Results of the application of a hydrophobic coating base polymer on stranded OHL Cu cable

Background

The project to apply an hydrophobic coating developed by LFL has its origin in a blizzard, which took place on 9 and 10 March 2010 in the NE area of Spain: the region of Catalonia as shown in Fig. 01.

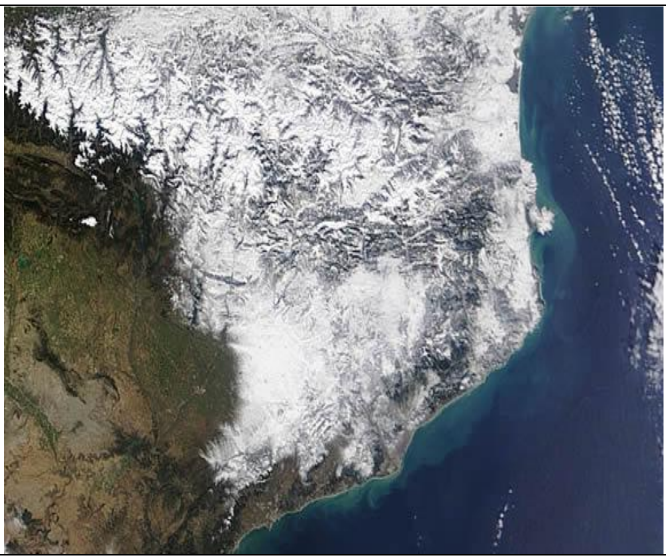

Fig 01: satellite image of the area affected by the snowstorm of March 2010

As the weather situation of 03/09/2011 described in Fig. 02 shows there was an ingress of a cold air mass from Eastern Europe. This air mass, before reaching the eastern coasts of the Iberian peninsula, went across the waters of the Gulf of Lion, in the NW Mediterranean and became saturated with moisture because of the always relatively high temperature of the Mediterranean surface waters (12 / 13 ° C at the beginning of March). Once the cold and moist air mass thus formed came in contact with the mountain ranges arranged along the NE Mediterranean coast of the Iberian peninsula it produced an intense and abundant snow fall at all heights in a way that areas close to the coast (offshore areas < 500 m above the sea level) had snow precipitation at temperatures between - 1 to 2 ° C which means that it was a very sticky wet snow.

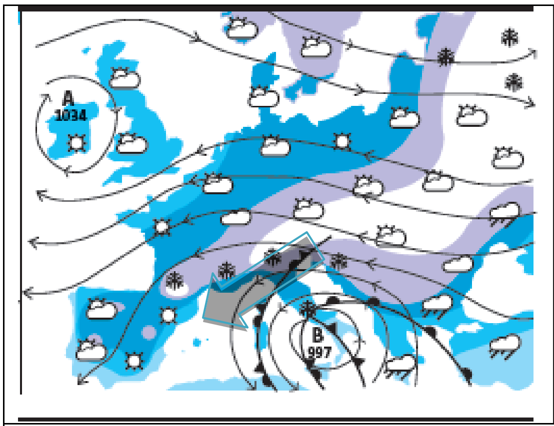

Fig 02: 03/10/2010 meteorological situation producing triggering the snow storm

During this episode in the geographical area shown in Fig. 03 a snowfall of 500 mm (equivalent to 50 mm of rainfall) of wet snow occurred over a period of time of 1.5 h, this resulted in the accumulation of layers of snow with a thickness of up to 300 mm on almost the entire 45 kV, 25 kV and lower voltages electrical distribution network, which jointly with winds of 50-70 km/h , produced the collapse of a large number of towers. This occurred area shown in Fig. 03 which includes populated and tourist areas such as the Costa Brava. I n total there were 11 days without electric service in the area with resulted in heavy economical losses both for the local D.S.O and its customers.

The standards applicable to electrical lines of medium and high voltage in the area affected didn't take into account the possibility of snow loads at altitudes below 500 m.

Analysis of the archives shows that the area affected by this snow storm have a history of other large snowfall incidents in the years: 1947, 1962, 1971, 1983,1985,2001,2010. The 1947 snow storm was the largest but at that time the grid was not as developed as it is today and the damage had less impact. In total there is an average recurrence period of 9 years during the studied time period.

