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Analysis of the Quality Indicators of Electric Energy of Electromechanical Equipment of Open Cast Mining

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ABSTRACT: Considered the energy indicators the basic electrotechnical equipment of mining excavators of open cast mining. By results of experimental research obtained values of the energy indicators of a full cycle of work career excavator, consisting of engines right and left cycle pressure, lifting and turning. Consumed power in the operating mode corresponding to 75% of the total consumed power. Considered the graphs measuring the electrical parameters of the main electric drives current and the voltage, active, reactive, apparent power and power factor for a period of time in operating mode. Made an analysis the composition of voltage and current harmonics up to 50 harmonics and for the period of time of 50 seconds. Derived forms of voltage and current for each period of each phase, and determined the total coefficient harmonic distortion. Influence of higher harmonics on work of electromechanical equipment will eventually is reflected on energy-efficiency indicators and stock of resource saving of the electromechanical equipment.

KEYWORDS:electromechanical equipment, energy indicators, higher harmonics, quality, harmonic distortion

I. INTRODUCTION

The mining - metallurgical enterprises of Uzbekistan are one of the largest consumers of energy resources, recently is characteristic of them outstripping growth of level of energy consumption. The development of the mining industry is largely on the basis of introduction of open cast mining.

Our research and researches of several authors indicate that, one of the factors influencing the quality of electric energy and energy and resource efficiency are the higher harmonics arising in considered systems [1-11]. The given questions require further study, since they are depend not only on the very sources of the higher harmonics, but also the modes of operation of technological equipment, electro-mechanical system which is powered by energy converters or other sources of electricity supply. The given question is particularly relevant, when the system works in dynamical modes. One of such objects is the electromechanical system of the equipment of mining excavators and drilling rigs.

The emergences of the higher harmonics are connected by wide application of semiconductor converters in systems of electric power supply of the enterprises in various industrial sectors. To questions of investigation of the composition the higher harmonics of current and voltage, and their impact on the quality of electrical energy are devoted to a number of works [12-22].

The main sources of the higher harmonics are: electric drives with the semiconductor converters, the rotating electrical machines, the saturated magnetic circuits, rectifiers and frequency inverters of all types, high-power single-phase receivers, electric welding of installations and lighting system with application of economical lamps.

Harmonics in structure of a current, voltage or simultaneously a current and a voltage influence on the quality of electric energy. The poor performance of the quality of electric energy leads to many negative consequences. The most unpleasant for industrial consumers: decrease in efficiency and an increase in energy consumption, overheating of cables, electric motors and transformers; decrease in reliability of system of electric power supply; decrease in the efficiency of production and increase of the specific energy consumption of unit of the final products; decrease in service life of an electrical equipment; damage to sensitive equipment; operation of circuit breakers; burning out of safety locks; premature wear of the equipment; an overheat and failure of the capacitors; the occurrence of strong currents in the neutral wires; the occurrence of resonance in the network; refusal in the connection to electricity supplying network in case of a too high level of harmonics; shutdown and downtime of technological equipment

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caused by accidents and switching in external networks; the direct losses, associated with the underproduction of final products; indirect losses because of possible repair work of mechanical equipment, as well as the costs of maintenance.

II. THE MAIN PART

The main equipment of the mining electromechanical equipment enters excavators and drilling machines. Mains supply has the branched structure, ranging from 35-10-6-0.4 kV. On the open mining careers, uses the following technique, which is shown in table 1.

Table 1. Usedtechnical equipment on the open mining careers

№	Name of equipment, type	Power, kW	Power of the transformer own need, kVA	Typeof electric motors
1	Excavator ECT-10	800 750 630	160 160 160	SE-800-6U2, TOP-160, SEE-750-6-U2, TOP-160, SEE-2-15-34-6U2, TOP-160
2	ExcavatorECT-8I	750 630 520	160 160 160	SEE-750-6-U2, TOP-160, SEE-2-15-34-6U2, TOP-160, SEEU-14-29-6, TOP-160
3	Excavator ECT-5	250	40	AE-113-4, TOP-40
4	Excavator ECT-20;15;12,5	1250	250	SEE2-16-6U2, TOP-250 SEE-1250-6U2, TOP-250
5	Drilling rigs RDR-250	-	400	TOB-400

On the excavators of different marks various systems of a drive are applied. So, on excavators of type ECT-8I, it is used system GE-EMA (the generator-engine with the electromachine amplifier) on the excavators ECT-5A is applied system GE-EMA (the same, but with the power of magnetic amplifier) the principle of action of both systems is similar. At the present time being developed and tested the systems of regulation of drives with use of thyristor converters. The engine on excavators of mark ECT-5 high-voltage asynchronous, on excavators of marks ECT-8I, ECT-10 and higher power - synchronous electric motor.

