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The Research of real-time identification system of types of lightning failures of UHV transmission lines based on UV detection technique

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Abstract. Egineering running experience shows that with the increase of the operating voltage of the transmission line, the lightning trip rate is increasing. According to theoretical calculation，UHV transmission lines should be provided with full lightning protection characteristics；however，running experience shows that the lightning withstand level of UHV transmission lines is high，not completely lightning protection; it puts forward higher requirements for lightning protection design of UHV transmission line in China. UHV transmission line is mainly against direct lightning stroke characteristics，one is caused by lightning counterattack trip，the other is the shielding failure of lightning around the line to strike the wound caused by the wire. The lightning fault type identification is based on the micro topography of UHV transmission tower，accumulation of historical data，the development of a more targeted and high voltage transmission line lightning protection scheme is of great significance. In this paper, a real-time identification system based on UV detection technology, which has high accuracy and fast response time, is proposed for lightning fault types of UHV transmission lines, the systems use ultraviolet light to realize online detection of high-voltage transmission line tower nearby lightning, can effective observation tower near lightning discharge, and it has the characteristics of continuous detection, long-distance, no power supply, no contact and no disassembly, it provides an advanced technology for the detection of lightning discharge in UHV transmission line.

1 Introduction

UHV transmission lines extend for thousands of miles，and spans over a large number of regions with complicated climate conditions. The poles and towers of UHV transmission lines are tall，and feature large area of lightning-induction; the lightning activities of the regions that belong to the line corridor are frequent, and such reasons as the high resistance rate in the soil of the mountainous region is high caused the frequent occurrences of the lightning accidents of the UHV transmission lines; as indicated by the operating experience of the UHV transmission lines of the former Soviet Union and Japan that lightning was the main cause of the UHV transmission line failures，with the time of the lightning trips accounting for over 80% of the total trips. Since the lightning disasters of the transmission lines are related to the microreliefs where the lines are located, in combination with the Lightning Location System (LLS) data ,the database of the types of the lightning failures of UHV transmission lines was established，and the lightning prevention measures that conform to the features of the UHV transmission lines was designed so as to safeguard the safe operation of the UHV transmission lines and provide references to the lightning protection design and operation of nation's UHV transmission lines. Currently，domestic and overseas scholars have conducted large amounts of research on the type identifications of the lightning failures of UHV transmission lines，and He Hengxin et al. established the lightning shielding models of the lightning prevention of the UHV transmission lines making use of the long-gap discharge [1]，and this model features strong theorization，and it needs to be verified by the engineering operation experience. Wang Jufeng et al. conducted real-time identifications of the types of the transmission line lightening failures using the magnetic tape method [2]; this method features maneuverability，and the accuracy and reaction speed call for further verifications. Although the analytical model and identification system proposed in the above system features certain guiding function on the stipulation of the lightning prevention scheme of the UHV transmission lines，it still fails to realize the

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accurate positioning and real-time identification of the types of the lightning failures of UHV transmission lines, especially that it was still impossible to effectively record the circumstance that the lightning impulse flashovers were not transformed into the short circuiting arcs.

This Paper proposes a UV detection technique-based real-time identification system of the types of the lightning failures of UHV transmission lines, which utilizes the UV imaging equipment for conducting tracing of the flashover electron direction of the extra high voltage insulator string discharges，thus realizing the whole process monitoring of the insulator string lightning discharge process， especially it conducted effective recording of the discharge process in which the lightning impulse flashovers did not cause short circuiting failures.

2 Characteristics of the lightning impulse flashovers of UHV insulator strings

The lightning prevention performance of the UHV overhead transmission lines features two characteristics: firstly. The counter prevention performance is good，and secondly the performance of shielding failure prevention is poor[3].The insulation level of the UHV overhead transmission lines is very high， and in case of the lightning prevention lines or the poles and towers，in comparison to the UHV overhead transmission lines，the possibilities of the insulator strings or air gaps being sparked over，and the lines ‘resistance levels to counter lightning is rather high. Since the poles and towers of the UHV transmission lines are rather tall and span over high mountains, rivers, lakes and oceans, the probability of the occurrences of the shielding failures was increased in comparison to that of the UHV transmission lines. In general，the shielding failures is the major factor that needs to be considered for the UHV lightning protection. The operation experience of the UHV transmission line performance of the former Soviet Union and Japan are shown in Table 1，and it can be seen that the lightning trip is the crucial factor that threatens the safe operation and system stability of the UHV overhead transmission line..

