SCREEN CONNECTION FOR MV CABLES WITH LAMINATED ALUMINIUM SCREEN

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ABSTRACT

Due to a price advantage, the medium voltage cable of the future will probably have an aluminium conductor and a laminated aluminium screen. This is no problem for standard medium voltage cross sections up to 300 mm². But the increasing use of higher conductor cross sections up to 1200 mm² leads to screen currents of much more than 100 A. This current can create contact problems for the grounding devices of such a cable. Because there is no international test standard for such devices CIRED established the working group "CIRED WG 2017-1 Test Recommendation for Ground Screen Power Cable Connections"

In addition to the future results of the CIRED WG this paper gives an overview on possible screen currents and shows test results of long-term tests with different grounding devices on cables with laminated aluminium screen

INTRODUCTION

The screen design of medium voltage cables in Europe is different according to the country and the cable manufacturer. For paper-insulated cables, it is mostly a lead or an aluminium sheath.

For polymeric cables, it can be a copper wire screen, a copper tape screen, a lead sheath or a laminated aluminium screen. The medium voltage cable of the future will probably have an aluminum conductor and a laminated aluminum screen. The insulation material will be XLPE, EPR or thermoplastic polypropylene. The advantage of such a cable is low weight, low price and the cable is radial water tight due to the laminated aluminum screen.

The problem for such a cable with laminated aluminum screen is the grounding device, which is necessary to connect the screen in a joint or in a termination.

The increasing use of large conductor cross sections of 630 mm² up to 1200 mm² leads to permanent screen currents of much more than 100 A, which has an influence on the life time of the screen connection. The application of cross bonding, like in high voltage cable construction, could be a solution of the problem, but in the medium voltage level the use of cross bonding is not just yet common.

Different screen connecting devices for cable with laminated Al- screen are on the market but not all of them show a good long-term behavior. In addition there is no international standard existing to test such ground screen connections, like it is available for conductor connections in terms of the standard EN 61238-1 [1].

This paper shows an overview on MV cable designs and screen connection devices and describes a test procedure for this screen connection, developed at the University of Applied Sciences Zittau/Görlitz together with cable accessory manufacturer in Germany before the foundation of the CIRED working group. The procedure has been already applied on different alternative medium voltage cables with laminated Al- screen and different screen connection solutions. The results of the test allow the evaluation and a classification of the different tested devices.

DESCRIPTION OF MV CABLES AND ACCESSORIES

Cable screen design in Europe

The introduction of polymeric cables in the seventies was the beginning of a tremendous diversification in the cable construction. In Figure 1 only a few of more than 100 medium voltage cable solutions are visible. The screen design of a modern medium voltage cable is a copper wire- or tape screen, a lead- or aluminium sheath, an aluminium wire or steel mash screen or a combination of tape and wire screen. For all those cables, the accessories have to provide an appropriate screen connection. This is in general no problem for all kinds of copper screens using a constant force spring in combination with a copper mesh tube. But it is more difficult for all cables with laminated aluminium screen (bonded or not bonded to the outer cable sheath).

Figure 1: Selection of MV Cables in Europe

Long term experiences in France show very good results for the conductor cross section up to 240 mm² and it becomes more complicated for the range of 630 up to 1200 mm² (See [2], [3])

The MV cable of the future

The medium voltage cable of the future will be with a great probability a 100 % aluminium cable. The price and weight advantage of an aluminum conductor is in the medium voltage level an important argument. To get the cable longitudinal watertight more and more solid aluminum conductors are used. For the radial watertightness is a laminated aluminium screen the best solution. This aluminium screen can be stuck together with the outer cable sheath or not. The insulation material can be XLPE, EPR or thermoplastic polypropylene. In some cases an additional mechanical outer protection layer can be an option to make the cable laying faster and easier.

Accessories and their impact on the design of screen connection

More and more “all in one joints” require even for cables with copper wire screen a special screen connection (see Figure 2).

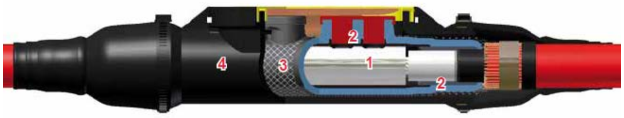


Figure 2: Screen connection by copper-mesh tube and a constant force spring

In this case it is not possible to connect the screen wires direct by a compression or shear bolt connector. Only a multipart joint, like shown in Figure 3, offers the possibility of a direct screen connection.

