ELECTRICAL STRESS CONCENTRATION AT THE TERMINALS OF M.V. & H.V. XLPE CABLES

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Abstract

Longitudinal and radial stresses in a M.V. and H.V. cables through terminals are computed using Schwarz Christoffel transformation for field sketching.

The terminals and associated cable are rated at 11KV, 33KV and 132KV a.c insulated by cross–linked polyethylene (XLPE). The electrical field sketching at the cable terminations is carried out theoretically and the results are confirmed by experiments.

It seems that the maximum stresses occurs in the cable insulation and the maximum longitudinal stresses along the screened outer surface of the cross-linked polyethylene (XLPE) insulation occurs between the cable and the termination center.

The results show that the maximum longitudinal stress is many times the oncorrespding maximum radial values.

Key Words: Stress distribution for XLPE cable, Termination of XLPE cables

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Introduction

Cross-linked polyethylene power cable have been widely used for M.V., H.V. and recently EHV distribution systems on the world. Because of its many advantages in compression with oil-impregnated paper cables.

Such as easy-maintenance and easy handling in addition to the fact that no oil is used most newly insulated 11KV, 132KV transmission lines have used cross-linked polyethylene (XLPE) cables.

In addition approximately many thousand of kilometers cables class cross-linked polyethylene (XLPE) cables are now in service in Iraqi national grid.

In determining the construction of the outdoor sealing ends its must be considered that the stress distribution on the surface of the busing is always uniform. Stress relief core type sealing ends are generally adopted for the construction of sealing ends for cross linked polyethylene (XLPE) cable below 195KV cable classes .For extra H.V cables, stress relief cone a high stress concentration occurs at the lower part of the bushing surface, which may cause surface flashover at the voltage lower than the required. Condenser Cone and oil-impregnable paper can be used to avoid the above problems. In the present paper most of the samples used 11KV, 33KV and 132KV are of cross-linked polyethylene (XLPE) cables used in the Iraqi network. Such systems are suffering from many faults in the cable termination especially at a distance of a bout 90-cm from the cable ends.

Theoretical Analysis

At rated supplied a.c voltage on a cable the stress can be given by the following equations [1-3].

The stress near conductor E_r is,

$$E_r = \frac{V}{r \, \ln R/r}$$

And the stress near sheath E_R is,

$$E_R = \frac{V}{R \, \ln R/r}$$

Where V : supplied voltage in Kv

R : Radius of conductor in meter

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This means that the maximum stress is usually near the conductor area .In a.c cables at no load and at load, the stress distribution around the cable is seems to be linear.

In both cases of no load and full load the region near the conductor suffers from high stress and that stress seems low at the region near the sheath.

At cable terminals the electric field (stress) seems to be non-uniform because of the longitudinal stress [4-6].

In order to sketch the non-uniform field at the cable terminals, the method called Schwarz Christoffel transformation is used in this work, this method is a very accurate [3][6].

The general form of this method is [3][5]:

$$\frac{dZ}{dW} = S(W-a)^{\frac{\alpha}{\pi}-1}(W-b)^{\frac{\beta}{\pi}-1}(W-c)^{\frac{\gamma}{\pi}-1}(W-d)^{\frac{\delta}{\pi}-1}\ldots$$

Where S: rotation constant.

a, b, c, d : Values on the real axis used to assure transformation conditions

$\alpha,\beta,\gamma,\delta$: Right or zero angle of the polygon.

By this method any polygon in Z-plane can be transferred to the upper half of W-plane. The polygon sides of Z-plane became the real axis of the W-plane as shown in fig (1).

