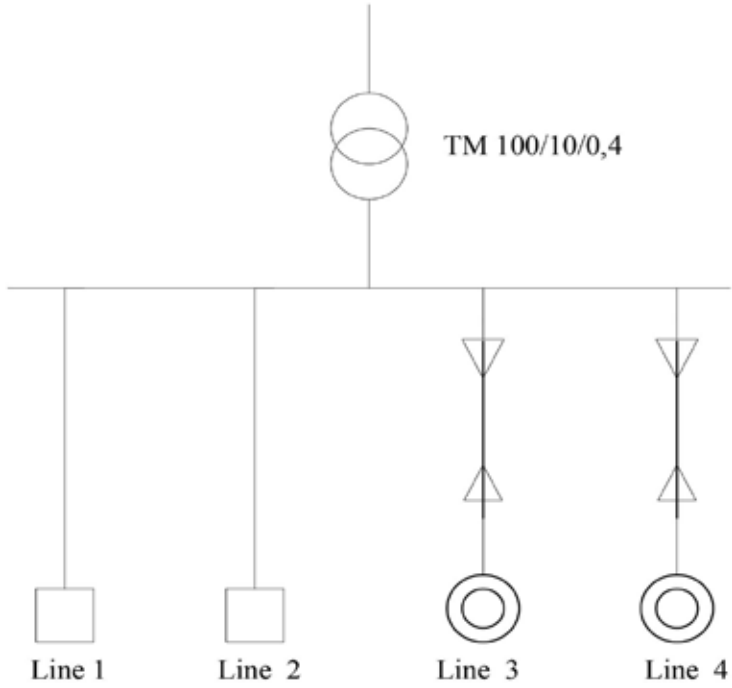

Fig. 2. The scheme of Taptugary village power supply system section

Table 1. Taptugary village grid section initial data

Parameter	Line 1	Line 2	Line 3	Line 4	TS
Power capacity, kVA	30.4	49.4	20.9	25	100
Current, A	80	130	55	65.7	330.7

1) line 1 – is routed with conductor AS-25, line distance – 350 metres, feeds 7 private houses with the furnace heating;

2) line 2 – is routed with conductor AS-25, line distance – 50 metres, line distance double-storeyed house, the primary school, the kinder garden, the administration building, the library;

3) line 3 – is routed with conductor AVVshv 4*50, line distance – 70 metres, feeds the boiler house of two boilers with the electrical motors: type 4A132S4Y3 with Pn = 7.5 kW with 2 pieces, flue gas fan Pn = 3 kW, fan blower Pn =1.4 kW;

4) line 4 – is routed with conductor SIP 4*25, line distance – 150 metres, feeds two band saws type AI132M4 Pn = 11 kW.

The software program interface is well understood and plain Fig. 3–4. The software program interface presents and displays the power supply system initial information, the output of the summary information on calculation results.

Based on the results of the software program operation according to the considered scheme Fig. 2, it is much in evidence that it is economically feasible to install the balance-unbalance transformers type TST2 with power capacity 25 kW on line 3,4 having the motor drive load.

The necessity for using the symmetry devices for the industrial consumers in the investigated scheme was detected as a result of the software program implementation. Based on the capital

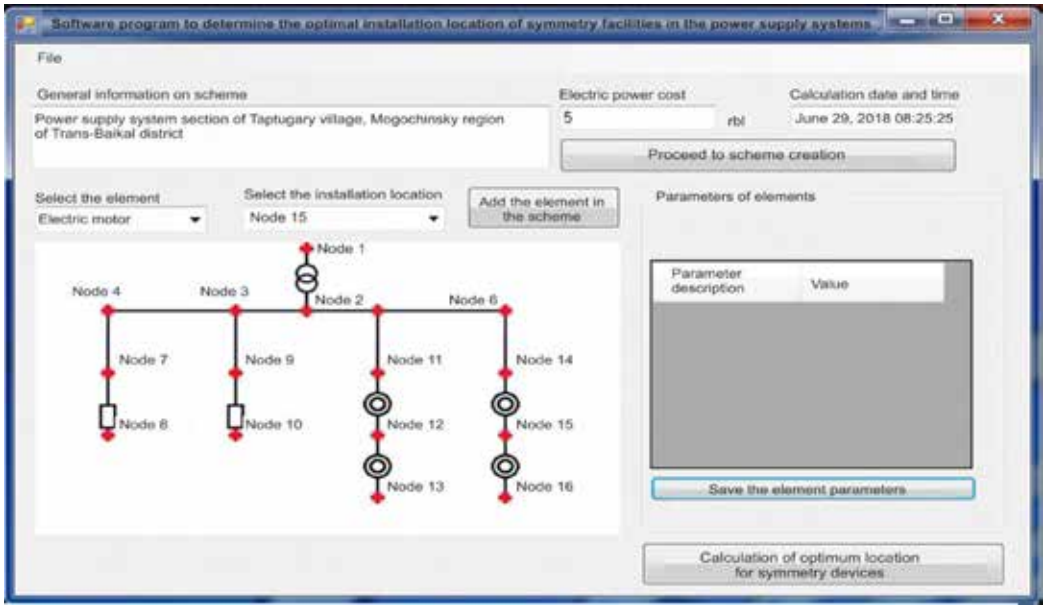

Fig. 3. Software program interface: addition of scheme elements by means of designing

