

# Latest Technologies for Surge Arresters

Yukio Tagami,  
Nariyoshi Toda

**Keywords** Surge arrester, Gapless, ZnO varistor, DC, Polymeric type

## Abstract

**Zinc Oxide (ZnO) type surge arresters (surge arresters hereafter) are indispensable protective devices for surge voltages and insulation design of substation facilities. Ever since surge arresters were commonly adopted in power network systems, we have delivered large numbers of surge arresters to substations of railways for the protection of electrical equipment.**

**Recently, in various areas in Japan, there have been many large-scale earthquakes and various Business Continuity Plans (BCPs) on stable power supply are being promoted. It includes the measurements of substation facilities to reduce disaster impacts, measures for early restoration from damage, and the introduction of mobile substations.**

**We worked on the development of ZnO devices with high gradient and high performance characteristics because they are the core elements of surge arresters. In addition, we are also promoting the development and commercialization of polymeric surge arresters that are expected to contribute to the reduction of arrester size and mass, the improvement of seismic-resistance performance, and reduction of delivery period.**

**Meiden surge arresters, including polymeric type surge arresters, are playing an important role in protecting traction power supply facilities for stable railway operations and promoting BCP programs.**

## 1 Preface

In 1975, we delivered metal oxide gapless surge arresters ('MOSAs') to a high-voltage substation for a power utility. These MOSAs employed Zinc Oxide (ZnO) varistors and it was a world-first achievement. Surge arresters are used to protect power transformers and switchgears from surge voltages caused by lightning. It protects from the occurrence of power outage, keeping it to a minimum level. When substation equipment is protected against lightning surges, insulation design limitations for substation equipment can be relieved. Such a surge arrester can lead to the reduction of substation equipment size and cost.

It is about 40 years since the first release of our surge arrester. While responding to the widening applications, we made improvements for a more compact size, cost reduction, and protective performance. In 2014, this product was honored with an Institute of Electrical and Electronics Engineers,

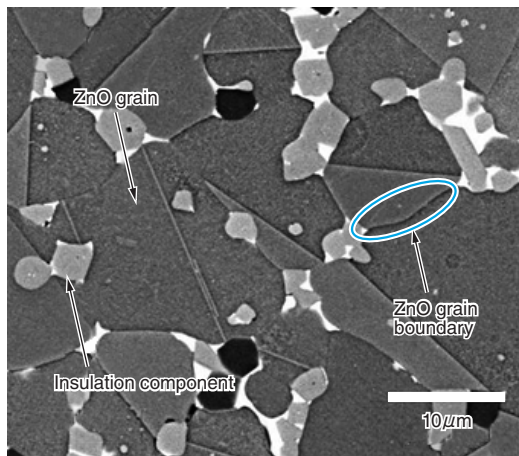
Inc. (IEEE) Milestone.

High-voltage substations are owned not only by electric power companies but also by railway companies. For safe and secure operation of railway services, stable supply of power is necessary. Even in this field, our surge arresters are playing a large role.

This paper introduces our surge arresters and associated products for railway fields, and also technical features and trends.

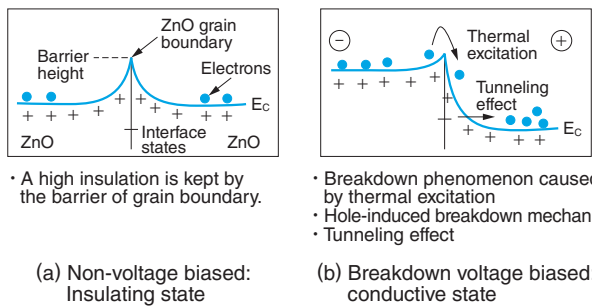
## 2 ZnO Varistor

ZnO varistors, the vital elements among the critical parts of a surge arrester, have outstanding non-linear voltage-current characteristics. This realized a gapless metal oxide surge arresters. Such a characteristic shows semiconductor property. The main material is a conductive crystal ZnO surrounded by high resistance components like bismuth oxide or antimony oxide which forms a double



**Fig. 1 Microstructure of the ZnO Varistor**

Conductive ZnO grains are surrounded by insulation components to form up a grain boundary. The double Schottky barrier is then formed.



**Fig. 2 Double Schottky Barrier Model**

A high insulation characteristic is regularly maintained with the effect of the grain boundary. When a voltage above the specified level is applied, however, the width of Schottky barrier at the grain boundary is lessened and a current flow with the movement of electrons due to the tunneling effect.

