The effect of electric exposure on the gas cleaning systems filter efficiency

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Abstract. This article discusses different characteristics of dust-gas flow and electrical action algorithms of perceiving fields providing better gas cleaning in gas-cleaning equipment. We consider the most promising for the gas purification maximum degree to combine these algorithms into one system, and it can significantly increase the gas cleaning equipment efficiency.

1. Introduction
February 9, 2014 Omsk, Russia was covered with black snowfall. It is not the first time in Omsk. There were recorded 2 more cases of black snowfall in 2012. Rosprirondnadzor of the Russian Federation stated that it was HES emissions. The contamination area was 7.7 thousand hectares. An unscheduled inspection revealed that the precipitation was Ekibastuz coal ash, Kazakhstan. The audit found out that the HES filters were ineffective, and the station authorities were given the responsibility to bring the degree of electrostatic gas cleaning system to the design values. The electrostatic precipitator as a gas purification machine operates through two main electrophysical processes - cleaned flue gas particles charging with corona discharge ions and the charged particles motion to the collecting electrode under the electrostatic forces influence. The electrical gas cleaning process is that at a certain voltage value applied to the interelectrode gap, the field strength near the corona electrode becomes sufficient for its appearance; its consequence is to fill the electrode gap outer part mainly with negatively charged ions. Under the influence of electric field forces they move from the corona electrode to the collecting one. Ash or dust particles meeting on their way ions adsorb them, charge, and under the force field influence they also move towards the collecting electrodes, where they are collected. The electrodes are periodically shaken, a layer of collected dust is destroyed, and the dust falls into the electrostatic precipitator hoppers, where it is intermittently or continuously removed. A feature of the electrostatic precipitator is that it provides the maximum purification degree of the electric field strength in the interelectrode space, when there are sparks in the electrostatic precipitator, but there are no transition arcs. The purpose of the article is to study the processes and to develop recommendations on optimization of electric power modes of electrostatic gas cleaning system.

2. Objects and experimental methods
The voltage level with sparks varies non-linearly over a wide range and depends on many factors: the properties of the exhaust gases, the dust content in the gas, humidity, temperature, dust particles size, chemical composition and their electrical conductivity, the layer formation conditions on the collecting electrodes and other factors. Thus, the first problem to be solved in the course of work is the development of interelectrode space intensity algorithms change in electrostatic precipitator considering the dynamics of the filtered gases properties. One of the most difficult problems in the electrical gas purification is cleaning gas from dust with high resistivity, which is Ekibastuz coal ash, Kazakhstan. Such gases give rise to back-corona on the collecting electrodes, decrease breakdown voltage, electric field voltage, increase the adhesive layer properties on the collecting electrode, its poor cleaning, and as a result, reduce of the current load due to the dust layer locking action. These processes result in decrease in electrostatic gas purification degree. Thus, the second problem is to reduce back-corona effects. The third problem is the secondary dust loss associated with the precipitator shaking mechanism operation. The dust loss that exists due to continuous collecting electrodes shaking can be significantly reduced if there is an optimum shaking mode implementation. The amount of ash loss reduction through shaking...
optimization depends on the physico-chemical properties of dust-gas atmosphere. The optimal mode of corona electrodes shaking must support the dust layer on the discharge tools where the corona current provides the most effective dust collection in an electrostatic precipitator. Thus, the next issue to be solved is the development and optimization algorithms of shaking electrodes control mechanisms. [1].

Electrooptical monitoring sensors (EOS-2) of the electrostatic precipitator dust and ash emissions were developed in FSBEI HPE "Omsk State Technical University" to solve the mode configuration tasks of dust and ash clearing equipment operation [5], the equipment operation processes control and qualitative assessment of the gas cleaning process in general, as well as for environmental monitoring purposes. The sensors are installed directly on the gas ducts and are electrooptical devices, carrying out continuous automatic monitoring of dust and ash emissions consisting of three blocks: a radiation source, radiation detector and control unit.

Analysis of the DVR-4 operation (digital voltage regulator) and determining the mode effectiveness with through periods form of feeding voltage at the electrostatic precipitator substations were carried out according to the following procedures:
1. Set the sensitivity and maximum dust meter scale.
2. Continuous shaking of all semifields during 6 minutes.
3. Installation of test mode for 4-8 minutes.
4. Trend analysis of the dust loss at the precipitator exit.
5. Repeat steps 3-5 for other supply modes of electrostatic precipitator fields.