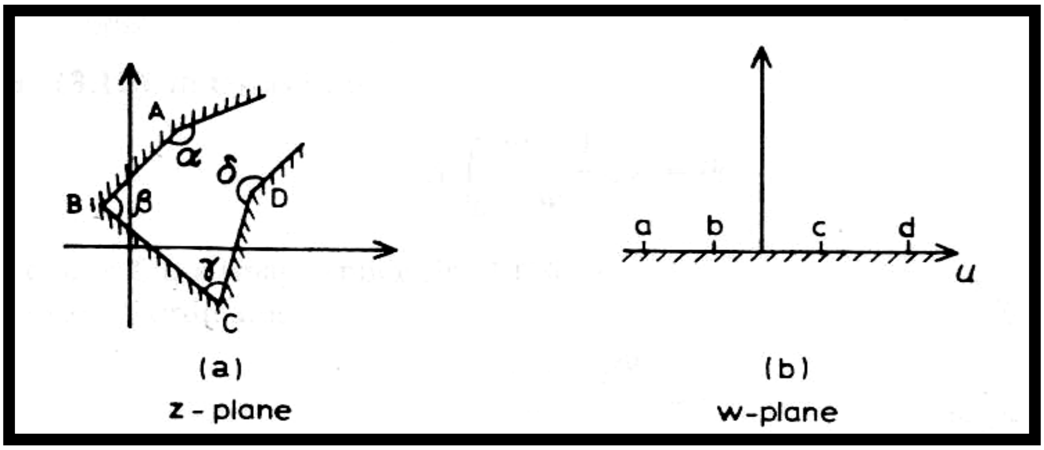

Fig (1)
Representation of Schwarz Christoffel transformation

The values a,b,c,d shown in the general form can be used in order to assure the transformation conditions shown above .The values $\alpha,\beta,\gamma,\delta$ represents the right angles or the zero angles of the polygon .S is a constant of scale rotation and A,B,C,D are representing the vertices of the polygon .

For a certain cable two angles are used, the first $\alpha = 2\pi$, and the second $\beta = 0$. As shown in fig (2) and the representation of Z-plane and W-plane both and $C' = -\infty$, $b' = +\infty$ [3].

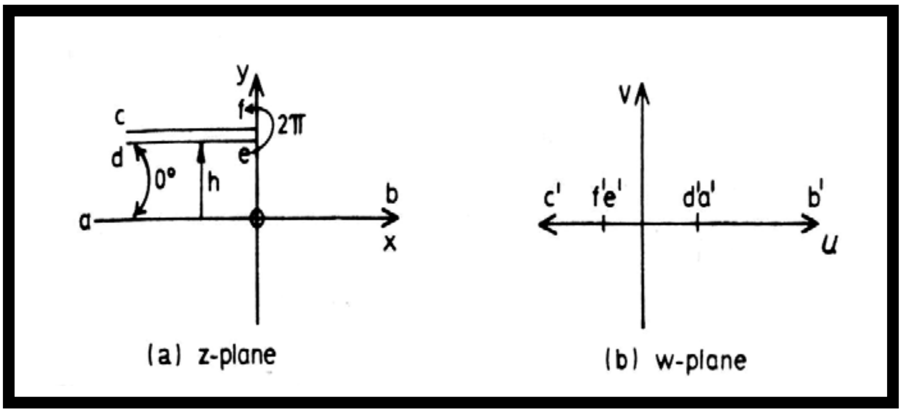

Fig (2)
Representation Schwarz Christoffel transformation for cable termination

The above equation will be:

$$\frac{dZ}{dW} = S(W-a)^{\frac{\alpha}{\pi}-1}(W-b)^{\frac{\beta}{\pi}-1}$$

a , b represents the values located to assure the transformation condition of ($a=-1$) and ($b=0$) , and the equation will be;

$$Z = S(W + \ln W) + k$$

The two unknown values $S \,\&\, k$, can be used as

$$S = k = \frac{h}{\pi}$$

Where h = conductor radius
So that the equation will be;

$$Z = \frac{h}{\pi}\left[W + \ln(W) + 1\right]$$

This equation represents the form of the equipotential lines.
From transformation condition and the arrangement in the above form a new form of equation can be developed as;

$$Z = \frac{h}{\pi}(e^{\omega} - \omega + jh)$$

This equation represents the form of the flux lines.
By representing the real and the imaginary parts from the above equation and plotting them the field distribution around the cable conductors can be defined.

Experimental work

In order to define the field concentration around the conductors at the cable terminals, many samples supplied from the Iraqi H.V transmission and distribution board in the north area are used at voltage levels of 11KV, 33KV, and 132KV.The samples are supplied by its rated voltage in H.V laboratory and kept on no load. The field distributions around the cable terminal are defined by using iron granules. The concentration of the iron granules gives a real sketching to the field distribution at the cable terminal. The Voltage is supplied by using H.V. test transformer of rated 100KV connected in cascade. The results obtained in the present work.

Theoretical and Experimental Results

The field distribution around the conductor at the cable terminal is computed by using a computer program based on the mathematical approach given above. The results given in fig (3) and fig (4). Shows that the field concentration are in the cable insulation a round the cable conductor at the cable termination. The experimental results given in fig (5) and fig (6) show that the field concentration are also in the same area as given in the theoretical work.

