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Analysis on Overcurrent Protection Action of AC Inlet Switch in Charging Test of Converter Transformer of DC Power Station System Debugging

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Abstract

The Matiari-Lahore ±660kV HVDC Transmission Project (hereinafter referred to as "Matiari-Lahore DC") is the only transmission project under the ''prioritized implementation'' project list of the China–Pakistan Economic Corridor; it is an important measure for State Grid Corporation of China respond to "The Belt and Road" initiative, it is also the first overseas investment project developed, built and operated by State Grid Corporation of China with BOOT mode, and its commercial operation period is 25 years. This project starts from the Matiari converter station in Hyderabad, Sindh, in southern Pakistan, and ends at the Lahore converter station in Lahore, Punjab, its DC line is 878km and tortuous coefficient is 1.08, it is the first HVDC transmission project in Pakistan, it is also the transmission project with the highest voltage level, the longest transmission distance and the largest transmission capacity in Pakistan. The site of the Lahore converter station is located about 55km southwest of Lahore, Punjab, Pakistan. The site area is 64 hectares, the converter station area is 21 hectares, the ground electrode line is 50km, the rated transmission power is 4000MW, the rated voltage is ±660kV, and the rated current is 3030A.

Keywords

DC station, charging test of converter transformer, AC inlet switch, overcurrent protection action.

1. Test Phenomenon

On October 22, 2020, during the charging test of converter transformer at the pole I/II Lahore converter station, because the switching current exceeded the overcurrent protection constant value, the switch overcurrent protection action occurred. The protection of the bipolar A/B/C converter transformers all started without action.

2. Overcurrent Protection Configuration Reasons and Action Condition

In order to ensure that the newly launched equipment will not affect the connected system when it fails, the verified protection of the already launched equipment is used as the backup protection, the specific way is to reduce its constant value and delay, increase the sensitivity of the protection action and better protect the connected AC system. Therefore, the overcurrent protection of the AC inlet switch is used as the backup protection in the charging of the converter transformer during the OLT test.

Before charging of the converter transformer at the Lahore converter station, the overcurrent protection constant value is set to 520A and the action delay is 50ms. At 17:02 on October 22nd, the effective value of the inrush current during the charging of the pole I converter transformer exceeded the overcurrent protection setting value, and the operating current was 970A, it caused the overcurrent protection action, tripped out of the commutation inlet switch B1Q1 and protected the correct operation. At 23:09 on October 22nd, the effective value of the inrush current during charging of the

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pole II converter transformer exceeded the overcurrent protection constant value, the action current was 540A, it caused the overcurrent protection action, tripped out of the commutation inlet switch B1Q1 and protected the correct operation. When the current flowing through the switch exceeded the constant value 540A within 50ms, the secondary current of the converter transformer exceeded the starting value 0.5Ie=0.343A (the transformation ratio is 2000:1) of the differential protection of the converter transformer, and did not reach the action condition. The protection of the bipolar converter transformer reached the starting value, and did not meet the protection action condition.

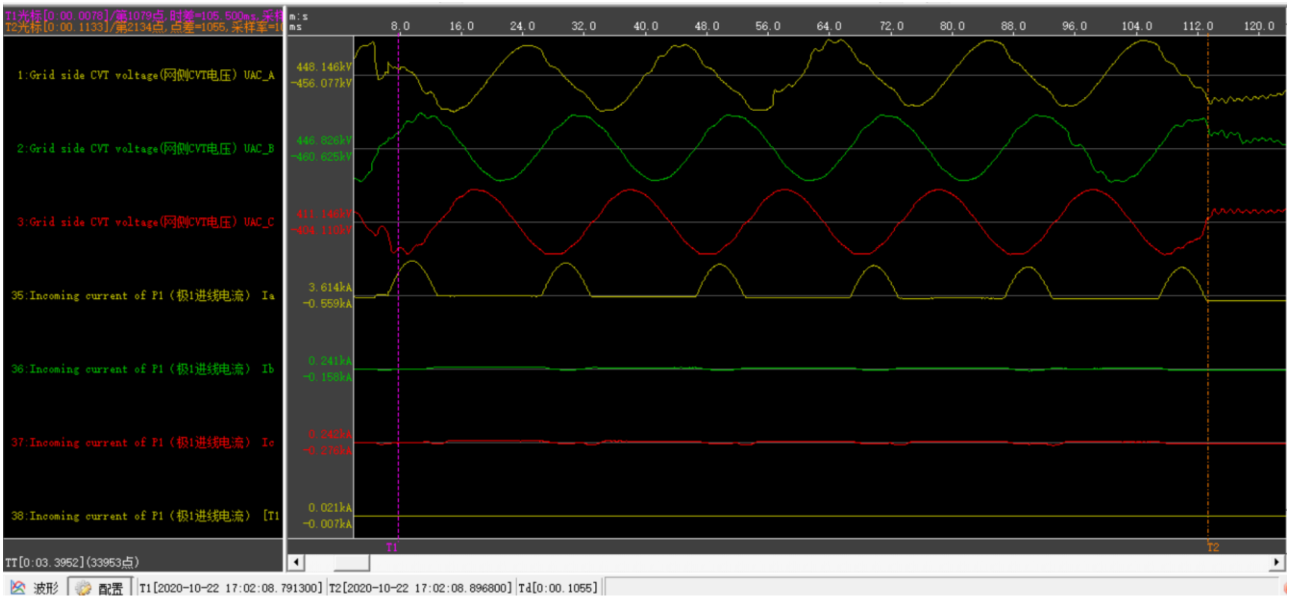

Fig.1 inlet switch current waveform of switch overcurrent protection action of charging of pole I converter transformer

