Modelization of the cables

Summarized:
The cables are flexible structures which can undergo large displacements. Their analysis is thus nonlinear. From the mechanical point of view, a cable cannot support any moment and is not the seat that of a normal force called tension. The statement of the virtual work and its differentiation compared to displacements lead to the modelization in finite elements: stiffness matrix depending on displacement on the nodes and constant mass matrix. One presents the iterative algorithms static and dynamics. Two examples are given: one, static, is the search of the figure of equilibrium of a cable subjected to a given horizontal tension; the other, dynamic, is the comparison between computations by finite elements and of the test results of short-circuits. Finally four appendices treat: computation of the forces of Laplace, change of the temperature of a cable subjected to the Joule effect, force exerted by the wind and of the modelization of the operation of installation.
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1 Notations

\( A \) area of the cross-section of the cable.
\( B \) matrix deformation.
\( C_v \) voluminal heat of conducting metal.
\( E \) Young modulus to the tension.
\( E_u \) current modulus of the cable.
\( E_c \) modulate with compression.
\( F_{\text{ext}} \) external forces given.
\( F_{\text{inc}} \) inertia forces.
\( F_{\text{int}} \) internal forces.
\( g \) measure of Green of relative lengthening compared to the situation of reference.
\( h \) thermal convection coefficient of a cable with outside.
\( i \) instantaneous flow intensity.
\( k \) coefficient of variation of the resistivity with the temperature.
\( L_i(\xi) \) shape function relating to the node \( i \).
\[ \begin{bmatrix} L_1(\xi) & L_2(\xi) & L_3(\xi) & \ldots \end{bmatrix} \]
\[ \begin{bmatrix} \frac{dL_1}{d\xi} & \frac{dL_2}{d\xi} & \frac{dL_3}{d\xi} & \frac{dL_4}{d\xi} & \frac{dL_5}{d\xi} & \frac{dL_6}{d\xi} & \frac{dL_7}{d\xi} & \frac{dL_8}{d\xi} & \frac{dL_9}{d\xi} \end{bmatrix} \]
\( N \) tension of the cable.
\( s_o \) curvilinear abscisse on the cable in situation of reference.
\( T, T_o \) temperature in current situation and situation of reference.
\( u(s_o, t) \) vector displacement at time \( t \) compared to the situation of reference.
\( x(s_o) \) vector position in situation of reference.
\( \alpha \) thermal coefficient of thermal expansion.
\( \beta, \gamma \) parameters of Newmark.
\( \rho \) density.
\( \sigma \) resistivity.
\( 1 \) stamp unit of order 3.
\[ \begin{bmatrix} \frac{\partial}{\partial s_o} \end{bmatrix} \] diagonal matrix
\[ \begin{bmatrix} \frac{\partial}{ds_o} & \frac{\partial}{ds_o} & \frac{\partial}{ds_o} \end{bmatrix} \].

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2 Introduction

the essential characteristic of the cables is that these are flexible structures, whose mechanical analysis is nonlinear because they are likely to undergo large displacements. They undergo some during the operation of installation, when one adjusts deflections to respect stresses of environment.

Thereafter, the cables can be animated motions of great amplitude under the impulse of the forces of Laplace or blast, fall pressure of sleeves of white frost, in the event of incident, resulting from flows of short-circuit. They exert then on their supports of the forces much higher than the static forces. One must take of it account in the design of the works.

For the old works, which can be subjected to intensities of short-circuit increased because of the extension of the network, it should be checked that reliability is always assured.

3 Mechanical assumptions

the cables are regarded as perfectly flexible wires, which can support any moment, neither bending, nor of torsion, and are the seat only of one normal tension. This tension plays the part of a generalized stress.