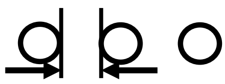
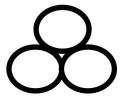
Figure 3: Direct connection of a copper wire screen

That’s why it is interesting to define test requirements for all kinds of screen connections, but especially for cables with laminated aluminium screen.

OVERVIEW OF SCREEN CURRENTS

To understand the importance of test requirements for medium voltage cable screen connections, this point will give an overview of screen current values for different cable constructions. It is calculated for 20 kV single core cables (laying in air) with three mostly used cross sections and a conductor current of 100 % of the nominal current for each cross section. For both types of the arrangement of the three cables (flat or trefoil formation). In case of the flat formation, the cables have a distance of 70 mm (see Table 1). This is the distance in Germany general use for medium voltage cables. The current in the screen is depending on the conductor current, the distance of the cables and the material and cross section of the screen.

Table 1: Symbolic for cable arrangement

Flat formation	Trefoil formation
	

Screen currents for Al-conductor and Cu-wire screen

Table 2 shows the screen current for three of the most common medium voltage cables in Europe (20 kV single core cables with aluminium conductor and the standard cross section of 150 mm², 240 mm² and 630 mm² and a copper wire screen). The flat formation shows quite high currents in the screen and for the cross section of 630 mm² the value of 216 A is critical.

Table 2: Screen currents for Al conductor cables

Conductor cross section in mm²	**150**	**240**	**630**
Screen cross section in mm²	25	25	35
Screen current in A 	82	103	216
Screen current in A 	20	27	62

Screen currents for Cu-conductor and Cu-wire screen

When in some countries copper conductors are used instead of aluminium, the nominal current of the cable is higher and so also the screen current is slightly higher (see Table 3).

Table 3: Screen currents for Cu conductor cables

Conductor cross section in mm²	**150**	**240**	**630**
Screen cross section in mm²	25	25	35
Screen current in A 	103	128	256
Screen current in A 	26	34	76

Screen currents for Al – conductor and laminated aluminium screen

The screen current in a 100 % aluminium cable depends also on the laying condition and on the thickness of the laminated aluminium screen. This thickness can vary between 100 and 400 µm. For the calculation a resulting cross section of 16 mm² (correspondent to approximately 200 µm screen thickness) and 35 mm² (correspondent to approximately 400 µm screen thickness) was assumed. The calculated screen currents are also quite high for the conductor cross section of 630 mm² (see Table 4).

Table 4: Screen currents for Al conductor cables and Al Screen

Conductor cross section in mm²	**150**	**240**	**630**
Screen cross section in mm²	16	16	16
Screen current in A	32	40	62
Screen current in A	8	10	17
Screen cross section in mm²	35	35	35
Screen current in A	70	88	135
Screen current in A	17	23	38

TEST PROCEDURE AND REQUIREMENTS

Preparation of the test specimen

Figure 4 indicate the preparation of the test specimen for the contact variants. For all cables, where the Al- screen is not stuck to the outer cable sheath, the contact device is above the laminated aluminium screen (left side of Figure 4). Is the Al screen stuck to the outer cable sheath, the contact device is underneath the screen, like the French system (right side of figure 4). The contact measuring point are indicated by the green arrows (see also on Figure 6a on the cable and on Figure 6h on the copper braid)

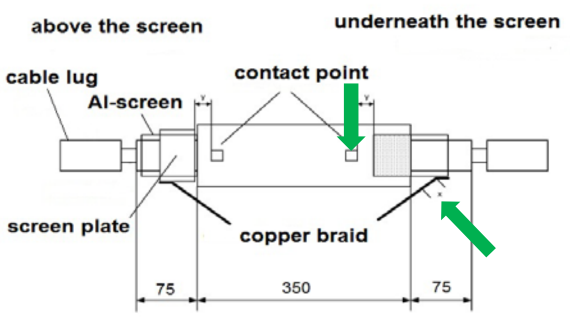


Figure 4: Test specimen

Test sequences

For each screen contact solution 3 test samples according to Figure 4 with 6 contact points were tested. Table 5 shows for 11 from more 20 tested screen contact solution the mean values and the range of the contact resistance at the beginning of the test in the year 2015 and more than 3 years later in 2018. Not all of them have seen the applied test procedure. This procedure included the resistance measurement after installation and a load cycling with a screen current of 50 A for 5 hours heating and 3 hours cooling by a constant conductor temperature of 95° C and a resistance measurement of all 9 load cycles. After 54 cycles a short circuit current of 9 kA for 0,3 seconds and continuation of load cycles up to 81 cycle and again a short circuit.