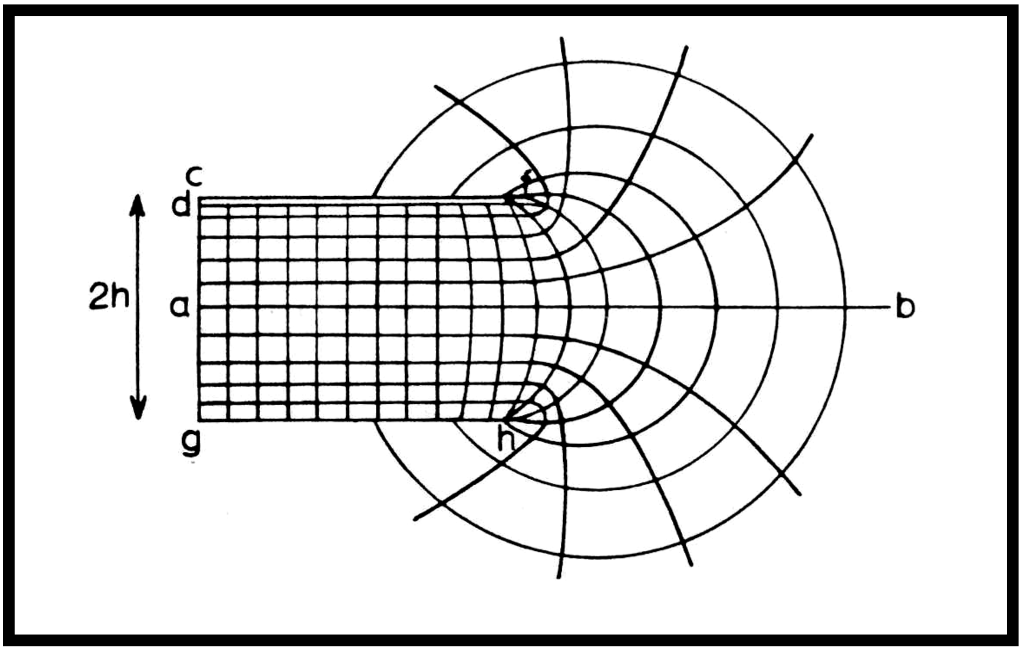

Fig (3)

Field map representation for cable termination (theoretical)

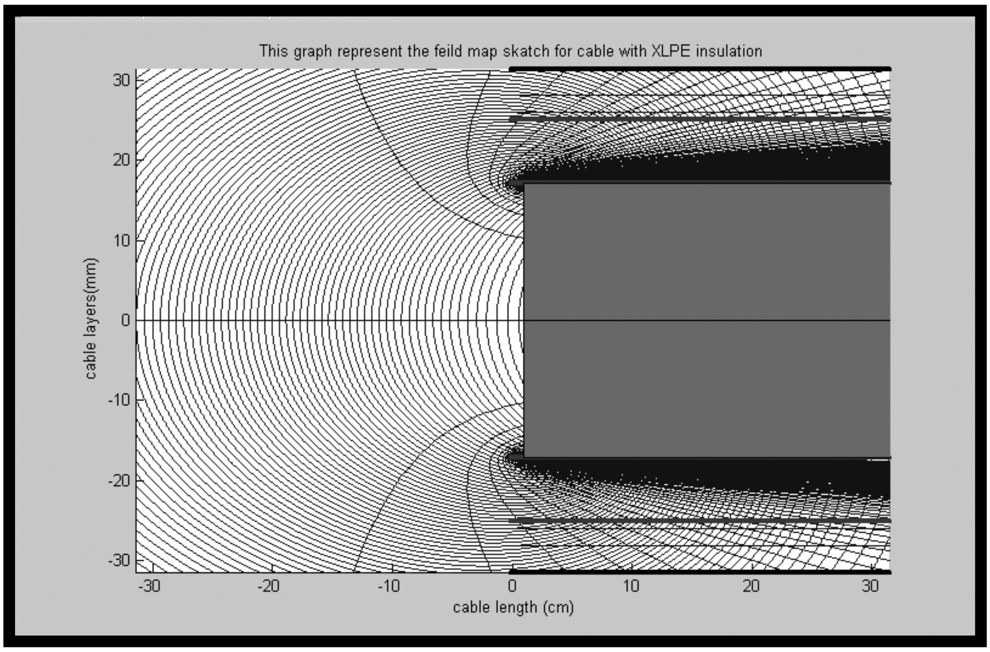

Fig (4)
Field map representation for cable termination
(by computer program " MATLAB 6.5 ")

