ABSTRACT AND REFERENCES

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ESTIMATION OF THE DYNAMICS OF POWER GRID OPERATING PARAMETERS BASED ON STANDARD LOAD CURVES (p. 6-12)

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Power grids are insufficiently equipped with means of monitoring of operating parameters. The infrastructure of commercial power consumption accounting systems is the most developed. However, power consumption information is stored in the aggregated form. This makes it impossible to determine the components of the balance losses of power and to analyze their structure without simplification.

It is suggested to use standard load curves to increase the adequacy of the results of estimating the operating dynamics of power grids. In order to match the measured operating parameters and pseudomeasures calculated by standard load curves, it is proposed to use an algorithm based on the least-squares method. Accuracy estimation is carried out by comparing power consumption curves of the absolutely observable network with simulation results.

It is found that the use of standard load curves allows restoring power consumption curves with acceptable accuracy in the complete absence of measurements. Conversion of aggregated information of commercial power consumption accounting systems into time graphs helps to improve the accuracy of simulation results of characteristic grid modes. As a result, the accuracy of determining technical losses and other components in the power balance structure is increased.

Clarification of the components of power losses in the balance structure allows identifying the problematic elements of power grids and developing better measures to improve their energy efficiency. In addition, the use of standard load curves and formation of pseudomeasures reduces the cost of monitoring systems of power grid parameters.

Keywords: power grid, parameter recovery, adequacy, standard load curve, state estimation.

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CONSTRUCTION OF A METHOD TO PROTECT A TRACTION ELECTRIC NETWORK AGAINST SHORT-CIRCUIT CURRENTS, BASED ON THE NEW ATTRIBUTE (p. 12-18)

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All types of relay protection are based on comparing the values for certain attributes under a system's normal and emergency operational modes. A new attribute for defining the emergency mode in a direct current traction electricity supply system has been proposed, namely, the speed of voltage drop in the feeder of a traction substation. It is known that at a short circuit in the traction network, its voltage is reduced. Its sharpest, almost linear, decrease is observed, first, at the first moment of the emergency transition process, and, second, at a short circuit site and at points near it. Therefore, the steepness of the front of such a reduction in a feeder voltage could become an attribute of short circuit. A given attribute makes it possible to determine the type of short circuit based on a distance from the power source. In addition, we have proposed the circuit solutions for implementing a system of protection based on this attribute. Three options for building such protection systems have been considered. A first option implies using a RC filter. A second variant employs a pulse transformer. A third option is to use a bridge scheme. Each scheme has its advantages and disadvantages; however, modern electronics and digital technology make it possible to implement any of them. In the future, this would facilitate the construction of a selective protection (in terms of distance) from short circuit. To this end, one needs to use as many protection kits as how many points along a traction line must be monitored. Such a system is also easily implemented by software using microprocessor equipment.

The practical results from our study at a section of traction power supply of the Dnieper Railroad make it possible to assert that the proposed technique for determining short circuits is rather effective. It could be used as an additional (backup) system in general relay-protective hardware. That would improve the reliability of power supply systems for traction networks. Overall, the considered technique for determining short circuits could be used in any DC power system.

Keywords: short circuit, feeder voltage, speed of voltage change, relay protection, duration of voltage drop, selective protection.

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STUDYING A VOLTAGE STABILIZATION ALGORITHM IN THE CELLS OF A MODULAR SIX-LEVEL INVERTER (p. 19-27)

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Multi-level autonomous voltage converters are increasingly used in industry, specifically: in wind and solar energy generation, high-voltage substations, in industrial and traction electric drives. In comparison with two-level inverters, multilevel inverters have a series of significant advantages, specifically, greater output power, greater efficiency value, smaller content of higher harmonics at loading and in a power grid. Reducing the content of higher harmonics in the output current of a multilevel inverter directly decreases additional losses at loading and improves the overall value of efficiency.