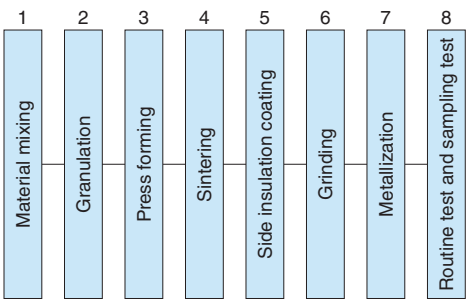
Schottky barrier at ZnO grain boundaries. **Fig. 1** shows a microstructure of the ZnO varistor. **Fig. 2** shows a double Schottky barrier model.

**2.1 ZnO Varistor Manufacturing Flow**

**Fig. 3** shows a manufacturing flow of ZnO varistors. The ZnO varistor is manufactured by sintering a mixture of ZnO, which is a main component, and multiple additives such as bismuth oxide and antimony oxide. Since the electrical characteristics of the ZnO varistors are greatly influenced by the conditions of special mixing, sintering, and side insulation coating, careful process control is required.

**2.2 Electrical Characteristics of ZnO Varistor**

In particular, for ZnO varistors, the three elec-



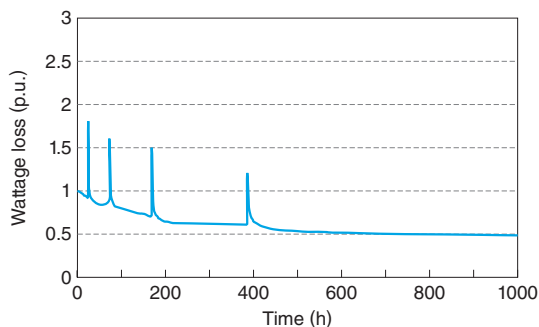
**Fig. 3 Manufacturing Flow of ZnO Varistors**

Under the manufacturing conditions of material mixing, sintering, and side insulation coating, the electrical characteristics of ZnO varistors are determined.

- trical characteristics shown below are required.
- (1) Voltage-current non-linear characteristics
  - (2) Energy absorption capability (Impulse withstand capability)
  - (3) Accelerated aging performance in applied operating voltage

According to the result of various verification tests, we discovered the optimal and well balanced manufacturing processes and conditions for the required performance listed in the aforementioned items. As ZnO varistors are used in surge arresters for traction substations, improvement of energy absorption capability and accelerated aging performance for the applied DC voltage is an essential factor. In order to improve energy absorption capability, we optimized the structure of insulation layers for the reduction of side flashover, and controlled the sintering conditions and homogenized the microstructure of ZnO varistors.

In regard to the accelerated aging performance, several application is suitable for various atmospheric conditions (dry air, N<sub>2</sub>, SF<sub>6</sub> or Oil) is required. For the protection of DC power supply systems for conventional railway lines and subway lines in urban areas, accelerated aging performance is needed. The accelerated aging performance for DC voltage application of our varistors for more than 15,000 hours of long-time test was at 110°C and it was verified that the leakage current decreased. Judging from the test results, our ZnO varistors can be expected its life to equivalent to 1000 years at an average ambient temperature of 40°C according to the accelerated aging coefficient (10°C, 2.5 times rule) defined in the prevailing standard. According to the IEC Standard 60099-9 "Metal-Oxide Surge Arresters without Gaps for HVDC Converter Stations," evaluations are required for the specified



**Fig. 4** Result of DC Voltage Application Aging Evaluation Specified by IEC 60099-9

The leakage current tentatively increases at the time of polarity reversal. This current, however, slowly decreases with the lapse of time.

voltage application time and the number of times under the reversed polarity. Our DC varistors are shaped in ideal conditions by controlling the forming substances of high-resistance layers at grain boundary in terms of the material mixing and sintering conditions. Fig. 4 shows the evaluation result of a DC accelerated aging test on ZnO varistors according to the latest IEC Standard. The leakage current flowing in the ZnO varistor increases at the time of polarity reversal. The result of aging test, however, indicates that this current slowly decrease with time.

### 3 Surge Arresters for Railways

We have a lineup of surge arresters to protect substations for railway for Shinkansen, conventional lines, subways, and Automated Guideway Transit (AGT). Table 1 shows applications and types of surge arresters for railways in Japan.

