Application of Partial Discharge Online Monitoring Technology in ± 660kV Converter Transformer

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Abstract: The partial discharge detection technology (UHF) is specially used in YD-B Phase of ± 660kV converter transformer pole I system, in connection with overheating failure problems. Through analysis by PRPD map to strengthen the monitoring for partial discharge defective of converter transformer, the continuous tracking for the running state of converter transformer can be achieved. Application results show that: the signal of partial discharge characteristics can be effectively found inside the converter transformer through UHF Online Monitoring techniques, which has good sensitivity and interference capability, providing guarantee for safe and stable running of power equipment.

Keywords: UHF, On-line Monitor, Partial Discharge, PRPD Map.

1. INTRODUCTION

With the increase of voltage grade of DC transmission, the insulator for ultra-high voltage direct current (UHVDC) equipments is becoming more and more outstanding. As the most important electrical equipment in DC system, the convert transformer will influence the whole system directly. Turn-on and cut-off of the rectifying valve will produce impulse voltage with high amplitude and steep waveform. When the impulse voltage superimposed on the winding voltage, it will form a kind of compound voltage that is similar to sinusoidal AC waveform, which is composed by direct voltage and alternating voltage (exists many harmonic waves) with heavy distortion. At the same time, the valve side winding have to endure the lighting impulse and voltage operation. What's more, the short circuit impedance and loss of converter transformer will make the equipment heat up more than ordinary transformer. And the internal temperature of converter transformer is 20% higher than the ordinary transformer's.

Therefore, the insulator failure rate of converter transformer coil is higher than the ordinary transformer. As the research shows, too hot insulator medium caused by partial discharge is the main factor that causes insulator failure. In this way, observing the partial discharge of converter transformer by installing Ultra High Frequency (UHF) partial discharge equipment will have high significance of improving the safe operation level of converter transformer.

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2. HF PARTIAL DISCHARGE DETECTION TECHNOLOGY

2.1. The Principle of UHF Partial Discharge Detection Technology

Insulator strength and breakdown field strength of electronic equipment's insulator are relatively high. When the partial discharge happens within a tight trading range, the breakdown process is fast, and it will produce very steep pulse current whose rise time will be less than 1ns and radiate a kind of electromagnetic wave with a frequency up to GHz. The method of UHF partial discharge detection was put forward by Central Electricity Generating Board Laboratory in the early 1980s. Its basic principle is to use UHF sensor to detect the signal of UHF electromagnetic wave (300MHz≤f≤3GHz) produced by the partial discharge (PD) of power equipment. This method can detect the signals of PD, and realize PD monitoring. According to different field devices, we can apply Built-in UHF sensor and external UFH sensor. Built-in UFH senor detects signals generally by oil drain valve, flange plate and standardized medium window into the transformer from inside, which can provide high detection sensitivity and strong anti-interference capacity. External UHF senor detects signals generally by Coupling with small amount of electromagnetic leaking from outlet port and seams, which can be easy to install and doesn't influence transformer's internal electric field. As the corona interference is focused on the frequency band below 300MHz, the method of UHF can have a good ability of avoiding the corona interference effectively, and realize PD on-line detection, positioning and flaw detection [1].

