How to Commissioning of 3600kV Impulse Voltage Generator Test System

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Abstract: Appropriate selection of instrument parameter helps to improve synchronization characteristic and efficiency of impulse voltage generator, generating impulse voltage waveform in accordance with the test criterion, hence guarantee efficient and reliable test result under the existing instrument condition.

Key words: High voltage electrical device; Impulse voltage generator; Synchronization characteristic

1. Foreword

Besides permanent working voltage, high voltage electrical device in power system is likely to bear instantaneous lightning and switching surge during operation, impulse voltage test is designed to examine insulating and protection performances of various high voltage electrical device under the impact of lightning voltage and overvoltage. In order to improve sensitivity and reliability of 3600kV impulse voltage generator, upgrading and transformation have been conducted to the instrument control system and measuring system applying OMRON CJ series PLC centered new control system.

2. Working principle of impulse voltage generator

2.1 Structure principle

Impulse voltage generator generates impulse high voltage via parallel charging and series discharge of capacitors. Impulse voltage generator generates both lightning impulse and switching impulse, impulse voltage generator normally comprises 5 components: rectification and charging power supply conducts remote control of performance characteristics of all structural element with parallel capacitor charging control system, measurement system measures performance characteristics and output waveform characteristics of impulse voltage generator and transfers data to the control center, voltage impulse generator is designed to generate different impulse voltage waveform and conduct signal transmission between components of the system in accordance with test requirements, as shown on figure 1.

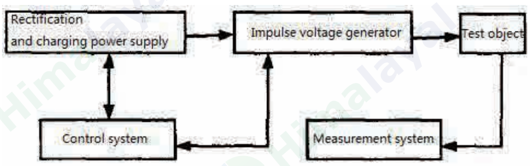

Fig.1 Structure diagram of impulse voltage generator

2.2 Electrical schematic diagram

The main body of 3600kV impulse voltage generator applies a three-column structure, a typical structure based on Marx principle, circuit principle as shown on figure 2.

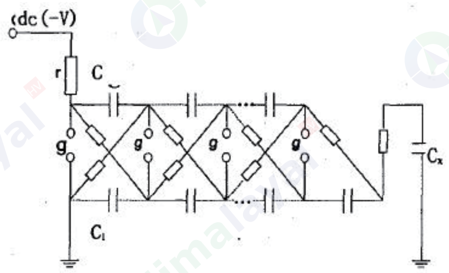

Fig.2 Schematic diagram of multi-stage impulse voltage generator

According to diagram above, C represents two single-stage 100kV parallel charging capacitor, parallel stage capacitance is 1.0μF, series discharge stage voltage amounts to 200kV, stage energy is 20kJ. The instrument main body is composed of 18 stage parallel charging capacitors, total series stage discharge voltage adds up to 3600kV, to meet test requirements of electrical devices at different voltage level, impulse test voltage within range of 200~3600kV can be generated through changing parallel capacitor stage number of the main body connected to discharge circuit. C_1 on the diagram represents stray capacitance on impulse voltage generator main body, according to impulse voltage generator discharge principle, existence of stray capacitance intensifies favorable condition of impulse voltage generator movement; g represents discharge spark gap, during the test, breakdown begins from first-stage sphere gap and moves successively to stages above after charging is complete and the trigger signal is sent from the control system, forming a serial discharge circuit connecting charging capacitors, which generates high amplitude impulse voltage on test object.

3. Synchronization characteristics of impulse voltage generator

3.1 Requirements on impulse voltage generator waveform

According to national standard GB/T16927.1 and updated IEC60060-1ED.3.0 standard, standard lightning waveform equals 1.2(1±30%)/50μs(1±20%), standard switching surge waveform equals 250(1±20%)/2500μs(1±60%). During the practice of impulse voltage test, output waveform of impulse voltage generator is highly affected by characteristic of the test object and environment, causing shorter wave front or wave tail. Therefore, to obtain effective waveform in accordance with standard criterion, corresponding parameters of impulse voltage generator are necessarily set which usually cause difficulty on synchronization of the generator, meaning successive breakdown of sphere gap in the middle isn't applicable under normal circumstances, affecting series discharge circuit of the capacitors, hence study on synchronization issues is essential for realization of series discharge of capacitors and access to up-to-standard impulse voltage waveform.

3.2 Sphere gap synchronizing range test

Synchronization characteristic of discharging sphere gap is the key influencing factor of simulated transient overvoltage performance of impulse voltage generator. Discharging sphere gap of impulse voltage generator has a certain synchronizing range T_d, qualified synchronizing range guarantees synchronous discharge of 18 sets of discharging sphere gap on generator main body within proper voltage range at different discharge sphere gap settings during the test.

To study sphere gap synchronization characteristics at different impulse voltage stage, the test applies stage-by-stage voltage rise, and find out maximum trigger discharging sphere gap D_{max} and minimum non-self-discharging sphere gap D_{min} correspond to all stages of discharge voltage, conduct discharge range test on each point and calculate synchronizing range at that point based on formula (1), D_{max} and D_{min} as well as synchronizing range at all voltage stages as shown on table 1.

