70 YEARS OF MV CABLES IN BRAZIL, RELIABILITY OF: CABLES, SPLICES AND POTHEADS

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ABSTRACT

The electrical insulated underground cables have been installed since early 20 in this Country but a massive underground system distribution began in middle 40. In that occasion PILC cables was seen the unique solution until middle of 60 when a lot of EPR and XLPE have been installed till total replacement of PILC cables at the end of 70.As the PILC cables still continue to work at present days even the most of them spliced with EPR and XLPE, one need know how long the PILC cable endure in service in the major cities. This paper treat a large collection of cable failure during the cable life watching the modes of failure and measuring some parameters which given some indication of residual life of the PILC cables..

KEYWORDS

Cables, PILC, EPR, XLPE, Insulated Papers, Reliability

INTRODUCTION

PILC cables can be considered the best cables constructed until this moment, even watching the methods of manufacturing, skilling in splices and potheads and so on. This assessment derives of 70 years of experience and service of this kind of cables in this Country in the worst condition that one can imagine.

Nowadays there is no more a large scale cable manufacture and the Utilities which have this kind of cables maintain PILC cable splicing them with EPR and XLPE cables. The reliability work took a sample of 70 specimens of PILC and EPR XLPE installed along the last 70 years, applying Weibull statistics for time to failure (MTTF parameter). For PILC cable the same treatment have been made for loosing cellulose polymerization in order to measure the kinetics of degradation, while for EPR and XLPE water diffusion have been considered.

This investigation shows that PILC cables can be used for further time instead of to be replaced by solid dielectric cables.

SCOPE OF THE STUDY

AES ELETROPAULO began as Utility in this country at 1899 as ***The São Paulo Tramway, Light and Power Company***. In middle 1920 the first underground distributions circuits were installed, but since 1940 a massive underground lines using PILC cables has been installed. After 1970 XLPE and EPR and EPDM cablescame to replace PILC cables until 1977, when this type of cable did not any more.

Today AES has 500 km of PILC cables working, but many electrical failuresoccur and the paramount question is: “It is possible to maintain the presents PILC cables in service or should we change all of them?”

The aim of this work is to answer this question with scientific basis and in case to continue with in service to develop a method of the preventive maintenance [1].

The aim of this work concerns only in bulk statistics in whole system.

CABLES SPLICES AND POTHEADS

PILC cables have its construction summarized forward: copper (or aluminum) Conductor; double face semiconductor applied above conductor (conductive face in contact with conductor), mass impregnated paper, semi conductive layer, lead sheath and plastic covered.

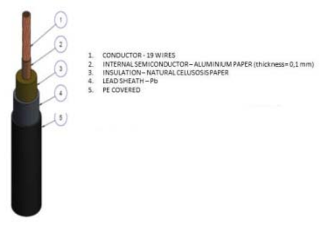

Figure 1

Original PILC cable construction

XLPE cables replace all paper parts of the PILC cables by cross linked polyethylene (even semi-conductive layers). Instead of lead sheath the metallic outer screen is constructed by copper wire tie up by a copper strip, Outer Covering extruded in plastic PE.

EPR cables have the same construction of XLPE ones replacing only cross-linked PE by cross linked EPDM. The figure (2) shows the main features of these constructions.

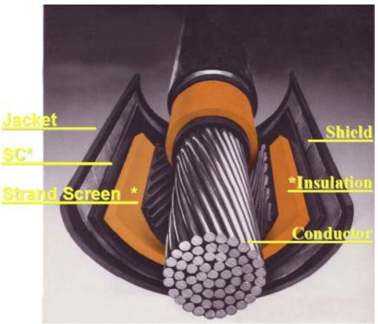

Figure 2

MV CABLES CONSTRUCTION

SPLICES and POTHEADS for EPDM and XLPE cables are the type: Pre molded or Cold Shrinkable, but for PILC cables there is the OLD constructions handle made and Hybrid constructions when one connect a PILC cable with XLPE or EPDM cables. The picture of old pothead and spliceare shown in figure (2)

