Network composite insulators for overhead lines: disconnecting due to unidentified reasons

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Abstract. The characteristics of disconnecting overhead transmission lines 110–400 kV due to unidentified reasons (DUR) are under consideration. An explanation of DUR associated with settling the web on line insulation during mass migration of spiders.

1. Introduction

When operating overhead power lines with ceramic and, in particular, with polymer insulation, problems arise that are not taken into account by the current regulations. This requires a description of emerging phenomena (e.g. [1-7]), as well as work on the creation of new normative documents, which is carried out continuously within the working groups of CIGRE and IEC [8-11], as well as at the national level (e.g. [12]).

Experience in operating overhead high voltage power lines indicates a systematic outages due to unidentified reasons (DUR). This circumstance, which reduces the reliability of power supply to consumers and associated with significant economic losses, has long been an object of study for specialists in the field of electric power transmission. As an example we can point to in [13-15], which analyzes the conditions and the possible reasons for such disconnecting. To present tense, a considerable amount of factual material is accumulated, what allows to describe these conditions adequately. An analysis of the accumulated material allows to specify a possible correlation of DUR with spiders activities.

2. Descriptions of the DUR - the actual material

To In [14], published in 2013, analyzed the circumstances of unexplained blackouts that have arisen on the overhead line 110 - 400 kV in the period from 2008 to 2012. The main results are as follows:
- all DURs occur under normal operating conditions in the absence of lightning or switching surge
- DURs are not associated with impairment in the design and installation of overhead lines
- DUR caused by external influences.

Among the main factors that determine the occurrence of DUR, there is, first of all, seasonality: DURs occur in the period from May to November, with a clear peak in the summer and autumn months. For four of the observed overhead line 400 kV is shown in Figure 1.
The second factor is also quite clear – it is the time of day. As seen in Figure 2, the overwhelming share of DUR occurs in the morning hours.

The third factor - the temperature and relative humidity. Figure 3 from the same source [14] shows the temperature of occurrence of the DUR and the dew point at this time. It is shown that the temperature is always equal to, or was not much higher dew point.
The disconnections occur by a pure state of isolation, including the absence of traces of bird droppings, as well as the absence of visible correlation with the length of the insulating gap. A very important fact is that when trying to identify the causes of DUR on the overhead line insulators with pin-and-cap insulators, all of which were recorded at the lower phases. In addition, in [14] it is clearly indicated the DURs correlation on type insulators used: the most exposed to this are the composite insulators. For example, the ratio of polymer and glass insulators in the investigated overhead line 110 kV was 63.9% to 35.8%, while all DURs (100%) occurred on polymeric insulators. For overhead line classes 110 - 400 kV, these data are summarized in Table 1.

Table 1. The relative number of DURs on HVL 110-400 kV with composite, glass and porcelain insulators [14].

| Voltage Class | The Ratio of the Number of Insulators % | The Number of DURs% | The Number of DURs% | The Number of DURs% |
|---------------|-----------------------------------------|--------------------|--------------------|--------------------|
|               | Composite / Glass / Porcelain           | 2010               | 2011               | 2012               |
| 1 110 kV      | 63.9/35.8/0                             | 100/0/0            | 100/0/0            | 100/0/0            |
| 2 220 kV      | 47/0.04/53                              | 85/0/15            | 71/0/29            | 71/0/29            |
| 3 400 kV      | 7/17/76                                 | 76/19/5            | 63/28/9            | 91/7/2             |
| 4 Total       | 21/17/67                                | 68/24/8            | 63/26/11           | 85/8/7             |

As can be seen, by a relatively small number of composite insulators (21% total), the number of DURs is on them ranges from 63 to 85%. As shown below, this fact indicates a possible cause of the DUR. It was also noted that the characteristic condition of the DUR was the lack of, or weak wind strength.

Observations the DUR places showed that traces of burns on the wires can be located at a distance of 1 m from the wire attachment points to the insulators, as shown in Figure 4.
Figure 4. Burn to the overhead line wire at DUR [14].

The observations and conclusions made in [14], to a large extent confirmed by the work [15]. In [15] considered outages of 110 kV overhead on the territory of Tyumen, where the share of trips for unclear reasons reaches 53.7%. For example, Figure 5 shows a histogram distribution of DURs on the time of year and time of day.

![Histogram Distribution of DURs](image)

**Figure 5.** Distributions of DURs for the months of the year (a) and the time of day (b) [15].

It can be seen that they are very well correlated with the above on Figures 1,2. It is saved as the characteristic time of the year - summer - autumn and preferential times of day - the morning hours before sunrise.

It is noted that DURs occur either in a good calm weather, or in the presence of precipitation, with a wind speed of not more than 4-5 m / s.

DURs occur at high relative humidity (more than 80%). DURs are concentrated in areas of the overhead lines approach to substations.

In contrast to [14] are not observed any correlation of DURs with the type of overhead line tower, or insulation (glass, polymer).

All of them took place in the absence of lightning, switching or quasi-stationary overvoltage.
The conclusion is that under these conditions of isolation operation, its pollution could lead to overlaps. As the most probable causes of DUR are considered the bird’s activity. However, there is no evidence that this is exactly so.