Our study of a six-level modular inverter has shown that the algorithm of a spatial-vector modulation causes a disbalance in voltage on the capacitors of cells. In this case, voltage in half the cells tends to zero while in the other half of the cells it increases two-fold, which leads to a significant distortion of the output voltage. This paper gives reasons for this instability, as well as presents the improved spatial-vector modulation algorithm of the multilevel converter, which makes it possible to stabilize voltage in cells.

We have proposed an algorithm of voltage stabilization on the cells of a modular multilevel inverter. The voltage stabilization is achieved by a hysteresis regulation with an alternating transition of the spatial-vector pulse-width modulation and inverse vector control system under condition that the voltage deviation on the cell is above or below the predefined permissible level.

The MATLAB 2017b software was used to conduct simulation of the six-level voltage inverter, which confirmed effectiveness of the proposed modulation algorithm.

Keywords: modular multilevel inverter, transducer, space-vector modulation algorithm, pulse-width modulation.

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DETERMINING THE STRUCTURE OF A LAMINAR DETACHABLE CURRENT IN AN OPEN CAVITY (p. 28-37)

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The paper reports a three-dimensional numerical solution to the test problem about a viscous incompressible liquid flow in the closed square-shaped cavity with a movable upper face. Disadvantages in a mathematical statement of the problem about a flow of fluid in a closed cavity have been identified. A finite element method was applied in order to investigate numerically the structure of a circulating detachable laminar movement of viscous incompressible fluid in an open cavity considering the external flow. The profiles of vorticity, the thickness of a boundary layer, the constituents of velocity components in different cross-sections of the cavity, in the boundary layer, as well as in the blending layer, have been given.

Typically, studying laminar currents in cavities employs a model of the cavity with a movable wall. However, such a statement of the problem imposes a restriction on the flow pattern in the form of a straight line of the flow that connects the upper corners of the cavity, which results in the distorted structure of vorticity formation in the cavity in general. Within the framework of the current study, the problem statement that overcomes the specified disadvantage has been proposed. The movement of fluid in a cavity occurs due to the shear stress of the external flow in a channel above the cavity, which rules out the straightness of the flow line, which connects the cavity's corner points. Reliability of the reported results has been confirmed by comparing certain parameters to known experimental data by other authors. The study's scientific result in the form of the vorticity structure of a viscous incompressible laminar flow in an open cavity with a channel is interesting from a theoretical point of view. As regards the practical point of view, the identified structure of the flow makes it possible to define the conditions to control a flow in the cavity and, therefore, allows determining the conditions for optimizing the aerodynamic forces acting on a cavity. The applied aspect of the obtained scientific result is the possibility to employ it for a flow over industrial facilities: buildings, inter-carriage space in a railroad train, etc.

Keywords: flow detachment, laminar mode, flow in a cavity, numerical modelling, vorticity formation structure.

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DESIGNING A SINGLE-CASCADE THERMOELECTRIC COOLER WITH THE PREDEFINED TIME TO ENTER A STATIONARY MODE OF OPERATION (p. 38-46)

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The paper reports an established analytical relation of the time it takes for a thermoelectric cooler to enter a stationary mode depending on the thermal-physical parameters of structural and technological elements, a temperature differential, relative working currents, electric resistances, and geometric parameters of thermoelements.

A mathematical model has been analyzed in terms of temporal and reliability indicators for different current modes of operation and temperature differentials taking into consideration energy indicators and structural parameters of the thermoelectric cooler.

It has been shown that an increase in the time it takes to enter a stationary mode for various drops in temperature decreases a relative working current, and the functional dependence of the refrigeration factor on the time it takes to enter a stationary mode has a maximum, depending on a temperature difference. At the predefined time of entering a stationary mode, the dependence of the number of thermoelements on temperature differential has a minimum. An increase in the time it takes to enter a constant mode decreases the relative failure rate and increases the likelihood of a failure-free operation of the thermoelectric cooler. An increase in temperature difference for different current regimes increases the time it takes to enter a stationary mode, increases the working current magnitude, reduces the refrigeration factor, increases the number of thermoelements and the intensity of failures.