Figure 3

OLD SPLICES AND POTHEADS FOR PILC CABLES

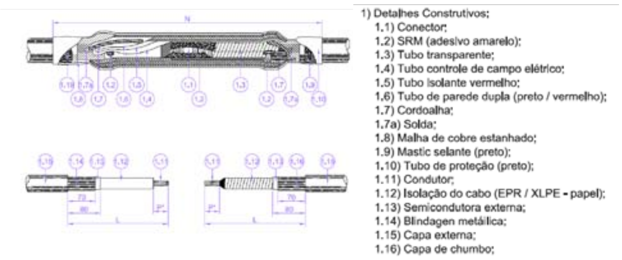

Figure 4

HYBRID SPLICES (PILC AND XLPE CABLES)

STATISTICS

The modeling of this study has been based on the reliability theory. The free variable is the time and the choose statistics of extreme value was the WEIBULL [2].

Starting of 5 parameterWeibullstatistics

$$F(E_0, t_0, \varepsilon, \tau, N) = 1 - Exp\left[-\left(\frac{E-\varepsilon}{E_0}\right)^{\beta}\left(\frac{t-\tau}{t_0}\right)^{\alpha}\right] \quad (1)$$

Where

E	$Effective\ Electrical\ field$	MV/m
E_0	$Characteristic\ electrical\ field\ (63,2\%)$	MV/m
ε	$Threshold\ electrical\ field$	MV/m
t	$Time$	$Year$
t_0	$Characteristic\ time\ to\ failure\ (63,2\%)$	$Year$
τ	$Threshold\ value\ for\ time\ failure$	$Year$
β	$Scale\ parameter\ for\ field$	
α	$Scale\ parameter\ for\ time$	

$$N = \frac{\beta}{\alpha}$$

When $E \sim Constant$ the 5 parameter weibull statistics become 3 parametric and the Weibull statistics become exponential (if, α=1)

$$F(t_0, \tau, \alpha) = 1 - Exp\left[-\left(\frac{t-\tau}{t_0}\right)^{\alpha}\right] \quad (2)$$

SAMPLES AND SPECIMEM

AES ELETROPAULO is considered a good sample for whole Brazil when the reliability is PILC cables (The others cities are Rio de Janeiro and Brasilia with systems smallest when compared with São Paulo city).

In this study a 70 specimens of PILC cables, Splices and Potheads were withdraw after 20 years to 70 years of working. All of them had some kind of electrical failure as summarized forward.

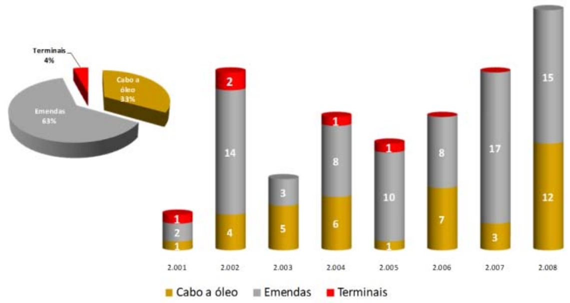

Figure 5

FAILURE IN PILC CABLE SYSTEM

DATA TREATMENT

Considering blind information (cables, splices, potheads) all failure data for PILC cables, and using equation (2) we get

	Cabo	Emenda	Total
□	3,888034	4,98497	4,935234
□	26,60286	25,05552	23,55173

t	F(t)=1-e^(-((t-γ)/η)^β)) Cabo	Emenda	Total
14	0,0791	0,0535	0,0739
15	0,1022	0,0746	0,1023
16	0,1293	0,1014	0,1379
17	0,1608	0,1347	0,1814
18	0,1966	0,1749	0,2331
19	0,2368	0,2226	0,2928
20	0,2809	0,2776	0,3600
21	0,3288	0,3395	0,4332
22	0,3798	0,4072	0,5105
23	0,4333	0,4793	0,5892
24	0,4883	0,5538	0,6663
25	0,5440	0,6281	0,7388
26	0,5994	0,6996	0,8039
27	0,6533	0,7658	0,8595
28	0,7048	0,8245	0,9045
29	0,7530	0,8741	0,9387
30	0,7972	0,9141	0,9632
31	0,8368	0,9444	0,9794
32	0,8714	0,9661	0,9893

