ABSTRACT
This paper describes a totally new concept of operating mechanism insensitive to environment for medium voltage cubicles. Moreover its insensitivity to the environment, this new range of mechanisms, thanks to the “new” employed materials for this kind of products, presents several advantages concerning the maintenance, the reliability, the operating and the impact on environment.

INTRODUCTION
Network reliability is key to service continuity. Switchgear plays an important role protecting the network against faults and allowing maintenance operations and network configuration changes. Over the past 40 years, the history of switchgears has been one of increasing reliability. Until the 1960s, current was broken in open air, an operation that was subject to atmospheric pollution, with risks including non-breaking and even explosions. In the 1970s, sealed chambers filled with SF$_6$ were introduced. However, the busbar and cable connections remained air-insulated, with pollution and insulator-ageing potentially generating electrical arcs.

The 1980s saw a solution to the problem of insulator pollution: the gas-insulated switchgear (GIS). The switches and the busbars were all sealed inside a tank of SF$_6$, and tight plugs were used for cable connections, giving the GIS its reputation of being unaffected by the environment. With one exception: the operating mechanism is not in the sealed container and remains susceptible to corrosion and grease alteration, particularly in industrial areas or near the sea.

AREVA T&D took the next logical step when, after over three years of material research and thorough testing, it designed the Compodrives, operating mechanisms made entirely of composite materials and impervious to environmental conditions.

DESIGN APPROACH
The operation of medium voltage switchgears requires high speeds and important forces which are given by drive mechanisms. These mechanisms are therefore essential and for that reason have to be reliable and efficient during many years (up to 50 years). That is why AREVA - and its competitors - have always mainly built them with metals. However, despite their interesting mechanical properties, the metallic parts present some drawbacks such as corrosion or grease alteration for example. Solutions intended to suppress these disagreements exist but are not always reliable and are not environmentally friendly: the surface treatment employed against the corrosion contain noxious products and the regular lubrication of the mechanisms, which facilitates their operation, is not ideal in terms of ecology.

Always eager to increase our customers satisfaction and aware of the need to provide environmentally friendly products, we permanently try to increase their quality regarding their reliability, their safety, their maintenance...
and their impact on the environment. Concerning the mechanisms, we realized that it would be impossible to reach these different targets with steel made mechanisms. We concluded that we had to realize a technological breakthrough and that is why we decided to investigate in mechanisms in composites. Indeed, these materials are insensitive to environment and recyclable, they don’t need to be lubricated and they allow to obtain very light mechanisms.

**SELECTION OF THE MOST APPROPRIATE MATERIAL**

Despite numerous advantages, composite materials are relatively young and their ageing is not always well known and/or not always sufficient. Consequently our first challenge was not to design a new mechanism made of composite parts but to check that it existed materials able to keep their mechanical properties during more than fifty years. To do so, we set up a study with a laboratory specialized in polymer ageing which has already tested its methodology on numerous materials in several domains such as nuclear energy, aerospace, armament, canalizations, automotive... Their methodology to predict life span couples the analysis of structural changes at all pertinent levels with advanced polymer physics.

In collaboration with the lab, AREVA T&D chose a high-strength semi-crystalline engineering thermoplastic often marketed as a metal substitute for corrosive environment: polyoxymethylene (POM). The first step of the study consisted to identify the type of degradation for the selected material. To do that, samples were moulded and put in ovens in several conditions of temperatures and of environment chosen for the following reasons:

- the high temperatures allow to boost the degradation of the material and so to reduce significantly the time of study.
- the environment (pressure and type of gas) permit to identify the cause of the degradation.

The samples placed in the ovens were then regularly taken to be weighed in order to determine their loss of mass. The PhD in charge of the study rapidly observed that the oxygen pressure, the loss of mass and the mechanical properties were linked. These findings allowed her to conclude that the degradation of the selected POM was due to an oxidation of its amorphous phase. Indeed, an oxidation is characterized by the apparition of oxidation products which are due to structural modifications caused by the oxygen contained in the air which attacks the amorphous phase of a thermoplastic.