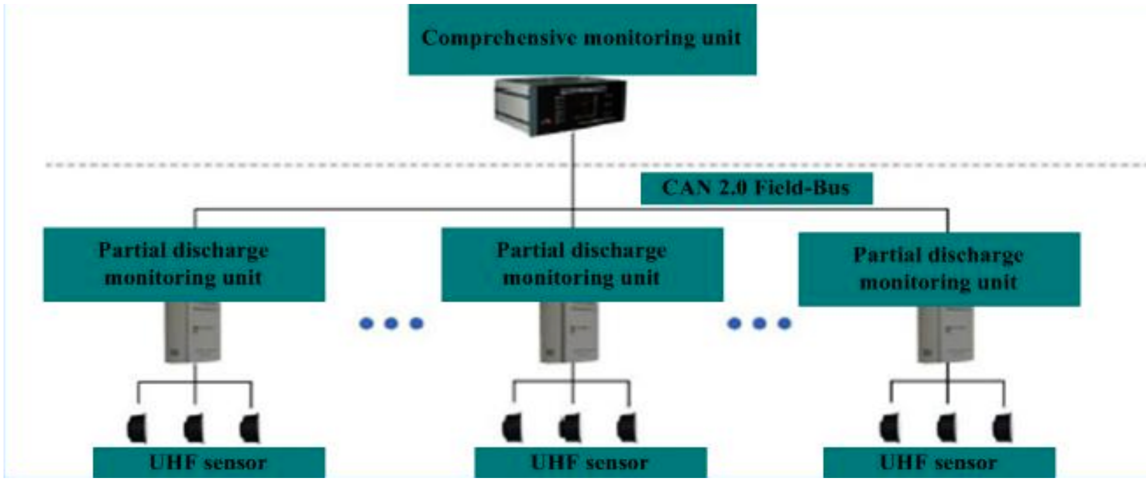

Fig. (1). The monitoring system of UHF partial discharge.

2.2. The Contrast of UHF Detection Methods and Traditional PD Methods

Compared with other PD online techniques, UHF detection methods have many prominent advantages:

1) High detection sensitivity

The signals of UHF electromagnetic waves generated by PD will fade out in the process of converter transmission. If the influence of the insulator is ignored, the signal of UHF electromagnetic waves with 1GHz can only be reduced to 3~5dB/km. And when electromagnetic waves reflect on the inner discontinuity of converter transformer, it will cause resonance in the shell of converter transformer to make the oscillation time of PD signals longer and easier to be detected. Therefore, UHF detection methods have high sensitivity. Furthermore, compared to ultra-sonic detection, UHF detection methods can detect more effective range and need less necessary sensor data to detect converter transformer online [2].

2) Strong anti-interference capacity

As there is a large amount of electric interference when the convert transformer works, it will bring some difficulties to partial discharge detection. The corona interference between high voltage transmission line and equipment is the most common field interference. The frequency of discharge energy is mainly below 200MHz. Detection frequency band of UHF method is usually 300MHz~3GHz. So it effectively avoids the field corona interference, and has strong anti-interference ability.

3) Benefit for insulation defect recognition

For different types of insulation defect, their UHF signals, produced by PD, have different frequency spectra. So, the time domain signal distribution of conventional method can be utilized. Also, it can be combined with frequency distribution characteristics of UHF signal for PD type recognition, and realize diagnosis of insulation defect types.

According to the propagation property of UHF electromagnetic waves, we know that applying Built-in UHF sensor to detect signals has higher sensitivity and stronger anti-interference ability than external UFH sensor, by extending the sensor into transformer through the oil discharge valve, flange and the standardization of dielectric window.

3. ANALYSIS OF UHF PD ONLINE MONITORING FOR CONVERTER TRANSFORMER APPLICATION EFFECT

3.1. Case

In 2014, oil chromatography online monitoring system found that YD-B occurs due to the phenomenon of excessive acetylene. Subsequently, hydrogen, acetylene and hydrocarbon components rapidly grew. Through theoretical analysis, it was confirmed that B-phase of the equipment exists due to inner overheat Fault. When shifting from converter to running state, the monitoring is too simple. In order to guarantee the safety and stable operation of convert transformer, we use UHF PD monitoring technology and install SIM3-PD portable PD online monitoring device. UHF signal sensor is installed on the oil valve at the top of converter transformer, and it is used to monitor PD of B-phase whose oil chromatography is abnormal [3].

The date of intelligent monitoring unit in field is uploaded to the integrated processing unit by CAN2.0B Field Bus. Integrated processing unit deals with the date. Then the field monitoring unit is uploaded to station CAC (Status information of the access controller) by the way of MMS, through the LAN based on IEC61850 Communication Protocol. It can also be uploaded to the backstage diagnosis center. The system structure of UHF PD monitoring is shown in Fig. (**1**).