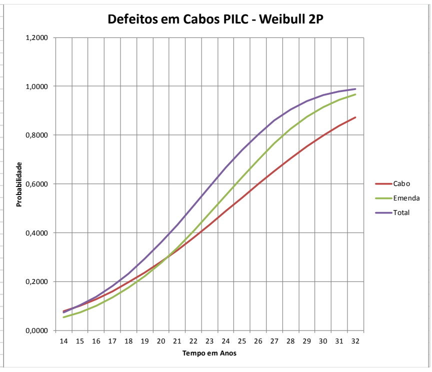

Figure 6

WEIBULL STATISTICS FOR

PILC CABLES SYSTEM

Where

β *Scale parameter*

η *Threshold value*

The threshold values for these statistics were calculated searching the best linear correlation when some value is subtracted from each time failure value. This search fits when the scale parameter calculated become close to 1 (one). These means that equation (2) looks like an exponential statistics, and no memory statistics could invocated. By other hand we have causes for the failures and all of them the exponential statistics came up as we can see in figure 7.

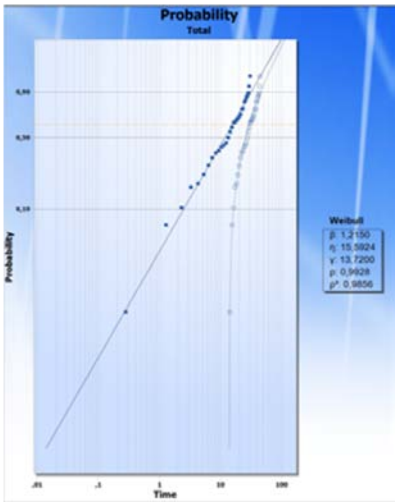

Figure 7

THRESHOLD VALUE FOR PILC CABLES, SPLICES AND POTHEADS

In order to evaluate how much of cable life consumption occurred, a kinetics of paper degradation as function of degree of cellulose polymerization was measured. Decrease of polymerization degree is associated to ageing of material specially connected to electrical and thermal effects. In the next figure 8 is shown the evolution of probability in Weibull concept of the DPol as function of time

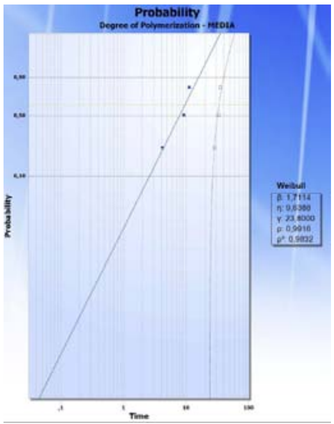

Figure 8

DEGREE OF POLIMERIZATION OF THE CELLULOSIS

If the thermal and electrical effects are the unique ageing mechanisms PILC cables can be used further on. Although, splices (special hybrid ones) are responsible by 63% of all failures, which means that ulterior attention must over then.

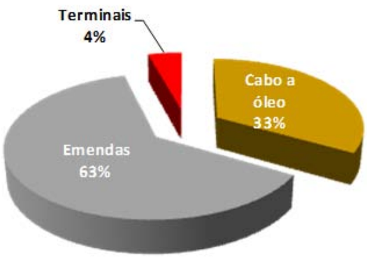

FIGURE 9

SHARED FAILURES: PILC CABLES,

SPLICES AND POTHEADS

CONCLUSIONS

Based in this preliminary analysis we are recommending:

1-To keep in service all PILC cables in network of São Paulo City.

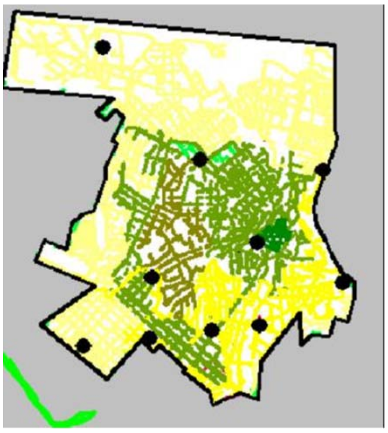

Figure 10

NETWORK SYSTEM 13,8 KV 20KV

AND 35KV IN DOWNTOWN

2-To improve the design of the hybrid splices

3-To install over Downtown network a real time system of the partial discharge detection over PILC cables area.

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[2] The Weibull Analysis Handbook, Second Edition, Bryan Dodson, ASQ Quality Press, 2006, 167 Pages.