# Characteristics for Polycomposite Brackets for Direct Electric Supply of Railways

Mihail Arzannikov[1], Aleksei Kosakov[2][a], Yuri Kochunov[1,2][b] and Aleksandr Suhoguzov[2][c]
[1]Research and Production Enterprise «Elektromash», Ekaterinburg, Russia
[2]Ural State University of Railway Transport, Ekaterinburg, Russia

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Abstract: To evaluate the discharge characteristics of polymer composite brackets of 6-10 kV overhead lines, the possibility and necessity of protecting such structures from lightning overvoltage. Methods: Experimental studies are presented in the laboratory of high voltage engineering of the Ural State University of Railways, using a pulse voltage generator. Results: The results of the work are conclusions on increasing the reliability of operation of polymer composite brackets of power transmission lines. Practical significance: The results of the work can be used in the development of an overhead line protection system against direct lightning strikes and pulse overvoltages and as theoretical material for students of higher educational institutions.

## 1 INTRODUCTION

Overhead lines (OL) of 6-10 kV are of great length in the Russian power grid complex. In recent years, special attention has been paid to overhead line protection against impulse over voltages (IO) and direct lightning strikes (DLS), the consequences of which may lead to irreparable breakdown or overlapping of insulation, damage to the sheath of self-supporting insulated wires (SSIW) and, consequently, to power outages for consumers and additional costs of rehabilitation work.

Overvoltage protection is based on several principles:

1. Limiting the number of modes in which dangerous overvoltage can occur by means of schematic measures;
2. Limiting the amplitudes of steady-state over voltages, resulting in a reduction of transient overvoltage;
3. Limitation by means of hardware.

Hardware means a device that is installed near the equipment to be protected and that shunts the protected object when an overvoltage occurs. Overvoltage arresters, surge suppressors and hybrid circuits can be used as such devices.

The operating principle of the protective device is that it prevents dangerous over voltages from arising on the electrical system and does not prevent the electrical system from functioning at operating voltage.

## 2 MATERIALS AND METHODS

A literature review has shown that this problem is topical all over the world (Kissling, et al., 2018; Luk'yanov and Luk'yanova, 2020; Zielenkiewicz, et al., 2018; Long, et al., 2016; Dev Paul, 2005; Ono, et al., 2017; Nai, et al., 2019; Ono, et al., 2018; Arai, et al., 2018). In order to prevent the occurrence of over voltages on the protected object and its damage, the volt-second characteristic of the protective device (curve 1) should lie below the volt-second characteristic of the protected object (curve 2) (Figure 1). If this requirement is met, dangerous overvoltage cannot occur, because in the case of a voltage surge (curve 3), a breakdown of the protective device occurs, with a voltage drop at point A. If the protective device is missing, a breakdown of the object insulation at point B occurs. Following the

[a] https://orcid.org/0000-0003-3908-5999
[b] https://orcid.org/0000-0001-6955-283X
[c] https://orcid.org/0000-0001-8288-533X



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surge current, a residual current flow through the protective device, and a residual voltage $U_{res}$ appears on the protective device. When operating the protective device, the accompanying current must be extinguished at the first zero crossing, otherwise the protective device may trip the installation.

Accordingly, the following requirements can be formulated for the protective device: the volt-second characteristic of the protective device must be lower than that of the object to be protected; the protective device must have a certain guaranteed electrical strength; the residual voltage on the protective device, which characterizes its limiting capacity, must not exceed values that are dangerous to the insulation of the equipment; the follow-up current must be disconnected in a time lower than the tripping time of the protection; the protective device must allow for a certain number of trips without inspection and repair, and be safe for the surrounding equipment. The protective apparatus must be able to operate without inspection and repair and must be safe for the surrounding equipment.

As already mentioned, one of the types of overvoltage protection is the use of surge arresters on overhead lines: tubular, valve, long-spark and multicamera. In the literature (Podporkin, 2020; Napolitano, et al., 2019; Podporkin, et al., 2019; Ivanov, et al., 2018) the principles of arrester operation, methods of their fixing, methods of protection are presented in details. It is only worth noting that in any case there is a breakdown of the spark gap between the current-carrying part and the grounded part of the protected object.

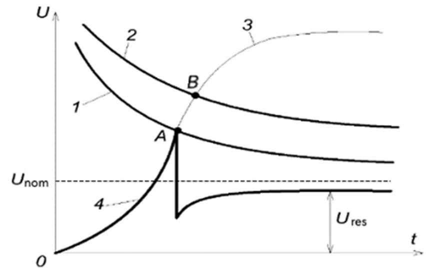


Figure 1: Operating principle of the protective device: 1 - characteristic of the protective apparatus, 2 - characteristic of the protected object, 3 - surge wave, 4 - sheared surge wave.

