CROSS-BONDED CABLES

AND

ANALYSIS OF NON-LINEARITIES

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SYNOPSIS

The present work investigates the problem of determining transient overvoltages in cross-bonded cable systems. It improves the efficiency of computation by determining short-cut methods and by organising the inverse Fourier transform in a more efficient manner. It also investigates the effect of assuming zero earthing resistances at the major bonding points wherein the analysis is simplified considerably.

This work also presents the difficulties encountered in representing non-linear voltage limiting devices when Fourier analysis is used and investigates an alternative method of analysis involving Duhamel's integral.

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LIST OF SYMBOLS

A, B	Parameters of 2 port network
Z, Y	Series impedance and shunt admittance matrices
P	Matrix Product Z.Y
Q	Modal Matrix of Matrix P
γ	Propagation Matrix
k	Eigen Value Matrix of P
Y_o	Characteristic Admittance Matrix
f	Frequency (Hz)
w	Angular frequency corresponding to f
T_o	Time of observation
w_o, f_o	Fundamental frequency associated with inverse Fourier transform
α	Parameter of modified fourier transform (shift factor)
n_f	Number of frequency steps considered
N	Number of time steps considered
t	Instant of time
x	Position considered along cable
ℓ	Length of one Major section
V	Voltage vector
I	Current vector
f(t)	Function of time as used in the fourier transform
F(w)	Fourier transform of the time function f(t)
c, s	Subscripts relating to the core & sheath
R_1,R_2,R_3	Slope resistances corresponding to the three regions of the non-linear CCPU characteristic

CHAPTER 1

INTRODUCTION

Cables are used extensively in built-up areas to distribute electric power at relatively low voltages. Moreover, when overhead lines prove unacceptable for aesthetic or technical reasons, underground cables are also used at extra high voltage for bulk transmission. In the latter case an end to end cable system is quite complex in configuration as it involves sheath cross-bonding, transposition, solid bonding points, single point bonded sections and non-linear devices for sheath voltage control under transient conditions. Consequently, the very important transient analysis of the system cannot be carried out in a straight-forward manner. Inevitably certain simplifying assumptions are introduced.

The present work endeavours to apply the modified Fourier transform approach in such a way that computation times are improved as much as possible without a significant loss of accuracy in system representation. In addition, difficulties involving the representation of non-linear cable covering protection units (CCPU's) are investigated by employing a substantially different approach to that which extends the Fourier transfom method to include such non-linearities.

In his earlier work on cable transient analysis, Wedepohl[1] used the Laplace transform/Lattice technique, assuming all the parameters of the cable to be frequency independent. However it was found that ground return path effects are particularly important so that frequency dependence in cable systems should always be considered. If frequency dependence is taken into account there is no analytic solution. Wedepohl then based his analysis on natural modes of