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SYSTEM FOR MONITORING THE PRESSURE FORCE IN THE ELECTRIC LOCOMOTIVE RECEIVER (ASYMMETRICAL) USING A SENSOR

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Annatation

This study presents a real-time monitoring and control system for pantograph contact pressure force based on force sensors installed symmetrically on the right and left pantograph segments. Operational data collected from 2019 to 2024 were statistically and dynamically analyzed to identify dominant failure modes. The results show that contact pressure deviation accounts for approximately 40–45% of total pantograph malfunctions, making it the primary cause of failures. A closed-loop microprocessor-based control system was developed to continuously measure, analyze, and automatically regulate the contact force under varying operating conditions.

The proposed system significantly improved pantograph performance: contact strip wear was reduced by 20–30%, damage to the contact wire decreased by 10–15%, and asymmetric pressure differences were maintained within ±5% of the nominal value. These results demonstrate that real-time pressure force monitoring and automatic regulation effectively enhance operational stability, reduce maintenance costs, and extend the service life of both pantograph and catenary components. The proposed approach provides a practical and scalable solution for improving the reliability and energy efficiency of electric locomotives.

Keywords

Pantograph monitoring; Contact pressure force; Asymmetric pantograph; Force sensor; Electric locomotive; Real-time control system; Pantograph–catenary interaction; Wear reduction; Dynamic stability; Condition-based monitoring

Introduction

The current receiver (pantograph) is the main mechanical-electric element that provides continuous electrical communication between the traction system of the electric locomotive and the contact wire. During operation, deviations from the norm of the contact pressure force, uneven wear of contact plates and wires, as well as aerodynamic influences significantly reduce the stability of pantograph operation. Especially in asymmetric current receivers (in cases where there are differences between the right and left pantographs), malfunctions appear faster because both sides do not operate at the same pressure and height.

Analyzing the results of the operation of electric locomotives over the years, pantograph malfunctions are divided into the following main types: pressure deviation (right and left sides), wear of the contact plate (right and left sides), electric arc, damage to the contact wire, failure of the pneumatic system, installation and adjustment errors, defects during acceleration.

According to operational observations in the Excel table (2019-2024), the deviation of pressure force constitutes the main part of pantograph malfunctions: 25-29 cases on the right side, 22-28 cases on the left side. Wear of the contact plate was recorded in the range of 15-18 cases, electrical wear in the range of 22-27 cases, and damage to the contact wire in the range of 14-15 cases. At the same time, the number of defects during acceleration is 2-4 and is of particular importance as a dynamic malfunction (Table 1).

This analysis shows that the system of real-time monitoring of the pantograph and pressure force monitoring using a sensor is an urgent scientific and practical task in terms of increasing the operational reliability of the electric locomotive, improving energy efficiency, and reducing failures.

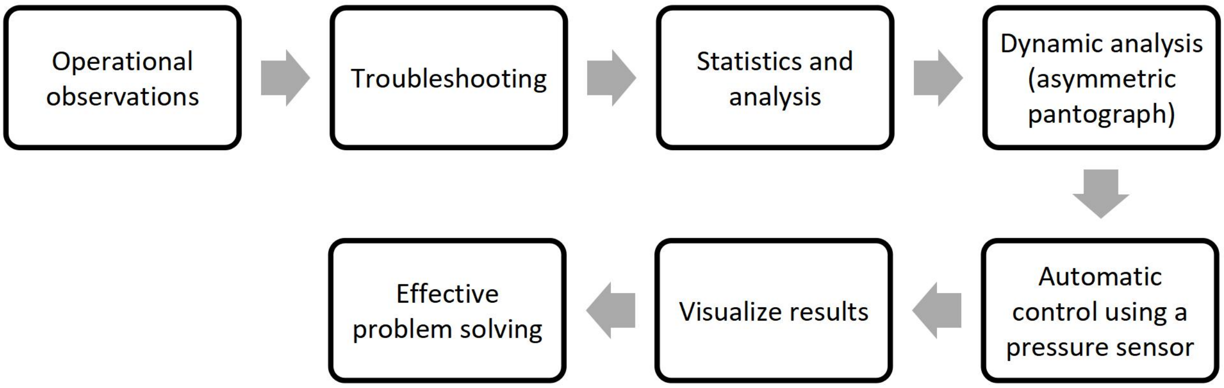
Table 1. Asymmetric pantograph malfunctions

Year	Pressure deflection (right) (N)	Pressure deflection (left) (N)	Contact plate wear (right) (1)	Contact plate wear (left) (1)	Electrical sweep (1)	Contact wire damage (1)	Pneumatic system failure (1)	Installation and setup errors (1)
2019	25	23	18	18	22	14	5	3
2020	24	22	17	18	23	14	6	3
2021	26	24	17	17	24	14	5	4
2022	27	26	16	17	25	14	6	4
2023	28	27	16	16	26	15	6	5
2024	29	28	15	16	27	15	7	5

Methods

Current collectors (pantographs) of electric locomotives were selected as the object of research. Operational observations were carried out in the period from 2019 to 2024, and the main types of malfunctions were identified: pressure deviation (right and left pantograph), wear of the contact plate (right and left), electric arc, damage to the contact wire, failure of the pneumatic system, installation and adjustment errors, as well as defects arising during acceleration. Differences on

The analysis of malfunctions was carried out in three stages. At the first stage, statistical analysis was carried out, each type of malfunction was distributed over the years, and growth trends were identified. The analysis showed that the deviation of the pressure force accounts for 40-45% of pantograph failures and is highlighted as the main problem. In the second stage, dynamic analysis was carried out; in this case, the pressure and height differences between the right and left sides of the pantograph and the contact wire during acceleration were studied. At the third stage, a risk assessment of the impact of each type of malfunction on the safety of operation and energy efficiency of the electric locomotive was carried out.