On overhead power transmission lines of direct current supply of railway transport, the surge arrester installation is carried out on the traverse by turns, on the same principle as power transmission lines 6-10 kV of the electric network complex of "ROSSETI" (figure 2) (Podporkin, 2020; Napolitano, et al., 2019; Podporkin, et al., 2019; Ivanov, et al., 2018).

However, it should be noted that overhead 6-10 kV lines supplying signalling, centralization, interlocking of railway (signalling and interlocking) devices and longitudinal power supply lines for non-



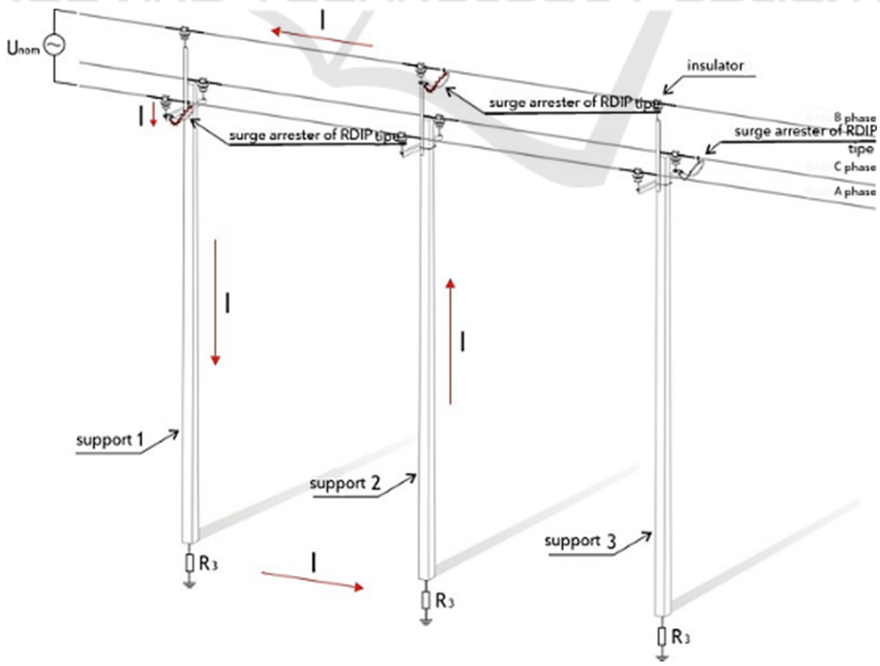


Figure 2: Diagram of installation of long-spark arresters RDIP on 6-10 kV overhead lines: http://streamer.ru.

traffic consumers (LP) can be placed on overhead system poles on brackets.

Today brackets are made of metal, wood and polymer composite materials (PCM). Moreover, wooden brackets and PCM brackets are dielectric and do not have a grounded part across the surface to which an arrester can be connected. This has raised the question of the protection of 6-10 kV overhead lines using insulating support structures.

The overhead line brackets and PE brackets are attached to a common ground electrode on the overhead line pole, i.e., all devices are grounded to the same point. We will consider the case of a metal bracket with insulators for a group grounding cable (figure 3). In this case, alternating between the phases of the arrester is not effective, and there are several factors to account for:

1. A direct lightning strike (DLS) on the overhead system. A direct lightning strike (DLS) may overlap the insulation of the catenary and transfer the discharge onto the bracket. Since the arrester is on a far side phase, an inter-phase short-circuit can be formed on phases A and B;

2. The flow of the discharge through the grounding cable will be similar to the DLS to the overhead line;

3. DLS in phase C, when the arrester is installed in phase A, can cause a MF short circuit in phase C and B;

4. DLS in phase A or C can cause an insulation breakdown, but no MF is likely to occur because an arrester is installed in phase B.

This is confirmed by the application of the surge arrester (SA) shown in Figure 4, which operating principle is based on generating MF short circuits and disconnecting the line, which is undesirable for signalling devices, while not protecting the insulators against breakdowns.

# 3 RESULTS AND DISCUSSION

According to the above mentioned, the installation of phase-sharing arresters is not effective in protecting the over voltages of the overhead line because the line can be disconnected from the MF short-circuit. The use of arresters on each phase is not cost-effective.

