# POLYPROPYLENE/SIO2 NANOCOMPOSITE WITH IMPROVED DIELECTRIC PROPERTIES FOR DC CABLES


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# Introduction

High voltage direct current (HVDC) cables are gathering more and more interest, reaching an all-time high. The most important reason for this is probably the world wide attention for harvesting renewable energy at a scale never seen before. A new European project, GRIDABLE was launched in 2017 with the aim to develop a new generation of nanostructured polymeric materials suitable for DC cables and VSC capacitors (Fig. 1).

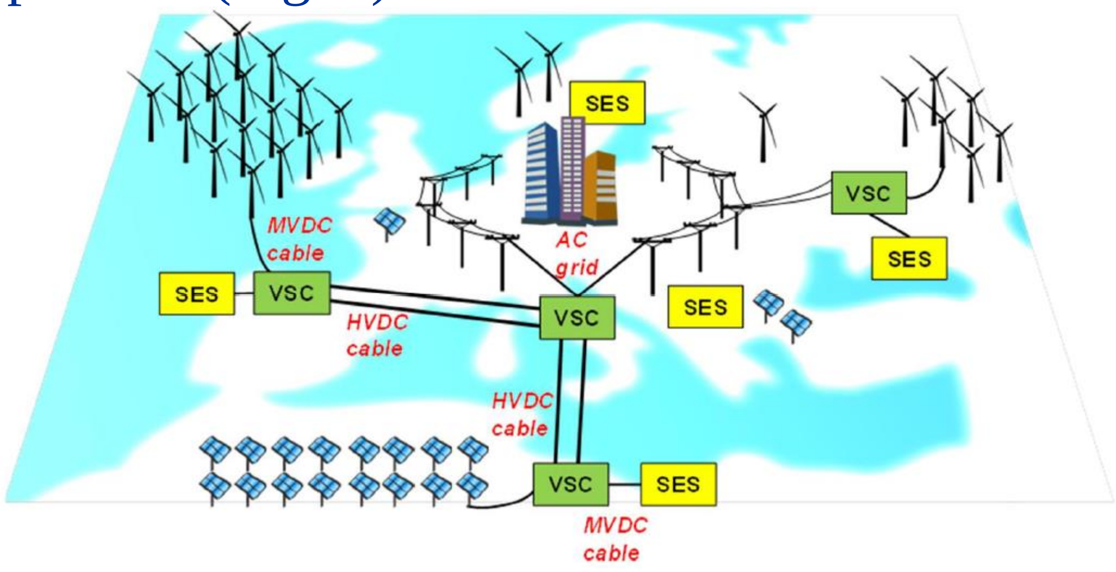


Fig. 1. Fields of application of the GRIDABLE project. SES stands for Stationary Energy Storage and VSC is Voltage Source Converter

The accumulation of space charge in electrical insulation has been recognized to be a major aging factor in DC insulation [1].
As an example, Fig. 2 shows how a small amount of accumulated space charge can distort the Laplacian electric field. This will in turn influence the degradation rate and life expectancy of the insulating material. Any material which has to be used as DC insulation, therefore, has to be characterized to be space charge free at the operating field and temperature.

# Materials

The base material chosen for this project is polypropylene (PP); having excellent electrical and thermal properties for energy applications, and good potentiality regarding mechanical properties, besides being completely recyclable. The addition of nanofillers, specifically $SiO_2$, fits to the objective to improve the electrical and thermal properties and reach higher design field and temperature for the same design life and reliability of the present DC technology, that is, XLPE.

