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USE OF AN ECOCONCEPTION SOFTWARE TO DESIGN A HV CABLE CONNECTION

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ABSTRACT

After the presentation of the Ecoconception software EIME, in Jicable'03, new modules have been integrated in the database, concerning the integration of new raw materials and manufacturing process, transportation, construction works and accessories.

Regarding the cable design, the simulations have shown the advantage of aluminium for the conductor and metallic screen, to decrease the environmental impacts of the cable, with the same electrical transport capacity.

This paper shows also the heavy impact of the line operation. To reduce this impact, it is essential to decrease the losses of the cable link.

KEYWORDS

Environmentally Conscious Design, EIME, HV cable underground link

INTRODUCTION

Even if insulated cables used for the power transmission are not polluting in the common understanding, they have impacts on the environment :

- Consumption of natural resources (materials, energy),
- Impacts linked to the manufacturing (cables & accessories),
- Impacts linked to the construction and installation works (civil works and accessories),
- Impacts due to the line operation (Joule losses).

A presentation made in Jicable'03 (P.Mirebeau, P.Argaut and PM.Dejean) has shown the interest to use the EIME software (Environmental Information and Management Explorer) from Codde to predict the environmental profile of a HV insulated cable link.

The first identified conclusions were :

- EIME is an appropriate software to determine the environmental profile,
- Aluminum vs copper conductor reduces the impact of the cable,
- The impact of the line operation is larger than the cable and accessories manufacturing,
- There is a lack of data on accessories, manufacturing and construction work phases.

For the last two years, this task has been carried out by a working group composed by Nexans, Prysmian, Silec Cable, and Codde.

This has been done in the scope of a project supported by ADEME (French Agency for Environment and Energy Control), for which the manufacturers will here be grateful. This paper describes the work that has been performed during these two years.

EIME SOFTWARE PRESENTATION

EIME is a simple and pragmatic tool which was developed 10 years ago by 6 major companies of the electronic sector (Alcatel, Alstom, IBM, Legrand, Schneider Electric and Thomson).

The EIME methodology and software allow :

- Designers to easily understand and assess environmental issues during the cable connection design,
- The company to implement in a practical way its environmental product strategy.

EIME is based on scientific and official data:

- The data base is regularly updated thanks to the trade associations and scientific institutions. It is based on life cycle analysis information complying with the standards of the ISO 14040 series,
- The environmental impact assessment methodology is based on the works of the greatest world organisations. For example, the IPCC (Intergovernmental Panel on Climate Change) for the calculation of the greenhouse additional effect, and the WMO (World Meteorological Organization) for the depletion of the ozone layer, etc...

Since 2003 the EIME methodology has been chosen as a reference for the environmental assessments of electro mechanical products by the FIEEC (French Federation Of The Electric And Electronic Industry).

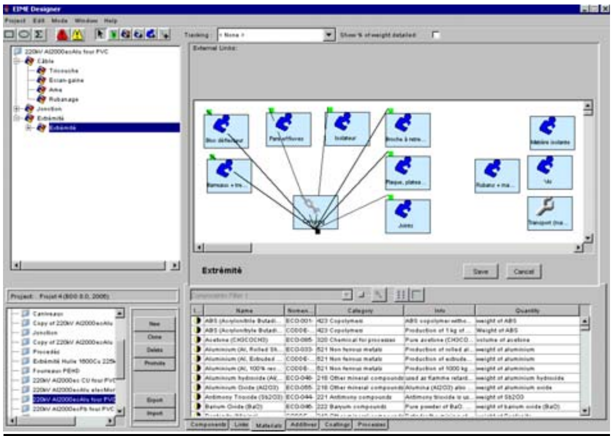

Figure 1 : screenshot of the EIME software

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SOFTWARE UPDATE REQUIREMENTS FOR THE HIGH VOLTAGE CABLE LINKS

To update the EIME for the cable industry , 4 steps were necessary :

- o Adding to the EIME database specific raw materials.
- o Adding to the EIME database specific manufacturing processes,
- o Validation by environmental experts of the coherence of the associated data (materials and process for example),
- o Integration of the design of the underground cable link elements (cable, accessories, civil engineering), and the associated processes. It was made by the designers (cable manufacturers).

