System for measuring and analysis of vibration in electric motors of irrigation facilities

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Abstract. This article analyzes the vibration process that occurs in electric motors in irrigation facilities. It has been studied that various failures and electric motor imbalances and vibrations that can occur during the operation of electric motors at pumping stations have a negative impact on the whole system. Electrical and mechanical failures affect the normal operation of the electric motor, i.e. increase power consumption, increase current, increase heat, and also increase vibration. Balancing is an important requirement for electric motors and all rotating components. A modern SD-21 vibrodiagnostic device was used to detect vibration. The research was carried out using the method of comparing the trajectory obtained in the mode of synchronous accumulation using the vibrodiagnostic device SD-21. In the course of the research, the main factors that cause vibration in electric motors, the method of identification of decentralization that causes high vibration, the spectral and informative properties of vibrating signals were studied. The advantages of predicting the deviation of vibrations in electric motors from the allowable are highlighted. A virtual tool has been developed to detect and analyze vibration.

1. Introduction

We all know that electric motors play an important role in starting large and small power pumps. Different kinds of failures can appear in different part of the motors, in electrical part and/or mechanical part. A motor drive system consists of more components; the motor is powered directly from the electrical net or through an adjustable speed inverter. The motor is coupled to the load by belt or gearwheel. Every component is fixed, mounted on a stand or frame or in a box. During the functioning each part influences the other and the whole system vibrates with a certain frequency. In time this vibrations can cause failures, damages. [10] Even during the installation or in the functioning stage can appear misalignment between motor and load and cause vibration which increase in time. Inside the electrical motor can appear broken rotor bar in case of induction motor, bearing usage, heat generation, short circuit between wires, mechanical imbalance, wrong electrical contact, etc. The load also can influence the motor by improper amount of mechanical load, radial misalignment, and inadequate belt tension or gearwheel damages. These faults influence the normal functioning, increase the power consumption, the current, more heat is generated and vibrations are growing too [1,2].

Electric motors must always be in good condition to provide timely water to crops in areas where water resources are not available. One of the causes of failure of electric motors is the deviation of the
level of vibration that occurs in them. If the vibration level exceeds the allowable value, it will cause some malfunctions in the pumping devices. Funding is required for timely troubleshooting. Therefore, there is a need for modern devices that predetermine the level of vibration that occurs at pumping stations.

Based on this, our scientific team visited the pumping station that supplies water to 1073 hectares of land belonging to the Chirchik Ahangaron ITHB. It is equipped with 2 centrifugal pump units with water lift $Q = 3-3.2 \text{ m}^3/\text{sec}$, pressure $H=45 \text{ m}$ and power of each electric motor $P=2400 \text{ kW}$, connected to the electric motors via a semi-rigid coupling. These pumping stations are critical objects and their water supply to large settlements and crop fields depends on their operation [1]. The failure of these pumping stations could cost billions of rupees.

2. Methods

Including failure of the electric motor rotor that drives the pump units in such pumping stations, improper centering of the shaft and imbalance can cause large vibrations and cause the pumps to shut down quickly and reduce the time between repairs. Research shows that the main reason for the formation of vibrations is that the electric motor support is not placed on a single axis.

As we know, the main sign of the different centering of the two shafts connected by a coupling is an increase in the second harmonic of the rotational frequency in the radial axis derived from the bearing support and an increase in the axis direction spectrum. This is true for a rotor system with linear or very low nonlinear regenerative characteristics [4,5].

Experience of such vibration loss shows that in systems with significant nonlinear regenerative characteristics, it is more difficult to identify the decentralization of the shafts using the above symbols, as it can also be characterized by high-frequency spectral imbalance [6]. The electric motors of the aggregates we are analyzing have bearing stability on a platform attached to the motor frame.

In general, such a design has a significant nonlinear regenerative characteristic and is sensitive to excitation at the rotor frequency. The rotational frequency of the rotor is 16.67 Gts and the entire information spectrum lies in the range up to 400 Gts. Identifying the decentralization of the axes in such systems requires the analysis of the entire information spectrum and the use of several additional characteristics [2]. The use of such a technical solution requires the use of a two-channel analyzer with synchronous processing on two channels.

Currently, SD-21 is used to measure and analyze vibrations at pumping stations [3]. Its structural scheme is shown in Figure 1 below.