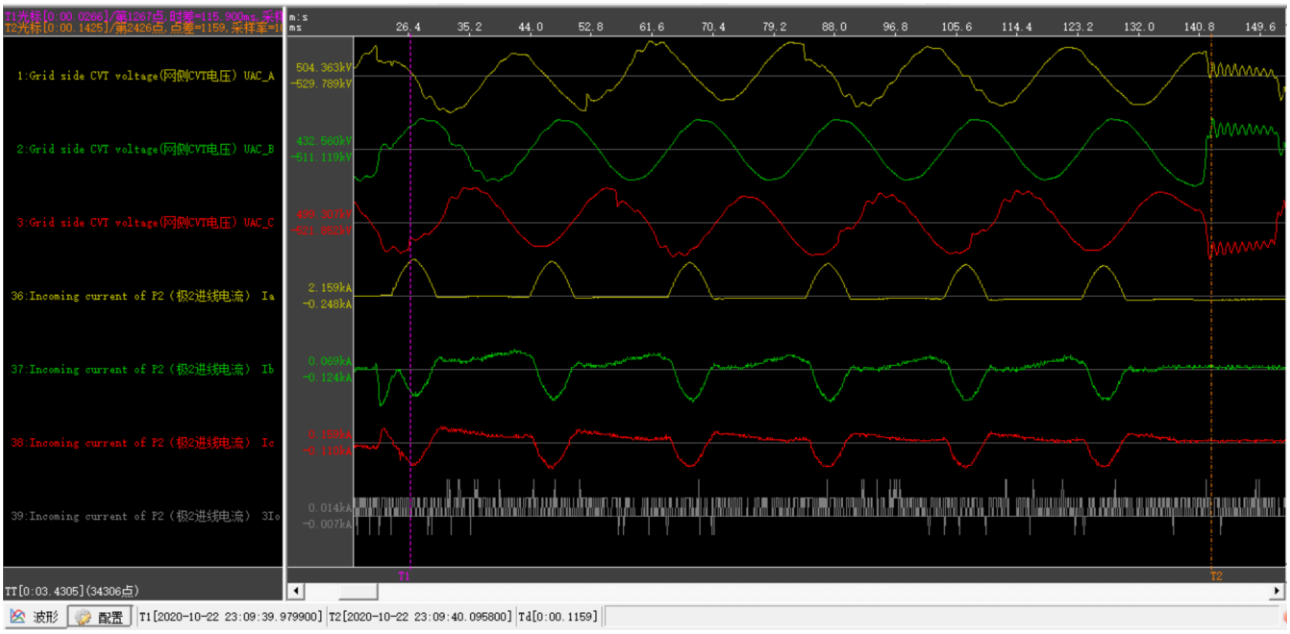

Fig.2 inlet switch current waveform of switch overcurrent protection action of charging of pole II converter transformer

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3. Judgment Methods of Excitation Inrush Current

By comparing this station converter transformer protection, domestic main transformer protection and consulting literature, it was found that there are two main judgment methods of excitation inrush current, harmonic judgment method and waveform judgment method.

The second harmonic value of Xuji PAC-886 converter transformer protection in this station is greater than 0.15 times of fundamental value, namely, the current is considered to be the excitation inrush current at this time, and the three-phase differential protection is blocked.

3.1.4 Inrush Current Criterion 3.1.4.1 Second Harmonic Criterion

When changing rheological airdrop, there is often a large number of second harmonics in the three-phase inrush current. The device uses the second harmonic content in the differential current to identify the inrush current. Discriminating equation：as follows

$I_{op.2}>K_2*I_{op.1}$

The: $I_{op.2}$is the second harmonic in the differential flow, the$I_{op.1}$ is the fundamental wave in the differential flow, the K_2 is the second harmonic braking coefficient, and the fixed value is 0.15.

If a phase difference flow meets the upper formula, the three-phase differential protection is locked at the same time. 3.1.4.2 Waveform comparison criteria

According to the different working conditions of the converter, the device automatically selects the differential current or phase current to calculate the asymmetry of the waveform, and calculates that the asymmetry of the inrush current waveform is more real and the protection performance is more reliable. Discriminating equation：as follows

$$S_{SUM+}>k*S_{SUM-} \tag{3-1-6}$$

$$S_{SUM+}=\sum_{1}^{N/2}\left|I_i+I_{i+N/2}\right| \tag{3-1-7}$$

$$S_{SUM-}=\sum_{1}^{N/2}\left|I_i-I_{i+N/2}\right| \tag{3-1-8}$$

The： S_{SUM+} is the asymmetry value of the differential current sampling point, the $S_{SUM-}$is the symmetry value of the corresponding differential current sampling point, and the K is a fixed coefficient.