IMPROVEMENT OF THE DATABASES

Codde computed the impact indicators of the raw materials used for cables and accessories, and the ones used for construction work, by consulting the international databases or asking directly the suppliers.
Cables and accessories manufacturers, described all processes from metal drawing to the sheathing in terms of natural resources consumption (energy, water), and also in terms of wastes (in air, water, ground).
Regarding delivery, the main data was available; Cable manufacturers only added information about metallic drums.
A particular effort has been made to describe civil engineering, cables and ducts laying, joint bays construction and accessories installation.

Finally, 14 new materials, 22 industrial processes, 2 construction techniques, were added to the data bank, and now suitable information is available to describe the main cable system connection types, and calculate their environmental profiles.

ENVIRONMENTAL IMPACT OF AN UNDERGROUND CABLE LINK

In the following calculations, with the help of the EIME software, we have compared different configurations in terms of :

- o Cable design
- o Manufacturing
- o Construction and installation works
- o Line operation.

We have considered accessories of standard dimensions for all types of underground cable links.
To make it easier, the authors have developped excel spreadsheets which automatically calculate, for the length of the connection, as long as all information has been put into the EIME software (see appendix).

Cable design

To point out the impact of cable design, we have selected a 225 kV cable, with a rated ampacity of 1200 A, and a short circuit current rating of 31.5 kA – 0.5 s

It is possible to use following chosen solutions :

- o a conductor of 1200 mm² copper, or 2000 mm² aluminium
- o a lead or aluminium or copper screen

The following graphic compares a cable with a 1200 mm² copper condutor and a lead screen, to one with a 2000 mm² aluminium conductor and an aluminium screen. Obviously, quantities of the other components have been respected to assure the same electrical and mechanical properties.

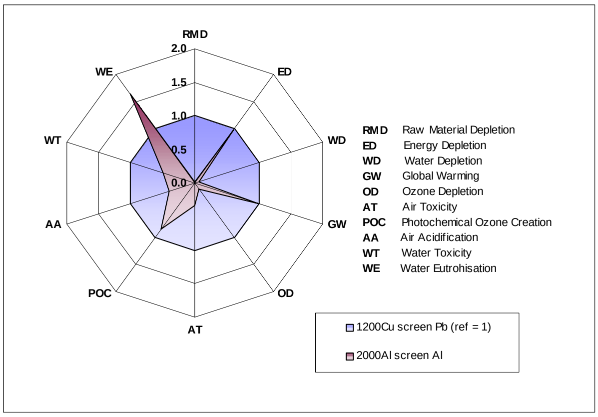

Figure 2 : 2000 mm^2 aluminium 225kV cable vs 1200 mm^2 copper 225kV cable – material + manufacturing

Concerning these 2 cables, only the WE (Water Eutrophication) is higher in the case of the 2000 mm² Al conductor/Al screen. This is due to the aluminium refining phase. For all other indicators, the impacts appear smaller by using aluminium rather than others metals (copper or lead).
If we look at the screen impact (figure 3) we can see that the lead gives the worst result. This is mainly due to the quantity needed to obtain the same conductivity which is 20 times higher compared to that of aluminium.

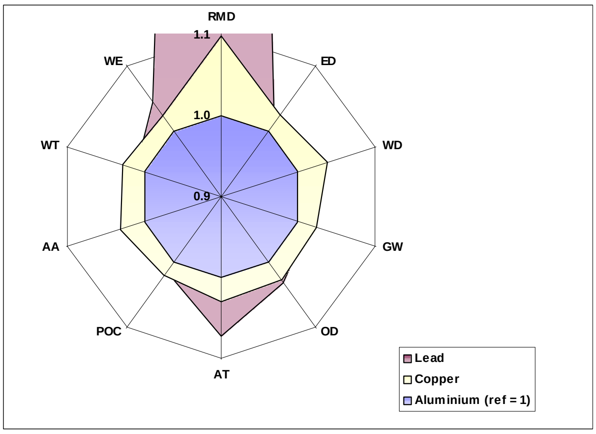

Figure 3 : comparison of different metallic screens

These 2 schematic presentations show how it is possible by a carefully choice of the metallic components to decrease the environmental impact of a cable.