Sphere gap synchronizing range at all voltage stages

Table 1

U (kV)	D_{min} (mm)	D_{max} (mm)	Td (%)
30	13.0	17.5	34.6%
50	22.8	29.7	30.3%

70	33.2	42.3	27.4%
90	42.3	54.1	27.9%
110	53.6	65.5	22.2%
130	62.8	79.7	26.9%

Note: U—single stage charging voltage; D_{min}—minimum non-self-discharging sphere gap; D_{max}—maximum trigger discharging sphere gap; Td—synchronizing range.

$$Td = \frac{D_{max} - D_{min}}{D_{min}} \times 100\% \quad (1)$$

As shown on table 1, synchronizing range of 3600kV impulse voltage generator is above 20% at all voltage stage, sphere gap maintain good synchronization characteristics under all impulse voltage stage, which satisfies the requirements of impulse voltage test.

4. Commissioning of lightning impulse voltage wave

4.1 Lightning full wave

According to GB/T16927.1-1997, standard lightning impulse wave front length equals 1.2±30%μs, wave tail length equals 50±20%μs, overshoot impulse at peak value or oscillation amplitude no larger than 5% peak value voltage, oscillation amplitude no larger than 20% peak value voltage at 50% wave front.

Lightning full wave impulse test system includes impulse voltage generator main body and divider. Due to limited test condition, the test mainly examines whether frequency of standard lightning wave and standard wave can be generated without load, as well as stability of system parameters during the process of charging and discharging of the whole set.

$$T_1 = 3\frac{R_1 R_2}{R_1 + R_2} \cdot \frac{C_1 C_2}{C_1 + C_2} \quad (2)$$

$$T_1 \approx 3R_1C_2 \quad (3)$$

$$T_2 = 0.7(R_1 + R_2) \cdot (C_1 + C_2) \quad (4)$$

$$T_2 \approx 3R_2C_1 \quad (5)$$

Formula (2) ~ formula (5) show calculation principle of lightning impulse voltage waveform parameter generated by impulse voltage generator, among which formula (3) and formula (5) are respectively simplified expressions of formula (2) and formula (4). In the formula, T_1 and T_2 respectively represent wave front and wave tail time, C_1 and C_2 respectively represent charging capacitance and load capacitance, R_1 and R_2 respectively represent wave front resistance and wave tail resistance.

In consideration of divider equivalent capacitance and based on standard lightning wave form parameter and impulse voltage generator parameters under no load circumstances, calculated wave form resistance parameter $R_f \approx 30\Omega$, $R_t \approx 70\Omega$. Taking into account of auxiliary resistance characteristics of impulse voltage generator, $R_f = 30\Omega$, $R_t = 73\Omega$ are selected for no load test.

In verification of rationality of the selected wave form resistance, charging stage voltage U=±110kV and U=±150kV are selected respectively to conduct multiple charging and discharge test, wave form and parameter output as shown in table 2 and table 3.

In table 2, t represents charging time, select charging time properly prevents overvoltage within the charging circuit while improving charging efficiency. As drawn from oscillograph of table 2(omitted), lightning impulse wave parameters meet standard requirements, efficiency of impulse voltage generator maintains around 90%, which means parameter calculation of impulse voltage generator main body is rational.

Wave form parameter at U=±110kV, t=70s

Table 2

Polarity	Frequency	Peak Value(kV)	Wave Front Time	Wave Tail Time	Efficiency(%)
-110kV	1	1784.02	1.34	54.67	90.1
	2	1784.20	1.33	54.71	90.1
	3	1785.46	1.34	54.82	90.2
+110kV	4	1763.80	1.30	56.75	89.1
	5	1760.58	1.29	56.80	88.9
	6	1759.46	1.29	57.07	88.9

Wave form parameter at U=±150kV, t=90s

Table 3

U(kV)	Frequency	Peak Value(kV)	Wave Front Time	Wave Tail Time	Efficiency(%)
-150	1	2399.98	1.38	56.10	88.9
+150	2	2334.66	1.31	T_c=2.81	86.5

4.2 Chopped lightning impulse

According to stipulation in national standard GB/T16927.1-1997: standard time to chopping of chopped lightning impulse T_c=2~6μs, factor of zero crossing 0z≯0.3, to examine lightning impulse generator response characteristic to chopped wave, the test applies single-stage charging voltage of U=-55kV and U=+115kV, wave form parameters are set to be the same as lightning full wave, test result as shown on table 4.

As drawn from table 4 and its oscillograph (omitted), standardized chopped lightning impulse wave form can be obtained under circumstances of impulse voltage generator without load, R_f=30Ω, R_t=73Ω, chopped wave delay setting between 0.1~2μs.

Chopped wave characteristics at U_1=-55kV, U_2=+115kV

Table 4

Polarity	Frequency	Peak Value(kV)	Wave Front Time	Time to Chopping	Delay Setting
-55kV	1	889.74	1.34	3.40	0.1
	2	892.29	1.33	3.21	0.1
	3	889.28	1.34	4.30	1.1
+115kV	4	888.51	1.33	5.26	2.1
	5	1856.04	1.30	3.67	0.1
	6	1858.86	1.34	3.49	0.1
	7	1855.54	1.34	5.29	2.1

5. Conclusion

This article combined improvement practice of high voltage test hall 3600kV impulse voltage generator, recounted structure and configuration principle of impulse voltage generator and came up with correlative theories. Calculation of all parameters under no-load circumstances of the impulse voltage generator has been conducted and eventually led to corresponding parameters of wave front and wave tail resistance, authenticity of theories mentioned in this article has been verified through multiple operational practice of lightning full wave and chopped lightning impulse.