VERY HIGH BIT RATE IN RURAL AREAS THANKS TO ADSS SOLUTIONS ON AERIAL MEDIUM VOLTAGE LINE

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SUMMARY

The telecommunications sector is crossing a strategic time in France with the deployment of next generation infrastructure, both fixed and mobile with 4G. This is for the fixed part of the gradual renewal of the historic copper local loop by a fiber optic infrastructure (FTTH). This renewal began in the mid-2000s in very dense areas, is gradually extending today to less dense areas. This is a site of considerable infrastructure of over 20 billion €.
In rural areas France is populated with a lot of small cities and villages that represent 40% of the population.
On way to reach these small cities and villages by optical cables to implement Very High Bit Rate is to use medium voltage power lines mainly operated by ERDF in France for which few millions of medium voltage towers could be used.
This paper presents the different solutions that are under development or will be implemented on these lines to get reliable installations with the minimum adverse effects or overload increase on the towers when high speed wind or a combination of wind and ice increase dramatically the cable strains on the towers.

1- BACK GROUND ON ADSS CABLES

All Dielectric Self Supported cables (ADSS) are well known solutions used on power lines for more than 25 years.
On power lines there are 4 different solutions that may be used and the selection of one or the other of these solutions depends of a lot of parameters and constrains that the power utility has to take in account. The voltage of the line is also a key parameter that will influence the final choice.
The 4 possible solutions are the following:

- **OPGW**: Optical Ground Wire. In this case fibres are incorporated in the core of the ground wire.
- **OPPC**: Optical Phase Conductor. In this case fibres are incorporated in the core of the phase conductor.
- **Lashed or Wrapped** optical cable. In this case a special small diameter dielectric cable is lashed or wrapped to a metallic conductor that may be a phase or a ground wire.
- ADSS: In this case the cable is dielectric and totally independent of the other cables of the aerial line.

In this article we will focus on ADSS cables and we will explain why this solution is the unique solution selected by ERDF in France for the installation on medium voltage lines.

1.1. – Experience on ADSS cables around the world

During the last 25 years, some hundred thousand kilometres of ADSS have been installed on power lines around the cable on medium voltage or high voltage lines. ADSS cables may be good candidates for all type of power lines but when going on high (more than 35 Kv) or very high voltage lines, it's very important to take care of the tracking effect that may occur on the cable jacket as presented on figure 1 and 2:

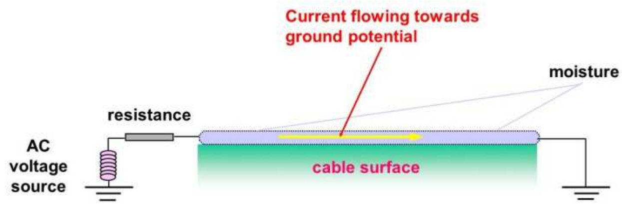


Figure 1: Current Flow over ADSS Surface

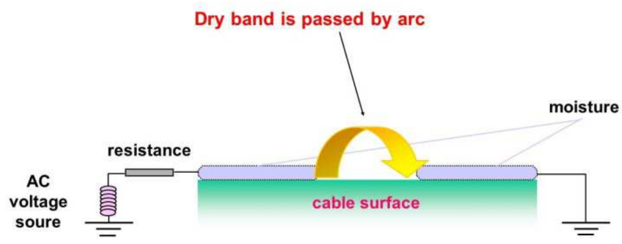


Figure 2: The Effect of Dry Band Arcing

Figure 3 and 4 represent the damage that dry band arcing may create on high density polyethylene jackets. When the field voltage where the ADSS cable is located exceed some values, variable versus humidity, pollution, marine atmosphere, then anti-tracking jacketing materials need to be used and the computation of the field voltage is also a key point in the engineering of the line. In some circumstances ADSS cables by burn under tracking effects.

Figure 3: Damages due to Dry Band Arcing on Usual HDPE Sheath

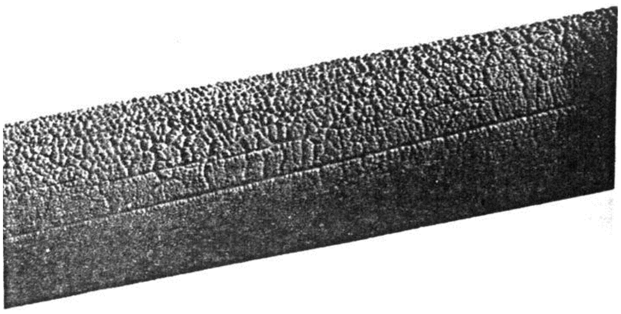


Figure 4: ADSS with Anti Tracking-Sheath after Salt Fog Test

The other important points in the design of ADSS cables are the mechanical and thermal properties such as:

- Cable diameter
- Weight
- Young modulus
- Crush resistance
- Shot gun resistance
- Creep test
- Thermal tests
- Aging tests

Just to give an idea of the mechanical constraints that an ADSS cable may support we can look at the figure 5 where we can see an ADSS cable well loaded with ice/snow. This cable was installed 18 years ago in Canada and is still perfectly in operation, including when the cable is fully loaded.