3.2. Analysis of Application Effect

By analyzing monitoring data from July 3 to July 25, during this time, continuous typical PD signals related with power frequency voltage were basically not found. But there had been short continuous time (2-3 hours), during which B-phase happened, and had typical PD signals as shown in

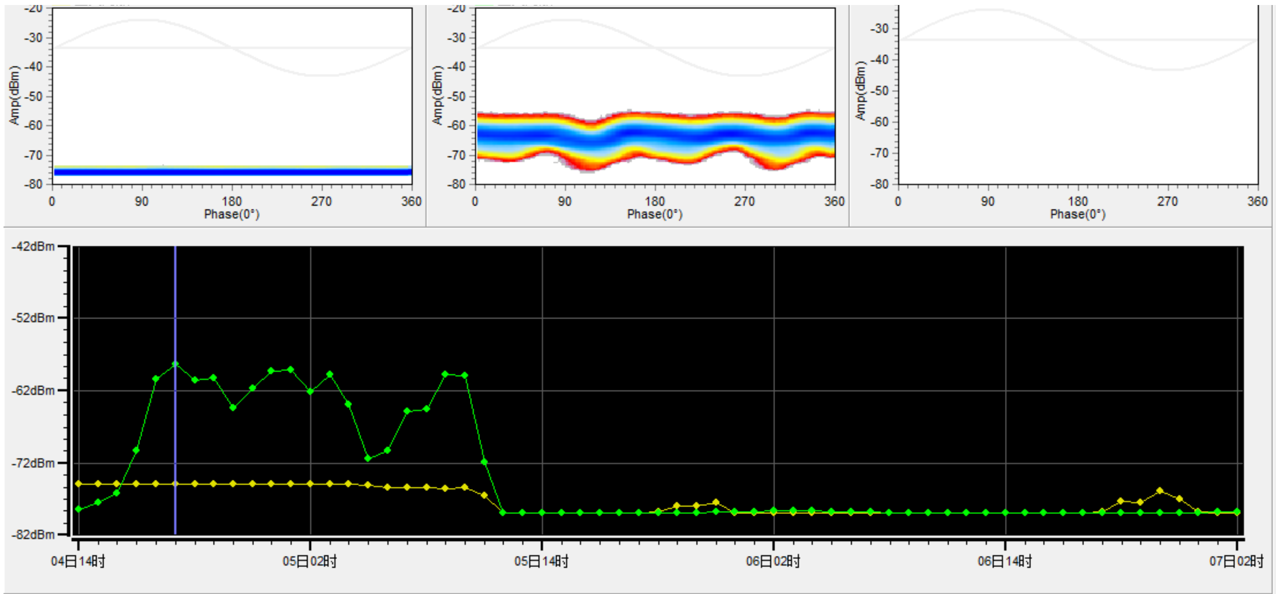

Fig. (2). The persistent abnormal PD signal in the B phase during 18:00 on July 4th to 11:00 on July 5th.

