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Law of Distribution of Maximum Overvoltage

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Annotation: *The article theoretically examines the process of maximum overvoltage distribution in power lines with and without a single-phase overvoltage protection device. It is based on the fact that the service life of lines where the overvoltage limiting device is installed is significantly longer.*

Keywords: overvoltage protection device, power transmission line, overvoltage distribution law, OPN, OPN-L.

INTRODUCTION

For the last 30 years, linear insulators (OPN-L) have been used to protect against single-phase overvoltage at substations in order to increase the reliability of the power transmission line in the railway power supply system.

METHODS.

Linear insulators for protection against single-phase overvoltage were first manufactured in Japan and the United States and are widely used in 66kV, 77kV and 138kV power transmission lines. In 1992, 29,580 OPN-Ls were installed on Japan's power transmission lines. Of these, 840 (2.84%) on OPN-L 10-35 kV overhead lines, 26495 (89.57%) on OPN-L 66-77 kV overhead lines, 1879 (6.35%) on OPN-L 110-220 kV overhead lines and 366 (1.24%) on 330-500 kV overhead lines. In Japan, about 7,000 OPN-Ls are installed each year. Along with Japan, the same indicators can be observed in the United States. In the United States alone, protection devices are mainly installed on 35-220 kV lines. Since 1994, OPN-L has been widely used in Japan on 500 kV overhead lines. Today, OPN-L is also used in 750 kV overhead lines.

Statistical analyzes show that a significant increase in reliability can be observed in the power transmission lines used in OPN. Simultaneous shutdown of two phases is not observed in the power transmission lines of the railway power supply system with separate OPN installed in each phase. In 60% of cases, a chain failure occurs. If a separate OPN is not installed in the phases, then 60% of the two circuits will be switched off under the influence of the overvoltage, and the rest may be switched off in other cases.

We, like other countries, have so far installed more than 2,500 OPN-Ls to increase the reliability of power transmission lines. It should be noted that currently 30-40% of damage to power transmission lines is caused by lightning. In our case, this indicator was chosen based on our climate. In Brazil, 50-70% of injuries up to 220 kV are caused by lightning, and the number of OPN-Ls currently installed in Brazil exceeds 10,000.

In France, OPN-L is installed on 69-90 kV lines in parks and playgrounds. There, protective devices are installed on each base. It should also be noted that the distance between the phases on the 5 km 420 kV line is 5 meters and OPN-L is installed instead of a lightning protection cable as a protective device. Each base is equipped with 23 separate OPN-Ls.

Calculations show that the failure of linear insulators in power transmission lines with OPN-L is reduced by 10.5 times compared to other types of protection installed lines.

In general, it is advisable to install OPN-L on each base. However, depending on the reliability level requirements of the chain to be protected, it can also be installed on 2 of the 4 bases. If OPN-L is installed on each base, the reliability probability of the power transmission line is very high. The 115 kV transmission line in the United States, built on the basis of this project, has been used for 5 years without shutdown. The reason is that every base and every phase is highly protected. It should also be noted that if OPN-L is installed on at least one of the 5 bases, it is possible to observe a 4-year shutdown from the effects of overvoltage.

As can be seen from the table below, OPN-L can be applied in any country and at any voltage. In Russia, lightning strikes on 220-500-750 kV lines from lightning until 2003 accounted for 11% of the total number of outages, although the number of outages was very high. To date, it is possible to observe that OPN-L protection devices are not installed on each voltage line (except for 500 kV lines, lightning protection rope is still used as protection). OPN-LI can be used in 220 kV railway power supply system. The use of OPN-LI in the transmission line only causes the line to shut down 1-2 times a year. It can be observed that if the OPN-LI is installed on each phase and on each base, the line will not be switched off for 5 to 10 years.

Demand	OPN-LI	OPN-L

Place of application	At lightning surge	At lightning and switching overvoltages
Overvoltage limitation	The presence of a low residual voltage	magnitude of sensitivity
When the lightning strikes in the distance	2 OPNs are activated	Many OPNs are activated
Detect hardware deficiencies	From cracks in the shells	Special control is required
Detect hardware damage	From the lines of injury	From the start of the driver
Effects on atmospheric conditions	The spark depends on the effects the intermediate atmosphere	No
The effect of spark gap	Have	No

Note: OPN-LI is a single-phase overvoltage protection device (made of a linear insulator through a spark gap); OPN-L is a single-phase overvoltage protection device (made of linear insulator).

The value of the overvoltage that occurs when the power transmission line is connected via an automatic reconnector will have different magnitudes depending on the following factors:

electromotive force;

residual voltage in the power transmission line.

