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The journal is published 4 times a year and contains publications in the following main areas:

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Tashkent State Transport University had the opportunity to publish the scientific-technical and scientific innovation publication “Journal of Transport” based on the Certificate No. 1150 of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. Articles in the journal are published in Uzbek, Russian and English languages.

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Asymmetric modes in transport

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Abstract: As the voltage increases, losses in the steel of power transformers increase, which leads to an increase in the temperature of the steel. With an increase in voltage, the generation of reactive power by overhead power lines and batteries of static capacitors increases, which can lead to large voltage rises in the network and the danger of breakdown of the insulation of electrical equipment. The listed harmful effects of voltage deviations in the network from the nominal values require measures to regulate the voltage in the network.

Keywords: asymmetric, technical, symmetrical, multifunctional.

1. Introduction

Asymmetric modes can be long-term and short-term. Short-term asymmetric modes are associated with emergency processes, long-term ones are due to the presence of asymmetry in the elements of the electrical network.

The reasons for the asymmetry may be:

- asymmetry of current sources;
- incomplete-phase modes of electrical network elements;
- electric receivers with different loads in phases.

It should be noted that the development of industrial and municipal energy is characterized by an increase in the number and capacity of electrical installations with an asymmetric load, which worsens the operation of other electrical receivers[1]. The asymmetry can be longitudinal, associated with phase-by-phase disconnection of lines and transformers, and transverse, due to phase load asymmetry.

2. Materials and methods

Usually these are electric receivers, the manufacture of which in three-phase design is irrational according to technical and economic indicators. These include induction electric furnaces, electrified alternating current transport, utility loads, single-phase motors in agriculture. Electrical networks of power supply systems, depending on the class of rated voltage, have different designs and, accordingly, react differently to load asymmetry.

Electrical networks of power supply systems for industrial, municipal and agricultural consumers at a voltage of up to 1000 V are three- and four-wire [2]. The operating modes of such networks are the same under symmetrical load, and different under asymmetric load.

Voltage symmetry in power supply systems

To reduce the effect of voltage asymmetry, voltage symmetry is performed, while special additional balancing devices are used only in cases where the following measures are insufficient:

- connection of unbalanced loads on network sections with the highest possible power efficiency;
- allocation of asymmetric loads of significant power to individual transformers;

-uniform distribution of single-phase loads across all phases. Phase-by-phase load redistribution does not always ensure that-

-stress symmetry within acceptable limits. This is due to the fact that a number of electrothermal installations are not constantly in operation according to the conditions of technology and operation [7].

If there is an asymmetry (more than 2%) and other measures have been exhausted, a decision is made to balance the load with additional devices. A symmetrical device solves two problems at once:


- load balancing;
- reactive power compensation.

Asymmetric modes are characterized by the presence of component currents and voltages of the reverse and zero sequences, which lead to the following adverse consequences:

1. There is a danger of overloading three-phase electric motors with reverse currents. Synchronous and asynchronous motors have low reverse sequence resistance [6]. Even small reverse sequence voltages in SES can cause significant reverse sequence currents in motors, which, superimposed on direct sequence currents, cause current overload of individual phases of the engine and, consequently, additional heating of the stator and rotor, which leads to accelerated aging of insulation and a decrease in available engine power[3].

2. Additional losses of active power and electrical energy appear due to the flow of reverse and zero sequence currents in SES elements up to 1 kV.

Incomplete-phase modes in SES are one of the varieties of emergency modes. The most common non-phase modes occur in electrical networks protected by fuses (in case of fuse box burnout in one of the phases). However, in the practice of SES operation, other cases have occurred (breakage of the phase wire in the loop of the anchor support of overhead power lines, loss of electrical contact in one of the phases of the cable or wire, and a number of others). An unfavorable feature of incomplete-phase modes is that they are usually not detected by conventional types of relay protections (maximum current, minimum voltage) and, therefore, can exist for a long time. The incomplete-phase mode, as an asymmetric one, is characterized by the presence of significant components of currents and voltages in the reverse sequence. AC electric motors have low reverse

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sequence resistance and are loaded with reverse sequence currents in non-phase modes. In many cases, protection against overload of motors from incomplete-phase modes turns out to be ineffective and due to thermal effects caused by reverse currents, massive damage to electric motors is possible.