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Manufacturing

The use of EIME gives a better understanding of the processes environmental impact. The figure 4 gives a comparison of the processes regarding the Energy Depletion, which is the most significant impact in the cable manufacturing.

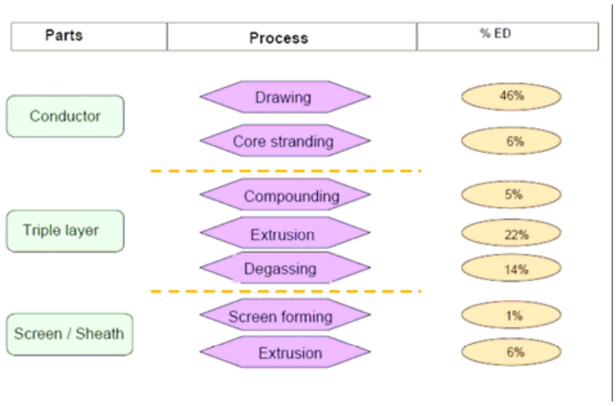

Figure 4 : Energy depletion of the different processes used for a 2000 mm² Al 225 kV cable manufacturing

We can notice that the drawing of the 9.5 mm aluminium rod is the highest electrical energy consumer.
It is also interesting to note that the degassing phase is of first importance for the energy consumption.

The cable manufacturing phase has a very low impact as compared to any of the other phases.

Construction and installation works

For this phase, we have compared a trefoil configuration link with 2 different construction and installation techniques:

- o In urban area with PVC ducts in concrete, and a bitumen cover trench
- o In rural area with HDPE ducts directly buried in controlled backfill.

The joint bay is the same for the both laying arrangements.

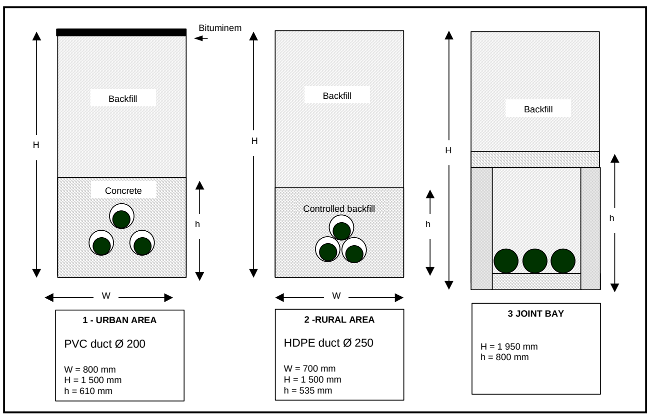

Figure 5 : schematics of 2 construction types and a joint bay

The flow diagram below shows the main steps of the 2 considered construction techniques.

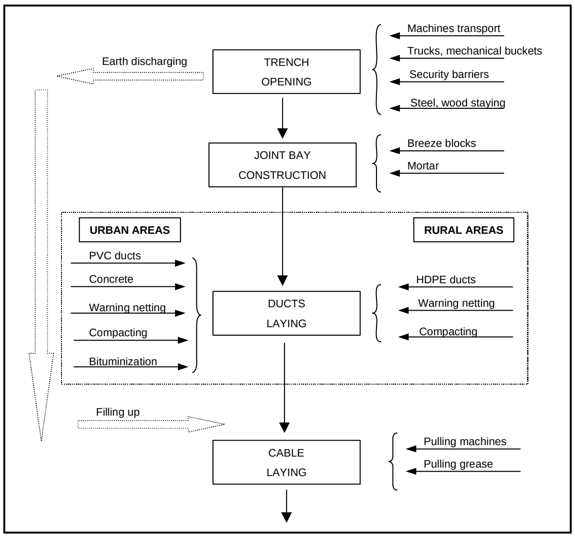

Figure 6 : main steps of construction techniques

The radar presentation (Fig 7) gives a comparison of the 2 types of construction considered, for a 2000 mm² Al 225 kV (the cable is not included).

