ABSTRACT AND REFERENCES

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CONSTRUCTING A METHOD OF MULTI-COORDINATE CONTROL OVER THE STATIC THYRISTOR COMPENSATORS WITH FORCED COMMUTATION (p. 6–16)

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The configuration and the principle of operation of the static thyristor compensator of reactive power with the forced commutation and voltage addition for networks with a compensated neutral have been considered. The integrated indicators of the compensator energy process have been defined for the case when it is powered by a rectangular-shaped voltage in the case of independent control over the switching thyristors. At certain values of thyristor control angles, the specific losses of active power become less than the similar specific losses when the compensator is powered by a sinusoid voltage. This ensures its competitiveness relative to other static compensators.

A method of multicoordinate control over the static thyristor compensators with forced commutation has been proposed. It implies independent control over all switching thyristors in a compensator in accordance with the objective function of the system, which is determined under condition that the specific losses of active power do not exceed their economically justified level.

A circuit to control the static thyristor compensator with forced commutation and voltage addition has been suggested. The application of the circuit makes it possible to reduce active power losses in the compensator when controlling the reactive power and to execute independent control over the phase reactors. Real-time microprocessor control over all elements of the system makes it possible to enable the required algorithm for switching commutation thyristors and to implement multi-coordinate control over the compensator energy processes. An algorithm for operating the microprocessor system of the static compensator when controlling the reactive power has been constructed. The algorithm, due to an increase in the voltage addition coefficient during the action of a negative half-wave of supply voltage, makes it possible to reduce the specific losses of active power in the electrical network and compensator.

Keywords: static thyristor compensators, forced commutation, reactive power, multi-coordinate control, voltage addition.

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IMPROVING THE HARMONIC COMPOSITION OF OUTPUT VOLTAGE IN MULTILEVEL INVERTERS UNDER AN OPTIMUM MODE OF AMPLITUDE MODULATION (p. 17–24)

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One of the most important parameters of multilevel inverters is the sinusoidal output voltage. There are many different modulation algorithms, which make it possible to obtain different indicators of the sinusoidal output voltage and different content of the higher harmonics. This paper reports a universal modulation algorithm, which makes it possible to obtain the shape of the output voltage of a multilevel inverter at any number of stages, optimized for the content of the higher harmonics, namely a minimum of the coefficient of harmonic distortions. The proposed algorithm enables obtaining the lowest possible THD for any level voltage. The advantage of the proposed algorithm compared to similar optimization algorithms is ensuring smaller harmonic distortions, as well as its relative simplicity. The reported algorithm is based on the amplitude modulation of the sine signal with a 25 % modulation relative to the highest discreteness. The analytical expressions have been given that make it possible to determine the time (angle) of enabling each level of the output voltage to form a minimum of the root mean square value of higher harmonics. To confirm the optimum analytic point, the MATLAB/Simulink programming environment was employed to design a series of multi-level voltage inverters, which form the five-, seven-, nine-, and eleven-level shapes of output voltage. The current study has shown that the optimum points for all shapes of multilevel voltages are achieved at the same coefficient of amplitude modulation. It has been demonstrated that the proposed modulation algorithm could also be used to control the amplitude and frequency of the output voltage in a multilevel inverter. The paper gives a control characteristic of the output voltage of a multilevel inverter at the pulse amplitude modulation.

Keywords: amplitude modulation, total harmonic distortion, an optimum of the sinusoidal output voltage of an inverter.

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DEVELOPMENT OF A POWERFUL LOWVOLTAGE DC CONVERTER FOR SYSTEMS OF ELECTRIC POWER ACCUMULATION (p. 25–34)

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The study offers a solution to the problem associated with the use of batteries in autonomous solar and wind power plants, power installations, and electric vehicles. It is known that one battery element can produce 1.2–4 V, which is not enough for subsequent transformations. There is a need to complete the battery, in series-parallel connection, with several elements to several thousand elements. During its operation, slight deviations of the voltage of the elements occur, which subsequently accumulate and lead to the battery failure. To prevent such phenomena, diagnostics with an accuracy of 0.1–0.001 V per element is necessary. This complicates the control system and forces the entire battery to be rejected in case of failure of a certain number of elements. The load on the surrounding space for the disposal of lead, lithium, and cadmium is increasing. It has been established that effective converters of direct current to direct current at the indicated voltages and capacities do not exist. Voltage converters from level 3 use an intermediate link to convert the magnetic field. This type of low voltage converter is used only at low power.

It was proved that a significant number of battery elements connected in a series in parallel can be replaced with one equivalent in energy. The conducted tests have established that it is advisable to produce a subsequent increase in voltage with ionistors by charging them in parallel followed by a discharge in the series.

A mathematical description of the operation of the converter was developed, starting from the moment of switching on and reaching the steady state with subsequent response to a change in the load. Since the operation of the converter involves significant currents, the components of the internal resistances of all elements are taken into account. This approach helps study possible technical implementations, identify patterns when varying its parameters, and optimize conditions, depending on the type of chemical elements and consumer power.

Keywords: battery, ionistor, parallel charge, sequential discharge, electric field energy, charge balance.