Figure 5: ADSS cables installed in Canada in 1997 and working well including when loaded with ice.

1.2. – Possible ADSS cable designs

Different ADSS cable designs are possible. The design is very dependent of the performances to be achieved and the targeted reliability and expected life time.

Based on these inputs the main designs are as presented on figure 6, 7 and 8.

Figure 6: Examples of ADSS loose tube cables generally used for longer spans

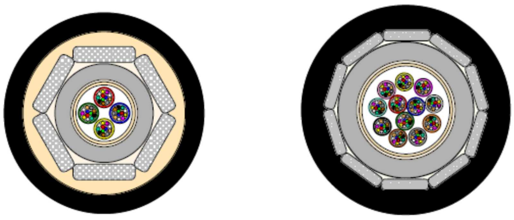


Figure 7: Examples of ADSS micro-module cables used on medium or low voltage lines and shorter spans

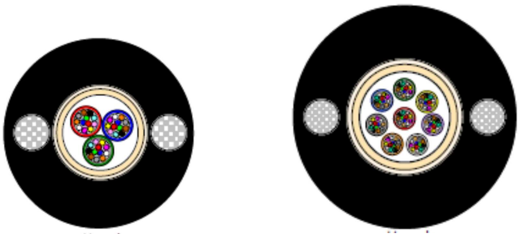


Figure 8: Examples of ADSS micro-module cables used on low voltage lines and short span (less than 70 m)

Different standards may be used as reference for the developments of which:
-IEC 60794-4-20, Optical Fibre cables – Part 4-20: Aerial optical cables along electrical power lines – Family specification for ADSS (All Dielectric Self Supported) Optical cables
-IEEE Std P1222/D21- 2009-9-29, IEEE Standard for Testing and Performance for All-Dielectric Self Supporting (ADSS) Fiber Optic Cable for Use on Electric Utility Power Lines.
In any case the applicable climatic conditions must be well specified.

1.3. Sag and tension vs Span and climatic conditions:

All these mechanical parameters need to be well computed starting from the basic mechanical equation and parameters:
When a cable is suspended from 2 points, its sag is due to its own weight. The value of the sag depends on the tension with which the cable is pulled at its ends: see figure 9.

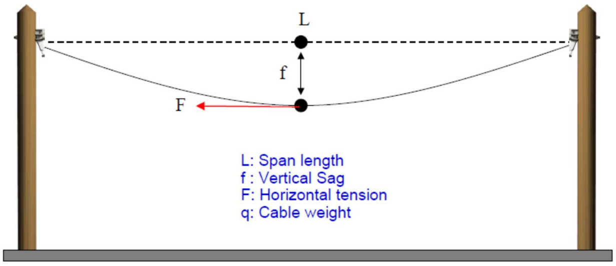
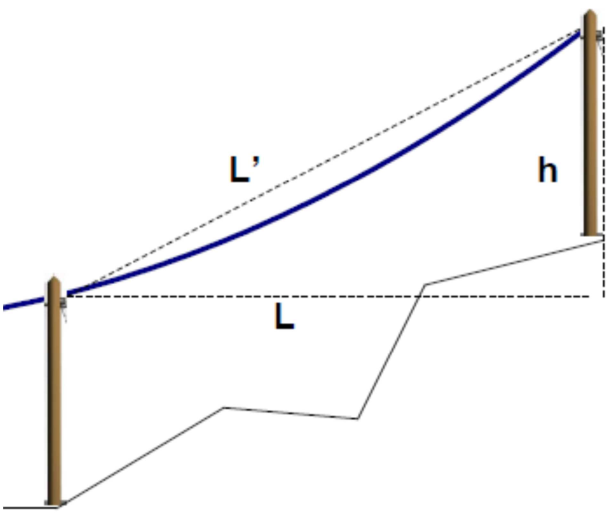


Figure 9: Catenary presentation

Catenary general equation: y-y0 =a*ch((x-x0)/a) constant a=T/q (mechanical), T horizontal tension approximation of hyperbolic functions are sufficient for almost cases: a=L*L'/8f (geometrical) T= L*L'*q/8f max
$F = L*L'*q/8/f)*\sqrt{(1+(4f+h/L)^2}$



Considering the effect is the same along the span, we can define the new position of the cable by balancing the internal forces coming from the variation of the initial cable length, and the external forces.