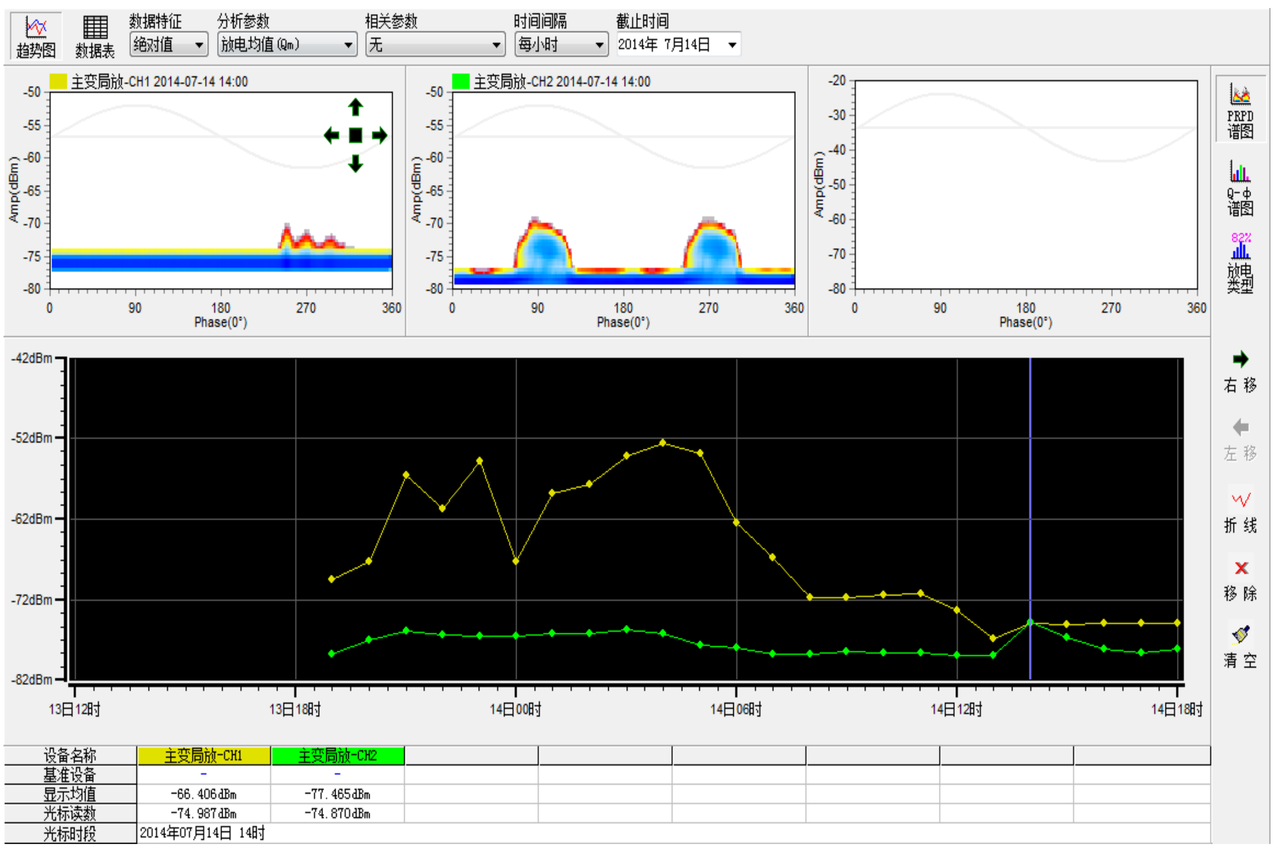

Fig. (3). Only three hours abnormal PD signal in the B-phase during 14:00 to 15:00 on July 14th.

Fig. (**2**). At the same time, B-phase monitored abnormal signal that is unrelated with power frequency voltage. It often occurred between 18:00-11:00 the next day as shown in Fig. (**3**). But it did not occur every day.

1) The effect of switch position on Partial discharge signal

From July 25th to July 30th, pole I operated power reduction to 1200MW, meanwhile the switch was changed from

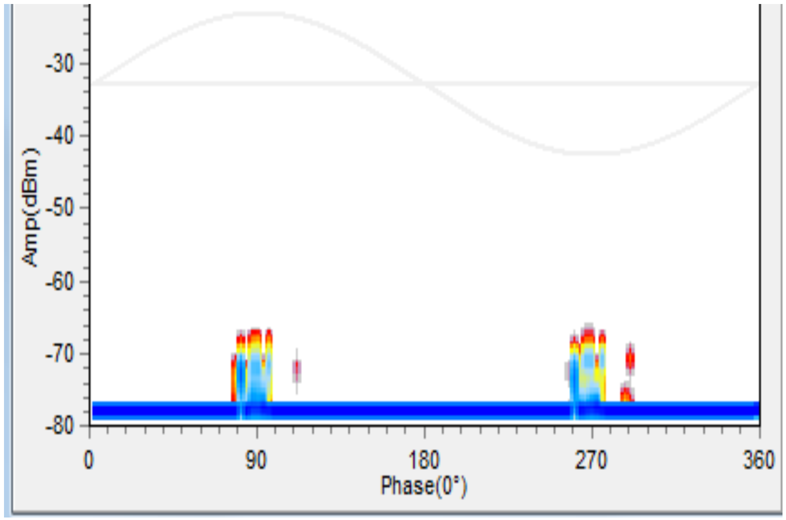

Fig. (4). Similar characteristics PRPD map during 20:00 on July 26th to 5:00 on July 27.