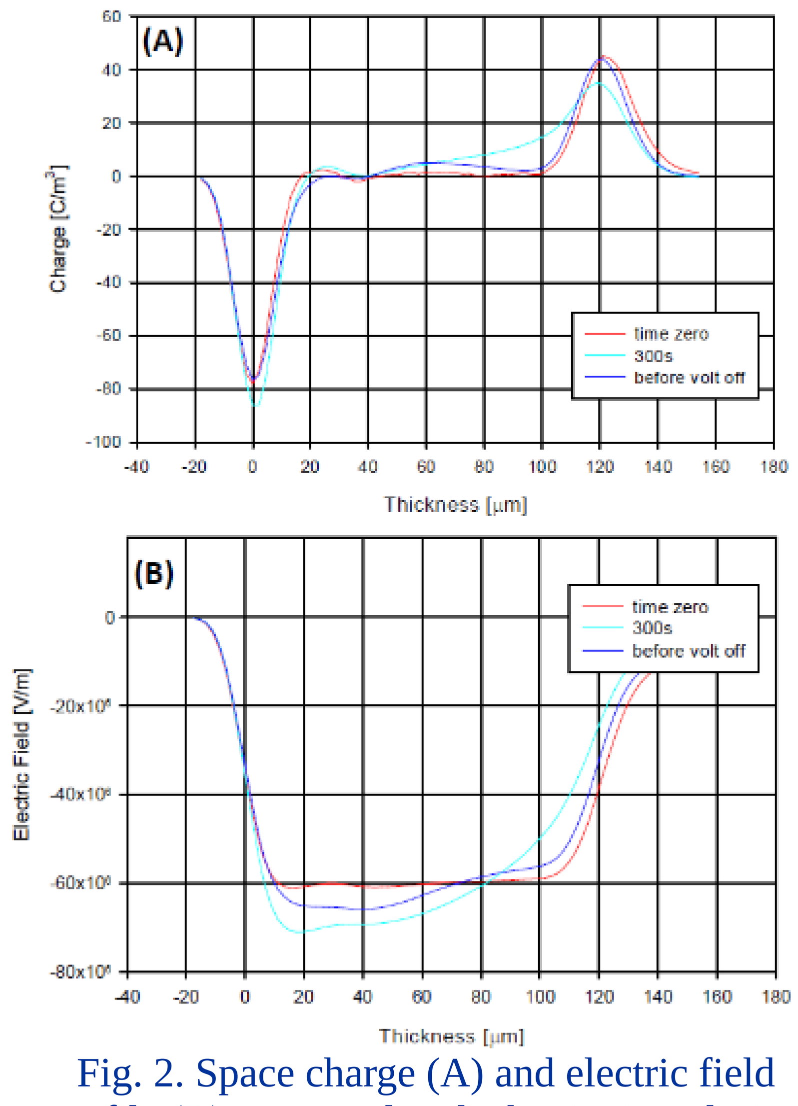


Fig. 2. Space charge (A) and electric field profile (B) measured at the beginning, during and at the end of polarization with (laplacian) field of 60 kV/mm. The maximum field bulk material is subject to is about 70 kV/mm, after 300 s.

# Results

## INFLUENCE OF NANOFILLER CONTENT ON SPACE CHARGE ACCUMULATION

Fig. 3A shows space charge accumulation for the tested materials at different filling percentages (from 0% to 4.5%), in poling fields from 5 to 50 kV/mm. The introduction of nanofiller reduces the amount of accumulated charge at medium-high fields and decreses the threshold for space charge accumulation to lower fields. On the other hand, the rate of charge accumulation as a function of poling field diminishes significantly from base (pure) to filled material.

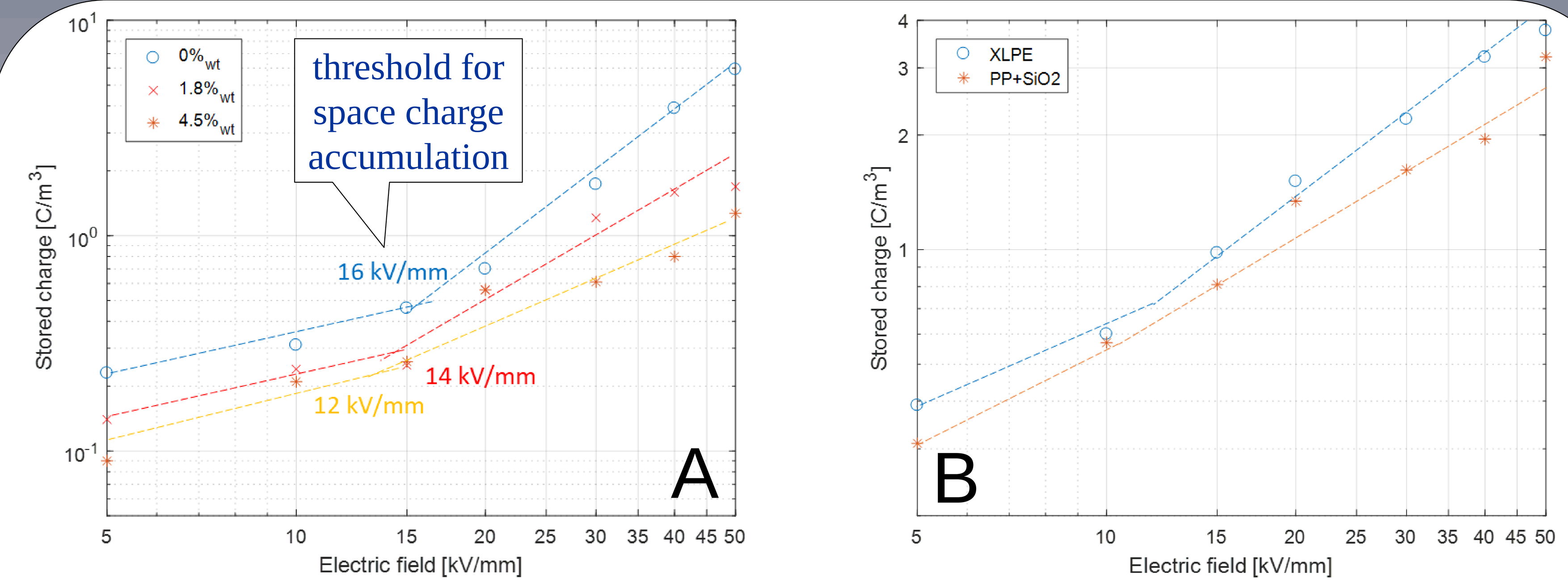


Fig. 3. Space charge characteristics for PP pure and filled 1.8 wt% and 4.5 wt% (A) and performance comparison with XLPE (B).