If a phase difference flow meets the upper formula, the three-phase differential protection is locked at the same time.

Fig.3 judgment method of PAC-886 excitation inrush current of Xuji line converter transformer protection

NR Electric PCS-978 main transformer protections add the judgment of third harmonic. It was found from the waveform comparison that the differential current is basically the power frequency sine wave when the fault occurs. During the inrush current excitation, there are a lot of harmonic components, and the waveform is distorted, discontinuous and asymmetric. The protection device uses the asymmetry of the contrast waveform to judge the excitation inrush current.

3.5.1 harmonic identification of inrush current

A series of PCS-978 transformer protection device uses the content of second harmonic and third harmonic in three-phase differential current to identify excitation

Current inrush, discriminant equation：as follows

$I_{2nd}>K_{2xd}*I_{1st}$

$I_{3rd}>K_{3xd}*I_{1st}$ formula 3.5-1

of them

I_{2nd} , I_{3rd}in each phase differential current, respectively.I_{1st} is the differential flow fundamental wave of the corresponding phase.

K_{2xd} pumping andK_{3xd} are the second harmonic and third harmonic braking coefficient setting values, respectively. tz fixed to 0.2. When a phase in the three phase is identified as inrush current, only the ratio differential element is locked.

3.5.2 Waveform Distortion Identification of Inrush Current

When fault, differential current is basically power frequency sine wave. Inrush current, there are a large number of harmonic components, waveform distortion, discontinuity, asymmetry. Using the algorithm to identify this distortion, the inrush current can be identified.

At fault, the following expression holds :

k_p*S_+ formula 3.5-2

$S>S_t$

them

S is the full-cycle integral value of the differential current.

S_+ full-cycle integral value of the instantaneous value of the differential current + the instantaneous value of the differential current half a week ago.

Fig.4 NR Electric PCS-978 excitation inrush current judgment methods of main transformer protection

Therefore, when we observe the fault record, on the one hand, we can compare the ratio of the second harmonic, the third harmonic and the fundamental component, if the ratio is larger, greater than 0.15 and above, it is considered as excitation inrush current, on the other hand, we can observe the characteristics of the waveform, distortion, discontinuity, and asymmetry, then it is basically regarded as the excitation inrush current.

4. Causes of Excitation Inrush Current

At the moment when the no-load transformer is closed, a random current will be generated, which will return to the normal range over a period of time. This high current is not a short-circuit current; this randomly generated current is called the transformer excitation inrush current. The magnitude of the excitation inrush current is related to the no-load closing time, and its maximum amplitude will reach 2-3 times the rated current, and it contains a lot of second and third harmonics and DC components.

On the one hand, the transformer is regarded as a strong inductive load, namely a nonlinear inductance, when closing, the voltage on the transformer also generates a magnetic flux inside the transformer. When the transformer has residual magnetism, if the magnetic flux generated after closing has the same polarity as the residual magnetism, the total magnetic flux inside the transformer will increase as the voltage rises, and the excitation inrush current will increase accordingly; if the magnetic flux generated after closing is opposite to the residual magnetism, and the total magnetic flux inside the transformer will decrease as the voltage rises, thereby weakening the excitation inrush current.

On the other hand, if there is no residual magnetism in the transformer when closing, it can be closed when the closing angle is 90 °(namely the voltage peak), when the closing angle of capacitive loads (such as filters) is 0 °, the generated excitation inrush current is the smallest. Due to the discrete type of switch closing characteristics, the filter closing target angle of the station is set at 12.6 °.

At this stage, the reason why the filter switch is equipped with phase selection closing device but the AC line switch of the converter transformer is not equipped with phase selection closing device is: the filter field switch is frequently switched on and off; the switch of converter transformer is switched on and off less, after the first power transmission, after verifying the correctness of the converter transformer protection, the overcurrent protection of the switch can quit, in the power transmission

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process after maintenance, the excitation inrush current will not cause the protection action of converter transformer to trip.

5. Treatment Suggestions of Excitation Inrush Current

According to the above analysis, due to the existence of transformer residual magnetism and the chance of the closing angle, it is difficult to eliminate the excitation inrush current generated when the no-load transformer is closed. Generally, demagnetization is used before power transmission to reduce the influence of residual magnetism. Because the usage of phase selection closing device of converter transformers is extremely low, generally, phase selection close is not used to avoid chance of closing angle.

First, when it is put into operation after overhaul, if the secondary current circuit is affected by the change of converter, there is no need to input AC inlet switch overcurrent protection, it is not necessary to input the overcurrent protection of the AC inlet switch, the converter transformer protection logic can judge the excitation inrush current and excitation inrush current with larger brake to a certain extent.

Second, in the charging process of transformer charging, after the switch is tripped, protection action behavior, fault record and analysis, typical characteristics of excitation inrush current can judge whether the protection trip is caused by the excitation inrush current. When the second judgment is determined to be a trip caused by the excitation inrush current, the second trial power transmission can be carried out after there is no problem in device.

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