Fig 03 Detail of the most affected area, highlighted in yellow the affected set of distribution lines

Figures 04 and 05 exhibit some of the damage caused by the accumulation of snow and ice weight on the distribution lines in the area shown in Fig. 03.

The development of a new type of cable for OHL lines with a polymer type coating overlay whose purpose is to act as passive protection against accumulation of wet snow and the further ice on OHL cables as a possible solution to this recurring problem has been made by the company LFL.

The result of such action is the CAC cable which is a hydrophobic polymer-coated copper stranded wire


Fig 04 : Tower line 110kv, 2 circuit , bent by the combined action of wind and snow


Fig 05 : Tower of 25kV line , 2 circuit, collapsed by the weight of the snow

Coating:

The solution adopted includes coating each stranded wire of hydrophobic polymer material

This solution presents the main challenge of being outdoors which may deteriorate the coating for several reasons; mainly:

- Action of the UV RAYS from the Sun
- Corrosion
- Variations in temperature both for meteorological environment or for the cable heating by electrical current flow

Fig 06 : CAC coated section

Tests on the coated wire have determined that the coating keeps its properties for a minimum period of 7 years. The exact number depends on the environmental conditions of the power line deemed: if it is a more or less sunny or for a highly corrosive area.

The maximum working temperature is established to 170 ° C which is a temperature only occasionally reached in an overhead electric line (usually in N-1 or N-2 situations).

Fig 07 : Quality test of coating: the "tie" test

In Fig. 07 can be seen one of the quality procedures conducted to check the coating adherence to the wires to be stranded , this test ,known as "tie" , winds the yarn around a equivalent diameter to itself : in practice between 2.0 and 2.5 mm; the coating must remain perfectly bonded to copper surface as can be see in Fig. 07.

Until now only polymeric coating adhesion has been achieved on the polished surface of freshly drawn copper; in the case of the aluminum the constant existence of an Aluminum oxide layer on the surface gives a lower adherence of the coating on the Aluminum surface and as a consequence the "tie" test failure .

A basic concept in hydrophobicity is the contact angle or angle which a drop of water has when placed on a flat surface; this angle must always be higher than 90 ° to be considered an hydrophobic surface.

Blaock polimer	test 01	test 02	test 03	test 04	test 05
1	129,0	136,8	138,7	141,2	129,1
2	128,8	151,0	136,6	138,4	129,0
3	122,9	125,4	136,4	119,5	131,6
4				129,4	
Average	**126,9**	**137,7**	**137,2**	**132,1**	**129,9**

Table 01 : contact angles found with the black polymer coating .

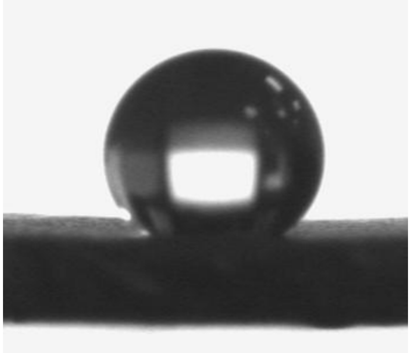

Fig 08 : Angle of contact obtained on polymer coated surface

The results obtained from contact angle measures are in a range of 125 to 137 °which gives the hydrophobicity propriety to the treated surface.

Tests carried out on Dead Water Fell

Tests conducted on Dead Water Fell facilities in the UK during the winter of 2013-2014 were designed to test the behavior of the polymer coating on CAC HLS-95 and 150 cables (95 and 150 mm^2 cross-sections) against a non-coated ACSR-180 cable

