RESULTS OF EXPERIMENTAL HIGH CURRENT IMPULSE 4/10μs OF METAL OXIDE VARISTORS ZINC IN THE HIGH VOLTAGE 220KV SURGE ARRESTER

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ABSTRACT

This paper presents the results of experimental researching the technical characteristics of metal oxides varistors zinc (V-ZnO) in the 220 kV surge arrester at the National Key Laboratory for High Voltage Techniques - Institute of Energy (HVLAB). The results of experimental researching the peak value of discharge current having a 4/10μs impulse shape which is used to test the stability of the arrester on direct lightning strokes. The voltage-current linear characteristics of metal oxides varistor zinc V-ZnO at current on resistor plate of surge arrester. When voltage apply to the V-ZnO larger U_{peak}, a small increasement of voltage will make the current through the V-ZnO increase quickly. This feature is used to discharge the lightning when the over-voltage current appeare. U_{peak} is based reference limits to design the core of V-ZnO. From the results of this test allow to assess some category of the V-ZnO quality arrcording to IEC 60099-4, to install surge arrester into the grid with high efficiency.

Key words: Metal oxides varistor zinc; V-ZnO; V-SiC; Surge arrester.

I. INTRODUCTION

The surge arrester (SA) is one of the critical lightning protection device for substations, its quantity and installation location is selected from the specific protection requirement. [1]. Since the 1970s, a new type of SA which nonlinear resistor were made from zinc oxide ZnO (V-ZnO) has been appeared. They have been used instead of classical SA with gap which non-linear resistors were made from Cacbuasilis SiC (V-SiC). Cause the value of V-ZnO's α nonlinear parameter was only 1/10 of the V-SiC, the basic structure of lightning has been changed.

Analyze the characteristics volt - ampere we will see:

$$U = k \cdot i^{\alpha}$$

When setting the α in different value, the nonlinear parameter of V-SiC vary in the range from 0.18 to 0.24 (average is 0.2) and the nonlinear parameter of V-ZnO is 0.02 (smaller 10 times than the V-SiC).

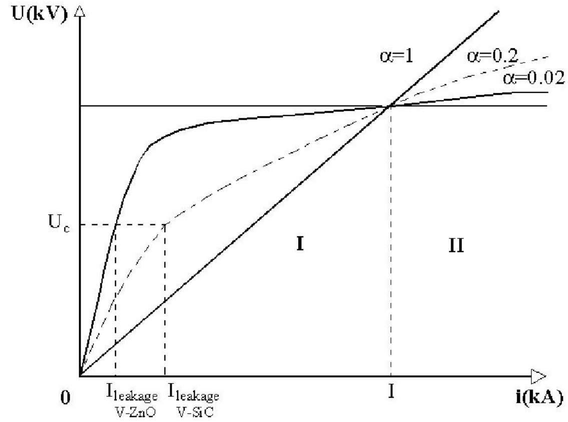


Figure 1: The α nonlinear parameter of SA

We can also see : with a current zone I > 1kA, the residual voltage of SA when using V-ZnO is very small compared to the V-SiC.

Thus, with the using non-linear resistors V-ZnO will have a higher level of safety and could lower the level of pulse insulation around electrical equipment. This will bring economic efficiencies for the industrial of power equipment manufacturing. [2].

In zone I – the working zone ($I_{leakage}$) the leakage current through the nonlinear resistor V-ZnO is much smaller than the leakage current through the nonlinear resistor V-SiC, and it's small enough to be able to connect directly to the power grid without isolating with the discharge gap as in the classic lightning (Figure 2) . The non- gap discharge not only simplifies the structure of protection devices, miniaturization, but also eliminates the problem of arc extinguishing the power electric with continuous frequency.

Besides, using the new lightning types (V-ZnO) with residual voltage lower than V-SiC type will allow us to study the changing in lightning protection scheme for substations and others high voltage equipments. Research the plan to change the quantity, placement in the diagram or shorten the front protection of the station.

The changes menttioned above will not only bring economic efficiency of investment in equipment for the station lightning protection but also ensures the reliability of lightning protection for devices and also resolve the difficulties in setting up the node stations which have to improve the line on both side from the node point.

As we know, the synthesis of anti wave transmission from line can not guarantee the absolute reliability for the equipment in the station . So the ultimate goal is to find a set of solutions ò lightning protection for the station with a minimum cost of investment in constructing and operating the protective equipment as well as the smallest damage due to lightning strike. To archive this, we have to know the specific over voltage levels on the device in the protection diagram to determine the reliability of the diagram and select proper SA.