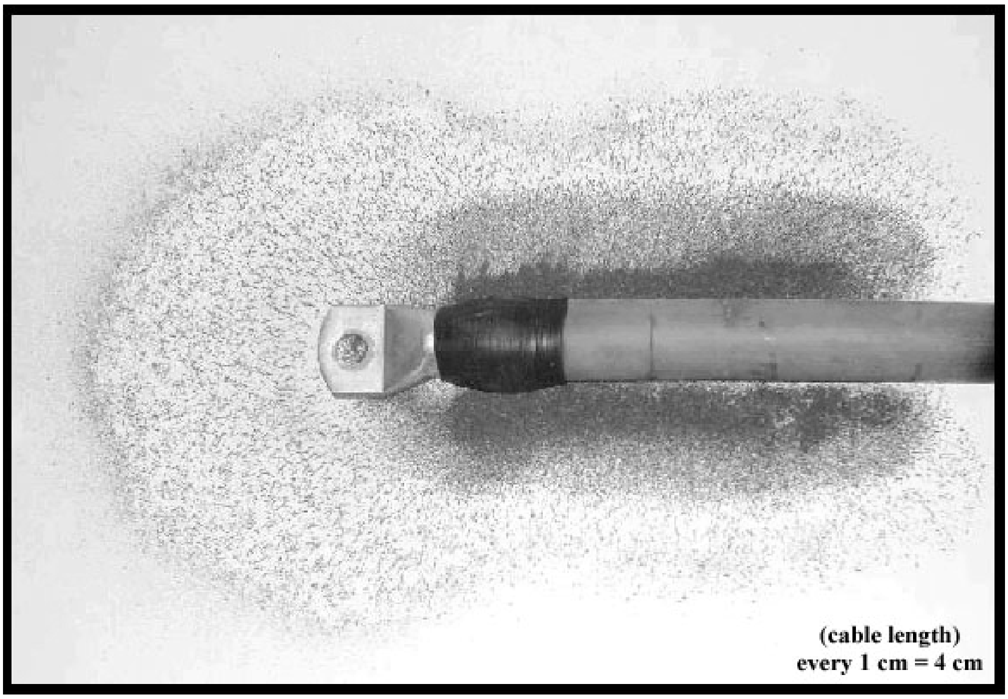

Fig (5)
Experimental field distribution for cable termination with XLPE layer only and for cable rated 33KV

Fig (6)
Experimental field distribution for cable termination with all cable layers & for cable rated 33KV & for length 90-cm

At loaded cable the field concentration became less concentrated due to the results given in fig (7).

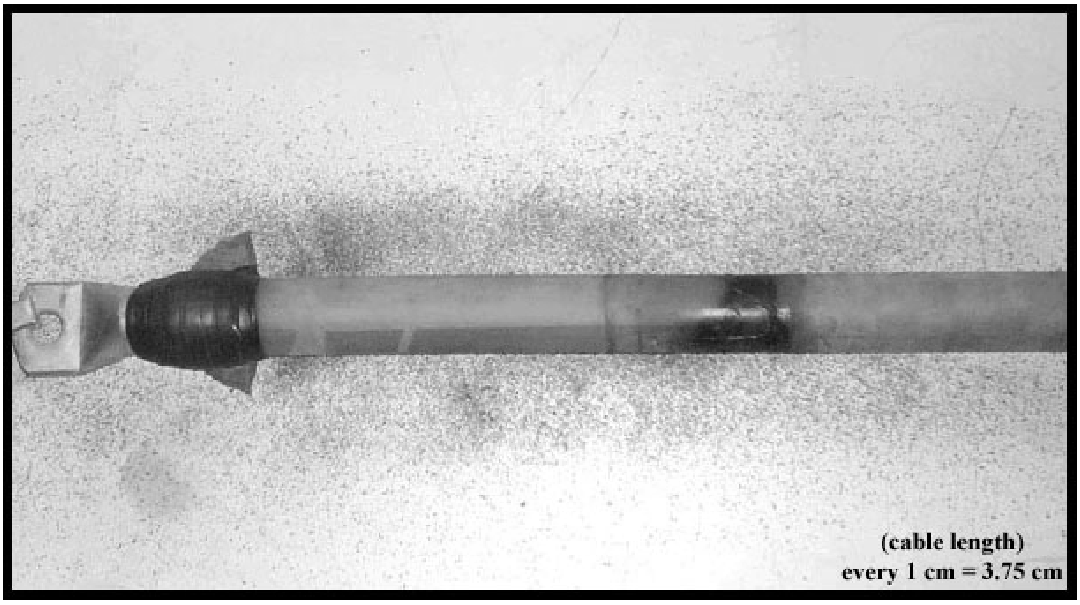

Fig (7)
Experimental field distribution of the cable at 10% load

Conclusions

The field concentration around the cable conductor at the cable terminals is defined by longitudinal and radial stresses in M.V and H.V cables. The computed results are carried out using Schwarz Christoffel transformation subjected to a computer program and such results are confirmed by experiments. Both theoretical and experimental results are consist with each other and shows that the field are concentrated around the cable conductor at cable terminals and also in the cable insulation and such concentration becomes less as far as the distance increased from the cable end. Such field concentration is responsible for cable failure at the termination and especially at distance of less than one meter from the cable end.

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