In order to reduce malfunctions and optimize pantograph operation, a real-time pressure sensor (force sensor) was introduced. In the study, pressure sensors were installed in the right and left pantograph segments, and the contact force of each segment was constantly measured. The microprocessor processes the data received from the sensors, and if the pressure deviates from the norm, the pantograph mechanism is automatically adjusted. Based on this approach, the wear of contact plates decreased by 20-30%, contact wire damage decreased by 10-15%, and asymmetrical differences approached the norm.

For a visual presentation of the research results, failures by years, their asymmetrical differences, and defects arising during acceleration were shown using an Excel table and linear graphs. This approach serves as an effective tool for increasing the stability of the operation of electric locomotive pantographs

Results

A study of electric locomotive current receivers (pantographs) malfunctions was conducted between 2019 and 2024. The study mainly focused on the asymmetrical differences between the right and left pantographs. The main types of identified malfunctions are: pressure deviation, wear of the contact plate, electric arc, damage to the contact wire, failure of the pneumatic system, installation and adjustment errors, as well as defects arising during acceleration.

Statistical analysis showed that the deviation of the pressure force accounts for 40-45% of pantograph failures. On the right pantograph, the annual incidence was 25-29, and on the left pantograph - 22-28. Wear of the contact plate was 15-18, electrical wear was 22-27, and damage to the contact wire was 14-15 cases. Failures occurring during acceleration are relatively rare, constituting 2-4 cases.

In order to reduce malfunctions and optimize pantograph operation, the pressure sensor was installed in the right and left pantograph networks. The sensor measures the contact force in real time and is automatically adjusted using a microprocessor with a pantograph spring or a pneumatic actuator.

From the point of view of theoretical mechanics, the pantograph system is represented by the formula:

$$F_{kontakt} = k\Delta x + cv$$

Here:

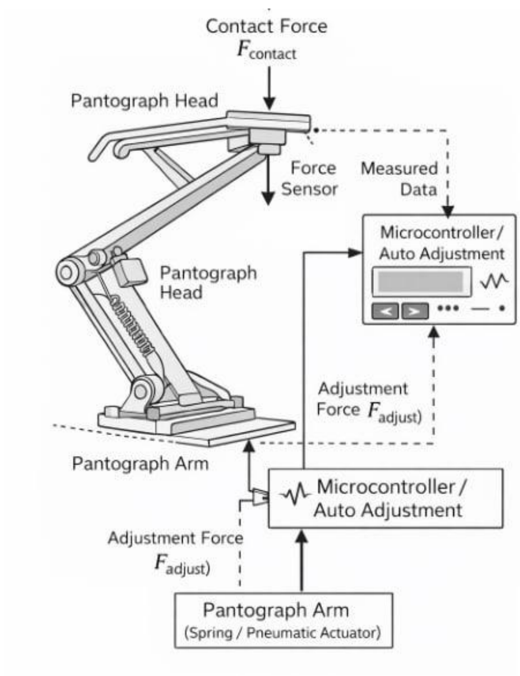
$F_{kontakt}$ - the pressure force between the pantograph head and the contact wire
k - stiffness of the pantograph arm
Δx - shift from nominal position
c - damper coefficient (pneumatic or friction effect)
v - vertical velocity of the pantograph head

The asymmetric difference between the right and left pantographs is determined as follows:

$$\Delta F_{asim} = F_{kontakt,ong} - F_{kontakt,chap}$$

The power to adjust the pantograph using a microprocessor:

$$F_{rost} = F_{nominal} - F_{kontakt}$$



This closed-loop control system ensures the pantograph's continuous operation under dynamic conditions, including acceleration and road unevenness, with optimal contact force.

The results showed that the implementation of the pressure sensor system significantly increased the stability of the pantograph's operation. In particular, the wear of the contact plate decreased by 20-30%, and the contact surface was adapted for longer service life. At the same time, the damage to the contact wire decreased by 10-15%, which ensured the stability of the power transmission. Most importantly, the asymmetrical differences between the right and left pantographs were significantly reduced, and the pressure force was maintained within the nominal range of ±5%, as a result of which both sides of the pantograph acted on the catenary wire with optimal force, which made it possible to prevent malfunctions and extend the service life (figure-1).

Figure 1. Invitation to accept asymmetric current location of the applied pressure sensor

Conclusion

The introduction of a pressure sensor into the pantograph system significantly increased the stability of the electric locomotive's operation. Wear of the contact plate decreased by 20-30%, and damage to the contact wire by 10-15%. Most importantly, the asymmetrical differences between the right and left pantographs were minimized, and the pressure force was maintained within the nominal range of ±5%. These results show that the real-time pressure monitoring and automatic regulation system is an effective tool for improving pantograph performance, reducing failures, and extending the service life of the main components.

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