Atmospheric overvoltage caused by lightning creates a huge current, can reach hundreds of kA and make the electric devices in dangerous.

To protect over voltage for electrical equipment, the surge arrester need to connect in parallel with electric devices. When over-voltage appears, the non-linear characteristics resistor of the surge arrester (Figure 2) fall down very quickly to small values, V-ZnO allows the current of over-voltage pass through (early discharge) and conduct lightning current to ground. Thus, electrical devices are protected and grid operation safely. [3].

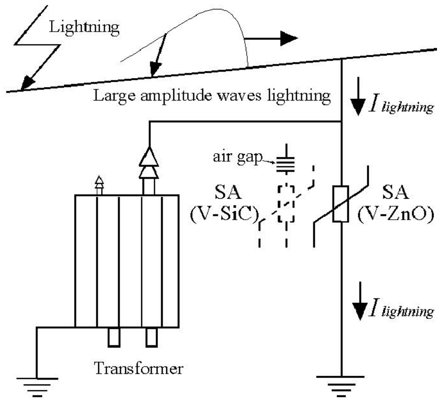


Figure 2: Diagram of surge arrester (V-ZnO) protection in parallel with devices require to protect; V-SiC with air gap.

II. TESTING FOR V-ZnO.

The SA as other products of electrical engineering, from the research stage to the manufacturing stage before commissioning phases, must pass the quality control testing for the purpose of ensuring the specifications to safety protect for electrical equipment and keep out the problems during the grid operation. [2]; [4].

1. Type tests

These tests are to research in designing and creating new products. The test will calibrate a product to determine the characteristics and to demonstrate its compliance with manufacturing standards. These test do not need to do again in other products, unless the design proccess change its the characteristics. In that case, only the experiment involved need to test again.

2. Routine tests

These test are to perform on each surge arrester, the SA element, the lightning protection materials, to ensure products meet the technical regulations required, including the following types of test:

- Periodic test for batches of product: Check quality of V-ZnO or SA periodically or check the batches of products.
- Factory finished SA tests: qualify surge arrester quality before using.
- Test before installation: check the basic quality field of the SA, all the transporting storaging proccess the SA must meet the technical criteria for installation.

3. Acceptance tests

These tests are performed when the agreement between the manufacturer and the buyer at a kind of product was meet. Nonlinear resistor block (V-ZnO) is the core element of the SA, the quality test for it becomes very important. [4].

Within the scope of this article and the later article we will only mention the test before installing SA to the grid.

III. SPECIMEN PREPARATION AND MEASUREMENT CIRCUIT.

The specimen is non-linear resistor block (V-ZnO) which were obtained from 220kV SA of ABB manufacturer.

The capacitors in the impulse current test set of HighVolt-IP 125/100Ssp (German) are arranged in a semicircle to keep a specified distance with the specimen. This design ensures the circuit have small inductance for short time impulse current. (Figure 3).

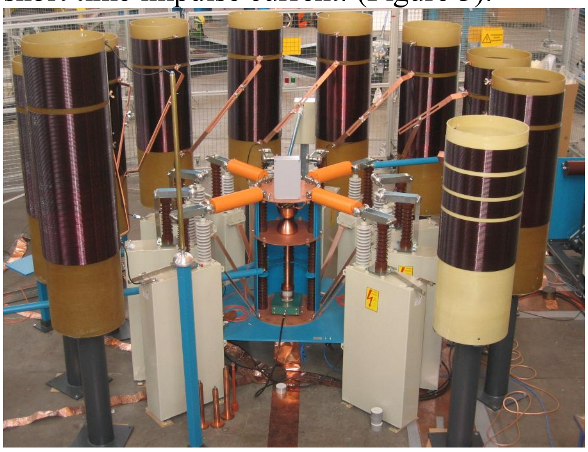


Figure 3: Test high current impulse 4/10µs for V-ZnO resitor block at HVLAB

1. The system functions.

Impulse current testing system IP125/100Ssp is designed to test the SA components arrcording to IEC 60099-4 with the line discharge level is 2 and 3. [5].