When measuring vibration, the vibrating sensor is mounted on the bearing cover and oriented along the axis of the electric motor to the X axis. The vibration in each sensor (direction X, Y and Z) and the signal in the sensors are recorded synchronously on a magnetic tape. A similar signal is recorded from a sensor mounted on each bearing. Such analysis can be performed in the laboratory and in the field.

Our object recorded a very high vibration in one of the pump units (No.2) during the next vibration inspection, which called into question the operation of this pump unit. Spectral analysis of the signal recorded on a magnetic tape in the range up to 500 Gts showed that the front and rear support spectra of the electric motor have high frequency components with a rotational frequency of 2-6 times. Due to the decentralization of this spectrum, it was found that such a spectrum was also present in other pump units. After such a deficiency was corrected, the intensity of the high harmonics decreased sharply.

Figures 2 and 3 below show the vibration spectra of the cases before and after the decentralization correction.
Experiments conducted at the pump station No. 2, i.e., to check the centralization of the shafts, showed that the decentralization was above the norm. After this fault was rectified, the pump unit was restarted. However, it was found that its vibration condition did not improve. More experimental work was continued.

The imbalance of the rotor of the electric motor was checked. In this case, the level of the first harmonic of the rotor (characterizing the imbalance [7]) was taken from the base, separating the electric motor from the pump unit, and it was determined that it was normal.

**Figure 2.** Vibration spectrum on the axle on the rear bearing of the electric motor before repair.

**Figure 3.** Vibration spectrum along the shaft on the rear bearing of the electric motor after repair.
3. Results and Discussion
Experimental work was continued using the method of comparing the trajectory obtained in synchronous accumulation mode using the SD-21 vibrodiagnostic device. In this case, channel A was given a transverse vibration signal of the base, and channel B was given a vertical vibration signal of the base and recorded synchronously. A signal from the rotation sensor was used as the start signal. Using a filter, the signals were pre-synchronously filtered. The filter adjustment frequency was 16.6 Gts (first harmonic) and the bandwidth was 3.16 Gts. The average number of measurements is 50. The obtained characteristics showed the trajectory of the oscillation of the base to the frequency of rotation at the point of measurement in the transverse plane in terms of content. Figures 4, 5, 6, and 7 below show the vibrational trajectories on the rear bearing of the electric motor in the presence and absence of decentralization.

The analysis of the characteristics shown in Figures 4-7 showed that the decentralization does not affect the change in the shape of the trajectory, but changes its, i.e. the width of the oscillation arm. In addition, the characteristics obtained from the No.2 pump station differ qualitatively. From the appearance of the graph obtained from the rear support, it can be concluded that the vertical oscillation is compressed because the shape of the curve differs sharply from that of the standard, i.e., compared to the curve shown in Figure 6. It is assumed that the base of the electric motor is not centered. It was necessary to determine whether the rear base was lower or higher than the front base. Ongoing research has shown that the rear support of the electric motor is slightly lower than the front support.
To correct this fault, the thickness of the base placed under the rear support of the engine was increased. The unit was then assembled and centralized, as well as commissioned. The vibration decreased sharply and the trajectory shape came close to the normative shape shown in Figure 7.

The situation discussed above shows that it is very difficult to identify the rotor defect (decentralization) in the vibration spectrum of the pump unit in the base systems with a high level of nonlinear characteristics. For more accurate information on vibration, it is necessary to observe synchronous changes along the radius and axis, as well as to obtain additional characteristics. The vibration characteristics studied in this article made it possible to center the base of the electric motor and restore the working capacity of the pump unit. The considered vibration detection method can be successfully implemented using the SD-21 portable vibrodiagnostic device, which provides a simultaneous vibration level detection on two channels.

![Figure 8. Scheme of vibration detection in electric motors.](image)

4. Conclusions
In this research paper, the causes of vibration in electric motors at pumping stations were identified and eliminated. Based on the analysis, it was determined that the main cause of the vibration was that the electric motor support was not properly centered.

The vibrodiagnostic device has been proven to be the most efficient method of detecting the vibration process occurring in electric motors through two channels.

If it is detected in advance that the vibration in electric motors exceeds the allowable value, rapid failure of the devices will be prevented.

The application of the SD-21 vibrodiagnostic device to the facility will extend the current repair intervals of electric motors and, as a result, also achieve economic efficiency.

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