Table 1. Experience of the Soviet Union and Japan's UHV overhead transmission line lightning performance

Line location	Line type	Operating time (year)	total trips	Lightning trip condition		
				Total times	Trip rate [time/(100km·a)]	Number of unsuccessful reclosing
the former Soviet Union	1150kV Single circuit	1985～1994	19	16(84%＊)	0.6	6(32%)
Japan	1000kV Double circuits of the same tower	1993～2007	68	67(98%＊)	0.9	2(3%＊＊)

* Percentage of the lightning trips in the total trips

＊＊ Arching horns are adopted in Japan’s high-voltage lines, thus greatly the probabilities of the unsuccessful reclosures.

The operational data of the lightning trip rates of the former Soviet Union and Japan’s UHV transmission lines indicated that they greatly surpassed the required values at the time of design，and the lightning protection design of Chinese UHV overhead transmission lines is faced with two major problems : firstly, which economic and effective lightning prevention measures should be adopted，and based on the lightning performances, the relevant parameters of the design were evaluated，the lightning trip rates of the line reduced to the scope of the design requirements of the lightning trip rates；secondly, how to establish a more scientific lightning performance analysis model and accurate assessment method of the UHV transmission lines. The key for the solution of the above two problems lies in the accumulation of the original, accurate and zero-omission data of the UHV transmission line lightning failures.

3 Lightning impulse discharge characteristics of the UHV insulator strings

The process of the lightning impulse discharge of the UHV insulator strings can be roughly divided into four phases: initial corona, dark discharge phase, leader discharge and the final discontinuity. When the lightning shockwaves act on both ends of the insulator strings, and when the lightning overvoltage value is greater than 50% of the breakdown voltage of the insulator strings, it can be held that the impulse flashover discharge process of the insulator strings has occurred. The difference lies in that in case of a counter failure, the pole arm discharges towards the conducting wires; in case of a shielding failure, the conducting discharges towards the pole arm. The shielding failure and counter process of the UHV transmission lines are shown in Fig. 1.

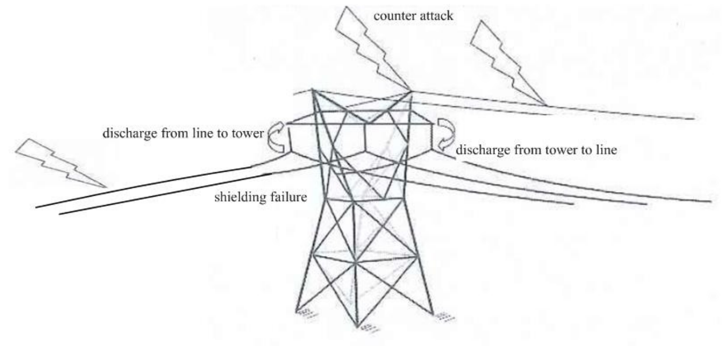

Figure.1 The shielding failure of transmission lines and counter process

By using the different directions of the discharge developments, it is possible to judge the lightning failure types of the conduct repaid detection of the UHV transmission lines conducting rapid detection of the electronic transitions of the process of the initial corona of the process of discharge process.

