ECOLOGICAL DESIGN UP-GRADE OF A ZINC OXIDE VARISTOR SUITABLE FOR DISTRIBUTION POLYMERIC SURGE ARRESTERS

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ABSTRACT

As the world is becoming more environmentally aware and European legislation is evolving with more stringent restrictions in this field. Rather than follow the emerging legislation and market requirements, AREVA T&D is anticipating this trend and adapting its products accordingly. Besides maintaining technical quality and being cost effective, the manufacture of ZnO varistors for lightning arresters must comply with environmental concerns and constraints, which are becoming more demanding and rigorous.

The present communication will describe a number of actions taken to develop an environmentally friendly product the manufacturing of which has reduced or eliminated the use of materials posing health risks or contamination concerns. The new processing line does not require an acid etching step to increase the adhesion of the metal electrode to the ceramic body. A leadless glass has replaced the lead containing enamel used for passivation and at the same time the coating deposition process has been optimised. The varistor powder manufacturing process has also been redesigned to make it more efficient with less consumption of energy and material. The quantification of these environmental accomplishments during the manufacturing of ZnO varistors for distribution arresters has been evaluated using the EIME software design tool.

INTRODUCTION

Environmental considerations in the electrical industry are becoming of increasing importance due mainly to legislative pressure. For instance, The ROHS Directive aims to protect human health and the environment through the restricted use of certain hazardous substances. From 1st July 2006, lead, mercury, cadmium, hexavalent chromium and polybrominated diphenyl ether will be banned from new electrical and electronic equipment. The Waste Electrical and Electronic Equipment (WEEE Directive 2002/96/EC) has, as a first priority, the prevention of waste electrical and electronic equipment, and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, e.g. producers, distributors and consumers and in particular those operators directly involved in the treatment of waste electrical and electronic equipment. Finally, the Eco-design of End Use Equipment (EUE) directive proposal. This Directive aims to ensure the free movement of end use equipment within the internal market of the European Union through the creation of a framework for the integration of environmental aspects in the design and development and for setting eco-design requirements for electrical and electronic equipment.

Polymer housed surge arresters are being widely implemented throughout the world as an effective mean to protect electrical network systems and at the same time to improve the quality of electric power delivered to both industrial and residential users.

Strict control of the manufacturing processes of metal oxide varistors (MOV’s) and well designed surge arresters are necessary conditions to achieve routinely high reliability electric power delivery at a competitive price. Besides the above-mentioned key criteria, environmental protection has also become a main concept for the design of surge arresters and their components.

The manufacturing of metal oxide varistors is based on technology that requires intense material processing and recycling operations, which can have a significant environmental impact. Proper product design and processing must reduce this environmental impact to the minimum.

MOV MANUFACTURING PROCESS.

AREVA T&D operates its own manufacturing line for distribution MOV block production. This line is highly automated and is also characterised by parallel processes intended for the treatment and recycling of waste.

The different stages presently implemented for the production of MOVs, using the manufacture process based in a conventional mixed oxide route are as follows:

- Weighing of oxides and mixing and milling using an energy intensive comminution. Temporary binders; lubricants; plasticizers and defloculants are added to the aqueous slurry.
- Spray drying of the slurry followed by sifting to eliminate oversized agglomerate particles.
- Compaction of the agglomerate powder using double action uniaxial pressing with fixed die.
- Binder burn off of temporary organic additives and high temperature sintering of the ceramic parts.
- Glass coating on the blocks cylindrical surfaces for passivation and glass firing of the said coating.
- Precise grinding of the contact faces to achieve full planarity and parallelism between both flat surfaces.
- of the discs using a warm ultrasonic process and forced air convection.
- Metallisation of the contact faces with Al metal.
- Electrical characterisation at low and high currents of the ceramic blocks, printing of the batch number and main product and electrical features for further use, and final visual inspection.

Treatment, recycling and revalorization of waste
The purpose of procedures so far implemented has been to limit any negative environmental impact. Waste, which can be either in solid, liquid or gaseous form, is generated at each stage of the MOV manufacturing process as shown in figure 1. The solutions implemented to eliminate or reduce such a waste and to improve the device electrical properties are presented in figure 2 for varistor powder production and in figure 3 for the production of varistor blocks.