III. EXPERIMENTALPARTAND RESULTS

We have carried experimental investigations on ECT-10, exploited in the career KalmakyrAlmalyk MMC, in which regulation of electric drivers of the main mechanisms of an excavator is carried out on AC system the controlled rectifier - autonomous inverter of a current - asynchronous engine (CR-AIC-AE) with frequency-current control, instead of existing electric drives on system G-E.

The electric equipment of an excavator EKT-10 feeds from three transformers. The transformer №1 for powering of all auxiliaries equipment (fans, lighting, oil pumps, winches). The transformer №2 feeds the side party electric motors of the lifting engine, the turning engine, the pressure of engine, accordingly the transformer №3 feeds electric motors left-hand side electric motors. Intable 2 dataof measurements arecited.

Energy indicators of the consumption of electric energy on three transformers are shown in Fig. 1, where 1 corresponds to the total power consumption of 1st transformer TS-1 of power supply of auxiliary equipment 20.86 kW, 2 corresponds 2nd transformer TS-2 of power supply of the right cycle of power supply of engines of lifting, turn and pressure - 173.47 kW, 3 - transformer TS-3 accordingly power supply of engines of the left cycle - 35.70 kW. The difference of powers 2- and 3-rd is defined by that the cycle of work of the excavator is carried out on the right side. Thus, 75 % of power are necessary on operating mode that is on creation of pressure, realization of lifting and turn of the filled bucket.

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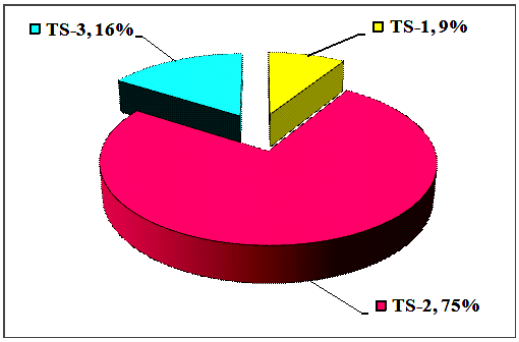
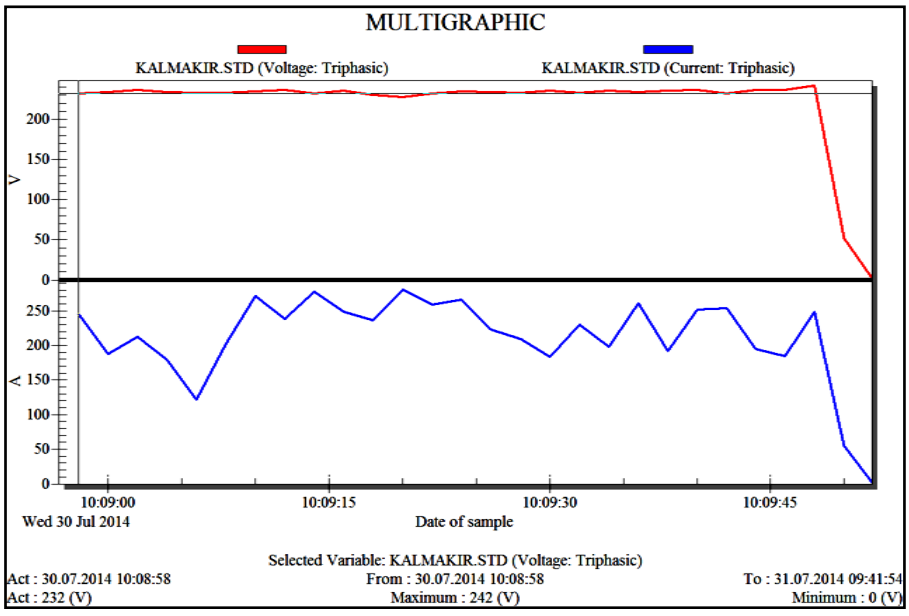