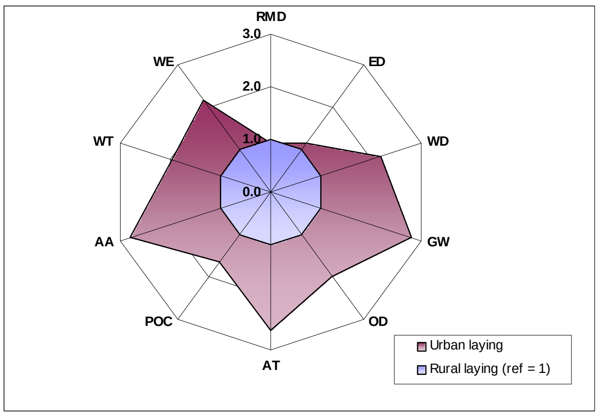

Figure 7 : comparison of the 2 types of construction and installation

The main impacts are linked

- o to the civil engineering machines (trucks, mechanical buckets),
- o additionally, in the case of urban laying, to the concrete and bitumen.

The difference between the 2 types of construction is very important.
To have a better understanding, the table below (Table 1) gives the quantities used for a 1 km construction.

Raw materials	Urban area, tons	Rural area, tons
Fuel	10	6
Wood	7	0.1
PVC duct	10	0
HDPE duct	0	49
Cement	130	4
Sand	330	31
Gravel	500	450
Steel	0.4	0.4
Bitumen	66	0

Table 1 : Materials quantities used for 1 km construction

To make a 1 km connection, it is necessary to use about 1000 t of materials in urban areas, and about half in rural areas.
The excavation represents about 2700 m^3/km for the urban case and 700 m^3/km for the rural case, and this is for the installation of 50 tons of cable

The impact of both rural and urban laying method can also be reduced, see fig 8.

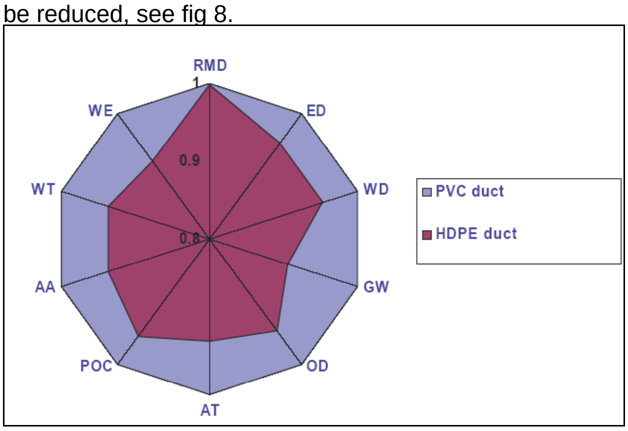

Figure 8 : impact of a rural installation using PVC ducts (reference) vs HDPE ducts

Line operation

For the line operation, we have considered a 40 years period with the following repartition :

- o 80 % of time ➔ 50 % of rated current
- o 18 % of time ➔ 80 % of rated current
- o 2 % of time ➔ 100 % of rated current

We compare the complete environmental impact (design + manufacturing + construction and installation + line operation) of a cable link made of a 1200 mm² copper with a lead screen installed in PVC duct and a link made of a 2000 mm² aluminium with an aluminium screen installed in HDPE duct (Fig 9).