TESTED SCREEN CONNECTING DEVICES

On the market is a great variety of screen connecting devices for aluminium screened cables available. The most used design is the French screen plate according to the French standard NF C33-014 [4] with pikes from inside to outside (see Figure 5c). It is the best solution for cables with Al screen bonded to the outer cable sheath. The installation of this plate is underneath the Al screen (see also Figure 6a). For cables where the Al screen is not stuck to the outer sheath the installation above the Al screen can be better. For such an application, the screen plates with pikes from outside to inside (see Figure 5a) can be used or a screen plate without pikes (see Figure 5b). In Figure 6 only a small selection of tested screen contact solutions are illustrated.

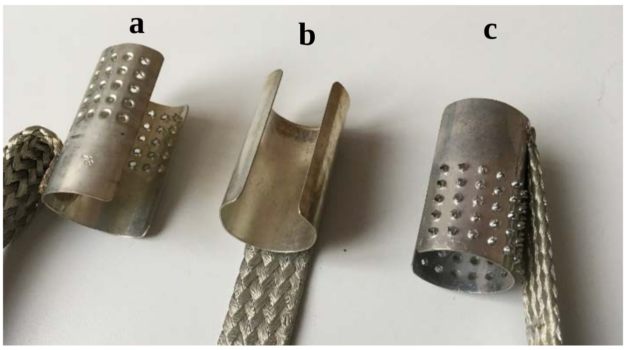


Figure 5: Different solutions for a screen plate

Description of 11 tested screen contact solutions

1. The French standard solution contact plate underneath the Al screen fixed by Ligarex (see Figure 6a)
2. Copper braid above the Al screen and contact sheet fixed by Ligarex (see Figure 6b)
3. Copper braid direct above the Al screen and

fixed by one constant force spring (see Figure 6c)

4. Copper braid via Cu- mesh tape above the Al screen fixed by one constant force spring (see also Figure 6c)
5. Copper mesh tube above the Al screen over the whole screen coverage fixed by two special clips (see figure 6f)
6. Copper braid direct above the Al screen and fixed by two special clips (see Figure 6h)
7. The French standard solution contact plate underneath the Al screen fixed by two special hose clips (see Figure 6d)
8. Copper mesh tube above the Al screen over the whole screen coverage fixed by two constant force springs (see figure 6e)
9. Copper braid above the back folded Al screen and contact sheet fixed by a hose clip (see Figure 6g)
10. contact plate according to Figure 5a above the Al screen fixed by a heat shrink tube
11. contact plate according to Figure 5b above the Al screen fixed by a heat shrink tube

