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Design and construction impulse voltage generator for equipment testing in low voltage system with IEC 60439-1 standard.

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This article presents the design and invention of impulse voltage generator of 6 kV open circuit 1.2/50 μs waveform for testing low voltage electrical equipment according to IEC60439-1 standard. This presented impulse voltage generator consists of 3 parts: (1) charging control circuit for capacitor (2) circuit generating ignite voltage. These two parts are control through optical device for safety and accuracy operation (3) highly voltage inductive coil for break down at spark gap. Waveform results from impulse voltage generator fall into IEC60439-1.

Keywords: IEC 60439-1 Standard, Impulse Voltage, 1.2/50 μs, low voltage system

1. INTRODUCTION

Now, there are various production of Distribution Board such as Switchboard, Switchgear and Consumer Unit to satisfy the expanded industry. These distribution boards must be tested of insulator tolerance as IEC 60439-1 standard and low voltage electrical equipment have to be tested by using 6 kV and 1.2/50 μs impulse voltage waveform. Presently, impulse voltage generators for low voltage electrical equipment testing are imported from foreign countries and also high price.

Therefore, this article presents the design and invention of impulse voltage generator by using available device that can be purchased in our country to reduce invention cost and thus it is also lower cost than bought from foreigner. In addition, this design and invented generator can produce impulse voltage according to IEC 60439-1 standard.

2. FUNDAMENTAL CIRCUIT FOR IMPULSE VOLTAGE GENERATOR

Fundamental circuit of lightning impulse voltage generator used for design of impulse voltage generator as presented in fig.1

Lightning impulse voltage Principal circuit as fig. 1 direct current voltage source (U_g) charges to impulse capacitor (C_s) until the voltage is equal U_o in which R_L eliminate current charge to C_s. When spark at S occurs, voltage resulting from U_o charging would drop at R_d and C_b enabling Capacitor C_s discharge to testing material, which is capacitor of the load (C_b).

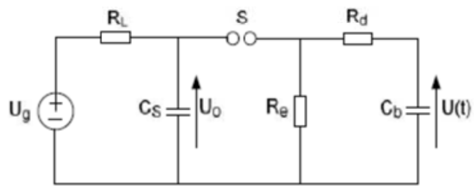

Fig.1 Principal circuitlightning impulse1.2/50 μs.

U_g is Dc voltage source
U_o is Dc voltage charger of capacitor
C_s is Impulse capacitor
C_b is Capacitor of load
R_L is Resistor Current limit charger
R_d is Front resistor
R_e is Tail resistor
S is Switching spark gap

The impulse voltage shape generated on the RC transient circuit can be described by two exponential functions with different time constant. Whereas the lightning impulse front time T_1according to IEC 60439-1[1] is essentially determined by resistance of front resistor R_d and capacitor of load C_b see fig. 1, the time to half-valve T_2 is determined by the impulse capacitance of the impulse capacitor C_s and the resistance of the tail resistor, T_2 is varied according to R_e and time constant of discharge capacitor equal $C_s R_e$ being part of impulse voltage testing generator. According to IEC 60439-1, there are the following time parameters and tolerances for the standard lightning impulse 1.2/50 μs.

3. IMPULSE VOLTAGE

Impulse voltage is waveform voltage simulated overvoltage resulting from outside factors as:

1.Overvoltage caused by lightning known as Lightning impulse.

2. Overvoltage caused by power supply system known as switching impulse.

Generating impulse voltage for testing of low voltage electrical equipment before application has to test whether the insulator properties of low voltage electrical equipment can tolerate voltage. The voltage tolerance of insulator is not only depended on the highest voltage but also on voltage shifting over the time. Therefore, impulse voltage waveform standard is defined by holding the actually simultaneous waveform as requirement.

1. Voltage magnitude refers to peak voltage.

2.Voltage electrode may be positive or negative compared with ground.