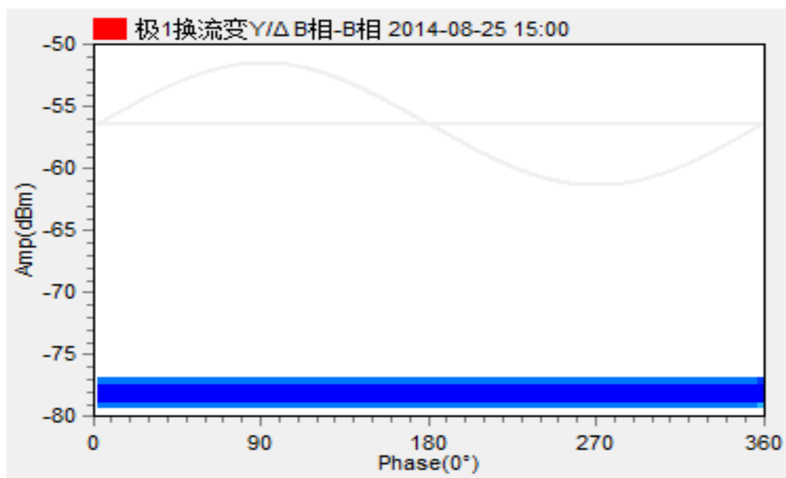

Fig. (5). The PRPD map of pole□ system YD-B phase at 15:00 on August 25.

the previous automatic regulating state to manually adjusting state, so that the switch could operate in "22, 23, 24" gear for two days. During this period, there is Partial discharge characteristic signal shown in PRPD maps through UHF on-line monitoring device from 8 p.m. to 7 a.m. every day, and presents the obvious characteristics of the phase, the discharge intensity of peak and average is less than -65 dBm, taking the PRPD maps at 20:00 on the 26th - at 5:00 on the 27th respectively, as shown in Fig. (**4**). The high frequency signal strength keeps up -80dBm in PRPD map during other period, only occasional signal pulse is weak, but there is no correlation with the frequency of the voltage, not even having obvious characteristics of the discharge phase [4].

2) The effect of current load on partial discharge signal

At 1:00 on August 25, the system will run for three days with raising the power to 1600MW (80% load), and at 1:00 on August 28, the power will be raised to 2000MW (100% load). After six days of following observation, no continued and fundamental typical PD signal associated with frequency voltage was found, but from 19:00 to 6:00 the next day, a signal with typical characteristic of PD appeared, which had confirmed that the signal is caused by High-voltage Sodium lamp in firewall of Converter transformer indoor.

From 8:00 on August 25 to 18:00 on August 25th, it has similar PRPD map features during this period, as shown in Fig. (**5**).

From 19:00 on August 25 to 6:00 on August 26, it has similar PRPD map features during this period, as shown in Table **1** and Fig. (**6**).

From 0:00 on August 28 to 6:00 on August 28, it has similar PRPD map features during this period, as shown in Fig. (**7**).

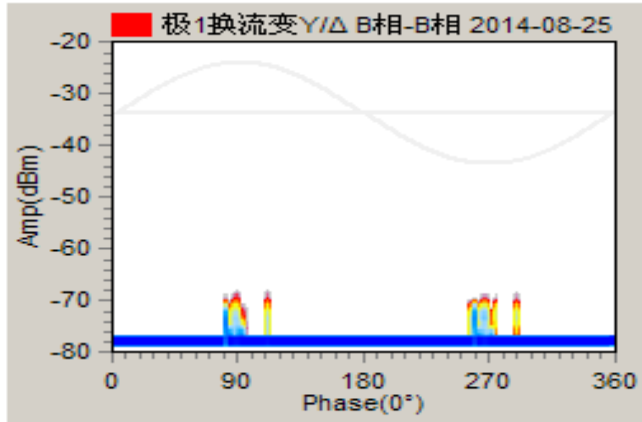

Fig. (6). The PRPD map of pole□ system YD-B phase at 19:00 on August 25.