Types and characteristics of SA can be tested:

- Operating voltage of SA : Up to 765kV
- Voltage range of SA elements: 3 ÷ 12kV
- Line discharging level arrcording to IEC 60099-4: 2 and 3
- SA type : Metal Oxide Aresster

2. System technical specifications.

- Loaded voltage: 10 kV
- Nominal Pulse Energy : 125kJ
- Pulse capacitance: 25µF (10 x 2,5 µF)
- The minimum time between 2 pulses : 60s
- Supply voltage: 400/220V, 50Hz , 3W + N
- System power capacity : 30kVA ~
- Operating Conditions and Test:
  + Altitude : less than 100 meters from sea level.
  + Ambient temperature : $+5^0$C to $+40^0$C
  + Moisture : < 90 %

IV. TEST RESULT AND ANALYSIS.

The voltage-current linear characteristics of non-linear resister V-ZnO. (Figure 4) show the linear of V-ZnO at 1mA current. When voltage apply to the V-ZnO larger U_{peak}, a small increasement of voltage will make the current through the V-ZnO increase quickly. [4].

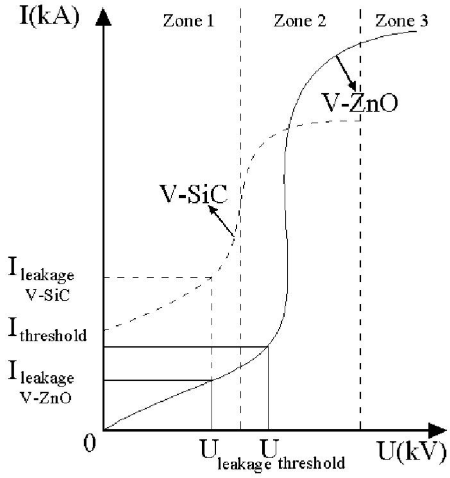


Figure 4: Voltage-current linear of V-ZnO compare to V-SiC resistor.

This feature is used to discharge the lightning when the over-voltage current appeare. U_{peak} is based reference limits to design the core of V-ZnO. The designer often take the range value of (50÷70)% U_{peak} to design the nominal voltage of the V-ZnO. Before and during the test, HVLAB' staff calibrated the IP-125/100Ssp test set by calibration specimen to accurate measurement result. [6].

Zone 1: The V-ZnO linear domain, V-ZnO leakage current is very small ($I_{leakage} = 10^{-7} \div 10^{-6}$ A). When over-voltage occurs, the V-ZnO applied voltage increase suddenly, this non-linear resistor V-ZnO change to operate in Zone 2.

Zone 2: Due to the nonlinear properties of V-ZnO in 2 slope area, when the voltage increase a small value, the current through the V-ZnO increased rapidly and turn the ligtning current to the ground, prevent electrical devices from breakdown due to lightning. Relations between current and voltagesin the Zone 2 is represented by the equation: $\mathbf{I = k.U^{\propto}}$

Legend: $\propto$ - non-linear parameter,

k - constant

Zone 3: Area of V-ZnO saturation. In Figure 4 - Voltage of U_{peak} corresponding with the value 10^{-3}A current through the V-ZnO.

- Working voltage U_c is the voltage which can matain long time on the 2 plole of V-ZnO, has the value about (50 ÷ 60)%U_{peak} (depend on the manufacturer's design).
- Leakage current $I_{leakage}$ which is passing V-ZnO, correspond to the working voltage U_c applied on the poth poles of V-ZnO.
- $\propto$ nonlinear parameter in Zone 2 of non V-ZnO linear characteristics can be determined by the formula:

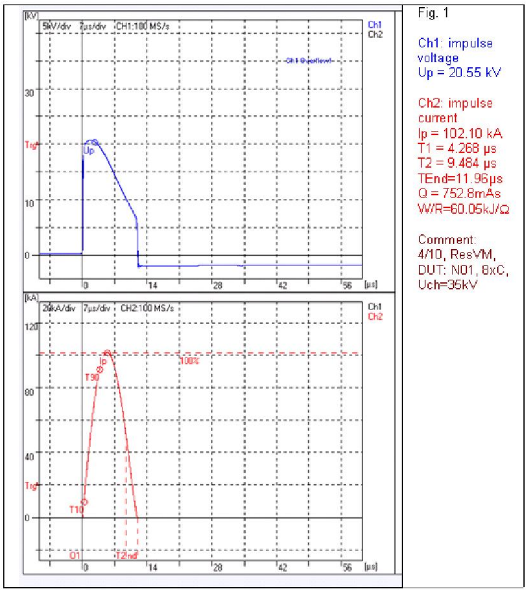
$$\alpha = \frac{\lg I_2 - \lg I_1}{\lg U_2 - \lg U_1}$$

