Reference [4] in Japanese

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777 酸化亜鉛を主成分とするギャップレス電力用アレスタ

錦織亨　増山勇　松岡道雄　　日永田春一　小林三佐夫　水野充
（松下電器 無線研究所）　　（株式会社 明電舎）

1. まえがき

松下電器が世界に先がけて開発した酸化亜鉛を主成分とする非直線抵抗体ZNRバリスタは、その優れた非直線性により、サージアブソーバとして実用化され、すでに多くの実績が認められている。[1,2,3] 本稿では松下電器のセラミック技術と、明電舎のアレスタ技術の結合によって得られた世界最初のギャップレス電力用アレスタの概要について紹介する。このギャップレスアレスタの適用により、ミニクラ用アレスタの小形化、理想的耐塩活線洗浄形アレスタの製品化、アレスタ内蔵の支持碍子の小形化（実用化）等々電力用アレスタのあらゆる分野での画期的進歩が可能となった。

2 特長

本アレスタは、低抵抗のZnO微粒子（10ミクロンオーダー）の周りを高抵抗の境界層で囲んだ、セラミック焼結体から成り、その電圧一電流非直線特性が、従来のSiC抵抗体に比較してはるかに優れているため、直列ギャップがなくても電力回路に接続使用出来るものである。従来の直列ギャップ式SiCアレスタに比較して以下の点で特に優れている。

(1)ギャップ不要のため急峻波サージに対する応答が極めて速い。従って急峻波頭サージ、およびギャップ放電時の急峻截断波サージによる変圧器巻線の事故を解消できる。

(2)続流を全く発生しない（μAオーダー）ので動作責務能力は完璧である。

(3)焼結体自体が高誘電率（ε≒1000）を有しているので、直列ギャップ式SiCアレスタに於ける直列ギャップ 並列コンデンサ 並列抵抗体 SiC特性要素の4種の機能をSiC特性要素よりはるかに小さい容積の素子内に均一分布で兼ね備えており、SiCアレスタに比較して（ア）大巾に小形化出来る。（イ）耐塩特性が理想的である。等の大きな利点がある。

(4)単位面積当りの放電耐量がSiCより倍以上大きい。

(5)ギャップレスであるため、ガス中、油中 モールド適用が容易であり、応用範囲が広い。

3 特性比較

従来のSiC特性要素との特性比較を（表1）に示す。

表1　　　　直径約60mmの場合

特性項目	単位	SiC 特性要素	ギャップレスアレスタ素子
非直線指数 n（於1mA）	−	0.5〜1.0	≃0.02 (α≃50)
〃 n（於100A）	−	0.3〜0.5	≃0.04 (α≃25)
〃 n（於10KA）	−	0.15〜0.3	≃0.08 (α≃12)
V_{10KA}/V_{1mA}	−	＞100	≃1.8
V_{10KA}/V_{100A}	−	2〜3	≃1.3
誘電率 ε	−	1	≃1,000
放電耐量（4×10μS）	KA	≃100	≃200
〃（2000μS）	A	≃400	≃800

※非直線指数の定義：$V=KI^n$,　$I=(V/C)^{\alpha}$　$\therefore n=1/\alpha$

4 特性上の問題点

(1)温度特性として150°CでV_{1mA}が約8%低下、200°Cでは約35%低下するので150°C以上の高温で長期間使用する場合にはV_{1mA}の選定に注意を要する。