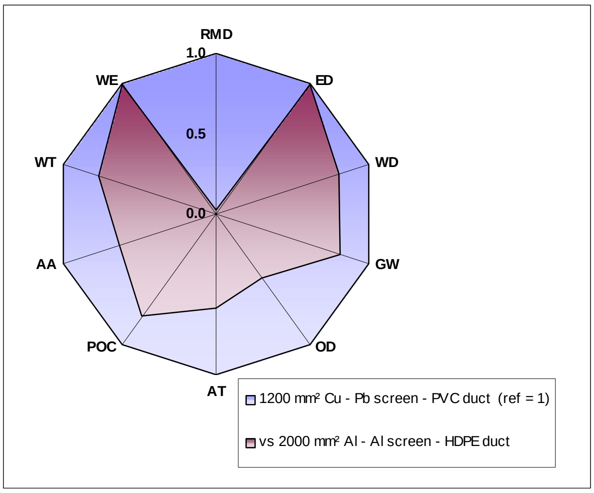

FIG 9 : Complete environmental impact evaluation : 1200 mm² Cu - Pb screen - PVC duct vs 2000 mm² Al - Al screen - HDPE duct

The environmental impact of the aluminium solution (conductor and screen) with rural construction is the lowest. In this comparison, the Energy depletion and Water eutrophication values are equals due to the fact that the two compared cable links have the same losses.

We have compared the relative impacts of cable and accessories manufacturing, construction work and line operation for the 2000 mm² Al link.

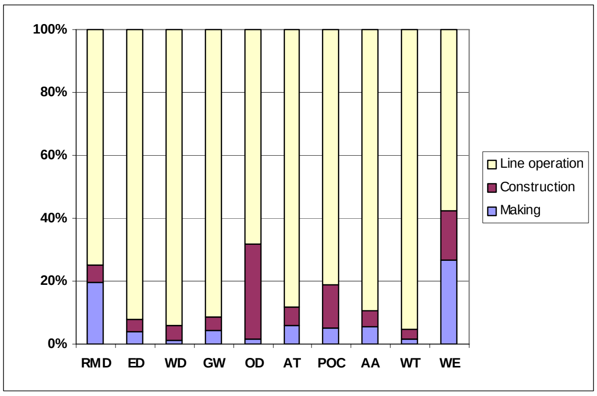

Figure 10: Environmental impacts of a 2000 mm² Al 225 kV underground cable link

The figure 10 shows the influence of each phase on the different environmental parameters :

The line operation phase has more environmental impact than the two others.

Regarding the impacts of the Manufacturing and Construction-Installation phases the main contributions are:

- o cable and accessories manufacturing on RMD and WE,
- o construction on OD and POC.

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To reduce the impact of the line operation phase, it is essential to decrease the losses of the cable link.
This is pointed out in the following figure, where we have compared the total environmental impact of a1600 mm² aluminium vs. 2000 mm² aluminium (Fig 11).

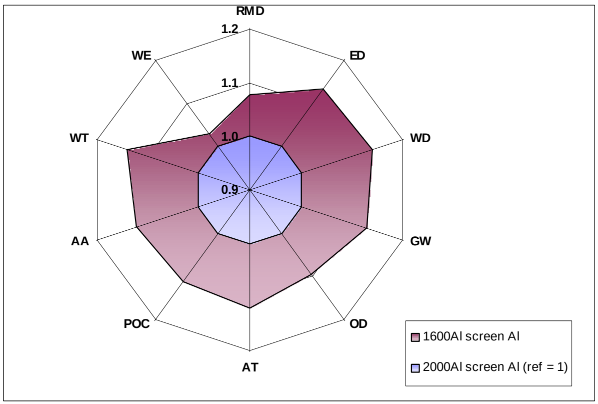

Figure 11 : 2000 mm² Al (reference) vs 1600 mm² Al

CONCLUSION

For the last 2 years, new developments have been performed to increase the reliability of the EIME to predict environmental impacts of a HV underground cable link.
We have now a complete tool, including raw materials, cable and accessories processes, construction work and line operation
For the cable design, aluminium conductor and metallic screen minimise the impact.
For the construction and installation technique using HDPE duct directly buried in controlled backfill is the best way to decrease the environmental impact.
But the most important environmental impact of an underground cable link is due to the line operation, and to limit this impact, the best solution is to increase the conductor size.

REFERENCES

[1] P. Mirebeau, P. Argaut, PM. Dejean "*Environment Conscious Design of VHV transmission links by cable systems*", Jicable 03

APPENDIX :

Diagram of the excel spreadsheet which automatically calculates, for the length of the connection, as long as all information has been put into the EIME software