We have given the calculation of the cooler with a predefined time of entering a stationary mode at the assigned temperature changes, external conditions, thermal load, the geometry of thermoelements' branches. The obtained results of the research make it possible to design single-cascade thermoelectric coolers with the predetermined dynamics of functioning and to predict basic parameters and reliability indicators over any time period.

Keywords: thermoelectric cooler, the time it takes to enter a mode, reliability indicators, mode of operation.

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PROCEDURE FOR CALCULATING THE THERMOACOUSTIC PRESSURE FLUCTUATIONS AT BOILING SUBCOOLED LIQUID (p. 47-54)

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This paper reports a study of the thermoacoustic phenomena in steam-generating channels of the cooling system of heat-loaded devices. The examined cooling modes are characterized by surface boiling of the heat carrier, which occurs due to high heat flows at the cooled surface and large underheating of the flow core to the saturation temperature. Under such conditions, high-frequency pulsations of acoustic pressure may occur in cooling channels. It has been established that the emergence of thermoacoustic oscillations could lead to the formation of a standing wave in the channel, one of the conditions for whose formation is the presence of a wave reflection boundary. We have proposed a mathematical model describing the generation of thermoacoustic vibrations in a cooling channel. It was assumed that fluctuations with a high amplitude arise due to the resonance observed when the frequency of forced vibrations of steam bubbles coincides with the vapor-liquid column's natural frequency of vibrations or their harmonics. To calculate the amplitude of pressure fluctuations in the channel, the dependence has been derived, which takes into consideration the viscous dissipation of energy and energy losses at the ends of the channel. It has been shown that when approaching the resonance, the contribution of volumetric viscosity to the viscosity absorption factor increases. It has been established that for the examined conditions the losses of energy on the walls of the channel and losses in the boundary layer could be neglected. We have calculated the amplitude of thermoacoustic pressure fluctuations for conditions corresponding to actual processes in surface-boiling cooling channels. The reported procedure is proposed to be used in the design of liquid cooling systems for heat-loaded devices for which cooling modes imply a significant underheating of the heat carrier to a saturation temperature, as well as surface boiling.

Keywords: cooling channel, surface boiling, thermoacoustic pressure fluctuations, resonance, dissipation, fluid viscosity.

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UTILIZATION OF GUIDE VANES TO CONCENTRATE FLOWS TO THE BLADE AND BLOCK VORTEX TO IMPROVE THE POWER FACTOR OF SAVONIUS WIND TURBINE (p. 55-61)

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Simple design Savonius vertical-axis wind turbine can generate energy at low wind speed from any direction. However, its large static torque has a low power factor. Therefore, an innovation was made by providing 16 guide vanes around the shaft outside the blade with the angle is about 45° to a radial line. The specialty of guide vanes is that; they are able to concentrate the wind flow toward the turbine blade from any direction. The fluid motion around the turbine blade that produces torque on the turbine shaft was analyzed utilizing the Computational Fluid Dynamics (CFD) simulation and then verified by tracking actual fluid motion strings of threads attached on each side of the turbine blade. The result shows that without guide vanes the wind flow around the turbine blade generates vortex on the blade and Karman vortex at the downstream. These vortexes descend effectively kinetic energy in the wind flow so that the mechanical energy on the turbine shaft becomes small. At a certain blade position, the vortex becomes stronger and the fluid separation from the blade surface becomes thicker. The stronger vortex tends to descend stronger fluid kinetic energy while the thicker separation tends to reduce the lift on the blade. Consequently, these two flow conditions tend to produce negative torque. Installing guide vanes around the blade, the wind flows are concentrated by the guide vanes to the turbine blade, which effectively reduces vortex around the blade and blocks large vortex outside the guide vanes downstream. Flow separation is suppressed by the concentrated flow producing larger lift. As a result, the power factor increases by 61.6 %. This huge increase in power factor is achieved when the wind speed is 5 m/s though a stable turbine rotation is achieved at a lower speed.

Keywords: Concentrate Flows, Block Vortex, Power Factor, Savonius, Guide Vane, Karman Vortex, Downstream, Computational Fluids Dynamics (CFD).

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