(2)長期課電寿命について 実系統と同一条件に於て、10,000時間以上の長期課電試験を実施して問題なかったが、更に長期に保証するための検討が必要である。

(3)放電耐量試験および動作責務試験前後のV_{1mA}の変化（低下）が問題となる、く形波放電

耐量試験とか、動作責務試験では殆んど変化せず．4×10μS．40KA2回の衝撃大電流試験により、V1mAが約2%低下する。（直径約60mmの場合）

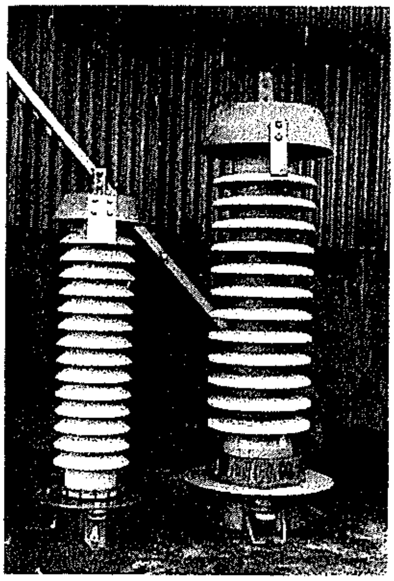
5 応用例

直列ギャップ，並列C，R，特性要素の4機能を兼ね備えているためGIS，固体ミニクラ用アレスタとして 又耐塩，活線洗浄用アレスタとして理想的であると共に、一般アレスタとしても、標準支持碍子の寸法内に納る程小形、軽量に出来る等々大きな利点がある。その他変圧器、断路器内蔵等の点でも従来形アレスタより格段と有利であり実用性が高い．寸法の一例を示すと、60号84KV定格10，000Aアレスタで、外径約200φ、長さ約800mmの小形碍管に収納出来る。（図1）は60号、84KV、0.06mg／cm²耐塩用アレスタと、60号、84KV一般用アレスタの外形写真である。（図2）に並記した旧マルチギャップ式および現用磁気吹消形、60号、84KVアレスタと比較すれば如何に小形軽量化されているか判る。尚従来の直列ギャップと組合せて、ZnO素子を用いれば制限電圧の極端に低いアレスタが可能であり、DLR≒2.0も容易に達成出来ると云う利点もある．又直流送電用アレスタとしても理想的なものになると考えられる。

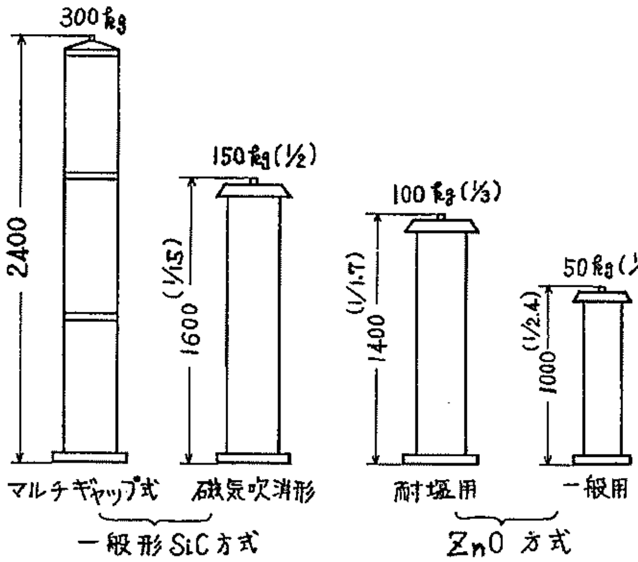
6 まとめ

以上に述べた如く、ZnO素子の適用により従来のSiCアレスタに比較して、特性、寸法、耐塩特性総ての点で大巾に優れた画期的な電力用アレスタが可能となった．今後更に特性の改良、寿命の確認等の諸点について研究を進める計画である．

（図1） 右…耐塩用， 左…一般用



（図2） 各種 84KV アレスタ比較



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777 Zinc Oxide-based Gapless Surge Arrester for Electric Power Systems

Toru Nishikori
Isamu Masuyama
Michio Matsuoka
Panasonic Corporation
Wireless Research Laboratory

Shun-ichi Hieda
Misao Kobayashi
Mitsuru Mizuno
Meidensha Corporation

1. Preface:

Panasonic Corporation developed a world-first zinc oxide-based non-linear ZNR varistor . With its excellent non-linear characteristics, it was commercialized as a surge absorber and already it received a recognition from many supply records. This paper discussed the overview of world-first gapless surge arrester for electric power systems as a result of synergy of engineering resources: Panasonic's ceramic technology and Meiden's surge arrester technology. By the application of gapless surge arrester, it made possible a big leap forward in every field of sure arrester applications for power systems. In Meiden's case, it enabled the compact design of surge arrester for mini-size metal clad switchgear, commercialization of ideal surge arrester capable of live line washing of porcelain housing to remove salty contamination. It also realized the compact design (commercialization) of supporting insulator with built-in surge arrester.