POWDER PRODUCTION WASTE:

Raw materials, milling and spray dry slurry: Several metal oxides, such as Bi₂O₃, Sb₂O₃, are added to zinc oxide to tailor its electrical and mechanical properties. Mixing and energy intensive milling are carried out in aqueous suspensions to obtain homogeneous slurry. Fugitive binders, plasticizers, lubricants and defloculants are also added so as to make the subsequent pressing and removal from the compaction mould easier. These organic compounds must be fully eliminated with no residue left in the ceramic body after firing it.

Washing and rinsing of wet room equipment generates substantial volume of served water with particulates in suspension. Lime is added under slow agitation to act as an agglomerating agent. Subsequently, this agglomerated suspension is passed through a filter press to separate the suspended solid particles from water.

The following wastage is collected at the filter press:
- Conglomerate and slightly wet solid residue, called "cakes", which is retrieved by an external company specialised in recycling and revalorization of industrial waste containing ZnO.
- The filtered water is treated through a micro-filtration device and its pH adjusted in the range 6.5 to 8.5 before being discharged into the area sewage.

Solid waste represents less than 0.1% of the total amount of raw materials used in MOV manufacturing.

Spray Drying. Sifting waste, as well as cyclone powder has essentially the same formulation as powder used to press the ceramic parts. The oversize waste and cyclone fines are collected and whenever sufficient quantity is available, this is reintroduced into a mixture prepared for recycling and preparation of a powder batch. This kind of recyclable waste is around 5% of the total weight of spray dried powder.
VARISTOR BLOCK PROCESSING WASTE

Pressing. The type of waste is similar to that generated during the production of spray dried powder, but it presents itself as compacted parts. Green ceramic parts produced during the press initial set up and parts with dimensions out of tolerance are kept apart for recycling. After being ground, they are introduced into the spray dry slurry prepared for the next manufacture batch through a crashing and shear mixing process. On average, this type of recyclable waste represents 1.8% of the total amount of spray dried powder.

Firing. This stage produces fumes due to the decomposition and burning of temporary binders. These fumes can create strong smells, which may become irritating as their concentration increases. To alleviate this inconvenience, an exhaust system has been implemented whereby the exhaust by-products are aspirated by a centrifugal fan and transferred into a special gas fired incinerating chamber which assures complete elimination of it into the atmosphere as carbon dioxide and moisture. Analysis are regularly performed to make sure that exhaust rate of burnt organic by-products actually complies with relevant guidelines and legislation.

Glass Coating. The glass coating sprayed on the external surface of the varistor is intended essentially to improve the dielectric strength of the MOV surface. In the past high lead surface of the varistor is intended to passivate. The glass coating sprayed on the ceramic block actually complies with relevant guidelines and legislation. This new glass coating offers all the advantages and electrical characteristics of the leaded glass but without its health hazards and environmental liabilities, which are not longer acceptable. For this reason, it has been replaced by a lead free glass based on bismuth oxide as the vitreous material.

This new glass coating ensures all the advantages and electrical characteristics of the leaded glass but without its health hazards and its negative environmental impact. This new glass coating fully complies with recent European and national regulations related to the usage of leaded glasses and specifically as regarding the ROHS directive.

The glass coating is sprayed by nozzles inside a chamber equipped with a water curtain in closed circuit. The waste waters are fed to a decanting tank, and are then recycled and re-sent to the water curtain. At the end of each working day, the sediments as well as the washing waters are treated like the washing waters used at the stage of powder preparation, i.e. through the filter press described earlier.

Surface Grinding. The purpose of this operation is to adjust the varistor height and to make its flat faces perfectly plane and parallel between themselves. Surface grinding is carried out using a diamond impregnated wheel and tap water is used as a coolant and lubricant. The particulate material generated during grinding is kept in suspension in water. This is accumulated in a decanting tank where a diaphragm pump has been installed to recirculate the suspension through a filter to separate the particulates from water. This system has cut water consumption by over 95% for the volume of water required for tank emptying and cleaning of the equipment. The sediments are treated by the same method as above.