Distorting power flows reflect the power losses in the SES elements from the flow of currents of the corresponding sequences. The greatest distorting power and voltage flows of individual sequences occur at the terminals of an asymmetric load and decrease as they move away from it. The significant spread of asymmetric loads leads to significant violations of the symmetry of currents and voltages in three-phase electrical networks, especially distribution networks. The consequence of the phase asymmetry of currents is the "skew" of the secondary voltage star of distribution transformers and the occurrence of additional losses in the modes of an asymmetric phase load.

Additional tasks arise under operating conditions. Systematic monitoring of asymmetry indicators in industrial networks is required (as a rule, this control should be statistical). For the full use of additional balancing devices and comprehensive technical and v of the current regime, special training of operational personnel should be carried out. Specific decisions have already been made for a number of installations. Individual single-phase electrothermal installations are equipped with special balancing devices.

The reliability of the research results is confirmed by the following: the correctness of the initial assumptions; the correct use of proven mathematical models of SES elements up to 1 kV; a good coincidence of the results of computational and experimental studies with various observational data on the consequences of real asymmetric and incomplete phase modes in SES up to 1 kV; a good explanation of the results of computational experimental studies by the physics of non-symmetric modes.

The most time-consuming and responsible stage of computational research is the preparation and loading of initial data. Previously, it is necessary to mark up the SES circuit by numbering the elements of the electrical network, the nodes of the replacement circuit, load nodes, switches, synchronous and asynchronous motors of the SES. In addition to the numbers, symbolic (letter) designations are provided for the elements of the electrical network and load nodes, which make it easy to identify the necessary network elements and load nodes in the printouts of the calculation results. Uploading the source data about the FEZ to the files .DAT and VOL.DAT is carried out according to a special program for the preparation of initial data. The load node simulates a section of a switchgear to which an arbitrary number of synchronous and asynchronous motors are connected, as well as a three-phase symmetrical other load set by active and reactive power. The absence of any of the loads in the node is reflected by setting zero values of the corresponding capacities.

Algorithms have been developed for calculating the mode for the components of the reverse and zero sequences in the incomplete phase mode of SES up to 1 kV by converting the EMF sources of the reverse and zero sequence at the point of phase interruption into two additional sources of nodal currents for the components of the reverse and zero sequences. The algorithms are based on the nodal stress method.

For four-wire electrical networks, transformers with circuits for connecting windings Y/Un, D/Un, Y/ZH can be

used. Transformers with a Y/YH connection scheme, the simplest in design and cost-effective in terms of material consumption, are still not widely used due to the high resistance of the zero sequence. The A/YH connection scheme is more preferable. The lowest resistance of the zero sequence can be obtained at Y/ZH, however, the transformer windings are switched on according to this scheme at a transformer power of 250 kVA or lower. The considered power supply schemes (Fig. 3.1-3.6) with a transformer capacity of 1600 kVA, which excludes the possibility of conducting computational and experimental studies using the Y/ZH connection scheme.

Based on the patterns of distribution of reverse and zero-sequence currents caused by an asymmetric load across the elements of the SES, it can be assumed that the main factor determining the range of permissible asymmetric loads is the nature of the electrical load in the SES up to 1 kV. This is explained by the fact that the motor load has a reverse sequence resistance 5-7 times less than the resistance of the direct sequence, while the non-motor (static) load (according to accepted terminology - other, S[^]) has a reverse sequence resistance commensurate with the resistance of the direct sequence. The electric motor load accumulates currents of the reverse sequence, reduces the total resistance of the reverse sequence of the SES and, thereby, reduces the voltage of the reverse sequence with an asymmetric load.

3. Results and explanations

The maximum permissible single-phase load for the zero sequence voltage is on average from 1.3 to 23% of the rated power of the supply transformer, and this is almost ten times less than for the reverse sequence voltage [5].

Since the voltage of the zero sequence does not affect the operation of three-phase consumers, and for single-phase consumers, voltage deviation standards must be met regardless of voltage asymmetry, it is appropriate to raise the question of eliminating the normalization of the voltage of the zero sequence. The range of permissible modes of single-phase zero-sequence load depends on the wiring diagram of the transformer windings of the workshop substation, on the remoteness of the connection point of the asymmetric load and the cross section of the zero core of the supply cable.

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