3. Spiders manage the transmission of electricity
As can be seen from this brief review, the causes of DUR have not yet been clarified. There is, however, a simple explanation is well known for the simple nature lovers as well as for specialists in the operation of overhead lines of different voltage classes. We are talking about a small spider family linifiidy (Linyphiidae) of 3-5 mm in size, with the ability to fly through the air on silk threads several meters long.

It is well known that in the summer, and particularly in the autumn, during the "Indian summer" in the air and on the ground appear thin webs. They can be seen in the bushes and branches of trees. It settled linifiidy spiders. Spiders can climb with the air currents over considerable height (up to 2-3 km) and travel long distances. There are cases of mass arrivals of small spiders on ships that are in hundreds of kilometers from the coast. This peculiar way of settling allows spiders to overcome great distances and even reach the lost in the ocean islands.

There is nothing surprising in the fact that flying in the air webs deposited on the overhead line insulators. In the morning hours at high humidity, the web thread covered, like beads, with tiny droplets of water, turning into a long conductor overlapping the insulator. Figure 6 shows a spider's web covered with water drops. A similar view has the longest single web thread lying on the branches of bushes or on the edges of the insulator. Of course, in the process of electric arc web thread is destroyed without any trace, and then overlap itself goes into the category of DURs.

![Figure 6. Spider web with drops of water deposited.](image)

Water droplets on the web are separated by air gaps, so the leakage currents are small and do not cause drying droplets. Electrical breakdown of the system included a plurality of series isolating gaps in the fraction of a millimeter in length has instant character and immediately leads to the breakdown of air insulation.

The proposed explanation satisfies all the mentioned above laws observed in practice. Indeed, resettlement of spiders occurs mainly in summer and autumn. Indeed, the dry web is a good insulator and the deposition of dew on cobweb occurs in the morning with high humidity. After sunrise web thread again becomes dry and safe.

Author observed repeatedly the webs of up to 3 m, covered with water droplets in the morning on the bushes and trees in the north-western part of Russia. The first appearance of spiders near Sankt-Petersburg can be seen in the end of March, long before the beginning of the melting of the snow
cover. Flight period ends in October – November. Author personally observed a new web thread on the branches of trees in a snowy forest in the middle of November.

Length of flying through the air should be sufficient to transfer the spider. It is also enough to overlap the insulators length of 1-3 meters. There is no correlation with the length of isolation gaps in the air, because a thin web thread torn, with no intermediate points of attachment to the insulator ribs. There is no doubt that the spider in the cobweb usually flying at low altitude. This is reflected in the observed occurrence of DURs in the lower phase, or in the places of entries of overhead lines at the substation.

It is clear that a long stay on the web facility is possible only in calm weather or in low, not more than 4-5 m/s wind. It is also a characteristic feature of the DUP. "Web" theory is also easy to explain why the burn marks on the wire (Figure 4) can be positioned away from the place of suspension: web thread caught on one end of the upper part of the insulator and the other - on the wire at a marked distance from it.

Of course, the number of webs in the air has nothing to do with pollution of insulators, and it also says researchers DURs.

The web settling on substation insulators probably hindered by the presence of the busbar. Busbar plays a role of protection - webs deposited on it, not getting on the high-voltage insulation. Pay particular attention to consider noted in [14] correlation of DURs with the type of line insulation. It is shown that the composite insulators are most prone to DUR, and it is also easily explained by the actions of spiders. Indeed, the overall height of the pin-and-cap insulator is 200-300 mm, while for the composite insulators are typical distance between the ribs is of 45-60 mm. Naturally, it is flying through the air better cobwebs clinging to the composite insulators with closely spaced ribs than smooth and spaced far edge of pin-and-cap insulators, and better retained on the composite insulator under the influence of wind. It is possible that there is also a difference in the degree of adhesion of the web to glass or silicone, most of which are made of composite insulators coatings.

4. Protection from spider web on insulators

Thus, the class of "bird" overlap add a new class of overlap "spider". We can formulate some measures to deal with them. First of all, we should consider the use of composite insulators with extended distance between the ribs. Polymer insulators manufacturing technology allows the ribs of 100-150 mm in diameter, to a minimum by reducing the distance between them. It is possible that the fight with the spiders should be increased the distance between the ribs, preventing sedimentation web on insulators. At the same time it is necessary to increase the diameter of the ribs, providing the normalized length of the leakage length. We can not exclude that this will lead to an increase in the cost of the insulators, due to consumption of polymer material, but may lead to an increase in the reliability of power supply. It is possible that for the 110 kV overhead lines should be chosen towers a greater height, as primary web stream moves through the air at low altitudes. In the future, along with the account migration flows of birds, in the design of the overhead line should take into account the migration flows of spiders.

In conclusion, we can say that to confirm or deny the proposed "web" theory is possible only by special studies involving specialists - electricians and biologists, but there is no doubt of the existence of flying through the air spiders. The real danger of the web for the overhead line should be set experimentally.

5. Conclusions

1. To date, the exact explanation of DUR was not found.
2. Possible causes of DUR are the overlap caused by settling of the web on line insulation.

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