ECOLOGICAL DESIGN APPLIED TO POLYMER HOUSED SURGE ARRESTERS

M. Hassanzadeh, F. Malpièce, C. Bilhère

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Nowadays, polymer housed surge arresters are widely used throughout the world. On condition that the manufacturing processes of metal oxide varistors and complete surge arrester are well controlled, this technology benefits from both high reliability and competitive price.

But in addition to continuous improvement in technical performance and reduction in costs, an acknowledged manufacturer has to care about environmental concerns. In order to take all relevant parameters into consideration, the environmental approach must be undertaken at the earliest stages of product design.

The paper presents an example of environmental management applied to the development of a new range of distribution polymer housed surge arresters, with the aim of anticipating foreseeable evolution of regulations and market requirements.

Thus, an analysis of environmental impacts across entire life cycle of the surge arrester and its components (manufacture, delivery, operation and disposal) has been made. In particular, many study researches on the manufacturing conditions of metal oxide varistors have been completed, leading to implementation of processes for emissions treatment (air, water, ground), recycling and valorization of waste, up to drastically reduce environmental impacts. Besides, the design of the surge arrester has been carefully studied, both in terms of optimization of the necessary quantity and selection of the type of materials used, and in terms of constraints and opportunities for dismantling and recycling.

This experience has clearly demonstrated that the product ecological approach and economy logic were complementary. The range of polymer housed surge arresters which has been developed does foreshadow a new generation of devices.
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ABSTRACT

In addition to continuous improvement in technical performance and reduction in costs, an acknowledged manufacturer has to care about environmental concerns. In order to take all relevant parameters into consideration, the environmental approach must be undertaken at the earliest stages of product design. This paper presents an example of environmental management applied to the development of a new range of distribution polymer housed surge arresters, with the aim of anticipating foreseeable evolution of regulations and market requirements. Thus, an analysis of environmental impacts across entire life cycle of the surge arrester and its components (manufacture, delivery, operation and disposal) has been made. In particular, many study researches on the manufacturing conditions of metal oxide varistors have been completed, leading to implementation of processes for emissions treatment (air, water, ground), recycling and revalorization of waste, able to drastically reduce environmental impacts. Besides, the design of the surge arrester has been carefully studied, both in terms of optimization of the necessary quantity and selection of the type of materials used, and in terms of constraints and opportunities for dismantling and possible recycling.

INTRODUCTION

Nowadays, polymer housed surge arresters are widely used throughout the world. On condition that the manufacturing processes of metal oxide varistors and complete surge arrester are well controlled, this technology benefits from both high reliability and competitive price (1). However, taking environmental protection into account also becomes a main concept when designing the surge arrester and its components. Because of processes used, the metal oxide varistors manufacture requires many treatment and/or recycling operations to be implemented, in order that environmental impacts are reduced to the minimum. On the other hand, the design and the materials of the surge arrester must be selected with consideration of ecological concerns, which is quite complementary with searching of technical and economical optimization.

PRODUCTION LINE FOR METAL OXIDE VARISTORS

ALSTOM Parafoudres S.A. operates its own production line for metal oxide varistors (MOVs). This line is highly automated and is also characterized by parallel processes intended for treatment and recycling of the waste generated at different manufacturing stages.

Manufacturing method for metal oxide varistors

Figure 1 shows the different stages required for the production of MOVs, using the manufacture process operated by conventional ceramics industry.

In this case, the successive operations are as follows:
- Weighing of various metallic oxides, then mixing and ball milling of powders laced with temporary binders and lubricants in liquid phase
- Spray drying of the mixture obtained (mix ZnO / additives / binders in liquid phase) followed by sifting in order to get the required grain size
- Pressing of the sifted powder inside a cylindrical cavity
- Elimination of temporary additives and high temperature firing for molded pieces
- Glass coating on the external surface
- Vitrification of the said glass coating
- Precise surfacing of the contact faces
- Cleaning and drying of these faces
- Plating of the contact faces with a metallic alloy
- Electrical characterization at low and high currents, marking of the batch number and main features for further use, and final visual inspection.
Treatment, recycling and revalorization of waste

The purpose of procedures progressively implemented is both to limit environmental impacts induced by the waste generated and to valorize the waste which results in an increase of production costs.
Waste, which can be either in solid, liquid or/and gaseous state, are generated at each stage of the manufacturing process.
Figure 2 describes the different arrangements made in production according to the type and the origin of the waste generated.