Sources of variations:
Cable load (ice, wind)
Temperature
Cable length (creep)
Span (DAC, pole crash)

$\Delta Lc = Lc2 - Lc1 = \mathbf{(L2 / L2')^2 * (L2^2/24) * (q2 / T2^2) - (L1 / L1')^2 * (L1^2/24) * (q1 / T1^2) = Lu(CT*(t2 - t1) + (T2 - T1)/Y + \alpha)}$

Results of computations provide a lot of information as presented on figure 10

Cable reference : **ADSS short span 3 kN**
Datasheet : **Std FADSLT-D-KP-3kN-12(12-72)**

Cable datas			Basic Hypothetis (C0)
Cable diameter:	**11,1**	mm	Temperature: **15** °C
Cable Weight:	**95**	kg/km	
Effective cross-sectional area:	**7,7**	mm²	Initial sag: **###**
Modulus of Elasticity:	**65,9**	kN/mm²	span range: **40 -> 120 m**
Thermal Elongation Coefficient:	**16,3**	*10-6/K	Denivellation :
MOT:	**300**	daN (maximum tension in operation, no fibre strain)	
MAT:	**400**	daN (maximum allowable tension)	
RTS:	**9**	kN (tension above which the cable may break, no optical consideration)	

Load Conditions
C1: NFC 11201-A1 BT A-ZVN 15 °C &wind 427,5 Pa
C2: NFC 11201-A1 BT A-ZVF 15 °C &wind 480 Pa
C3: NFC 11201-A1 BT G1 -5 °C &wind 360 Pa &ice 1 kg/m
(1) Wind applied to diameter without ice

pan (m) eniv (m)		Installation table / Behaviour against temperature (°C)											Load Conditions		
		C0	-30	-20	-10	0	10	20	30	40	50	60	C1	C2	C3
40	Sag(m)	**1,20**	1,01	1,05	1,09	1,13	1,17	1,21	1,25	1,28	1,32	1,36	1,43	1,46	1,64
0,0	max (daN	16	19	18	17	17	16	16	15	15	14	14	70	77	142
	Angle (°)												79,2	80,3	20,4
50		**1,50**	1,26	1,32	1,37	1,42	1,47	1,51	1,56	1,60	1,65	1,69	1,85	1,89	2,15
0,0		20	23	22	21	21	20	19	19	18	18	17	85	93	169
													79,2	80,3	20,4
60		**1,80**	1,52	1,58	1,64	1,70	1,76	1,82	1,87	1,92	1,98	2,03	2,28	2,33	2,69
0,0		23	28	27	26	25	24	23	23	22	21	21	99	108	195
													79,2	80,3	20,4
70		**2,10**	1,78	1,85	1,92	1,99	2,05	2,12	2,18	2,24	2,30	2,36	2,72	2,79	3,25
0,0		27	32	31	30	29	28	27	26	26	25	24	113	123	219
													79,2	80,3	20,4
80		**2,40**	2,04	2,12	2,20	2,27	2,35	2,42	2,49	2,56	2,63	2,70	3,18	3,26	3,84
0,0		31	37	35	34	33	32	31	30	29	29	28	126	138	243
													79,2	80,3	20,4
90		**2,70**	2,30	2,39	2,47	2,56	2,64	2,72	2,80	2,88	2,95	3,03	3,65	3,75	4,44
0,0		35	41	40	38	37	36	35	34	33	32	31	139	152	266
													79,2	80,3	20,4
100		**3,00**	2,57	2,66	2,75	2,84	2,93	3,02	3,11	3,19	3,28	3,36	4,13	4,25	5,07
0,0		39	46	44	43	41	40	39	38	37	36	35	152	165	288
													79,2	80,3	20,4
110		**3,30**	2,83	2,93	3,03	3,13	3,23	3,32	3,42	3,51	3,60	3,69	4,62	4,76	5,71
0,0		43	50	48	47	45	44	43	42	40	39	39	164	179	310
													79,2	80,3	20,4
120		**3,60**	3,10	3,20	3,31	3,42	3,52	3,63	3,73	3,83	3,93	4,02	5,13	5,28	6,37
0,0		47	54	53	51	49	48	47	45	44	43	42	176	192	331
													79,2	80,3	20,4