These first results were then confirmed and studied more accurately by additional experiments at 110, 130 and 150°C:

- Rheological measurements showed that the viscosity of the polymer decreased during the experiment, which means that the macromolecular chains were cut.
- An IR spectrometry showed that there was a release of formaldehyde during these tests.

These two experiments linked to the mechanical tests realized in parallel, also allowed to obtain data like the expected life duration of the studied material at 110, 130 and 150°C, the critical molecular weight of the polymer’s chains, the kinetic of the decrease of the molecular weight at each temperature, the kinetic of the increase of the macromolecular chains’ cuts...

Thanks to these many data the PhD was then able to build a model which allows to predict the selected POM – not all POM are equal – life span at several temperatures. This model is made of several equations which characterize the different steps of the degradation: the initiation, the propagation and the termination. For example, this model showed that this POM, was able to keep its mechanical properties during more than 95 years at 20°C.

After three years of studies, the excellent results obtained with this POM lead us to design a new range of switchgears mechanisms made of polymer parts.

**DESIGN OF A NEW RANGE OF MECHANISMS**

In a first time we decided to design a characteristic part of a current mechanism in order to validate the technology. We chose a part called “tumbler” because it has complex shapes and it is one of the most constrained of the mechanism: static forces and shocks.
The challenge was important because the design of thermoplastic parts was unusual for us and we had to take into account all the constraints linked to this technology. After a first draft, the new model was improved thanks to numerical simulations and then, when the shapes were validated, a prototype was launched and successfully tested.

Gradually, all parts were designed and finally a completely new mechanism was born. We called it CD10 and, thanks to its numerous advantages, such as its insensitivity to environment or its lack of maintenance, it is intended to rapidly replace the old steel mechanisms. The first realized tests with mechanisms from the try-out confirmed these results as they allowed to realize several thousand of operations while international standards asked to do one thousand.

At the end of this first study and thanks to the excellent obtained results, other mechanisms were designed.

Fig 09 – The « CD110 », a new composite drive for our compact cubicle

The ultimate step consists to validate this new range of mechanisms in real conditions. This phase is realized in partnership with ERDF (distribution subsidiary of EDF), one of our most important customer, who showed a great interest to this evolution from the very beginning of the project. Indeed, moreover to be attracted by technological evolutions intended to reduce the maintenance and to increase the reliability, ERDF, like AREVA, promotes solutions that respect the environment.

Fig 10 - Materials comparison for the CD110

A life cycle assessment realized with specific life cycle softwares (EIME then SIMAPRO) was then launched on each mechanism. The life cycle assessment consists in studying a product environmental impact “from the cradle to the grave” which means that we take into account all phases like the mining of raw materials, the manufacturing, the distribution, the use and the end of life. The purpose of a life cycle assessment is to evaluate a product impact on natural resources and environment by identifying the most important processes.

Concerning the CD110, which are the latest studied, it was demonstrated that new designed mechanisms were really better than the old ones concerning the environmental impact. Most of environmental impacts were indeed divided by two and some of them, like photochemical smog, nuclear wastes and air toxicity were reduced more significantly. Global warming, acidification and resources stayed at a similar level. The only impact which is in disfavor of “Compodrive” mechanisms is the production of hazardous wastes. A more detailed analyze of these results showed that the manufacturing phase was henceforward the most important concerning the impact on the environment.

Fig 11 – Comparison between a steel and a composite made mechanism

This life cycle assessment was finally completed by additional studies: an end-of-life guide and an eco-declaration were written and a technical and economic study about the recycling was also realized.
CONCLUSION

This new range of mechanism, realized with a never used before technology for this kind of application, presents numerous advantages. “Compodrive” mechanisms are more resistant to mechanical endurance and they are entirely insensitive to outside conditions with an added environmentally friendly touch. Indeed, maintenance operations and so grease alteration are suppressed, their dismantling is facilitated and their materials have a lower environmental impact and are recyclable. The ultimate result will be further improved service continuity of electrical networks. In conclusion, the new “Compodrive” range is more than an evolution, it is a revolution! Customers, like ERDF, who have already discovered these new mechanisms, applauded the technological breakthrough.