3. Front time, T_1refers to period of time increasing from zero to peak as well as reducing to half of the peak as presented in fig.2

The lightning impulse voltage standard as follows:

Front time $T_1 = 1.2\ \mu s \pm 30\%$ or($\pm 0.36\mu s$)

Time to half-value $T_2 = 50\mu s \pm 20\%$ or($\pm 10\mu s$)

Peak voltage $U_m = \pm 3\%$

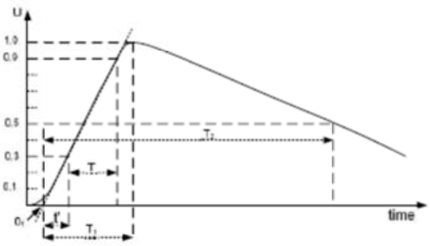

Fig.2 Lightning impulse voltage waveform 1.2/50 µs.

4. DESIGN OF CIRCUIT GENERATING IMPULSE VOLTAGE

Design of circuit generating impulse voltage through analysis on impulse voltage generating fundamental circuit by Kirchhoff's Law and Laplace Transform [2] and define the equation in term of time, then acquired the following equation 1.

$$U(t) = \frac{U_o}{k} \cdot \frac{1}{(\alpha_2 - \alpha_1)} (e^{-\alpha_1 t} - e^{-\alpha_2 t}) \qquad (1)$$

$U(t)$ is impulse voltage varied as time

U_o is charging voltageon C_s

K is voltage waveform constant

α_1, α_2 is time constant

t is time variable

Factors for impulse voltage waveform standard 1.2/50 µs.

Table 1: shows k_1 and $k_2$factors of impulse voltage waveform 1.2/50 µs.

T_1/T_2	k_1	k_2	$\frac{1}{\alpha_1}\mu s$	$\frac{1}{\alpha_2}\mu s$
1.2/50	0.73	2.96	68.5	0.405

In impulse voltage generating circuit design calculates the elements of circuit by determining capacities of capacitor C_b and then choosing the impulse capacitor C_s that fix to the capacities of capacitor C_b, finally calculating the resistance R_d and R_e. If front time and time to half-value are defined, R_d and R_e can be calculated by k_1 and $k_2$factors from equation 2 and 3. For highly effective design of impulse voltage generator, it should be selected the much higher capacities of capacitor C_s than capacitor C_b ($C_s >> C_b$)

$$T_1 = k_2 * R_d \frac{C_b \cdot C_S}{C_b + C_S} \qquad (2)$$

$$T_2 = k_1 * R_e (C_b + C_s) \qquad (3)$$

Efficiency of impulse voltage generator (η) can be calculated by equation 4

$$\eta = \frac{C_S}{C_S + C_b} \qquad (4)$$

Energy of impulse voltage generator can be calculated by equation 5

$$W = \frac{1}{2} C_S \times Uo^2 \qquad (5)$$

W is charging Energy as joule (J)

$C_S$is capacitance of capacitor C_S as pF

U_o is charging voltageon C_s

4.1 Spark gap electrode

Spark gap used for testing consists of high voltage electrode and ground electrode. Both electrodes made of copper are semicircle with 2.3 cm diameter and 5 cm long.

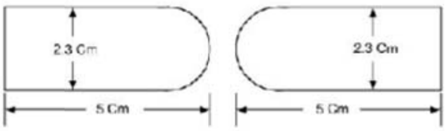

Fig. 3 high voltage electrode and ground electrode

4.2 Operation Control

Design of ignite circuit for sparking at spark gap must minimize the deferring time form operation. Block diagram operation presented in figure 4 by using light signal control the two parts operation. First, optical device controls charging circuit operation when the capacitor is fully charged and the secondly optical device controls discharge circuit to enable the capacitor discharge to high voltage inductor allowing the high voltage spark at the spark gap and break down.

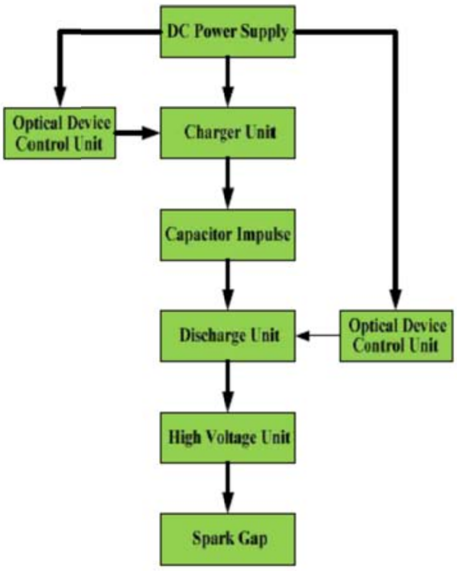

Fig. 4 block diagram of impulse voltage generator.