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Figure 10: Example of computed results on a dedicated cable

If we focus on some of these results, in this case we can see that for a span of 120 m we have a tension of:

- **47 daN** at 20 ° C with no wind and no ice
- **176 daN** in C1 condition: NFC 11201 A1 BT A-ZVF 15°C & wind 480 Pa
- **192 daN** in C2 condition: NFC 11201 A1 HTA A-ZVF 15°C & wind 640 Pa
- **331 daN** in C3 condition: NFC 11201 A1 HTA G1-5°C & wind 480 Pa & ice 1Kg/m

With the condition C3 we can see that the cable tension and consequently the pulling force on the poles is **7 times**

the tension at 20 ° C with no wind and no ice.
This simple computation demonstrates that it's important to take care of the potential mechanical consequences on the poles or on the towers of the addition of an ADSS cable. This why in France ERDF, thanks to Camelia software, requests to have a complete computation of the lines and to analyze the potential efforts each pole or tower will have to support.

If the analyzes demonstrate that the efforts are too high for the pole or tower then there are 2 options:

1) To reinforce or to replace the pole or the tower. This is a good solution but an expensive one.
2) To introduce a Fuse Type Suspension clamp solution. This solution allows the installation of ADSS cable on medium or low voltage lines in a competitive way and with a strong limitation of mechanical risks for the line as it's explained in the following paragraph.

2. FUSE TYPE SUSPENSION CLAMP FOR FIBER OPTIC CABLE: A NEW SOLUTION TO SECURE SHARED ELECTRICAL POLES IN CASE OF SRONG CLIMATIC CONDITIONS

The installation of fiber optic cables on existing power distribution networks allows a fast and economical deployment, especially in rural areas, which has a well meshed network. But the installation of an additional cable applies an extra mechanical load on the supports. Some poles which do not have sufficient strength could break prematurely in the case of storm, especially the alignment (suspension) poles that are the most sensitive to the load induced by a strong crosswind. To maintain an optimum reliability of electrical networks, it is necessary to check the existence of a sufficient mechanical load reserve on each support prior to installation. The mechanical calculations are usually made using Camelia software that integrates different data regarding the pole, line parameter and climate. The high cost for replacement of many poles or the implantation of intermediate poles can be avoided by the use of suspension clamps with mechanical fuse which release the fiber optic cable on the ground when the pole reaches the ultimate load as defined by the owner of the power distribution network. After the clamp triggering, the suspension pole is discharged from all efforts from the fiber optic cable, thus the pole is more resistant to the storm; continuity of the telecom line service of is also maintained. However, the implementation study shall check that there is no passage obligation under the line. In France, the utility ERDF has issued a specification (H-R22-2012-01208-EN) setting the requirements of these suspension clamps to be proposed in a range of eight mechanical fuses with a nominal value from 400 to 2000 N. The load calculation software can directly provide the value of the fuses needed.
SM-CI, a company of SICAME Group has developed a range of fuse suspension clamps type ESF FOP for ADSS cable, according to ERDF specifications. This system is sensitive to combined loads, vertical and horizontal. As the ADSS cable has a very light weight, the horizontal load becomes predominant in case of strong lateral wind, then the clamp cradle approaches the horizontal position before reaching the fuse value. The accuracy of the trigger threshold ensures an optimal protection of the pole during the network lifetime. The articulated components of the suspension assembly eliminates the bending stresses on the fiber optic cable which furthermore is protected by a unique sleeve made with soft material, and suitable for a range of cable diameter from 10 to 21mm. Finally, the installation is very fast thanks to the tool-free clamp locking device and the fastening method of the bracket by two stainless steel straps or one bolt: see figure 11.