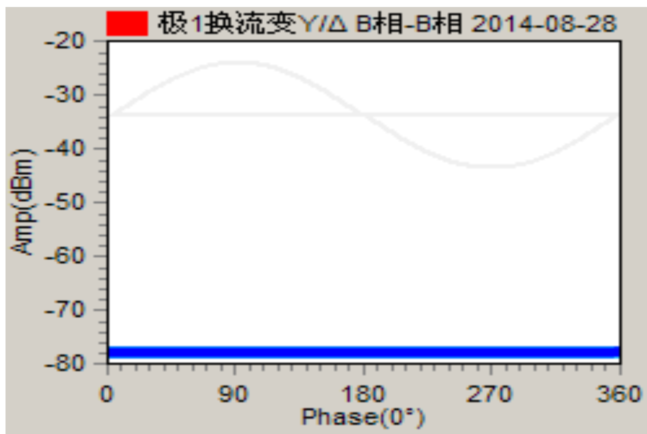

Fig. (7). The PRPD map of pole□ system YD-B phase at 0:00 on August 28.

Table 1. PD parameters of pole□ system as the power raised to 1600MW (80% load).

Time	Peak Discharge (dBm)	Mean Discharge (dBm)	Pulses Number (次/秒)	Phase Features (%)
08 月 25 日 16 时	-78	-78	0	0
08 月 25 日 17 时	-78	-78	0	0
08 月 25 日 18 时	-78	-78	0	0
08 月 25 日 19 时	-78	-78	0	0
08 月 25 日 20 时	-72.024	-73.793	56.6	11.269
08 月 25 日 21 时	-72.366	-74.098	39.1	2.463
08 月 25 日 22 时	-72.099	-73.857	45	4.805
08 月 25 日 23 时	-72.148	-73.978	41.2	1.543
08 月 26 日 00 时	-71.959	-73.668	48.3	2.637

Table 1. contd…

Time	Peak Discharge (dBm)	Mean Discharge (dBm)	Pulses Number (次/秒)	Phase Features (%)
08 月 26 日 01 时	-71.424	-73.248	57.2	11.018
08 月 26 日 02 时	-71.769	-73.596	49.7	6.604
08 月 26 日 03 时	-72.038	-73.867	44.3	0.075
08 月 26 日 04 时	-72.057	-73.834	44.9	0.787
08 月 26 日 05 时	-71.885	-73.743	46.3	3.927
08 月 26 日 06 时	-76.792	-77.154	9.2	0.48
08 月 26 日 07 时	-78	-78	0	0
08 月 26 日 08 时	-78	-78	0	0
08 月 26 日 09 时	-78	-78	0	0

Table 2. PD parameters of pole□ system as the power raised to 2000MW (100% load).

Time	Peak Discharge (dBm)	Mean Discharge (dBm)	Pulses Number (次/秒)	Phase Features (%)
08 月 28 日 16 时	-78	-78	0	0
08 月 28 日 17 时	-78	-78	0	0
08 月 28 日 18 时	-78	-78	0	0
08 月 28 日 19 时	-74.161	-75.03	46.3	17.169
08 月 28 日 20 时	-69.472	-71.569	82.9	42.471
08 月 28 日 21 时	-69.783	-71.799	80.8	34.674
08 月 28 日 22 时	-69.978	-71.973	75.8	33.098
08 月 28 日 23 时	-70.166	-72.159	74.9	23.537
08 月 29 日 00 时	-69.766	-71.758	78.9	34.864
08 月 29 日 01 时	-69.714	-71.728	78.5	36.909
08 月 29 日 02 时	-69.799	-71.712	81.4	28.183
08 月 29 日 03 时	-70.014	-72.003	77.6	21.907
08 月 29 日 04 时	-70.276	-72.273	72.1	29.321
08 月 29 日 05 时	-71.124	-73.037	59.9	19.408
08 月 29 日 06 时	-76.379	-76.831	14.1	3.617
08 月 29 日 07 时	-78	-78	0	0
08 月 29 日 08 时	-78	-78	0	0
08 月 29 日 09 时	-78	-78	0	0