Table 1: Technical characteristics of the MKS system arrester.

| Arrester type | RMKE | RMK |
|---|---|---|
| Voltage class, kV | 6 – 10 | |
| Highest permissible continuous operating voltage, kV | 7.2 – 12 | |
| Spark gap, mm | 60 – 80 | 40 – 60 |
| Impulse discharge voltage kV, max. | 120 | 100 |
| One-minute AC voltage, kV, not less: | | |
| - in dry state | 40 | 30 |
| - in the rain | 30 | 20 |
| Magnitude of expected main’s fault current at which at least 10 trips are guaranteed, kA, max. | 3.5 | 0.6 – 3.0 |
| Impulse current withstand duration to half fall of at least 50 µs, at least 2 exposures, kA | 20 | 30 |
| Arc extinguishing time of trailing current, ms, max. | 10 | – |
| Flow rate, Cl | 2.4 | – |
| Weight, kg | 3.7 | 0.9 |

Table 2: Technical data of the KPSIP-3-p bracket.

| Parameter name | Norm |
|---|---|
| Deflection, mm, max. | 13 |
| Insulation resistance, min. ohm | 1013 |
| Current leakage path length, mm | 500 |
| Short-term voltage in dry state, kV | 65 |
| Short-term voltage in the rain, kV | 45 |
| Withstand voltage in soiled and wetted condition, 50 % voltage, kV | 23 |
| Tracking and erosion resistance at 15 kV, h | 500 |
| Impulse withstand voltage with a steep front, kV | 250 |
| Adhesion of the protective sheath, grade | 1 |
| Weight, kg max. | 25 |

Therefore, the use of one arrester on the central phase and the use of transposition is the best option for the overhead line of signalling and overhead lines located on the pylons of the contact network of railways. In terms of the use of metal brackets with suspended or pinned insulators, the principle of mounting the arrester is described in detail by arrester manufacturers. One end of the device is fixed to the rod or shackle of the insulator, on the ground side, the arrester element is connected to the wire or through the air gap. Figure 5 shows the arrester with MKS system (Podporkin, 2020; Napolitano, et al., 2019; Podporkin, et al., 2019; Ivanov, et al., 2018).

Multicamera arrester are more effective, than those of RDIP type, because of the high currents and their application at overhead lines of signalling and power lines is preferable. Technical characteristics of these arrester are given in Table 1.

One of the perspective trends in increasing the reliability of signalling and power overhead transmission lines is the use of brackets made of polymer composites. Such brackets are insulation-supporting structures, which ensure mechanical and electrical strength of the line. Figure 6 shows an example of a polymer bracket.

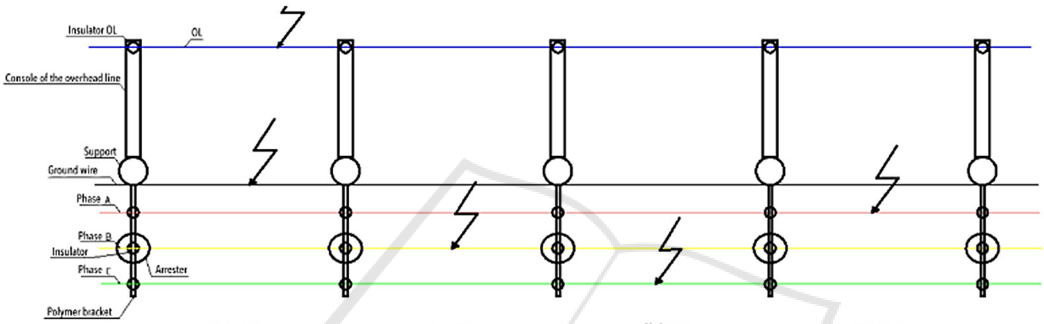


Figure 3: Protection operation when using an arrester on a polymer bracket with a glass insulator in the centre phase.

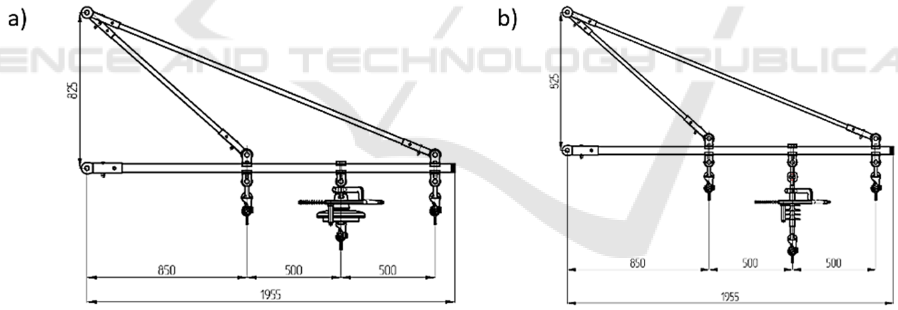


Figure 4: Polymer bracket KPSIP-3 BOREL with RMKE-20 arrester. a) - version with glass insulator; b) - version with plastic insulator.