The process of the initial corona is: when the field strength of the high-voltage electrode reaches a critical value, lighting fine lines begin to appear around the electrode, and coupled with the charge flow pulses, the charge flow will weaken the field strength of the rode electrode; it is indicated by the analysis of the photoelectric imaging that the corona bursts occur in the different locations of the rod electrodes, and the time delays between the corona bursts and the changes in the initial positions are dependent upon these two opposite functions of strengthening and weakening of the electric field; the spatial charge flow generated by the corona weakens the electric field, while the shockwave head that is applied in the high-voltage electrode strengthens the electric field. When the total electric field strength near the high-voltage electrode is smaller than 2600kV/m, the collision free coefficient is smaller than the de-free coefficient, the electron avalanche begins to stop development. The lighting phenomenon of this zone appears and enters the dark discharge phase. The initial corona discharge process of the lightning shockwaves is shown in Fig. 2.

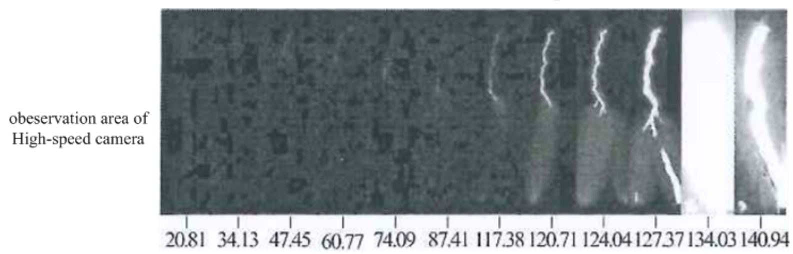

Figure.2 The process of shielding failure and couter attack of the UHV transmission lines

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4 Real-time identification mechanism of UV detection technique of the lightening failure types

The UV imaging technique can capture the electronic trace in the discharge process and further conducts imaging. The wavelength range of the UV ray is 40～400nm.The sunlight also contains UV ray; however, since the earth's ozone layer absorbs partial components of the wavelengths，actually the UV spectra that is radiated onto the earth surface are all above 300nm，and the wavelength zone lower than 300nm are known as the solar blind region. Making use of such a feature, people have worked out the daylight (blind region) type UV ray detector. The instrument's working wavelengths are between 240～280nm，and detection can be done under sunlight, thus featuring strong anti-interference capability [5].

The electronic traces are analyzed from the imaging，and through the identification of the lightning discharge process ， it is possible to identify whether the lightning of the poles and towers is a shielding failure lightning ， or a counter lightning; consequently，it is possible to judge whether the failures at the poles and towers that are prone to failures are shielding failure lightning trip accidents ， or counter lightning trip failures .The UV images of the counter failures at the insulator strings of the UHV transmission lines are shown in Fig. 3，and the UV images of the shielding failures at the insulator strings of the UHV transmission line poles and towers are shown in Fig. 4；

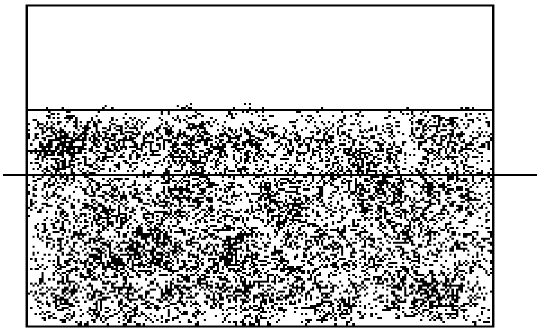

Figure.3 The ultraviolet image of the insulator string on the counter of the special high voltage transmission line

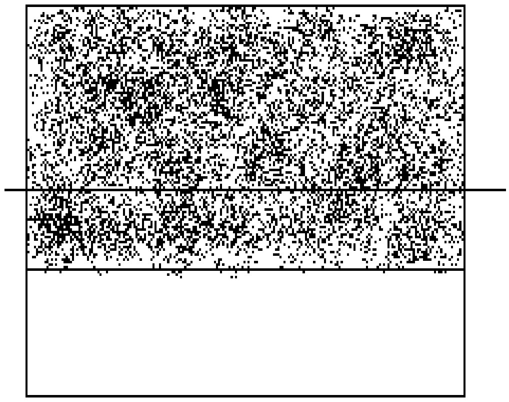

Figure.4 UHV transmission line shielding failure in tower insulator string at the UV image

