QUANTITATIVE JUDGMENT OF CORONA DISCHARGE FOR HIGH VOLTAGE EQUIPMENT

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Abstract : A quantitative criterion of corona discharge for the high voltage equipment based on UV-light imaging technology is presented in this paper. When the number of photons is more than 100, corona discharge starts. When the grading ring is covered with water droplets, corona inception voltage will reduce obviously and become about 0.7 time of that without water droplets. According to the quantitative criterion in this paper, an examination was carried out for the running high voltage equipment. The software, COMSOL Multiphysics, is used to optimize electrostatic field distribution and prevent the equipment from corona discharge in this paper.

1 INTRODUCTION

China is vast in territory. In China, the energy centres are in the west part of China and the load centres is in the east part of China. Both of them are far away from each other. With the development of economy, the requirement to power increase dramatically in China. Thus, China is one of the several countries who need to develop UHV/EHV project.

For EHV/UHV transmission lines, high electric field may be generated on the energized equipment. When the electric field is greater than the critical field strength, corona will occur [1~4]. Some problem will be brought with corona, such as energy loss, radio interference, noise and electrode corrosion [5~8]. If the corona will not be settled timely, it can induce breakdown. The environmental protection and energy conservation has received a great deal of attention by more and more person. Thus, it is important to detect corona timely and handily.

There are two kinds of instrumental, ultrasonic tester and infrared thermovision, used to detect corona. The principle of ultrasonic tester is to receive the ultrasonic generated by corona and convert them to audible sound. According to this signal, we can get the location and intensity of corona. However, it is difficulty to determine corona's position exactly and to analyse quantitatively. We can detect the temperature rise due to discharge and leakage current by infrared thermovision. But this is a method to detect corona indirectly.

Optics detection can avoid noise disturbance and have excellent sensitivity. Since 1970's, corona on high voltage equipment was researched by many researchers all over the world [9~11]. UV imaging was used to observe corona in many countries, including United Stated. That was also used in Hongkong [12]. But this technology only can be used for qualitative judgment. That is depended on the manipulator's experience. Thus, it is neccery to obtain a criterion.

According to the experiment results and calculation analysis, the quantitative judgment criterion and method of corona discharge are presented in this paper.

2 TEST PRINCIPLE

Ultraviolet imagery technology is to use a special equipment to receive the UV signal produced by corona discharge. After treatment, it can be superimposed with visible light image for determining the location and intensity of corona. It will help to evaluate the running state of equipment. UV wavelength range is 40 nm ~ 400 nm. There is some UV in sun radiation. Because a part of UV is absorbed by ozonosphere, the wavelength of UV that arrived on the earth is longer than 300 nm. So the wavelength range that is lower than 300 nm is called as solar-blind zone.

When N_2 in air was ionized, UV will be generated. The wavelength range is in 280 nm ~ 400 nm for most of UV. A little part of UV wavelength is shorter than 280 nm. That is in solar-blind zone. If the UV with wavelength shorter than 280 nm is detected, this part of UV must is produced on earth. The new generation photo camera CoroCAM IV + is used in this experiment. Its principle is to take advantage of solar-blind zone. The photo camera works in the range of 240 nm ~

280 nm. So, this photo camera can work during day.

3 RESULTS AND DISCUSSIONS OF LABORATORY TEST

The laboratory test was carried out in the large multifunction artificial climate chamber with the diameter of 7.8 m and the height of 11.6 m.

The power is supplied by YDTW-500 kV/2000 kVA pollution test transformer. The major technical parameters are as follows: rated capacity 2000 kVA, rated current 4 A, input voltage 0-10.5 kV, output voltage 0-500 kV, and short-circuit impedance less than 6 percent under a rated voltage of 500 kV.

The humidity in the chamber was adjusted by the dehumidifier and sprayer.

The experimental setup is depicted in Figure 1.

T is the voltage regulator, B is the transformer, R_0 is the protective resistor, H is the bushing, V is video compression box, K is the artificial fog chamber, S is the sample, M is computers, F is the ac voltage divider, G is the AC experiment table, C is the photo camera.