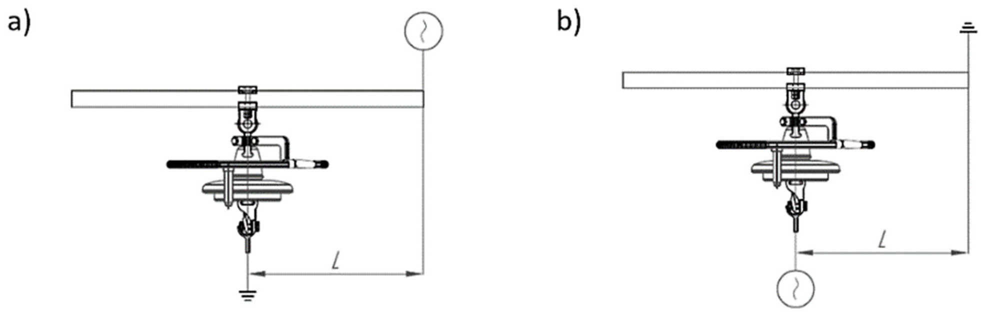


Figure 5: Schematics of the testing process. a) - Voltage supply to rod; b) - Voltage supply to wire.

Figure 6 shows polymeric bracket KPSIP-3-p BOREL produced by “SPE “ELECTROMASH”” Ltd. (Kochunov and Volgin, 2020), Table 2 shows its technical parameters.

From the data shown in Table 2 we can see that discharge parameters of the bracket are quite high (250 kV), but voltage at lightning discharge can be much higher. Similarly to the scheme shown in Figure 3, let us consider the operation of overhead lines with the use of brackets made of PCM (figure 7). Assuming that a DLS has occurred on a phase far from the pole, it is difficult to overcome the entire length of the insulating rod to the grounded part, so the overvoltage may occur on the adjacent phase and

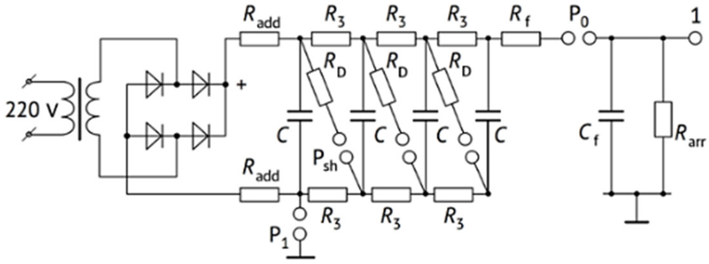


Figure 6: Schematic diagram of the pulse voltage generator installed in the laboratory of High Voltage Engineering of the Ural State University of Railway Transport.


Figure 7: Exterior view of the pulse voltage generator, installed in the Laboratory of High Voltage Engineering of Ural State University of Railway Transport.

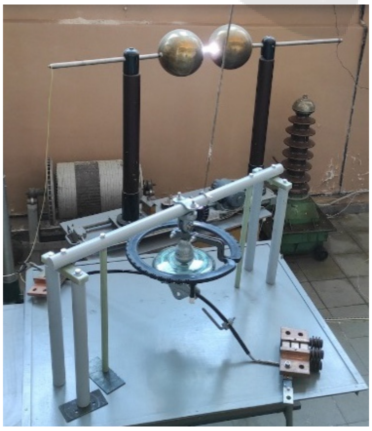

Figure 8: Test bench mounted in the Laboratory of High Voltage Engineering of Ural State University of Railway Transport.

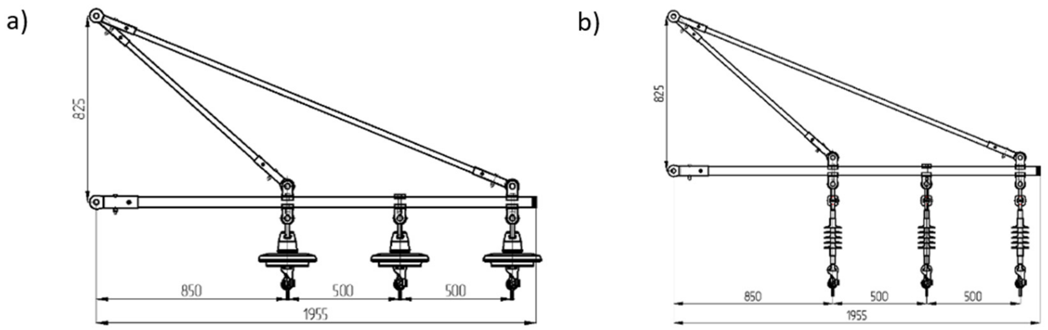


Figure 9: Polymeric bracket KPSIP-3 BOREL with insulators. a) - version with glass insulator; b) - version with plastic insulator.