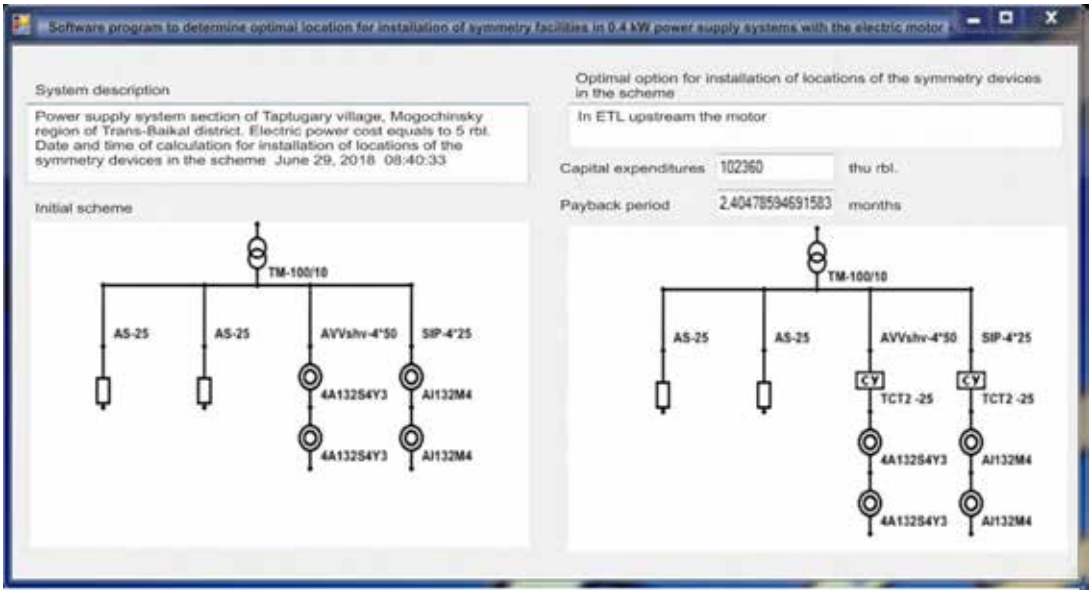

Fig. 4. Software program interface: window for calculation results output

expenditures and the payback period of actions aimed at asymmetry reduction, the most economically advantageous location of the symmetry facilities PSS was determined.

The use of the software program will allow of significant increase of AM and the whole power supply system operation reliability and efficiency due to using the symmetry facilities. The proposed software program allows for the power supply system calculation procedure simplification without significant increase of labor costs due to using computer equipment.

Conclusion

Practical significance of the developed software program consists in the fact that implementation of new research solutions in designing and operational practice ensures suppression of asymmetry of voltages in 0.4 kV PSS, and, at that, it improves the operation reliability of asynchronous motors.

The program provides for estimation of different symmetry options and selection of the most economically feasible one based on "Capital expenditures" and "Payback period" parameters. Taking decision on using symmetry facilities, their parameters and installation locations is based on comparison of performance indicators of the alternative options. The program provides optimal arrangement of symmetry facilities in PSS under any complex topology.

The developed software program is intended for the regions with available non-linear loads, where the actions directed for support of electric energy quality in the power grids are of the most priority.

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References / Список литературы

[1] Гусаров А.А. Влияние качества электрической энергии на тепловое состояние трехфазных асинхронных двигателей с короткозамкнутым ротором. *Электротехника и энергетика*, 2008, 8(140), 95 – 97 [Gusarov A. Influence of quality of electric energy on the thermal state of three-phase asynchronous motors with squirrel-cage rotor. *Electrical and Power Engineering*, 2008, 8 (140), 95 – 97 (in Russian)].

[2] Жежеленко И.В., Саенко Ю.Л., Горпинич А.В., Швецова И.А. Надежность работы электрооборудования при пониженном качестве электроэнергии. *Вестник Приазовского государственного технического университета,* 2005, 15(2), 25 – 29 [Zhezhelenko I., Sayenko Yu., Gorpinich A., Shvetsova I. Reliability of electrical equipment with reduced power quality. *Priazovsk National Technical University Reporter,* 2005, 15(2), 25 – 29 (in Russian)].