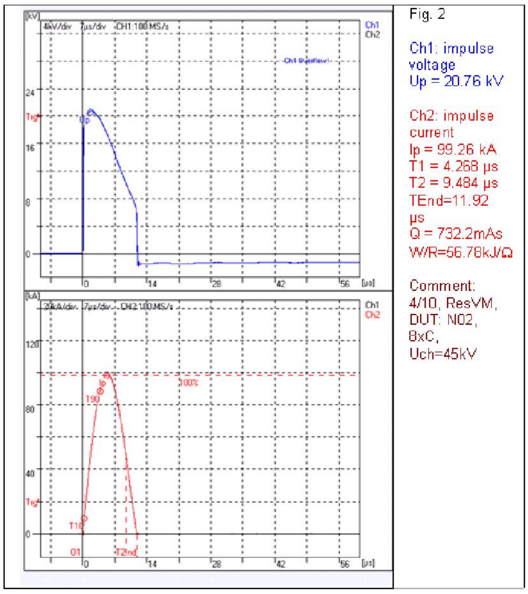
Table 1: Result of the test high current impulse 4/10µs for V-ZnO resitor block.

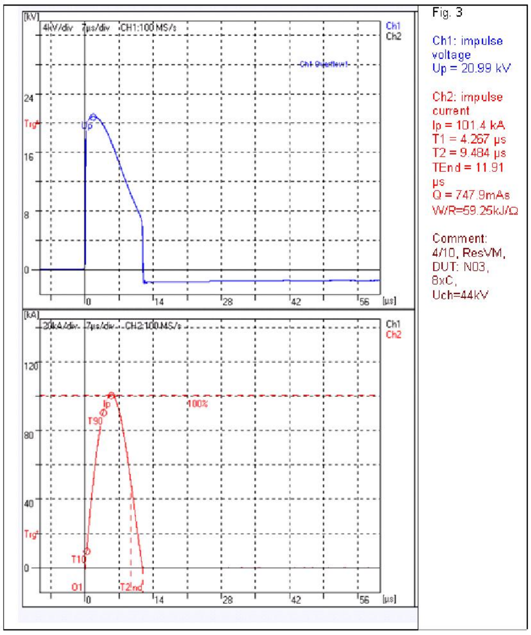
Fig	Comment	Ip/kA	T1/µs	T2/µs	TEnd/µs	Up/kV
1	4/10, ResVM, DUT: N01, 8xC, Uch=35kV	102.1	4.268	9.484	11.96	20.55
2	4/10, ResVM, DUT: N02, 8xC, Uch=45kV	99.26	4.268	9.484	11.92	20.76
3	4/10, ResVM, DUT: N03, 8xC, Uch=44kV	101.4	4.267	9.484	11.91	20.99
4	4/10, ODT, DUT: N04, 8xC, Uch=45kV	101.2	4.296	9.485	11.91	21.01
5	4/10, ODT, DUT: N05, 8xC, Uch=45kV	101.1	4.283	9.496	11.92	21.03
6	4/10, ODT, DUT: N06, 8xC, Uch=43kV	101.6	4.270	9.485	11.91	20.95
7	4/10, ODT, DUT: N07, 8xC, Uch=42kV	102.8	4.271	9.490	11.96	20.09

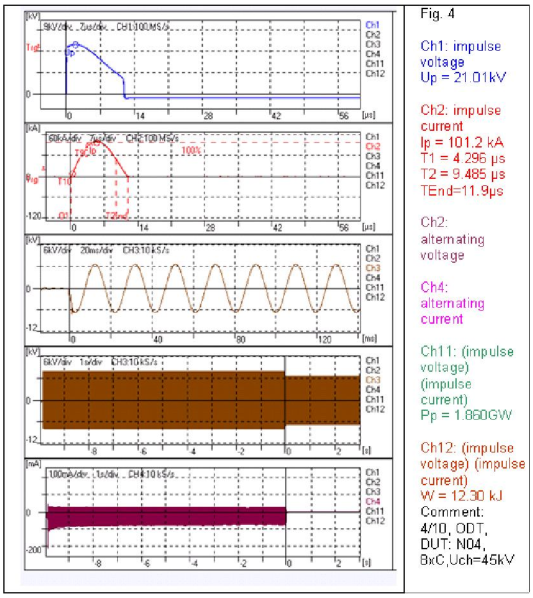
Before perform the 4/10µs high current impulse test, the officers had calibrated the standard value of 100 kA impulse current test for V-ZnO. High current impulse test of 4/10µ impulse current perform checking residual voltage of the V-ZnO. The results of experimental researching the peak value of discharge current having a 4/10µs impulse shape which is used to test the stability of the arrester on direct lightning strokes.