Fig. 1. Energy indicators of the consumption of electric energy on three components

Table2.Data of measurements Ore department "Kalmakyr", an excavator of ECT-10 №2 (2nd transformer)

Parameters		Experimental data				Passport data	
		phase-A	phase-B	phase-C	average	type	ECT-10
Voltage	V	236	237	236	236	Voltage, V	380
Current	A	246	243	245	244.67	The transformer for the main equipment	TOP 400/10/0,4
Active power	kW	50.51	49.53	50.30	150.34		
Reactive power	kvar L	28.62	29.39	28.51	86.52		
Reactive power	kvar C	0	0	0	0	From the 2nd transformer powered	The right lifting, turning, pressure engines
Power factor	cosφ	0.87	0.86	0.87	0.87		
Frequency	Hz	50	50	50	50		
Total power	kVA	58.06	57.59	57.82	173.47		
Date and time	day / hour: min.	30.07.2014 / 10:08 - 10:10				2-cycle work	2 min

Based on the presence of three transformers, we have removed oscillograms of the operating mode of the excavator ECT-10, which are shown in Fig. 2-6.



a)

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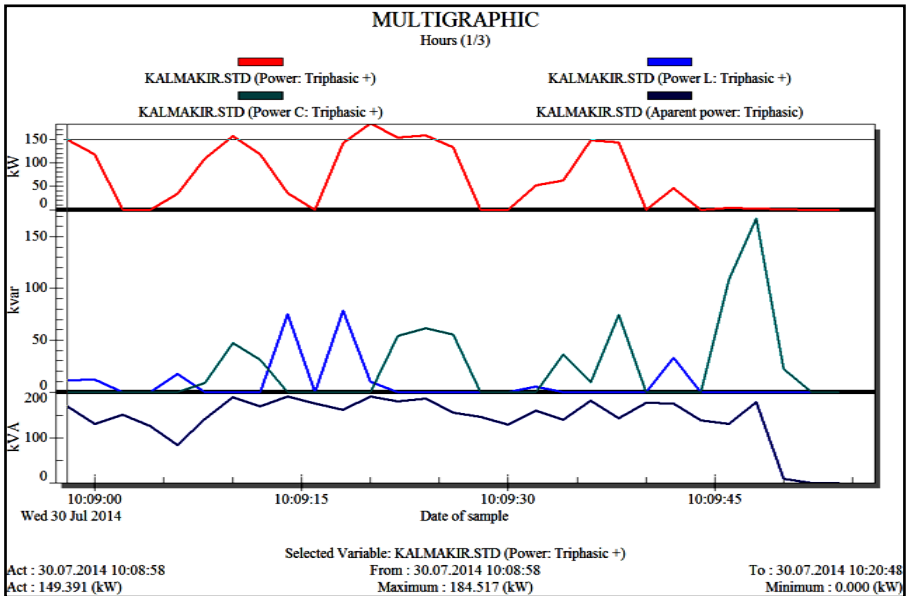
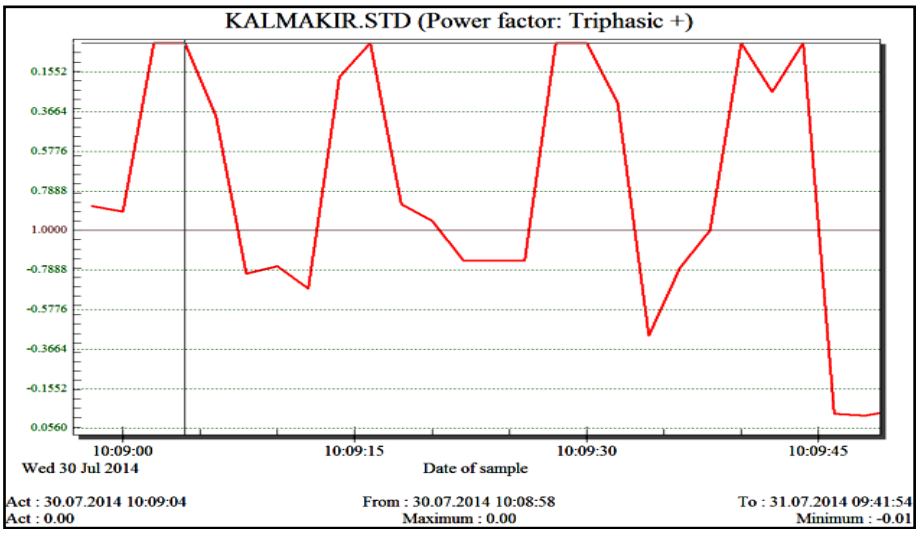


