NEW TECHNIQUE FOR POWER TRANSMISSION (A BEAM OF CONDUCTORS) MATHEMATICAL MODEL - NUMERICAL SIMULATION

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ABSTRACT

In case of short-circuit the beam of conductors are submitted to forces of electromagnetic origins susceptible to cause a throttle of the beam. The numerical study of this complex dynamic poses two significant problems.

- The first is due to an electrical connection between sub-conductors.
- The second is due to the mechanical impact between conductor elements upon contact. Indeed the introduction of shock introduces important nonlinearities (Variation of the stiffness elements in contact between zero and infinity).

Key words: Power Transmission, Numerical Simulation, Model, Conductor.


1. INTRODUCTION

In Europe, the most common standard voltage for large power transmission is 420 kV. In Cameroon, they 220 kV and 420 kV inevitably will reach for the interconnection between the countries of the Central Africa. For these voltage levels, the conventional technique of the transmission lines of the energy used so far, which is to take only one conductor per phase, must give way to more tailored structures (Beams drivers) So lines and busbars’ job will consist of several sub-conductors per phase (2.3 or 4 sub-
conductors). This geometry is needed to maintain the electric field below the corona threshold.

If current system, drivers undergo forces of electromagnetic origin that cause a 'choke' the beam. The result is a brutal combination of sub-state followed by contact (Clash between sub-conductors).

The phenomenon occur a few milliseconds after the fault causing a very substantial increase of the mechanical tension. The latter is transmitted to the whole structure (insulators, poles, gantries) as a pulsating force. The structure responds dynamically and interacts with the sub-state in a very complex depending on its mass, stiffness and other parameters.

Conclusion: The bundle structure appears imperative and solves the problem of large electric power transit. But the dynamic process must be well controlled to allow for accurate determination of the mechanical forces generated throughout the structure in order to achieve an optimal design.

2. MATHEMATICAL MODEL
First, to fix ideas we give the scheme a bundle of two conductors (Fig 1).

2.1. Assumptions and choice of mechanical formalism

- We neglect the bending stiffness of calces.
- We believe that the clash between sub-conductors is inelastic and that all the impact energy is transformed and heat.
- We neglect structural damping as well as externally
- The formalism will be the total Lagrangian.
- The structure is discretized into finite elements.

The rationale for these assumptions is amply detailed in [2].

2.2. Variational formulation of the problem

The elastodynamic flexible conductors has been studied by several authors, recently a comprehensive study [1] guided us to study beams.

We opted for the Hamilton principle:

$$\delta \int_{t_1}^{t_2} (T - U) dt = 0$$

$T$ is the kinetic energy of the cable $U$ is the total potential energy of the cable. It includes the potential energy of deformation of the cable over the potential energy of external loads.

The equation of virtual work governing the transitional regime for cables stretch is given by:

$$\int_{0}^{10} \left[ (-\rho_0 A_0 U_t + F^c_i + F^{NC}_i) \delta U_t - N \delta g \right] ds = 0$$

$\rho_0$: Density Cable
$A_0$: Right Section
$F^c_i$: Conservative force per unit length
$F^{NC}_i$: Non-conservative force per unit length
$U_i$ : Moving a material point of the cable

g: Measurement of Green deformation

N: normal force (voltage) in a cable

$S_0$: Current coordinate along the cable

2.3. Theory of contact

During the dynamic evolution in a beam, sub-conductors are subject to a series of shocks and separations. The modeling of a shock followed by a gradual bonding of sub-conductors introduces important nonlinearities. Several aspects will be taken into account [1], [2]

- The contact modeling
- The determination and introduction of contact conditions
- The incorporation of constraint equations, with the equations governing the other structure
- The preparation of initial conditions after contact;

After discretization of the beam (Fig 2), a number of nodes enter in contact. SAMCEF the library [3] provides a nonlinear stress element [4]. We adapted this element contact problem in the beam. This item will introduce six nonlinear constraints. Thanks to the scale factor, the tangent stiffness matrix remains well conditioned so that upon contact through separation.

The determination of the contact is based on two conditions:

- The distance between two nodes ($N_1, N_2$) candidates for a possible contact is equal to the diameter of a conductor (DIST)
- Efforts between $N_1$ and $N_2$ calculated from the Lagrange multiplier $\lambda$ are correspond to a compression ($\lambda > 0$). The region thus corresponds to a contact 1 (Figure 3).

The constraint equations for two nodes $N_1$ and $N_2$ along the axis OX:

$$C_x(q) = (CN_{1x} + DEPN_{1x}) - (CN_{2x} + DEPN_{2x}) = DIST_x$$

$C_x(q)$: Equation corresponding to stress on conveying

$CN_{1x}, DEPN_{1x}$: Coordinate and displacement of the node $N_1$

$DIST_x$: The distance between two nodes in contact.

A similar calculation is done for the other directions.
The constraint equations will be incorporated into the overall equation through the Lagrange multipliers.

3. DIGITAL MODEL

3.1. Spatial discretization
We opted for the finite element formalism especially given the basic software SALCEF. This will allow us to introduce new elements while keeping its disposal SAMCEF library.

Flexible structures (beams) are discretized CABLE element (1, 2 or 3 degrees), rigid structures are discretized in BEAM elements. The contact is shown by a nonlinear element constraint.

The discrete form of the equation of virtual work is given by:

\[ \delta q^T.[-M \ddot{q} + G_{ext} - G_{int}] = 0 \]

We derive the equation of dynamic equilibrium:

\[ M\ddot{q} = G_{ext} - G_{int} \]

\( q \): Moving generalized for a cable element
\( \ddot{q} \): Acceleration
\( G_{int}, G_{ext} \): Internal and external generalized forces
\( M \): mass matrix of a cable element.

3.2. Time discretization
Nonlinear differential equations resulting from the spatial discretization into finite elements undergo temporal integration step. The chosen time integration scheme is HHT (Hilbert - Hughes - Taylor), derives from the Newmark method [5]. This method has the advantage of introducing an artificial damping.

4. SOFTWARE DEVELOPED
The software developed based on the finite element generalizes CABLE module SAMCEF the problems of contact (shock) in nonlinear transient and takes into account large displacements.
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Currently, the module can calculate different structures (one conductor per phase or beams), taking into account all the components of the structure (frame, support or anchorage insulators bypass). [6], [7]

The perfect agreement between the results and experimental results (with EDF France and Holland KEIMA) (Fig 4) make it a powerful and unique tool. Finally we have the experimental film directed by EDF station 'Renardièr': and the film of our numerical simulation of the same station. This original and rich teaching document, a support video and can be viewed.

REFERENCES

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