One wants compared to to calculate the field of \( u(s_o, t) \) displacement at \( t \) time situation of reference. This one is a static configuration of the subjected cable, for example, with gravity and the temperature \( T_o \); it is defined by the field of vectors position \( x(s_o) \).

\[
\begin{align*}
\begin{array}{c}
x + u + \frac{\partial x}{\partial s_o} ds_o + \frac{\partial u}{\partial s_o} ds_o \\
x + u + \frac{\partial x}{\partial s_o} ds_o \\
x + u + \frac{\partial x}{\partial s_o} ds_o \\
\end{array}
\end{align*}
\]

**Figure 1**: Length of cable in situations of reference and moved

Like [bib1], one compared to the takes for strain the measure of Green of relative lengthening situation of reference [Figure1]:

\[
g = \frac{ds^2 - ds_o^2}{2 ds_o^2}
\]

\( g \) must remain small. The second member lends himself to computation because it comprises only elementary squares lengths. One sees on [Figure1] that:

\[
g = \frac{\partial x}{\partial s_o} \cdot \frac{\partial u}{\partial s_o} + \frac{1}{2} \left( \frac{\partial u}{\partial s_o} \right)^2 \tag{1}
\]

the behavior model is:

\[
N = E_a A \left[ g - \alpha \left( T - T_o \right) \right] \tag{2}
\]
4 Application of the Principle of the Virtual works

If one does not take depreciation account, the virtual work of all the applied forces to a length of cable during virtual displacement $\delta \mathbf{u}$ is:

$$W(u, \delta \mathbf{u}) = W_{int}(u, \delta \mathbf{u}) - W_{iner}(\dot{u}, \delta \mathbf{u}) - W_{ext}(u, \delta \mathbf{u})$$  \[3\]

by distinguishing works from the internal forces, the inertia forces and the external forces. According to [eq1]:

$$W_{int}(u, \delta \mathbf{u}) = \int_{s_1}^{s_2} (\mathbf{N} \cdot \mathbf{d}g) \, ds = \int_{s_1}^{s_2} \left( \mathbf{N} \cdot \left( \mathbf{T} \frac{\partial}{\partial s_o} \mathbf{u} \right) \right) \, ds = \int_{s_1}^{s_2} (\mathbf{N} \cdot \mathbf{B} \mathbf{u}) \, ds $$  \[4\]

where:

$$\mathbf{B} = \left[ \frac{\partial}{\partial s_o} \mathbf{1} \right] \left[ \mathbf{u} + \mathbf{u} \right]^T \left[ \frac{\partial}{\partial s_o} \mathbf{1} \right]$$  \[5\]

while indicating by the superscript $T$ transposed of a matrix.

$$W_{iner}(\dot{u}, \delta \mathbf{u}) = - \int_{s_1}^{s_2} (\rho \mathbf{A} \dot{u} \cdot \delta \mathbf{u}) \, ds$$  \[6\]

In all the cases, we regard work $W_{ext}$ as independent of $u$ during one time step, because:

- or if it is really, in the case of conservative forces like gravity;
- or, in the case of the forces of Laplace, the applied force with a cable element depends not only on displacement on this element (conventional follower force), but still on displacements of all the cables. It is considered whereas, during one time step, the force is constant and equal to its value at the end of time step preceding.
5 Linearization

With the equilibrium:

$$W(u, \delta u) = 0 \quad [7]$$

If, except for a tolerance, the preceding equation is not satisfied, one seeks a correction $\Delta u$ of $u$ such as:

$$W(u, du) + DW(u, du) \cdot Du = 0$$

$DW(u, \delta u) \cdot \Delta u$ being the directional derivative of $W(u, \delta u)$ in the direction $\Delta u$ [feeding-bottle2] and [feeding-bottle3]. According to [éq2], one has obviously:

$$DN \cdot \Delta u = E_a A Dg \cdot \Delta u = E_a A B \Delta u$$

According to [éq5]:

$$DB \cdot \Delta u = \left[ \frac{d}{ds} 1 \right] \Delta u \int \left[ \frac{d}{ds} 1 \right] \cdot \Delta u \left[ \frac{d}{ds} \right] ds$$