2. Features:

This arrester incorporates low-resistant ZnO grains (10 micron size) wrapped round by the high-resistance ceramic sintered boundary layers. Its non-linearity of V-I

characteristics is far more excellent that those of silicon-carbide (SiC) resistor. Even without the series gap, this arrester could be put into use in the connection for power circuit. Compared with the conventional
series gap type Sic arrester, this arrester offers the following excellent points:

(1) Since no series spark-gaps are required, it has a very fast response against the steep front lightning surge. This could solve the problem associated with the power transformer winding core damage by the steep front lightning surge or steep chopped wave front surge at the time of spark-gap discharging.

(2) Since no follow current (after the arrester operation) (in micro ampere scale) the operating duty performance is perfect.

(3) (The resistor element) sintered body itself has high dielectric constant (permittivity) ($\varepsilon \fallingdotseq 1000$), it could offer four (4) types functions of SiC surge arrester : series spark-gaps, parallel capacitor, parallel resistor and SiC characteristics elements. Metal-oxide arrester without gaps could offer the evenly distributed SiC characteristics in the compact size. Compared with SiC arrester with gaps, it could:
   (i) offer a drastically reduced compact design
   (ii) offer an ideal anti-contamination characteristics
   These are the some of the big merits.

(4) The discharge current withstand capability per the unit space is more than double in comparison with the SiC surge arrester.
(5) Being gapless, the application for inside gas or oil-immersed or mold could be possible. Very wider application range.

3. Comparison on the Characteristics:

The Table 1 below shows the characteristics comparison with the conventional SiC characteristics elements.

Table 1 In case of diameter about 60 mm

Characteristics Items	Unit	SiC Characteristics Element	Gapless Arrester Element
No-linear index* n (@ 1 mA)	-	0.5 – 1.0	≈ 0.02 ($\alpha \approx 50$)
No-linear index n (@ 100 A)	-	0.3 – 0.5	≈ 0.04($\alpha \approx 25$)
No-linear index n (@ 10 kA)	-	0.15 – 0.3	≈ 0.08 ($\alpha \approx 12$)
V_{10kA} / V_{1mA}	-	> 100	≈ 1.8
V_{10kA} / V_{100A}	-	2 – 3	≈ 1.3
Permittivity ε	-	1	≈ 1,000
Discharge Withstand Current Rating (4 x 10 μ Sec.)	kA	≈ 100	≈ 200
Discharge Withstand Current Rating (2000 μ Sec.)	A	≈ 400	≈ 800

* Non-linear index defined: $V = KI^n$, $I = (v/c)^\alpha$ $\therefore$ $n = 1/\alpha$

4. Issues on the Characteristics:

(1) As the temperature characteristics, at the temperature point of 150℃, V1mA is lowered about 8% and at 200℃, it is lowered about 35%.
In case of operation under over 150℃ high temperature condition for a long time, the care shall be exercised in selecting the suitable V1mA level.

(2) As to the long term under charging life, we conducted the long-term charging test given the similar conditions of the actual power grid and as the results after the 10,000 time tests, there was no operational problem. In order to make sure the long-term operational guarantee, such additional field test shall be considered as a

future action.

(3) In the discharge current withstand capability test and operating duty test (rating of before and after the test), the change of V1mA (lowering) becomes the issue. In the rectangular wave discharge current withstand capability test and operating duty test, it will not produce almost no change. By applying the impulse current test of two (2) times 4 x 10 μ Sec., 40 kA current, V1mA is reduced about 2% (in case the element diameter is about 60 mm.)