The mechanism of the UV detection technique device for the identification of lightening failure types is shown in Fig. 5:

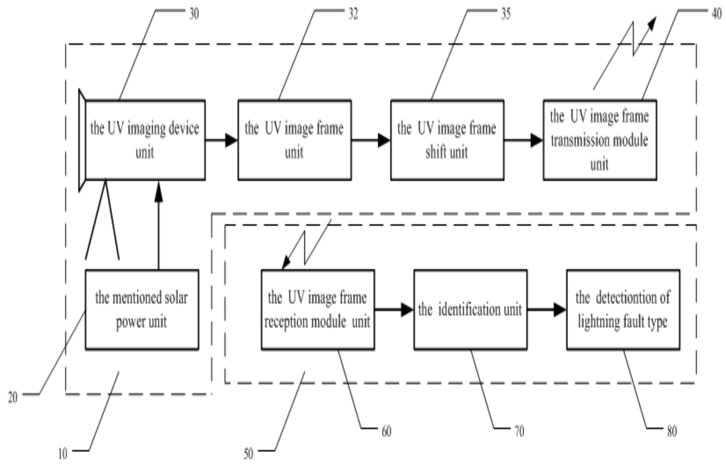

Figure.5 The schematic diagram of detecting lightning fault type device based on ultraviolet detection technology

The UV detection technique is an identification method that conducts the real-time the lightning failure types and it is characterized by: (1) regarding the extraction of the imaging parameters of the UV imaging, it uses the UV imaging devices and align the imaging field center on the geometric centers of the insulators of the insulator strings on the poles and towers of the power transmission lines, with an observation distance of 3-5m, and the image signals of the UV videos are recorded; (2) regarding the divisions of the UV facula light zones, the image frames of the image signals of the UV videos are continuously or randomly captured and the images were transformed into the gray scale image; then, the images were transformed into binary images, i.e. “1” or “0” using threshold segmentation. (3) regarding the wireless transmission of the image signals, the image transmission module transmits in a wireless way the mentioned binary image signals to the image reception module within the substation; (4) the physical significance of the judgment of “1” of the types of the failures of the lightning poles an towers was a highlight zone, while the physical significance of “0” is a dark spot area; on each image fame, the UV images of the counter lightning at the insulator strings of the poles and towers are characterized by that the highlight zones were concentrated in the power part of each captured image, and the judgment unit of the types of the lightning failures conducts real-time identifications of the failure types of the lightning poles and towers through the statistics of the statistics after a thunder storm.

The UV detection technique is a device that conducts the real-time identification of lightening failure types, and it is characterized by: The UV data acquisition unit 10 of the lightning signals provided on the poles and towers of the power transmission lines, including the UV imaging device unit 30, UV image frame unit 32, image shift unit 35 and image transmission module unit that are electrically connected in turn; the mentioned solar power unit 20 provides the various circuit units within the UV data acquisition unit 10 of the lightning signals with electricity, and the imaging field center of UV imaging device unit 30 is aligned with the geometric center of the insulators of the poles and towers of the power transmission lines, with an observation distance of 3-5m; and the lightning type identification unit 50 provided within the substation, including: the image reception module unit 60, image identification unit 70 and identification unit of the lightning failure types which are electrically connected in turn. The SONY XCDSX910UVUV CCD camera was adopted for UV imaging device unit 30; the JZ8-xx serial wireless transmission modules were adopted for the image transmission module unit 40 and image reception module unit 60.

5 Conclusions

This paper proposes a UV detection technique-based real-time identification system for the lightning failures of UHV transmission lines，which possesses such characteristics as continuous detections, long distance transmision , no power failures and no disintegration. It can eliminate the omissions of the lightning accidents that did not cause the short-circuiting failures; in combination with the lightning location system ，this device provides advanced technological means in the aspect of the survey of the lightning failures of UHV transmission lines, the accumulation of the characteristics of the corridor lightning of the UHV transmission lines and is beneficial to the perfection of our nation's lightning protection system of the UHV transmission lines.

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