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PERFORMANCE OF CYLINDRICAL AND PLANAR MESOSCALE COMBUSTOR WITH DOUBLE NARROW SLIT FLAME HOLDER FOR MICROPOWER GENERATOR (p. 35–43)

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This research compared the performance of a cylindrical mesoscale combustor against two planar mesoscale combustors, which include the shape of the flame front, temperature of the combustor axis and the combustor wall, and the resulting flammability limit. The combustor used has a circular, square and rectangular cross-section. All three combustors have the same cross-section area and combustion chamber volume. The flame holder used is a double narrow slit. The fuel used is liquefied petroleum gas with a pure oxygen oxidizer. The experiment results showed that the cylindrical combustor produces a more even flame shape that fills the combustion chamber and there is no clear separation between the sides of the flame on each side of the narrow slit. A high ratio of the entrance to average velocity results in a large adverse pressure gradient which generates vortex and recirculation behind the flame holder which gives the mixture a longer chance in the combustion chamber (prolonged residence time). The flame front shape affects the temperature of the combustor axis. The flame front shape that fills the entire combustion chamber has a higher flame temperature than the separate flame front shape. The circular combustor has the highest average axis temperature, but it has the lowest combustor wall temperature. This fact shows that the circular combustor has the smallest heat loss from the flame to the combustor wall. Furthermore, a circular mesoscale combustor has the most extensive stability map. For the same volume, the circular combustor has a lower surface area to volume ratio, thus the heat loss is also low. The dead zone area also becomes narrower, only at a low reactant rate. Rectangular combustors have the largest surface area to volume ratio, thus the losses are also the biggest. Despite the narrowest flammability limits, rectangular combustors have the highest average wall temperatures.

Keywords: cylindrical mesoscale combustor, planar mesoscale combustor, double narrow slit, entrance to average velocity ratio.

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FLAME BEHAVIOR INSIDE CONSTANT DIAMETER CYLINDRICAL MESOSCALE COMBUSTOR WITH DIFFERENT BACKWARD FACING STEP SIZE (p. 44–51)

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This research observes the behavior of the flame stability in a cylindrical meso-scale combustor at various backward facing step sizes. The backward facing step was varied by changing the size of the combustor inlet diameter while the size of the combustor outlet diameter was kept constant, keeping a constant contact area. Butane gas (C_4H_{10}) was used as fuel with air as the oxidizing agent. The results show that generally, the flame mode and area of the flame mode map are obtained for the conditions of the stable flame at combustor rim, stable flame in combustor, stable flame near the step, oscillating flame, oscillating spinning flame, spinning flame, flashback, and no ignition. Flame mode and flame mode map distribution depend on reactant flow velocity behavior, jet flow generating shear stress, vortex flow regulating wall-thermal interaction, and average flow generated by varying the backward facing step size at various equivalence ratio and reactant velocity in the test range. Jet flow destructs flame stability to be extinct due to strong shear stress. Vortex flow spins the flame while the transition from jet to vortex flow oscillates the spinning flame. Weak vortex at average flow plays an important role in wall-thermal interaction that keeps flame very stable. Decreasing the backward facing step size tends to widen the flame stability region, but the combustion process causes the flame to be flashed back. By setting the reactant velocity at a small backward facing step size to the condition where the weak vortex flow exists, flashback conditions could be avoided keeping the flame very stable. Stable flame tends to be performed around stoichiometric to the lean mixture and in the low to medium reactant flow velocity. At high reactant flow velocities, the flames tend to be unstable. However, at low to medium reactant flow velocity, the flame tends to be stable in the combustor.

Keywords: Cylindrical Meso-Scale Combustor, Backward Facing Step, Flame Behavior, Flame Mode, Flame Mode Map.

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AN EFFECTIVENESS ANALYSIS OF THE PULSED RESONANT FUEL COMBUSTION IN THE PROCESSES OF STEELCASTING LADLE DRYING AND WARMING (p. 52–59)

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This paper reports a technique of the pulsed resonant fuel combustion in the processes of drying and heating steel-casting ladles, devised to save fuel. The research method is based on the initiation of pulsations when burning fuel at a frequency equal to the frequency of natural fluctuations within the working volume of the ladle, which leads to the resonance of pulsations. This study aimed to define a technique to effectively burn fuel and to confirm a decrease in fuel consumption in the process of the pulsed resonant combustion. The experimental and industrial studies involving 8 drying operations and 5 ladle heating operations have established the possibility to comply with the normative requirements in line with the technological instructions at the level of 80–100 %. The possibility to search for the pulsed resonance frequencies under industrial conditions has been confirmed, despite the negative impact of high temperatures, acoustic interference, and inertia of the equipment. The feasibility of a pulsation unit has been determined, as well as the possibility to steadily maintain, during the drying process, the required resonance frequencies of gas pulsations. A more intensive course of the drying process has been observed, which makes it possible to shorten the process duration and, accordingly, to reduce fuel consumption. The high excitability of resonance frequencies in the ladle during heating has been detected, due to the short length and volume of the section of a gas pipeline between the pulsation unit and burner compared to the drying bench. The warm-up intensity was noticeably higher than that of drying due to the lower end temperature of the lining (777–910 °C instead of 900–1,120 °C) and the lack of moisture evaporation. Using the pulsed resonant fuel combustion mode at the posts of intensive heating of ladles for melting makes it possible to force the heating by the resonant pulsation of the torch. During pulsed resonant combustion, the usable utilization of fuel heat increases markedly, which leads to an increase in the drying and heating processes efficiency and corresponding fuel economy. The decrease in the consumption of natural gas when drying the ladles amounted to 2.7÷26.1 %; at the warm-up – 19.5÷37.8 %. These data indicate the energy efficiency of the pulsed resonant combustion and the feasibility of implementing a burning technique in the processes of ladle drying and warming.

Keywords: ladle, drying, warming, burning, pulsation, resonance, balance, fuel, savings.

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