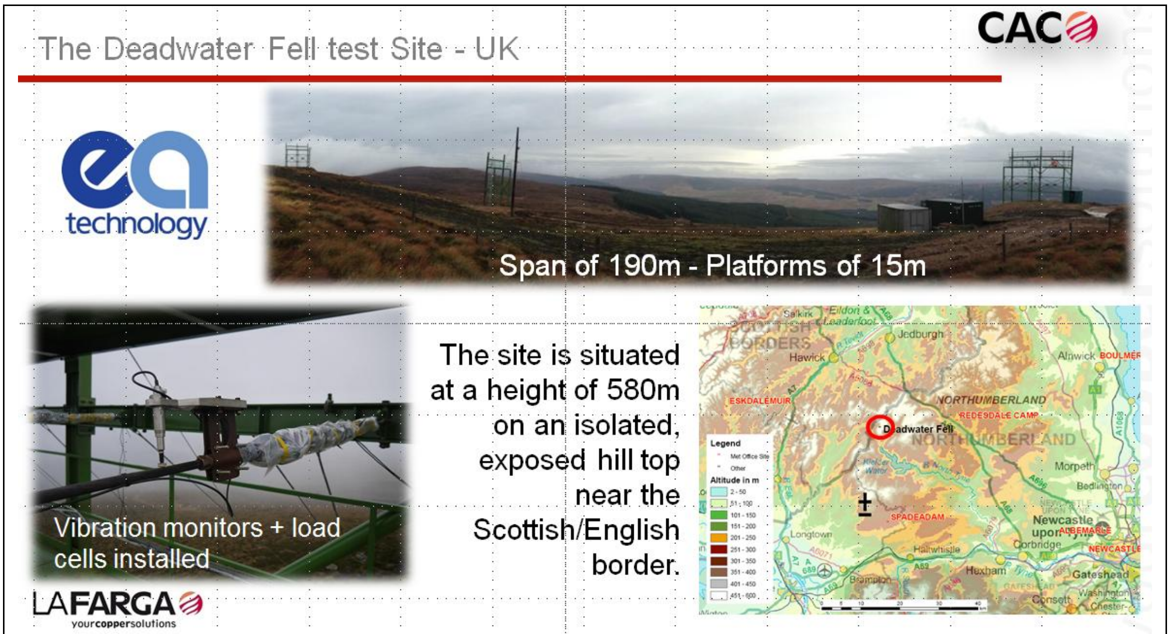

Fig 09 : Dead Water Fell facilities to test OHL cables against real whether conditions

The 2013-14 winter turned out to be one of the less harsh recorded on the location of Dead Water Fell, with only 7 episodes of snow between November 2013 and March 2014.

	CAC-HLS 95	CAC-HLS 150	ACSR LA-180
Material type	copper	copper	aluminium + steel
Conductor greased weight (kg/Km)	846	1335	676
Conductor diameter (mm)	12,6	15,9	17,5
Conductor strand size (mm diameter)	2,5	2,25	2,5 (Al) and 2,5 (Steel)
Number of strands	19	37	30 (Al) and 7 (steel)
Coefficient of linear expansion (10-6/degree ºC)	16,8	16,8	18,6
Modulus of elasticity (kN/mm^2)	50	50	75
UTS (kN)	47,5	75	63,9

Table 02 : Properties of the cables tested

In any case and because of the relative mildness of the winter, snowfall took place in conditions very similar to those outlined in the **background** point of this paper

The graphs displayed in figs 10, 11 and 12 give a synopsis of the behaviour found. The color code is:

- Dark blue : ACSR-180
- Red : CAC-HLS 150
- green : CAC-HLS 95
- Light blue: ambient temperature evolution

The most outstanding fact is that the cables coated with polymer facing ambient temperatures in the range: - 2 to - 3 ° C take much longer to put on stress as a result of snow or ice accretion; Furthermore it is also observed that cable ACSR-180 has a much higher mechanical stress than the cable CAC-HLS-150 despite the fact that the copper cable is significantly heavier than the aluminum cable.

Fig 10 presents the behaviour of the 3 cables under conditions of wet snow: temperature while the snow was falling was close to 0^{0} C . In this case the effect of snow on coated wires is practically negligible compared to the great increase of ACSR cable mechanical stress. The data presented in Fig. 11 was acquired in colder conditions and the increase in mechanical stress due to the ice load is bigger in the ACSR cable and remains for longer than on the coated cables.