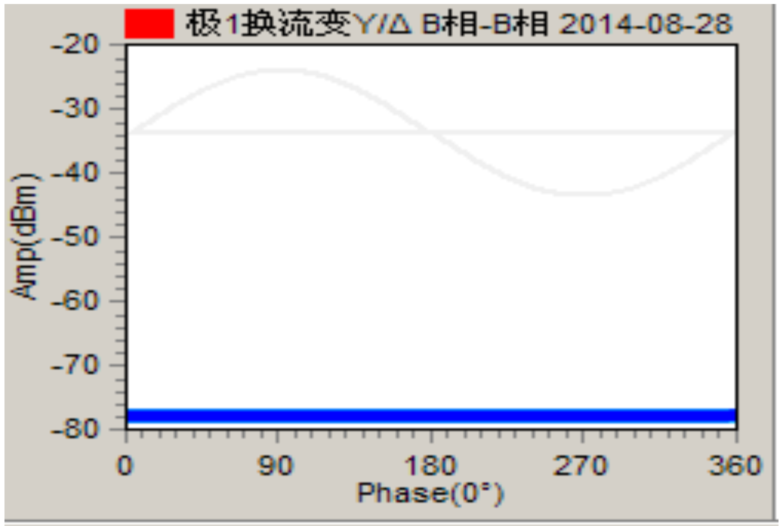

Fig. (8). The PRPD map of pole□ system YD-B phase at 18:00 on August 28.

From 7:00 on August 28 to 18:00 on August 28, it has similar PRPD map features during this period, as shown in Table **2** and Fig. (**8**).

4. ANALYSIS OF PARTIAL DISCHARGE DATA

After PRPD maps and dates acquired from July 13th to August 30th were analyzed, the following are the study points:

For the abnormal signal of B-phase is not related to frequency voltage during July 13 to July 25 (usually appeared between 18:00-11:00 the next day, but it will not be there every day), due to which the abnormal signals do not appear in the C-phase and B-phase at the same time, the interference from external space of Converter transformers can be ruled out. Since the abnormal signal is not synchronized with the power frequency voltage, and no interference is caused by commutated and rectifier of thyristor, the interference generated by SCR can be excluded. Whether the interference is caused by load change of Converter transformers, it needs to further analyze.

The signal with the typical features of partial discharge appeared at 19:00 to 6:00 every night from July 25 to July 30 and August 25 to August 30, which have significant phase characteristics. The peak discharge and mean discharge are less than -65 dBm (the equivalent discharge amount that do not exceed hundreds of pc, will not affect the insulating properties of the transformer).

Because the load of conversion transformer remained unchanged during this period, the impact of load changes can be excluded. Secondly, the impact of bad contact of tap changer can be excluded for tap-free operation. Although the signal appeared in the C-phase and B-phase simultaneously, and were synchronous with the frequency voltage, only in a fixed period of time, the interference of the SCR commutated rectifier outside converter transformer could be excluded. After analysis test, it is determined that the signal generates due to the influence of high-voltage sodium lamps of converter transformer interior.

The PRPD from the July 25 to July 30 and August 25 to August 30, UHF signal strength remained stable at -78dBm and there was not obvious pulse signal during other period daily.

Since August 28 the power of poleⅠ rose to 2000MW. The online monitoring discharge PRPD maps and discharge intensity, phase data and power YD-B phase of polo Ⅰ system was compared to 1600MW. The amplitude of the partial discharge signal increased to 2 ~ 3dBm, but the peak discharge and mean discharge is less than -65 dBm, which will not affect the performance of the transformer insulation.

CONCLUSION

After the conversion transformer in fault of overheating, there is no significant partial discharge and UHF signal strength is lower than -65 dBm. Only occasional weak partial discharge characteristics appear in PRPD map, which suggests that the monitoring system has strong anti-interfere capability.

UHF partial discharge monitoring combined with a variety of oil chromatography can effectively ensure security of conversion transformer in fault operation.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

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