[3] Соркинд М. Асинхронных электродвигатели 0,4 кВ. Аварийные режимы работы. *Новости электротехники*, 2005, 2(32), 102 –106 [Sorkind M. Asynchronous electric motors of 0,4 kV. Emergency modes of operation. *Electric Engineering News*, 2005, 2(32), 102 –106 (in Russian)].

[4] Федоров М.М., Ивченко Н.В., Ткаченко А.А. Особенности теплового состояния асинхронных двигателей при несимметрии питающего напряжения. *Научный вестник ДГМА*, 2013, 1(11E), 164 – 170 [Fedorov M., Ivchenko N., Tkachenko A. Features of the thermal state of asynchronous motors with asymmetry of the supply voltage. *Scientific Herald of the DSEA,* 2013, 1 (11E), 164 – 170 (in Russian)].

[5] Программа оптимального выбора мест установки устройств симметрирования в системах электроснабжения 0,4 кВ с электродвигательной нагрузкой [Электронный ресурс] – Режим доступа: https://www.e3s-conferences.org/articles/e3sconf/abs/2017/13/e3sconf_rses2017_04002/e3sconf_rses2017_04002.html – Заглавие с экрана [Software for optimal selection of places for installation of balancing devices in 0,4 kV electric power systems loaded with electric motors] – Access: https://www.e3s-conferences.org/articles/e3sconf/abs/2017/13/e3sconf_rses2017_04002/e3sconf_rses2017_04002.html

[6] Команды SQLite [Электронный ресурс] – Режим доступа: http://www.w3ii.com/ru/sqlite/default.html – Заглавие с экрана. [Team SQLite [Electronic resource] – Access: http://www.w3ii.com/ru/sqlite/default.html

[7] Неполное Руководство по SQLite для пользователей Windows [Электронный ресурс] http://er.nau.edu.ua/bitstream/NAU /10100/ 1/ SQLite.Allow.pdf. – Заглавие с экрана. [Incomplete Guide to SQLite for Windows users [Electronic resource] – Access: http://er.nau.edu.ua/bitstream/NAU /10100/ 1/ SQLite.Allow.pdf.

[8] Фрост Р., Дей Д., Ван Слайк К. *Базы данных. Проектирование и разработка.* М.: NT Press, 2007. 570 с. [Frost R., Day D., Van Slike K., *Databases. Designing and development.* Moscow, NT Press, 2007, 570 p. (in Russian)].

[9] Медведев В. *Особенности объектно-ориентированного программирования на C++/CLI, C# и Java.* Казань: РИЦ «Школа», 2010. 444 с. [Medvedev V. *Specifics of object-oriented*

programming on C++/CLI, C# and Java. Kazan: RIC Shkola (Russia Innovation Center), 2010, 444 p. (in Russian)].

[10] Симметрирующие трансформаторы [Электронный ресурс] – Режим доступа: https://www.liderteh.ru/katalog/transformatory/simmetriruyushie_transformatory – Заглавие с экрана. [Balancing transformer [Electronic resource] – Access: https://www.liderteh.ru/katalog/transformatory/simmetriruyushie_transformatory

[11] Частотные преобразователи для асинхронных двигателей [Электронный ресурс] – Режим доступа: http://chistotnik.ru/chastotnye-preobrazovateli-dlya-asinhronnyh-dvigatelej.html – Заглавие с экрана. [Frequency converters for asynchronous motors [Electronic resource] – Access: http://chistotnik.ru/chastotnye-preobrazovateli-dlya-asinhronnyh-dvigatelej.html

[12] Нормализаторы напряжения для трехфазных сетей [Электронный ресурс] – Режим доступа: http://energomakc.ru/text/normaliz.php – Заглавие с экрана. [The normalizers of voltage for three-phase networks [Electronic resource] – Access: http://energomakc.ru/text/normaliz.php

[13] Романова В.В., Хромов С.В., Суворов И.Ф. Новый подход к нормированию коэффициента несимметрии напряжений по обратной последовательности K_{2U} для узлов нагрузок систем электроснабжения с асинхронными двигателями. *Современные технологии. Системный анализ. Моделирование*, 2017, 1(53), 209 – 214 [Romanova V.V., Khromov S.V., Suvorov I.F. New approach to normalizing of the voltage asymmetry coefficient in negative-phase sequence K_{2U} for nodes of loads in the power supply systems with asynchronous motors. *Modern technologies. System analysis. Simulation,* 2017, 1(53), 209 – 214 (in Russian)].