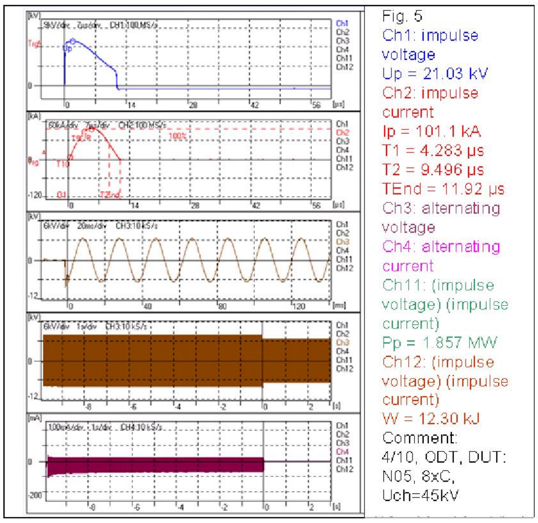
The voltage-current linear characteristics of V-ZnO at current on resistor plate of SA. When voltage apply to the V-ZnO larger U_{peak}, a small increasement of voltage will make the current through the V-ZnO increase quickly. This feature is used to discharge the lightning when the over-voltage current appeare.

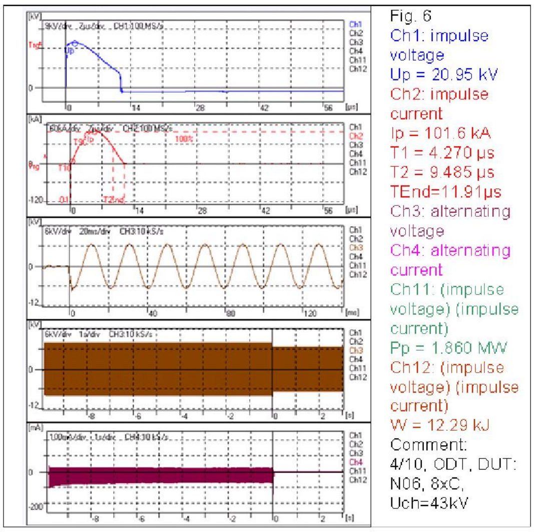


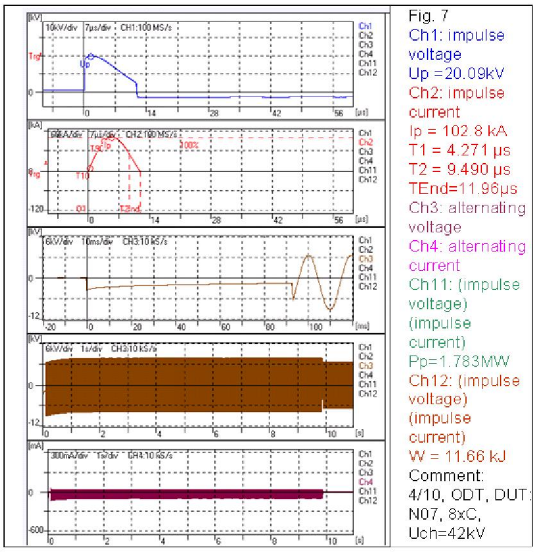












When lightning current flows through V-ZnO to the ground, due to existing ground resistive and resistance of V-ZnO; On V-ZnO appears residual voltage (U_{res}). If the U_{res} on V-ZnO is greater than the durability of electrical device insulation. The value of the high current impulse 4/10µs impluse current approximately 100kA more than.

According to IEC 60099-4, the V-ZnO plate resistors which used to produce 220 kV SA must withstand the value 100 kA of standard current impulse when the the 4/10µs high current impulse perform. [7].

V. CONCLUSION

Since the test results presented above, we can draw the following conclusions:

- When the load voltage increased from $U_{ch} = (35 \div 45)$kV, the pulse current flowed through the V-ZnO increased from I_p= (99.26 ÷ 102.8)kA and the samples did not crack during the test. This will support us to determine the insulating properties and the energy absorption capacity of the V-ZnO is completely achiseved the technical specifications of IEC60099-4 when perform the 4/10µs high current impulse test.

- The 4/10µs high current impulse values recorded in Table 1, are the impulse current which was discharged through the V-ZnO after being V-ZnO absorbed a part of the energy exceeds the standard value of 100kA. This showed the ability of V-ZnO samples in protecting elcetrical device when the over voltage on the grid apears.

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