To determine the mathematical maximum overvoltage, it is sufficient to determine the initial voltage in the distribution of the electric field voltage at a height of 1.8 meters above the ground and the overvoltages in the presence of EYuK. In this case the overhead line will be connected by the first system. A special program is used to calculate the overvoltages.

OPN-L parameters:

Maximum overvoltages of power transmission lines without overvoltage protection device:

UAmax = 1011 kV; UBmax = 1179 kV; UCmax = 1082 kV.

We use OPN-L on the line to protect against overvoltage and we can get the following results:

UAmax = 744 kV; UBmax = 698 kV; UCmax = 692 kV.

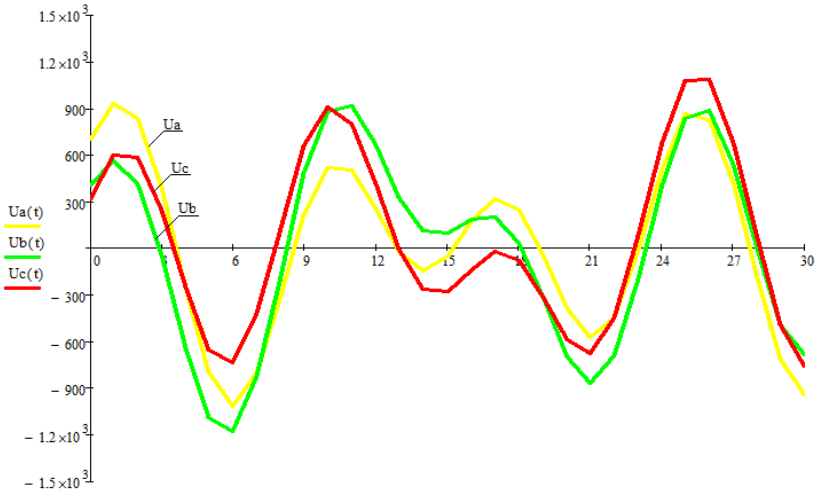

Figure 1. Voltage change in a power transmission line where an overvoltage limiting device is not installed

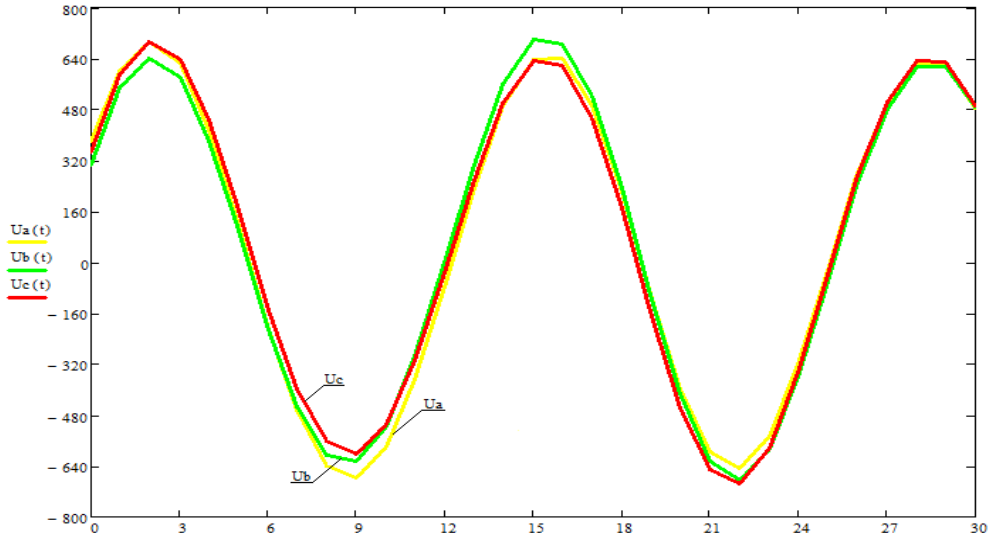

Figure 2. Graph of voltage change in an existing power transmission line with an overvoltage limiting device

RESULTS

The results of the calculations show that the value of the overvoltage in the middle and at the end of the power transmission line is significantly reduced. However, the level of nosinusoidality in the line is significantly higher.

When the overhead line is activated by automatic reconnection, the insulators on the supports installed along the line are exposed to overvoltage and the risk of damage increases. To observe the change in voltage in the line by means of a special program, we assume that the same voltage is distributed in the isolated intervals and describe the result as in Fig. 2.

CONCLUSION

From the results of the theoretical research it can be concluded that the law of overvoltage distribution along the linear insulator in the line in the power transmission line with a single-phase overvoltage protection device is sinusoidal, which leads to long service life of insulators in the system.

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