#### 3.1 Surge Arresters for AC Power Systems

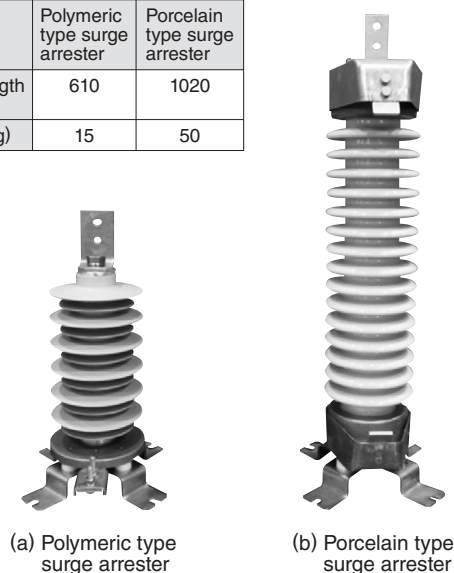
For the protection of high-voltage power receiving equipment and feeder facilities, installation of polymeric type surge arresters is more effective compared with porcelain type surge arresters. For all rated voltages available, we realized compact design and lightweight product. For example, we realized a reduction of total height by 40% and mass by 70% for the surge arresters to be used in 22kV traction power networks. Fig. 5 shows a comparison of surge arresters for 22kV traction power systems. Seismic resistance performance is also reinforced. For the surge arresters to be applied to 275kV power receiving equipment, the safety factor is 3.1 against three sinusoidal wave at resonant frequency with the acceleration of 3m/s<sup>2</sup>. In other

**Table 1** Applications and Types of Surge Arresters for Railways in Japan

Surge arresters for railways are classified into AC type and DC type.

Application		Power system	Classification
AC	For power receiving equipment	22~275kV	Porcelain type
			Polymeric type
	For feeding equipment	22~33kV	Tank type for GIS
			Porcelain type
DC	For control panels	750~1500V	Polymeric type
	For feeding equipment		Porcelain type
	For rolling stocks		Built-in type
	Surge absorber for high-speed DC circuit-breakers		Built-in type

	Polymeric type surge arrester	Porcelain type surge arrester
Total length (mm)	610	1020
Mass (kg)	15	50



**Fig. 5** Comparison of Surge Arresters for 22kV Traction Power Systems

Compared with porcelain type surge arresters, the total length is shortened by 40% and the total mass is decreased by 70% in the case of polymeric type surge arresters.

words, these arresters can withstand large-scale earthquakes.

#### 3.2 Surge Arresters for DC Power Systems

We are promoting the development and improvement of surge arresters to protect control panels and electrical equipment in systems of 750V DC and 1500V DC.

According to the Japan Railway Construction Specification (JRCS), a very high switching surge operating duty is required. This means that a large diameter of ZnO varistor is required. In such a case,



**Fig. 6** Surge Arresters for DC Railway Systems  
Manufactured by TRIDELTA MEIDENSHA GmbH.

For the rated voltages, the lineups of 1.2kV to 4.8kV are available. In overseas markets, the adopted area is expanding.

the specified energy absorption capability is designed by using ZnO varistors connected in parallel. At the same time, we are trying to curtail the number of parallels and reduce the whole diameter of the ZnO varistor by enhanced the energy withstand capability. In addition, the use of polymeric type surge arresters is promoted in DC railway systems. In overseas markets, our group company TRIDELTA MEIDENSHA GmbH. is producing this type of surge arresters and expanding the scope of application. **Fig. 6** shows surge arresters for DC railway systems manufactured by TRIDELTA MEIDENSHA GmbH.

We have a product lineup of surge absorbers for high-speed DC circuit-breakers. This system uses many ZnO varistors. Each varistor is connected in parallel. The applicable circuit voltages are 750V and 1500V. Although this depends on the specified surge absorption level, the number of varistor in parallel amount to 30 ~ 90 units. **Fig. 7** shows the surge



**Fig. 7** Surge Absorbers for High-Speed DC Circuit-Breakers

The surge absorber comes in a single column. Multiple device and ZnO varistor are connected in parallel and a large energy can be absorbed.

absorbers for high-speed DC circuit-breakers. With the use of higher performance and shorter diameter varistors, we are planning to develop these surge absorbers focused on total length reduction, downsizing and lightweight.

#### 4 Postscript

This paper introduced the features of surge arresters used in substations for railway and features of ZnO varistors as a vital element. In particular, polymeric type surge arresters offer a variety of advantages and they are expected to expand their application range. To support stable operation of railway services, we will work on improving performance and reliability. It protects substations facilities and power network systems.

· All product and company names mentioned in this paper are the trademarks and/or service marks of their respective owners.