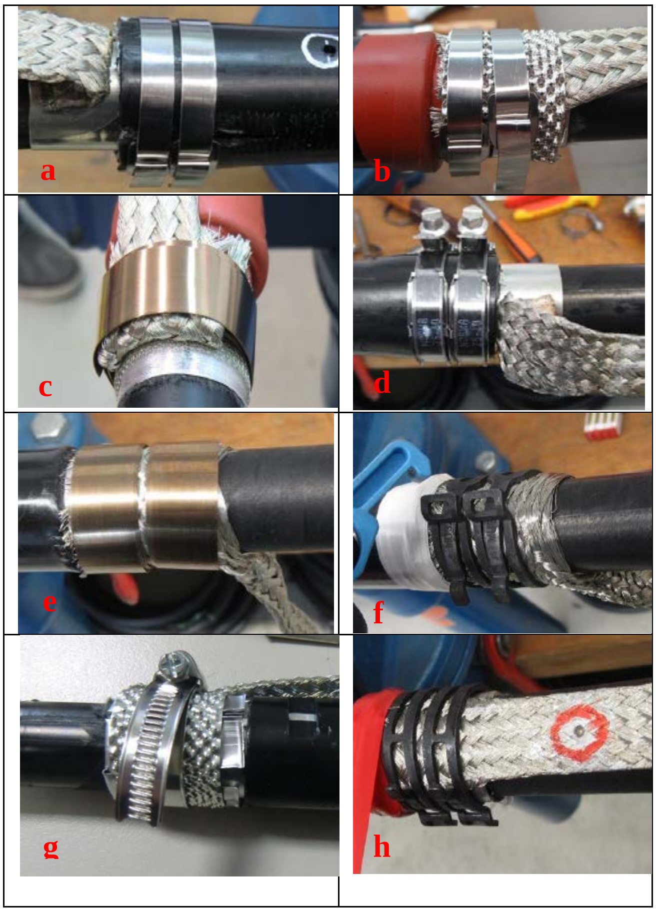


Figure 6: Photos of different screen contact solutions

Test results

Table 5 gives an overview on the contact resistance of 11 tested screen contact solutions. For each contact solution 3 samples with 6 contact points were tested. The mean value and the range between minimum and maximum value at the beginning of the test in 2015 is already an interesting information for the different contact solutions (left side of Table 5). The change of this mean value and the change of the range between minimum and maximum value after a time of more than 3 years in 2018 (see the right side of Table 5) is much more interesting. Only a few of the tested contact solutions shows a good long-term behaviour (see the green indication in Table 5).

In Figure 7 is the run of the curve of the contact resistance of contact solution number 9 in Table 5 indicated. The load cycling of the screen current increases the contact resistance of almost all samples. A short circuit of 9 kA after 54 cycles (see measuring point 6 in Figure 7) leads to reduction of the contact resistance.

A second short circuit after 81 cycles (see measuring point 9 in Figure 7) leads also to reduction of the contact resistance.

Table 5: Mean value and range of the contact resistance of 11 screen contact solutions measured in the year 2015 and 2018

Cont.	R in	µOhm	2015	R in	µOhm	2018
Sol.	Mean	Min.	Max	Mean	Min	Max
1	80	79	80	110	87	283
2	108	101	110	210	143	501
3	132	117	200	930	312	3600
4	210	174	260	1240	309	3800
5	121	115	130	560	154	1240
6	112	105	125	1570	861	2238
7	115	106	130	125	120	134
8	124	114	135	570	282	818
9	110	108	114	155	118	169
10	180	168	276	433	370	477
11	310	212	391	860	149	970

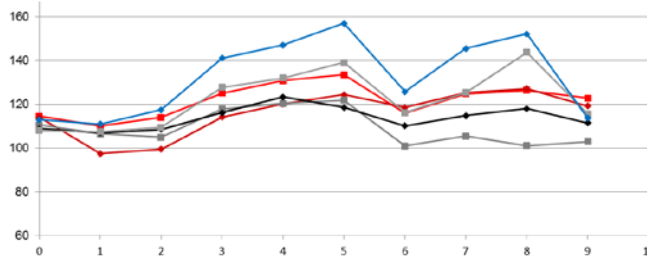


Figure 7: Contact resistance in µΩ of the 6 contact points of contact solution No 9 in Table 5

CONCLUSIONS

The test results of the 11 tested screen connection solutions in a distance of time for more than three years show clearly that only a few of the tested variants have a stable resistance behaviour. A direct contact of copper braid on the aluminium screen (see Figure 6 c, e, f, h) is not a stable contact solution. The best contact behaviour was observed by multi-contact systems (screen plate with pikes from inside to outside or contrary) but with the appropriate fixation. Such a fixation can be two Ligarex collar-ties, one or two constant force springs or two hose clips.

For medium voltage cables with laminated aluminium screen having a cross section up to 300 mm² and a maximum screen current below 50 A, according to the laying conditions, the French contact system is very good. In case of cables having a conductor cross section of more than 630 mm² the use of cross bonding could be a good solution to avoid high screen currents, contact problems and high screen losses in the cable.

The evaluation and standardisation of different contact systems for all kind of cable screen connections of medium voltage cables would be quite easy with a recommendation for a test procedure.

The CIRED WG 2017-1 will work on this and deliver a proposal.

REFERENCES

[1] EN 61238-1 EUROPEAN STANDARD "Compression and mechanical connectors for power cables for rated voltage up to 36 kV (U_m = 42 kV) Part 1: Test methods and requirements (IEC 61238-1 : 2003 modified)

[2] C. Tourcher, R. Tambrun, "Connection to MV cable aluminium screen", *CIRED 2013, paper 1018*

[3] C. Tourcher, F. Fortin, R. Tambrun "Connection to MV cable longitudinal aluminium screen", *Jicable 15, 2015, paper E9.2*

[4] NF C33-014; Screen tape for single core cables with rated voltage from 6/10 (12) kV to 18/30 (36) kV