b)



c)

Fig. 2. Measurements of the electrical parameters of the main electric drives of excavator ECT-10 № 2 (2nd transformer): a - current and voltage; b - active, reactive and total power; c - power factor

As is evident from the graphs of current and voltage (fig. 2a), at stable value of voltage, the amplitude of oscillations of the consumed current in operating mode has sharply variable character, that is, with a maximum ratio to a minimum more than 2 times. On fig. 2b shows graphs of consumed active, reactive and total power of the ECT in operating mode. Active and reactive powers have sharply variable character from a maximum to the zero, the total power more smoothed in comparison with active and reactive powers. On fig. 2, from change of value of a power factor in the operating cycle and depending on consumed active power, the power factor fluctuates within capacitor and inductive values.

On fig. 3 oscillograms of the instantaneous value of harmonious composition of a voltage and a current up to 50 harmonics ofECT-10 №2 (2nd transformer) are resulted. As seen from the graph of a voltage and a current composition in harmonics even and odd harmonics enter. In harmonics of a voltage and a current odd harmonics, especially 3, 5, 7 are allocated.

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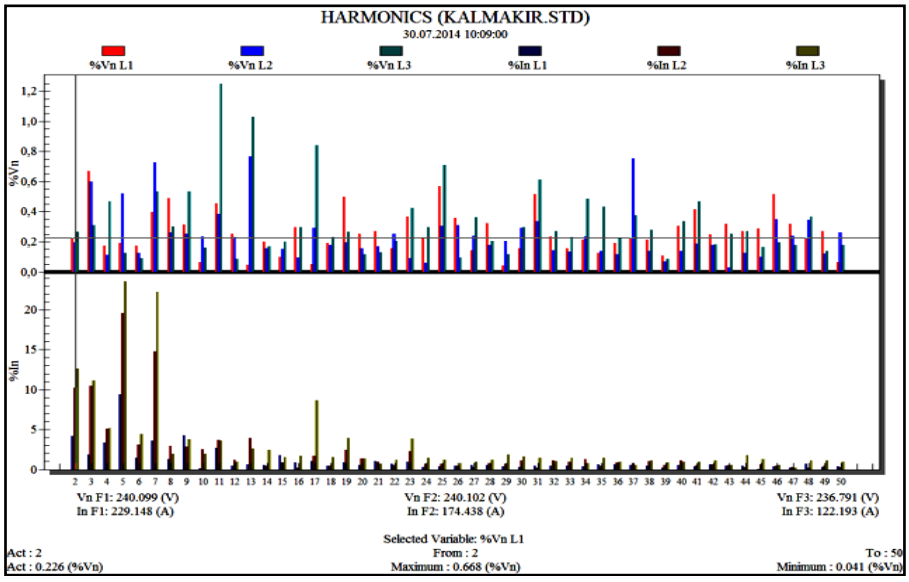

Fig. 3. Instantaneous value of harmonious composition of a voltage and a current up to 50 harmonics ofECT-10 №2 (2nd transformer)

On fig. 4 the composition of harmonics of a current and a voltage of each phase of the c cycle of work of the equipment feeding from the 2-transformer for the period of time of 50 secondsare presented. As seen, composition of the harmonic changes in current of time and each phase separately. The amplitude of harmonics on voltage remains invariable, and the amplitude of harmonics of a current changes depending on duration of a cycle - pressure, turning and lifting. Total harmonic distortion (THD) on voltage changes in limits from 2-6%, separate jump makes 85%. THD on a current changes in limits from 18-84%.