## NANOFILLED POLYPROPYLENE AS AN ALTERNATIVE TO XLPE

Fig. 3B shows space charge accumulation for XLPE and the polypropylene based material, in poling fields from 5 to 50 kV/mm. The amount of accumulated charge at low and medium-high fields is reduced in PP nanofilled specimens. Calculations for trap depth distribution (Fig. 4A) show how the polypropylene based material is characterized by deeper charge traps. In fact, charge is released more slowly than in XLPE, and the nanofilled material features higher residual charge after long depolarization times (Fig. 4B). This is a relevant issue in the case of insulations subjected to voltage-polarity inversions, such as cables interfacing with current source converters.

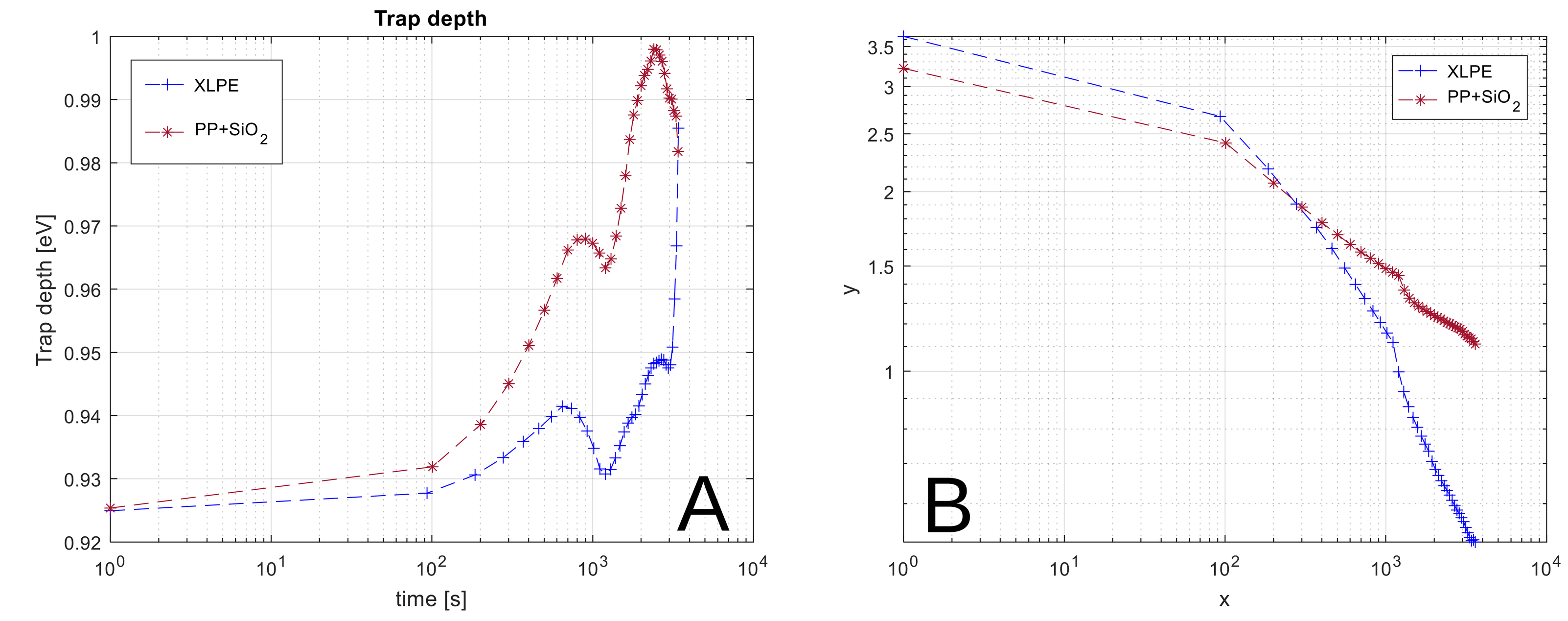


Fig. 4. Trap depth distribution in XLPE and cable-grade nanofilled polypropylene (A, after [2]) and their depolarization characteristics (B).

# Conclusions

The addition of $SiO_2$ nanoparticles to a bulk of PP has revealed interesting modifications of electrical properties that may affect positively HVDC cables and film capacitors design and performance on short term and long term basis. The decrease of trapped space charge at fields close to design stress might open interesting perspectives for the future of the GRIDABLE project. Further investigations are needed to understand the contribution of nanofillers to the modification of electrical properties, but the results here reported seem to indicate that the GRIDABLE project may have an important impact on insulation technology in the near future, suggesting that HVDC cables insulating materials with better thermal performances, higher ampacity and higher reliability are a viable option using polypropylene based materials. The problematics regarding their performance in depolarization introduces a problem that will be assessed in the future.

## References


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**[2] [18]G. Mazzanti, G. C. Montanari and J. M. Alison, "A space-charge based method for the estimation of apparent mobility and trap depth as markers for in-sulation degradation-theoretical basis and experi-mental validation," in IEEE Transactions on Dielec-trics and Electrical Insulation, vol. 10, no. 2, pp. 187-197, April 2003.**



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