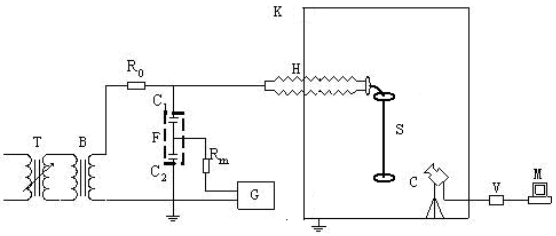

Figure 1: Test circuit

The photo camera CoroCAM IV+ made by CSIR in South Africa was used in this experiment. That is used widely for its excellent properties [11~12].

220 kV composite insulator with grading ring is tested under raining and no raining, respectively. The test results are shown as in Table. 1.

Table 1: corona experiment results of grading ring

Applied voltage (kV)	Average photo number	
	No rain	rain
80	0	30
90	0	40
100	5	50
110	5	110
120	10	140
130	10	230
140	15	300
150	15	360
160	105	430
170	160	470

For the same applied voltage, the average photon number under rain is bigger than that under no rain, as shown in Table 1. That mainly due to the fact that rain droplet will distort the electric field, increase the local electric field and induce corona. When there is no rain, as the applied voltage increased, the photon number increased from 0 to 105 abruptly. Hence, the initial corona voltage is considered as 160 kV. When there are several water droplets on grading ring surface, the photon number increase from 50 to 110 abruptly. The initial corona voltage is considered as 110 kV. Hence, the initial corona voltage under rain is lower than that under no rain. And the initial corona voltage under rain is about 0.7 times that under no rain. The photon number is about 110 when corona start. That is same with the corona onset photo number of conductor, 100.

4 RESULTS AND DISCUSSIONS OF FIELD TEST

The photograph of a coupling capacitor in a 220 kV substation was taken by corona camera under king's weather as shown in Figure 2.

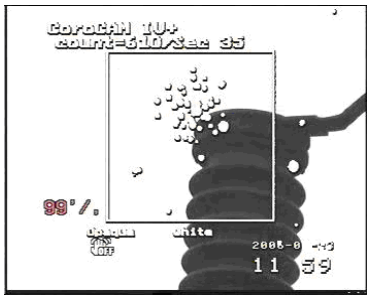

Figure 2: Photograph of a coupling capacitor in king's weather

There are about 600 photos on the top of the coupling capacitor as shown in Figure 2. This number is much higher than 100, which means corona happens on the top of the coupling capacitor.

5 SIMULATION AND OPTIMIZE

COMSOL Multiphysic was used to calculate the electric field. The state of corona discharge can be validated. COMSOL Multiphysic can also be used to optimize the electric field for avoiding corona.

A calculation model is built for a 220kV coupling capacitor, as shown in Figure 3. The calculated result is shown in Figure 4.

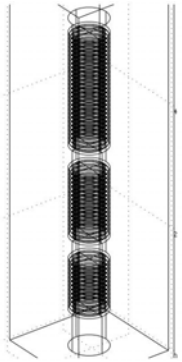

Figure 3: Simulation model of 220kV coupling capacitor

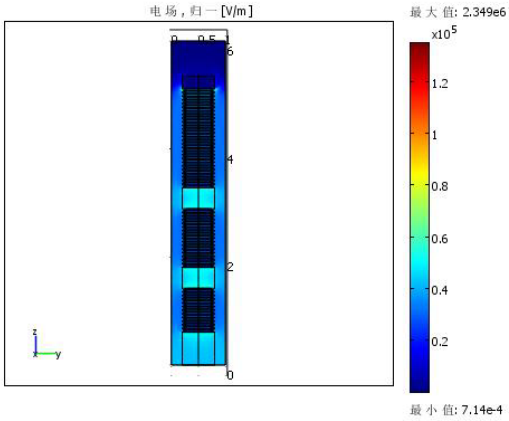

Figure 4: Computation results

The electric field strength on top of coupling capacitor is the biggest one, 2.349 kV/cm, as shown in Figure 4. That is bigger than the corona onset electric field strength, 2.2 kV/cm. That is agreement with the observation results taken by corona camera. For decreasing the electric field strength, we can install a grading ring on the top of coupling capacitor. After a grading ring with φ60 cm×12 cm is installed, the electric field strength can be reduced to less than 1.54 kV/cm, as shown in Figure 5 and Figure 6.