Powder preparation. Several metallic oxides, such as Bi$_2$O$_3$, Sb$_2$O$_3$, are added to zinc oxide which is the basis of the ceramics. These other oxides are additives which allow the electrical non linear characteristic of the final material to be obtained. Mixing and ball milling are carried out in a liquid phase in order to obtain an homogeneous mixture. Binders and lubricants are also added so as to make later pressing and removal from the mold easier. These organic compounds shall be eliminated with no residue before the firing cycle intended to make the ceramics more dense.
When cleaning the tanks, the washing waters clutter with raw materials. After addition of lime and slow agitation, these washing waters are led to a press filter.
The following waste go out of the press filter:
- conglomerate and slightly wet solid residue, called "cakes", which are collected by an external company specialized in revalorization of the zinc contained in industrial waste
- filtered waters which are treated under micro-filtration and pH adjustment (in the range 6.5 \(\div\) 8.5) before being transferred to the sewage pipe.
Solid waste represent approximately 0.01 \% of the whole quantity of raw materials used.

Spray Drying. Sifting waste, as well as cyclone powder, whose formulation is the same as useful powder, are removed and introduced into the mixture prepared for the next manufacture batch.
This kind of waste is around 5 \% of the total weight of powder dried.
Besides, a micro-filtration system has been recently installed inside the chimney of the spray dryer in order to capture the powder dust, which is around 1% of the total quantity of powder: the whole rejection rate is now well below 5 mg/m³ of air, as specified by relevant regulations.

Pressing. The type of waste is the same as the former, but under compact state. Moreover, raw pieces intended for initial settings and parts with dimensions out of tolerances are kept apart. After grinding, they are introduced into the mixture prepared for the next manufacture batch.

On average, this type of waste represents 1.8% of the total quantity of powder.

Firing. This stage produces fumes due to the decomposition and the burning of temporary binders. These fumes, which contain formaldehydes compounds (HCHO groups), acroleine (CH₂=CH-CH=O) and aldehydes (CH₃CHO groups), create strong smells which may become irritating as concentration increases. They are aspirated by a centrifugal fan to be transferred into a special chamber where a basic washing mist is sprayed. A fog having high surface exchange with the fumes is then created. In particular, this fog allows the formaldehydes compounds to be captured. The washing mist laced with organic compounds is collected so as to be incinerated.

Analysis are regularly performed to make sure that the rejection rate actually complies with relevant guidelines.

At the firing stage, cracked varistors may also be produced. They are then transformed into powder by grinding and appropriate sifting. The semiconducting powder thus obtained may be used as a filler for polymeric materials in order to improve their internal voltage distribution. It is more and more requested by electrical cables industry.

This kind of waste represents an average of 1.5% of the total quantity of ceramics manufactured.

Coating. The glass coating sprayed on the external surface of the varistor is intended for protection against chemical aggressions and improve of the dielectric strength. To make its transformation easier, the selected glass used to be highly filled with lead oxide.
Lately, an extensive study has resulted in a glass formulation which is able to fulfil both industrial and technical requirements, while completely unleaded. As a matter of fact, European regulations should forbid the use of lead inside electrical devices in the near future. The glass coating is sprayed by nozzles inside a chamber equipped with a water curtain in closed circuit. The waste waters are led 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 press filter described above.

**Surfacing.** The purpose of this operation is to adjust the varistor height and to make its faces perfectly plane and parallel. It is made with diamond cutting disks under projection of water. The ceramic particles in suspension are captured by the sprayed water and are transferred to a decanting tank associated with a pump for recirculating after filtration. This system has divided the water consumption by more than 100, thus reduced to some 300 liters required for tank emptying and cleaning of the equipment.

The sediments are treated by the same method as above.

**Cleaning of faces.** The varistor contact faces are cleaned in order to improve adherence of the metallic alloy sprayed at the next stage. The circulation and the treatment of the cleaning waters are carried out by the same way as at the surfacing stage.

**Plating.** This stage consists in spraying a melt metallic alloy onto the plane faces of the varistor, by means of arc pistols. Plating waste are the metallic particles captured by an immersed filter, and the wire scraps. Most of these waste are collected for revalorization by an external company.

**Final Control.** Quality of the varistors is checked through routine electrical tests including an application of high energy stresses. The recordings of voltage and current, as well as a final visual inspection, allow to eliminate pieces having electrical or mechanical flaws. The corresponding waste are also collected for revalorization by an external company.