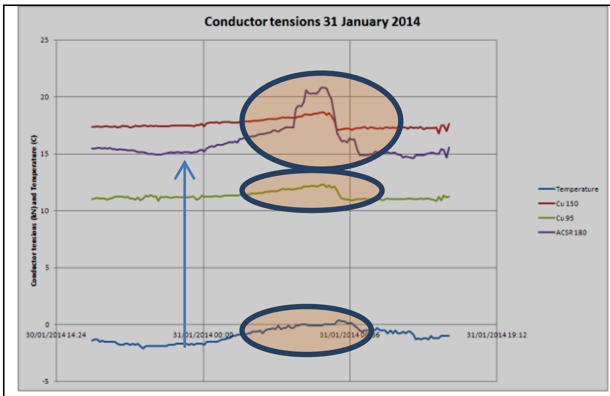

Fig 10 cables CAC behaviour in comparison of a ACSR 180 in wet snow conditions

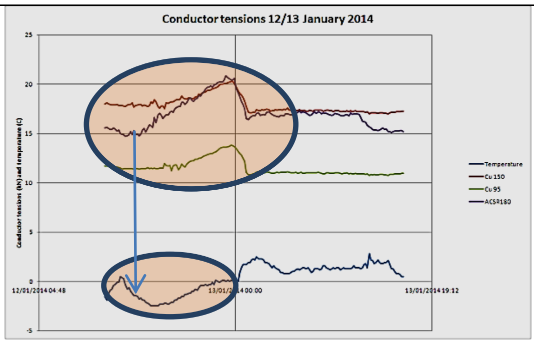

Fig 11 : CAC cables behaviour front ACSR 180 in wet snow conditions

Fig. 12 is a summary of the results obtained in the 7 episodes reported; the graph shows the maximum increases in mechanical stress recorded in each cable in each event. As shown in the graph there is a dependency between the ambient temperature and the increase of stress in such a way that at temperatures close to 0°C CAC coated cables hardly register increments of mechanical stress, unlike the ACSR cable that displays substantial increases in mechanical stress : more than double that of the CAC cables . When the temperature is lower than - 3 °C CAC cables have higher mechanical stress increases but, anyway, they are always lower than the uncoated ACSR-180 cable

Conclusions

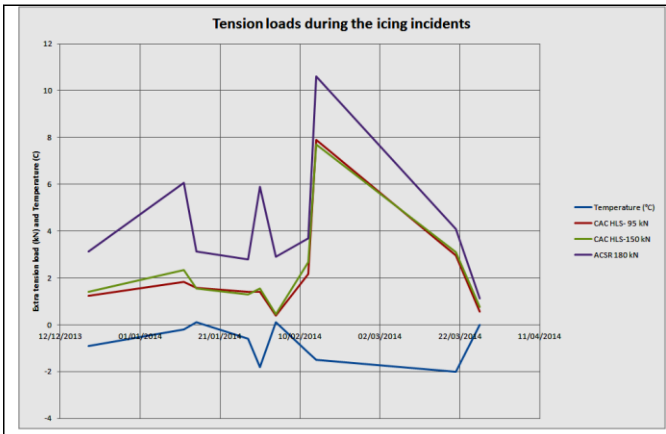

Fig 12 : Overview of stress increases experienced by strand coated CAC and uncoated ACSR..

- Coated Copper stranded yarn that shape copper cables have shown that snow and ice adheres less on it when temperature conditions are close to the 0 ° C which meets the aim of preventing collapses in OHL located in coastal areas not exceeding 500 meters above sea level located along the northern shores of the Mediterranean and other areas of similar climate.
- It can be seen that in case of lower temperatures: < - 3 ° C snow accretion increases but is always less than a non-coated cable.
- The time that the ice remains on the cable is less if it is coated: see Figure 11 in which it can be seen that a certain layer of ice remains on the cable ACSR-180 for ½ day while CAC wires lose the layer of ice accreted when the temperature reaches 0°C. Also, the ice accretion starts later in coated cables than on the uncoated. ***Then the ice layer is smaller and it remains less time over a polymeric coated copper cable***.

Further test and improvements to be carried out

A test conducted on Dead Water Fell facilities does not properly cover the area of ice and snow accretion at temperatures below - 5 ° C for long periods of time.

Tests performed are only related to one of the possible coatings whose hydrophobicity is moderate; it is of interest, to try a super hydrophobic coating: with a contact angles > 150 ° having good behaviour in the face of UV, corrosion and thermal cycles