Cleaning of faces. The varistor flat faces are cleaned to improve adherence of Al metal electrodes. The circulation and the treatment of the washing and rinsing waters for ultrasonic cleaning are carried out in the same way as that done during grinding.

Electroding. The deposition of Al metal electrodes is done through an arc spraying process whereby molten aluminium is projected by a compressed air jet onto the plane faces of the varistor. A bag filter captures waste metal dust particles. An external company takes the collected waste particles for revalorization.

Final testing. Varistors quality is checked through routine electrical tests including application of high-energy electric pulses. Voltage and current characteristics of the blocks are recorded and printed on the blocks, as well as carrying out a final visual inspection to sort out pieces having electrical or mechanical flaws. An external company collects rejected pieces for revalorization.
OVERALL ENVIRONMENTAL IMPACT

The overall environmental impact of the new and old ceramic processes to manufacture ZnO varistors has been evaluated using EIME (Environmental Information and Management). This is a software design tool created and developed by a conglomerate of major European companies including AREVA T&D.

Besides simplifying and standardising the environmental impact evaluation of existing products, this tool can help to improve the ecological profile of new products through a detailed quantification of several environmental impact indicators, namely design indicators, Bill of Materials and eco-efficiency indicators. During the present study of ZnO varistor manufacturing, thanks to EIME software the following indicators have been evaluated:

**EIME impact indicators**

1. Natural Resources Depletion Indicator (RMD)
2. Energy Depletion Indicator (ED)
3. Water Depletion Indicator (WD)
4. Global Warming Potential Indicator (GWP)
5. Stratospheric Ozone Depletion Potential Indicator (ODP)
6. Air Toxicity Indicator (AT)
7. Water Toxicity Indicator (WT)
8. Photochemical Ozone Creation Indicator (POC)
9. Air Acidification Potential Indicator (AA)
10. Water Eutrophication Indicator (WE)
11. Hazardous Waste Production Indicator (HWP)

**Design indicators**

12. Physical Characteristics
13. Use Characteristics
14. End of life Indicators

This tool allowed us to evaluate the total impact of our designs both absolutely and relative to the previous design as can be seen in the example shown (Table 1).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Old varistor (1,000 units)</th>
<th>New varistor (1,000 units)</th>
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<tbody>
<tr>
<td>RMD</td>
<td>1</td>
<td>0.79</td>
</tr>
<tr>
<td>ED</td>
<td>1</td>
<td>0.66</td>
</tr>
<tr>
<td>WD</td>
<td>1</td>
<td>0.72</td>
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<tr>
<td>GW</td>
<td>1</td>
<td>0.79</td>
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<tr>
<td>OD</td>
<td>1</td>
<td>0.66</td>
</tr>
<tr>
<td>AT</td>
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<td>0.72</td>
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<tr>
<td>POC</td>
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<td>0.79</td>
</tr>
<tr>
<td>AA</td>
<td>1</td>
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<tr>
<td>WE</td>
<td>1</td>
<td>0.79</td>
</tr>
<tr>
<td>HWP</td>
<td>1</td>
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</tr>
</tbody>
</table>

The new MOV shows significant improvement in every one of the EIME impacts and design indicators measured as illustrated in figure 4.

![Figure 4 – Radar plot of Environmental Parameter indicators.](image)

DISMANTLING AND RECYCLING OF SURGE ARRESTERS

AREVA T&D manufactures its distribution surge arresters using its own discs manufactured as described above. Usually polymeric distribution surge arresters have a monolithic design, which is difficult and cumbersome for dismantling. However, our arresters have been designed to allow their dismantling at the end of life.

Besides, these surge arresters are built with no hazardous materials such as lead or CrVI. Since they can be dismantled and they contain no hazardous materials, these arresters can be disposed as standard waste.

CONCLUSION

AREVA T&D has progressively implemented new processes and materials to produce a new MOV by considering the whole of the product life cycle from concept to disposal. In particular we have managed recycling the waste generated during the production of MOV to minimise its total environmental impact.

Consequently, these surge arresters are fully compliant with future European, legislation such as ROHS and WEEE directives.

LIST OF REFERENCES

1. Maciela F. et al, "French service experience with MV polymer housed surge arresters", CIRED 1999