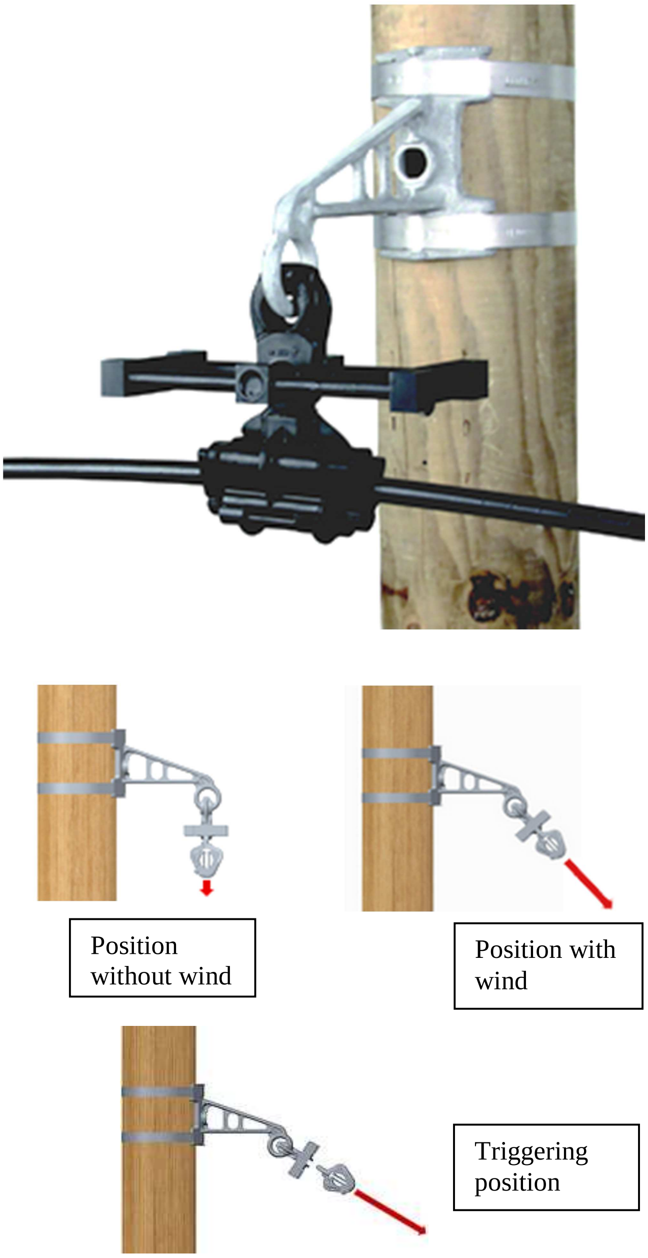

Figure 11: Fuse Type Suspension Clamp for ADSS.

3. ADSS RELIABILITY

The ADSS reliability is an important point that needs to be carefully addressed.
To be able to offer an expected life time of 30 years or more, a lot of parameters need to be taken in account by our engineers when they design the ADSS. From this long list of parameters the main important ones are:

- Span,
- Sag
- Cable diameter
- Climatic condition
- Maximum allowed fibre elongation at maximum tension
- Anti-tracking solution if needed
- Dead end clamp solution
- Shot gun resistance

We will not take each parameter one after the other but we will underline here how the shot gun resistance is important when ADSS cables are going through rural areas populated with hunters. In few cases it may be some vandalism to damage a cable but in most of the cases ADSS cables are shot when hunters are targeting birds passing in direction of aerial lines. Generally it’s a pure accident but the consequences are important with optical circuits that may be cut for more than one day and the repair may be very expensive.
Consequently it’s very important to have Shot gun resistant ADSS cables when used running in rural areas.
Different designs of ADSS shot gun resistance cables have been tested.
The most common Shot gun resistant cables are:

- ADSS with double layer of wooden aramid tape helically applied
- ADSS with a complete layer of flat FRP

Here are some pictures related to the second type of cable submitted to shot gun test according to IEC 60794-1-21:201X (86A/1638/FDIS) (EQV) specification or equivalent procedure. Figure 12 presents an ADSS submitted to the shot gun test.

Figure 12: ADSS submitted to the shot gun test.

By removing the cable outside jacket we can see on figure 13 that flat FRPs stop the pellets and consequently the modules and the fibres inside the cable are not damaged and there is no increase in attenuation.

Figure 13: Pellets are well stopped by the protection layer

Any ADSS cable designs with only one or 2 layers of stranded aramid yarns are strongly damaged and very often fibres are broken.

4. CONCLUSION

ADSS on low and medium voltage lines is a product / solution widely used around the world and very popular in some countries such as in US where this medium is largely used to bring very high bit rate in rural areas.
But as presented in this article we can see that the cable design, the compatibility with accessories, the protection (particularly shot gun resistance), the installation associated with fuse type dead end clamp to “protect” the poles or tower in case of high level of climatic over load, have to be well analysed if we want to be able to offer a reliable solution with an expected life time of 30 years.

Note:

- Figure 11 courteously proposed by SM-CI/Sicame
- All Other figures and pictures courteously proposed by Prysmian Group.