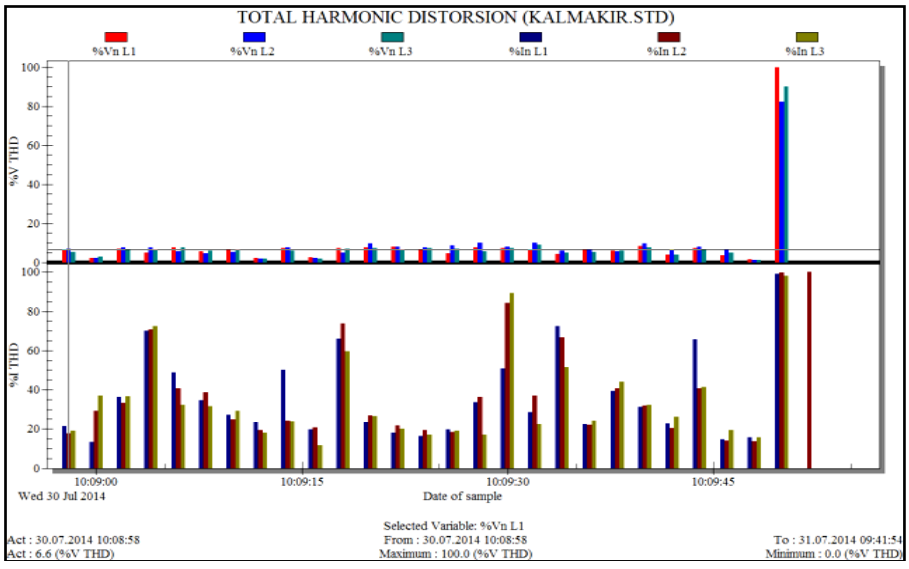

Fig. 4. Changesof harmonic of a current and a voltage for the period of time 50 seconds of ECT-10 № 2 (2nd transformer)

On fig. 5 forms of voltage and a current of each phase for each period of the right cycle, that is the operating cycle are presented. The form of voltage form in each half-cycle has distortion on each phase in the form of failures from odd

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harmonics. The form of the current of each phase has failures and splashes from an operating mode of the right cycle. THD on voltage each phases makes 7.5%, 7.4% and 7.7% respectively. THD on a current each phases makes 48.7%, 40.8% and 32.1% respectively.

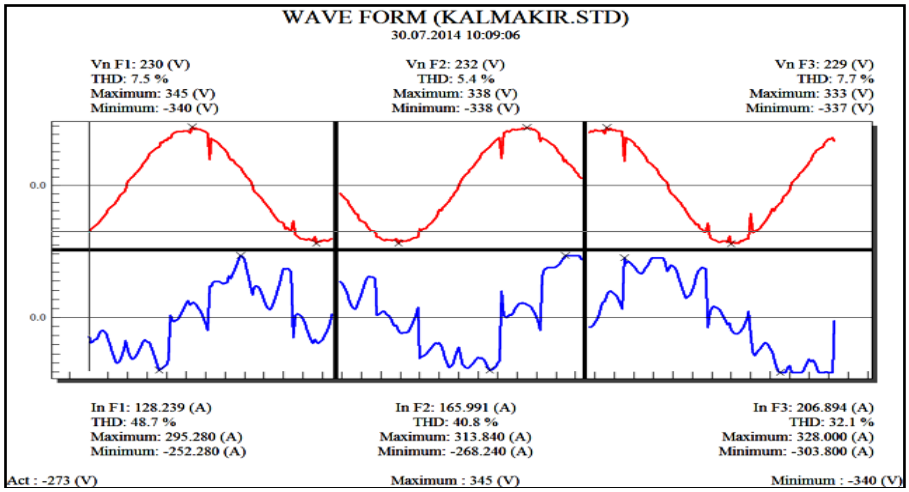

Fig. 5. Forms of a voltage and a current of each phase for each periodof ECT-10 №2 (2nd transformer)

On fig. 6 oscillograms of forms of voltage and current of each phase period start-up of the ECG-10 №2 from the 2-transformer are resulted. As seen from the oscillogramscomposition of harmonics of each phase on voltage and current differ from each other. Harmonics of current are more expressed in relation to voltage harmonics. THD on voltage each phases makes 99.8 %, 99.8 % and 100 % respectively. THD on a current each phases makes 100 %.