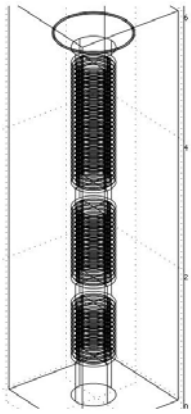

Figure 5: Computation model of a coupling capacitor

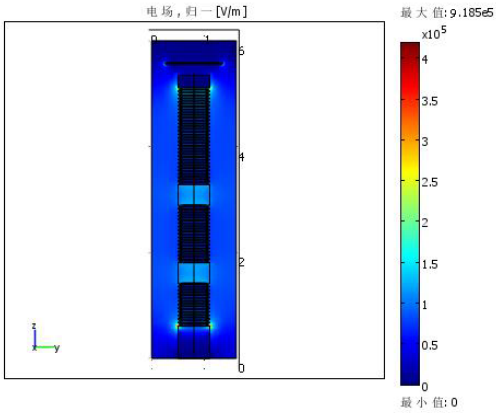

Figure 6: Computation result

6 CONCLUSIONS

(1) We can use corona camera to locate corona for conductor. When the photo number is bigger than 100, that means corona happens.

(2) Corona onset voltage of grading ring under rain is 0.7 time as high as that under no rain. When corona happens, the average photo number is about 110. That is same with the corona onset photo number of conductor.

(3) We use the software, COMSOL Multiphysics, to build the model and calculate electric field for high voltage equipments. According to the calculated result, we can validate the observation results taken by photo camera. That proves that it is feasible to use corona camera to locate corona for high voltage equipments.

(4) We can use corona camera to locate corona. If corona happens on the high voltage equipment, the software, COMSOL Multiphysics, can be used to optimize equipment configuration for eliminating corona.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Lin Xiaoyue, Chen Shixiu, Zhang Xiaomin: “High-voltage transmission line corona effects of electromagnetic radiation”, Power environment Protection, Vol. 20, No. 3, pp. 20-23. 2004

[2] Abdel Salam, S. Abdel Sattar. “Calculation of corona V-I characteristics of monopolar bundles using the charge simulation method”.

IEEE Trans on EI, Vol. 24, No. 4, pp. 669-679. 1989

[3] Liu Zhenya. “EHV Power Network”. China economic press, Beijing, 2005

[4] MAO Wen-qi , LIU Hai-yan , XU Hua , et al. “Discussion about impact of EHV transmission on environment”. Electric Power Construction, Vol. 25, No. 8, pp. 54~56. 2004

[5] Yang Baochu, Liu Xiaobo, Dao Yusong. “High Voltage Engineering”. Chongqing University Press. 2005

[6] Chen Jianyu. “EHV Transmission Line Survey of electromagnetic radiation”. Power environment Protection. Vol. 14, No. 4, pp. 30~37. 1998

[7] CHEN Shi-xiu , SHEN Yuan-mao , WU Yuan-li , et al . “Equivalent model of electromagnetic wave radiated from corona discharge between needle-plate electrodes in loop circuit”. High Voltage Engineering, Vol. 28, No. 3, pp. 9~11. 2002

[8] Ma Yi, Li Ming. “Analysis of wire corona quality control in control in electric transmission line project”. Yunnan Electric Power, 2003, 31 (3) : 51~53.

[9] ZHAO Wen-hua , ZHANG Xu-dong , JIANG Jian-guo , et al . “Spectrum analysis of tip-plane corona discharges”. Spectroscopy & Spectral Analysis, Vol. 23, No. 5, pp. 995~997. 2003

[10] YAN Ying , WANG Ning-hui. “The study of N’s spectrum in air high voltage pulse discharge”. Instrumentation Analysis Monitoring, Vol. 23, No. 1, pp. 40~43. 2004

[11] GUO Jun , WU Guangning , ZHANG Xue-qin , et al. “The actuality and perspective of partial discharge detection techniques”. Transactions of China Electrotechnical Society, Vol. 20, No. 2, pp. 29~35. 2005

[12] Ofil Ltd. DayCor □---Technology and Applications