5. Case Study of Application:

As the ZnO Elements have four (4) functions: series gap, parallel C and R, non-linear resistor, it could offer as an ideal surge arrester for gas-insulated switchgear (GIS), and for solid-insulated mini-clad switchgear. Further this is an ideal arrester for anti-contamination and for live line washing, As a general surge arrester, there are big merit features like being compact which could be within the size of standard support porcelain and it could be a very light one. .In case of other applications such as the built-in surge arrester for power transformer or for disconnector, it could offer far more advantage over the conventional SiC model. It offers the high usefulness. When it comes to the size, for example, as the size of 84 kV, 10 kA rating arrester for 66kV system, it could be housed in the compact porcelain housing of external diameter about 200 mm (200Φ) and the length of about 800 mm.

The Fig. 1 shows a external view picture showing an anti-contamination type surge arrester with 84 kV, 0.06 mg/cm2 and a general surge arrester 84 kV.

In Fig. 2, it shows the SiC arresters: multi-gap type model and magnetic blow-out type arrester and 84 kV

anti-contamination and general) arresters. It clearly shows how ZnO arrester gives the compact and light weight from the conventional (SiC).

Further, by combining the series gap and utilizing the ZnO elements, it will be possible to produce an extremely low control voltage model. "DLR ≈ 2.0"is easy to reach range – this is the merit. Also as an arrester for DC Transmission application, this could be an ideal product.

(DLR = Discharge Level Ratio = V_{10kA}/V_r)

Fig. 1: Right: Anti-contamination Model, Left: General Model

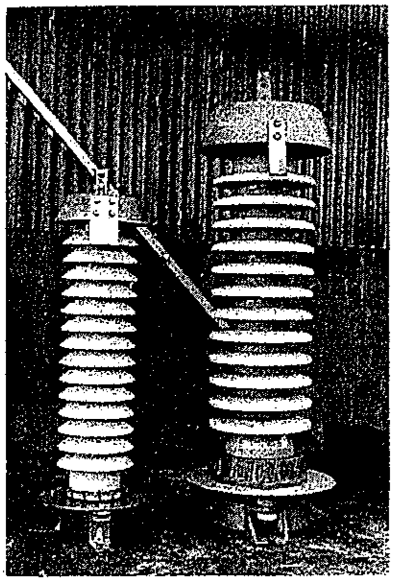
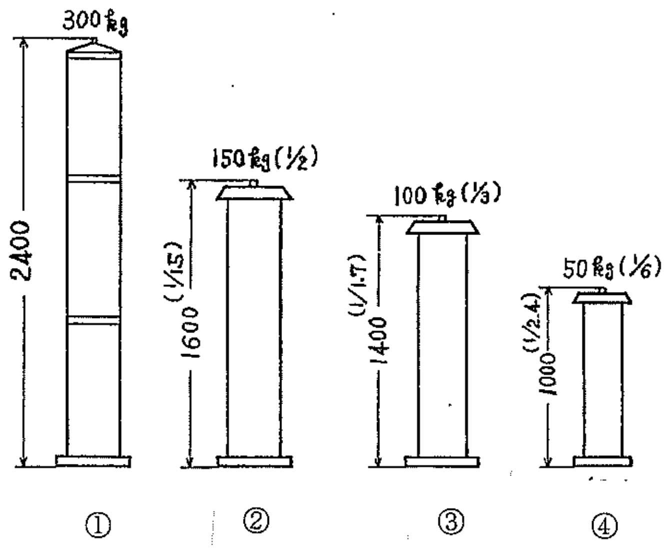


Fig. 2 Comparison of Each Type 84 kV Model

From left to Right:

- General Type SiC Element Model:
  - ① Multi-gap Type
  - ② magnetic blow-out type
- ZnO Element Model:
  - ③ Anti-contamination model
  - ④ General model



6. In Summary:

As discussed above, by applying the ZnO Elements, it became possible to make a drastically improved epoch-making surge arrester in terms of characteristics, size, and anti-contamination characteristics. Going forward, we would like to promote the research
on the points to improve the characteristics and to determine the product life.

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