3. Results and discussion
All electrostatic precipitator substations use the power supply units ATF-1000 Series. They are the third generation units; the main difference is that there is no a power magnetic amplifier in the unit circuit, it is replaced with a thyristor power regulator. The advantage of the ATF unit series is speed, compactness and the basic units’ durability, the size and weight of the unit are reduced. These power units are single-phase version units which used the silicon bridge rectifiers with symmetries shielding. The block of power thyristors (two thyristors connected in anti-parallel) combines the functions of smooth voltage regulation on the primary winding of the power transformer and the unit switching on and off. The survey proved that all power units are in satisfactory condition. Analysis of DVR-4 (digital voltage regulator) operation in electrostatic precipitation substations showed the overall operability of power supply units and automatic control modes maintenance of electrostatic precipitation voltage [3]. During the analysis of work and settings following shortcomings were identified:
   a) spark selectors excessive sensitivity;
   b) unstable operation mode with pulse skipping of supply voltages;
   c) visual mismatch of current sensor readings on the digital display DVR and milliammeter pointer of the regular voltage controller of converter-rectifier panel (CRP) type.

Air suction reduction is known to lead to improved gas purification degree. In addition, gas air-conditioning with water reduces the high dust resistance typical for Ekibastuz coals burning, and to exclude reverse crown formation. In this regard, the examination program included work on the examination of housing lining state of the electrostatic precipitator and flue gas conditioning scrubber. As a result of thermal imaging examination [2], we can draw the following conclusions: in general, the state of scrubbers and electrostatic precipitator flues linings is good (Fig. 1). The false air is found out at the sampling platform and the electrostatic precipitator inlet. The false air to detect on the electrostatic precipitator housing by means of the electrostatic imager is not possible due to the shielding effect of the coating around the electrostatic precipitator corrugated casing.

The digital control unit (DCU) analysis with shaking electrodes mechanisms showed that all DCU-1 installed in electrostatic precipitator substations are operating in the normal mode [4].

Experimental deviations indications studies of CPR regulator currents and voltages with respect to the CRP control readings have been completed. When reading the current-voltage characteristics the experimental data shown in Fig. 2, 3, 4 were obtained.
The experimental data led to the following conclusions:
1. CPR current regulator readings in comparison with the CRP control readings are practically the same (Fig. 2):
   - the minimum deviation error is 0.47%;
   - the maximum deviation error is 56% (at the beginning of CRP scale up to 25 mA);
   - mean error is 6.9% (CRP milliamperimeter accuracy class is 2.5 giving an instrumental measurement error of 5%, moreover at the beginning of the scale it is almost impossible to make an accurate visual counting. Besides the analogue-digital conversion error in DVR may be 100% at the beginning of the scale and 5% for 100 mA).
2. DVR regulator indications voltage in comparison with the CRP control readings are practically the same (Fig. 3):
   - the minimum deviation error is 0.29 %;
   - the maximum deviation error is 5.4%;
   - mean error is 2.6 % (accuracy class miliampermetra PVP is 2.5, which makes it an instrumental measurement error of 2.5%, the first samples were made with 18-22 kV).
3. The random error proves that DVR current regulator reading measurement is significantly less than CRP regulator due to malfunctioning of information visual assessment with pointer instruments. It was indicated due to a curve dependence comparison I_{comp.}, measured with an oscilloscope, and currents CRP and DVP.

![Figure 1. Lining of the scrubber and electrostatic precipitator walls](image1)

![Figure 2. Comparative experimental characteristics of current values for different measuring systems with respect to CRP milliammeter readings](image2)

![Figure 3. Comparative experimental characteristics of DVR voltage values relative to the CRP voltmeter readings](image3)
Figure 4. Comparative experimental characteristics of DVR and CRP currents values with respect to FLUKE oscilloscope readings (the mean value of current I mean)

The current-voltage characteristics taken in the flue gases (Fig. 5) allow estimating the fields’ state and the back corona presence.

Figure 5. The current-voltage characteristics of the electrostatic precipitator semifields operating on gas

Figure 6. Trends in the dust meter readings

The nature of the curves for electrostatic precipitator semifields allows concluding the back corona existence on these electrostatic precipitators and the need to apply for these semifields through periods supply and maintaining the voltage on the electrodes using electrostatic precipitators through DVR algorithms close to the current-voltage characteristics inflection point.

We show trends graphs of dust meter readings, current sensors and voltage fields in the transition from the skip pulses mode (2/8, 2/6) into a continuous flow voltage pulses mode at 100 Hz frequency in Fig.6. Relative dust and ash losses are decreases in 2 times at the supply voltage with through periods form.

The analysis revealed a dust meter trend to increase dust discharge from the electrostatic precipitator during normal shaking modes. In the period from 9 a.m. to 14 p.m. pauses were reduced and a palpitations electrodes shaking was carried out. It is clear from Fig. 7 that after the pause time reducing dustiness is also reduced.
There was made are graphs confirming the link between shaking mechanisms operation pause times and the voltage change on the electrostatic precipitator electrodes allowing justifying 3 minutes pauses (Fig.8).

4. Conclusion

The examination and adjustment of DVR and DCU of electrostatic precipitators provide the potential possibility for increasing the cleaning from ash efficiency. The quantitative results of the proposed solutions effectiveness can be obtained with controlling comparative measurements of ash and dust losses in normal and recommended modes using GRAVIMAT device.

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