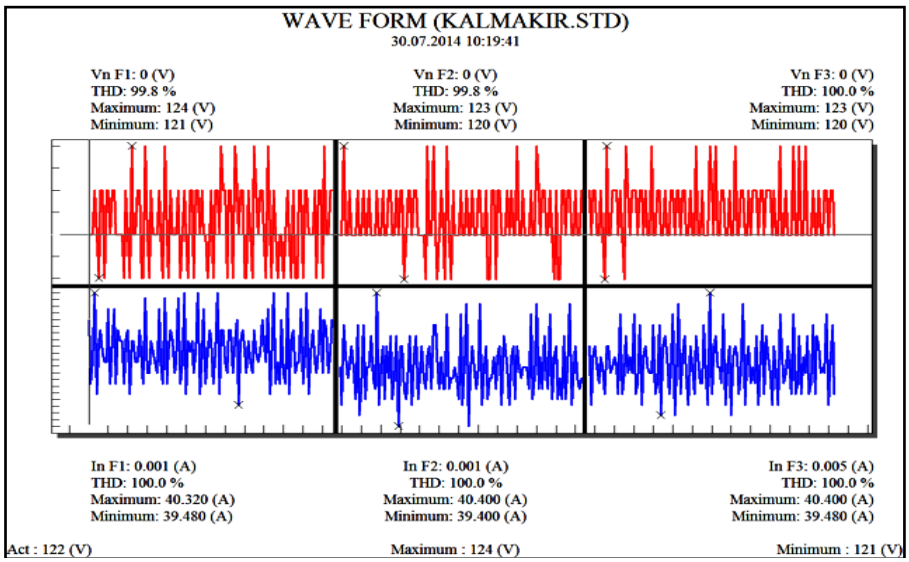

Fig. 6. Forms of a voltage and a current of each phase for each periodof start-up of ECT-10 №2 (2nd transformer)

IV. DISCUSSION

The most part of electric drives (with two engines) on a supply is executed in the form of equivalent 12-pulse schemes to which in the process of work steps of filters the compensating devices (FCD) are necessarily connected, adjusted on suppression of the fifth and seventh higher harmonics. Simultaneously filters compensate the jet power of the first

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harmonic consumed by transistor converters of the main drives. In general, an excavator from the network consumes practically pure active power [23-25].

CONCLUSION

1. Composition of a spectrum of the higher harmonics depends not only on sources of the higher harmonics, but also the operating mode of technological equipment, electromechanical system which eats from converters of energy or other sources of electro supply.
2. The energy indicators of consumption of electric energy at a full cycle of work of the career excavator at consumption constancy for own needs fluctuates in limits from 16 to 75 %.
3. Value of the total factor on a current is a consequence of nonlinear loadings in electromechanical systems of an excavator.
4. The total coefficient harmonic distortion by a voltage is the result of highly distorted consumed current the electric drive, the corresponding components cycle of work of the excavator.
5. Devices of compensation of the higher harmonics should be adjusted on a wide spectrum of frequencies or use active filters.
6. Influence of higher harmonics on work of electromechanical equipment will eventually is reflected on energy-efficiency indicators and stock of resource saving of the electromechanical equipment.

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OlimjonZuvurovichToirov, Doctor of Philosophy, Senior Researcher of Laboratory of "Automated electric drive" of the Institute of Power Engineering and Automation of the Academy of Sciences of Uzbekistan.He in 2012 has defended Ph.D dissertations on the theme: "Energy and resource saving modes of taped conveyor's installations on the basis of adjustable frequency electric drives".In 2016 he was awarded the academic title of Senior Scientific Employee. He under the leadership of T.S.Kamalov carries out scientific researches on enhance of energy efficiency of the electrical equipment of the mining industry. Under the leadership of O.Z. Toirov as part of the "National program of the training of personnel" 4 masters theses, more than 20 bachelor's degrees are prepared and defended. Recently, he participated in the program of the Indian Technical and Economic Cooperation (ITEC) and attended 3 months scholarship in CMC Academy, New Delhi, India. He has publishedmore than 60 papers in International and Nation Journals and Conferences.