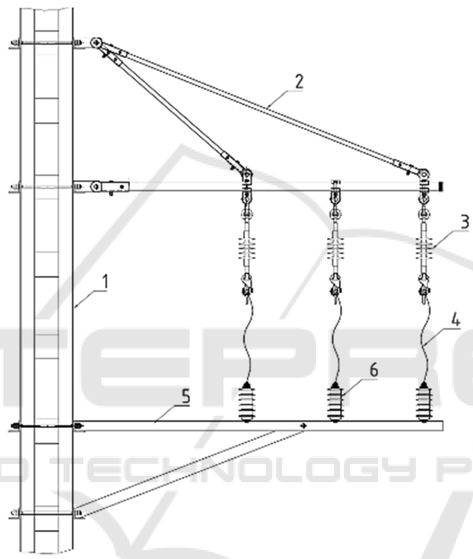


Figure 10: Schematic diagram of overhead power line protection with polymer brackets and surge arresters. 1 - support; 2 - polymer bracket; 3 - polymer insulator; 4 - connecting cable; 5 - metal bracket; 6 – arrester.



cause MF short circuit, there will be undesirable power failure of signalling devices.

Experimental tests were carried out in April 2021 in Laboratory "High Voltage Engineering" (HVE) of Federal State Budgetary Educational Institution of Higher Professional Education "Urals State University of Railway Transport" (USTU) by applying pulse voltages on a sample bracket with multi-chamber arrester RMKE-20. Figure 9 shows diagrams of testing. The L in Figure 9 is shown as the length of the insulating part of the samples.

The tests were carried out using a four-stage surge generator (figures 6, 7).

The test voltage was applied to a sample rod of a polymer composite bracket (figure 8) at different distances from the wire attachment point (measuring points). Observation of the discharge process with discharge voltage measurement was carried out for at least 50 discharges at each measuring point. The results of the tests are shown in Table 3.

According to the testing results, it follows:

1) when mounting the arrester on the polymeric bracket the discharge voltages of the system "arrester - polymeric bracket" exceed the rated values of the arrester mounted on the grounded metal bracket by 10 - 40%;

2) the polymer bracket itself does not protect against over voltages to neighbouring wires - when lightning strikes the wire, the discharge goes to the neighbouring wire, the breakdown passes through the air, and not through the insulating structure body (bracket);

3) the arrester only works when the grounding is in place.

Table 3: Test results of the discharge performance of the system “arrester-polymer bracket” system.

| Insulation rod distance L, mm | Test with insulator, Voltage application to the rod, $U_{imp}$, kV | Test without insulator, Voltage applied to the rod, $U_{imp}$, kV | Test without insulator, Voltage applied to the conductor $U_{imp}$, kV |
|---|---|---|---|
| 0 | 130 | - | - |
| 70 | 167 | - | - |
| 90 | 166 | - | - |
| 100 | 167 | 145 | - |
| 200 | - | 175 | 205 |

According to the test results, it was determined that the use of arrester without its grounded part on a polymer bracket is not effective, it is necessary to develop and use other arrester constructions. For example, in lightning-prone areas and in highly polluted areas, combined insulation can be applied (figure 9) with the use of surge arresters (figure 10).

The use of polymeric brackets with arresters on overhead lines can be similar to the wooden bracket with tubular arresters (figure 10).

The installation of protective equipment on overhead lines and overhead lines is in accordance with Russian national standards and SNiP.

# 4 CONCLUSIONS

Considering the theory of arrester operation on 6-10 kV overhead lines, it can be stated that installation of arrester on OL of signalling and power lines with alternating phases is not efficient enough due to possible inter-phase short circuits. The use of polymer brackets on overhead lines increases the electric strength of the overhead line, especially in combination with insulators, but does not protect the overhead line from direct lightning strikes and impulse over voltages. On polymer brackets, the use of arresters is only possible when the arresters are grounded, i.e., when dealing with different-potential parts of the overhead line. An increase in overhead line reliability can be achieved by combined insulation (polymer bracket and polymer insulators) with the use of surge arresters.

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