5. THE EXPERIMENT RESULT

5.1 Testing waveform compared with IEC 60439-1 standard

Testing of impulse voltage open circuit 6 kV with impulse waveform 1.2/50 µs positive electrode conform withIEC 60439-1 standard.

Front time measurement $T_1 = 1.67(t_{90} - t_{30})$

Time to half-valve measurement $T_2 = t_{50} - 0_1$

Testing of impulse voltage generator by enabling the generator produce 10 times of voltage open circuit 6 kV waveform 1.2/50µs and then the measured results are calculated as average in terms of voltage, front time and time to half value as shown in table 2.

Table 2: The average value of 6 kV 1.2/50 µs impulse voltage waveform testing.

Lists	Impulse std.	Measured value	Error value
U_m	6000 V±180 V	6070 V	+ 70 V
T_1	1.2 µs ±0.36 µs	1.85µs	- 0.10 µs
T_2	50 µs ± 10 µs	52.50µs	+2.50µs

The result of maximum impulse voltage measurement is 6018 volt see fig. 5

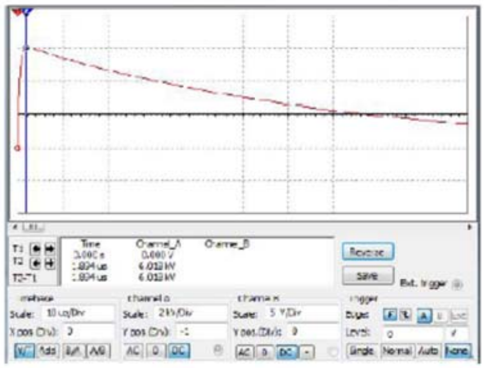

Fig. 5 Impulse voltage waveform measurement Peak Voltage

The result of impulse voltage measurement by oscilloscope compared time from T30 to T90 time period T equals to 710 ns or 0.71µs then T is calculated for Front Time T_1 From equation $T_1 = 1.67T$ then $T_1 = 1.18$ µs see fig. 6

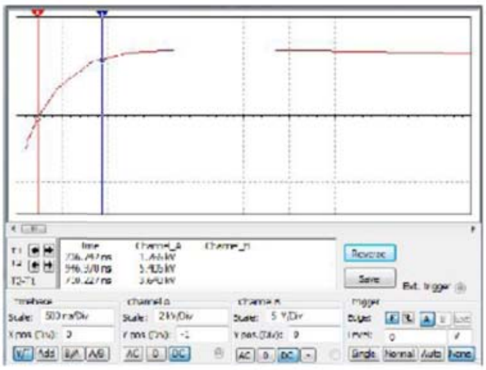

Fig. 6 Impulse voltage waveform Front time measurement T_1

Time to half value measurement of impulse voltage by oscilloscope compared from zero virtual to time to half value at 50% of maximum voltage is 49.81 µs see fig. 7

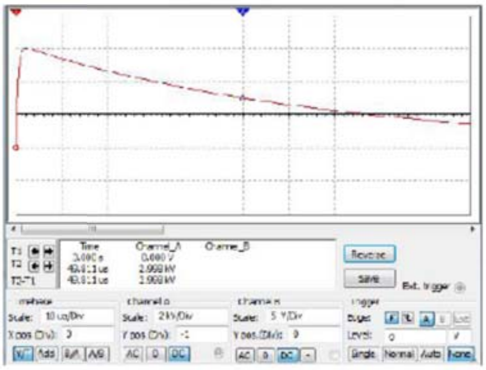

Fig. 7 Impulse voltage waveform Time to half-value measurement T_2

6 CONCLUSIONS

This article has presented the design and invention of lightning impulse voltage generator with 6 kV open circuit and 1.2/50 µs waveform for testing low voltage electrical equipment according to IEC 60439-1. As the results, the magnitude of voltage and waveform conform with IEC 60439-1 standard, consequently this impulse voltage generator can be used to test insulator tolerance of low voltage equipment as well as this designed and invented generator is cheaper than the imported one.

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