The implementation of these parallel processes allows almost 20% of the waste generated by the different stages of metal oxide varistors production to be directly recycled.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Powder preparation</td>
<td>Class 1 dumping for cakes from the press filter</td>
<td>Collected by an external company (valorization of zinc)</td>
<td>Study for possible internal recycling</td>
</tr>
<tr>
<td>Spray drying (sifting waste)</td>
<td>Class 1 dumping</td>
<td>Internal recycling with next batch</td>
<td>---</td>
</tr>
<tr>
<td>Pressing</td>
<td>Class 1 dumping</td>
<td>Internal recycling after grinding</td>
<td>---</td>
</tr>
<tr>
<td>Firing</td>
<td>Collected by an external company</td>
<td>Idem</td>
<td>Grinding and sifting for selling to cable industry</td>
</tr>
<tr>
<td>Coating</td>
<td>Idem Powder preparation for cakes</td>
<td></td>
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</tr>
<tr>
<td>Surfacing</td>
<td>Idem Powder preparation for cakes</td>
<td></td>
<td>Salvage and drying for selling to cable industry</td>
</tr>
<tr>
<td>Plating</td>
<td>Partial collection by an external company</td>
<td>Idem</td>
<td>Total salvage for re-selling to the supplier</td>
</tr>
<tr>
<td>Control</td>
<td>Collected by an external company</td>
<td>Idem</td>
<td>Study for possible internal recycling</td>
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**TABLE 1 - Management of MOVs waste**

In the near future, the most part of fired ceramics waste, which cannot be directly recycled, should be valorized, especially through cable industry whose needs for this kind of semiconducting material are increasing fast.

**DEVELOPMENT OF A NEW RANGE OF POLYMER HOUSED SURGE ARRESTERS**

Within the development of a new range of heavy duty distribution polymer housed surge arresters, ALSTOM has applied rules for both economical optimization and ecological approach of the product.

**Design of the surge arrester**

The global structure which was developed is quite standard for a polymer housed distribution surge arrester (2).
The stack of metal oxide varistors is wrapped by a fiberglass reinforced resin which is covered by an external housing made of HTV silicone rubber. However, some particularities (type and arrangement of the composite wrapping, shape of the external housing, ...) have resulted in an optimization of the number of parts required to build the product. The whole design, which is compact and void of internal gas volume, is able to provide expected electrical and mechanical properties and required withstanding to climatic stresses: indeed, its satisfactory behaviour has been assessed through relevant tests performed according to international standard IEC 60099-4 (1998) and its draft amendment dealing with polymer housed surge arresters (3).

Optimization of the components and selection of the materials

Table 2 summarizes the savings obtained on the different components when compared to the equivalent surge arrester from the former technology. The optimization was allowed by improvements completed in the performance of main raw materials and by grouping various functions to ensure.

<table>
<thead>
<tr>
<th>Type of component(s)</th>
<th>Savings in weight</th>
<th>Justification for optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal oxide varistors</td>
<td>20 %</td>
<td>Increase of the permissible voltage per unit height</td>
</tr>
<tr>
<td>Contact parts</td>
<td>10 %</td>
<td>Hollowing of the non functional areas</td>
</tr>
<tr>
<td>Composite wrapping</td>
<td>75 %</td>
<td>Use of a material proven in aeronautics industry</td>
</tr>
<tr>
<td>Polymeric housing</td>
<td>10 %</td>
<td>Profile with alternate sheds &amp; thickness rationalization</td>
</tr>
<tr>
<td>End fittings &amp; hardware</td>
<td>20 %</td>
<td>Suppression of the end caps &amp; simplification of the connections</td>
</tr>
<tr>
<td>Complete surge arrester</td>
<td>30 %</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 2 - Savings on the surge arrester components

Dismantling and recycling of the internal parts

In spite of their reliability, polymer housed surge arresters may fail in case that applied stresses exceed their own energy absorption capability. In such cases, or merely when the device is no more useful, it cannot be scrapped like a standard waste due to the wide variety of the internal materials. As a result of the monolithic design dictated by the absence of internal gas volume, this kind of surge arresters generally cannot be easily dismantled and the components cannot be separated from one another by simple means.

As far as the new surge arrester is concerned, the helicoidal arrangement of the composite wrapping and the presence of soft interfaces between layers of materials allow the major part of these difficulties to be solved. Thus, the dismantling and the removal of components are made far easier. Revalorization of metallic materials is now possible and relevant treatments for polymeric materials can be undertaken.

CONCLUSION

ALSTOM has progressively implemented special processes intended for treatment and recycling of the waste generated by the production of metal oxide varistors. Many investigations on this subject are still led in order to continuously improve environmental protection. Besides, ecological concerns have been strongly taken into consideration in the development of a new range of distribution polymer housed surge arresters. The results obtained have clearly demonstrated that the ecological approach and the economical optimization were complementary when designing new products.

LIST OF REFERENCES

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