Thus:

$$DW_{int}(u, \delta u) \cdot \Delta u = \int_{s_1}^{s_2} \left[ B \delta u \right] T E_a A B \Delta u \left[ \frac{d}{ds} 1 \right] \cdot \Delta u$$

$$+ \int_{s_1}^{s_2} \left[ N \left[ \frac{d}{ds} 1 \right] \cdot \Delta u \right] ds \quad [8]$$

According to [éq6]:

$$DW_{iner}(\ddot{u}, \delta u) \cdot \Delta u = - \int_{s_1}^{s_2} \left[ \delta u^T \rho A \Delta \ddot{u} \right] ds \quad [9]$$
6 numerical Realization by the finite elements

One notes by the subscript \( h \) the matrixes discretized in finite elements. If \( \mathbf{v} \) is a vector defined on the cable (position, displacement, acceleration,…) one has at the current point of a finite element of nodes \( i, j, \ldots \) : \( \mathbf{v} = [\mathbf{L}] \mathbf{v}_e \),

\( \mathbf{v}_e \) being the vector made up of the components of \( \mathbf{v} \) with the nodes. In the same way:

\[
\left[ \frac{\partial}{\partial s} \mathbf{1} \right]_{\mathbf{h}} \mathbf{v} = [\mathbf{L}'] \mathbf{v}_e.
\]

According to [éq5]:

\[
\mathbf{B}_h = [\mathbf{x} \mathbf{u}]^T \mathbf{L}^T \mathbf{L}'
\]

The internal forces \( F_{\text{int}}^e \) of a structure finite element \( e \) are the forces which it is necessary to exert in its nodes to maintain it in its current deformed configuration. According to the theorem of the virtual works for the continuums, the work of these specific forces is equal to the work of the stresses in the element, i.e. at \( W_{\text{int}} \), for any field of virtual displacement. One thus has, according to [éq4]:

\[
F_{\text{int}}^e = \int_{s_1}^{s_2} \mathbf{N} \mathbf{B}_h^T ds = \int_{s_1}^{s_2} \mathbf{N} \mathbf{L}^T \mathbf{L}' ds [\mathbf{x} \mathbf{u}]_e.
\]

In addition, one replaces the inertia forces distributed in the element by specific forces with the nodes \( F_{\text{iner}}^e \) such as their work is equal to that of the real inertia forces for any field of virtual displacement. According to [éq6], one thus has:

\[
F_{\text{iner}}^e = -\int_{s_1}^{s_2} \mathbf{L}^T \mathbf{M} \mathbf{L} ds \mathbf{u}_e
\]

In the same way, the external forces distributed are replaced by concentrated nodal forces \( F_{\text{ext}}^e \) equivalent within the meaning of the virtual wor. The differential of the virtual wor of the internal forces of a finite element of cable is written, according to [éq8]:

\[
D_h W_{\text{int}} [\mathbf{u}, \mathbf{\delta u}], \Delta \mathbf{u} = [\mathbf{\delta u}_e]^T (\mathbf{K}_M + \mathbf{K}_G) \Delta \mathbf{u}_e
\]

with:

\[
\mathbf{K}_M = \int_{s_1}^{s_2} \mathbf{B}_h^T \mathbf{F}_a \mathbf{A} \mathbf{B}_h ds
\]

\[
\mathbf{K}_G = \int_{s_1}^{s_2} \mathbf{L}^T \mathbf{N} \mathbf{L}' ds.
\]

\( \mathbf{K}_M \) and \( \mathbf{K}_G \) stiffness matrixes are called material and geometrical element. \( \{\mathbf{K}_M + \mathbf{K}_G\} \Delta \mathbf{u}_e \) is the principal part of the variation \( \Delta F_{\text{int}} \) of the internal forces to the nodes due to the correction of displacements \( \Delta \mathbf{u}_e \). The differential of the virtual wor of the inertia forces results from [éq9]:

\[
D_h W_{\text{iner}} [\mathbf{\dot{u}}, \mathbf{\delta u}], \Delta \mathbf{u} = -[\mathbf{\delta u}_e]^T \mathbf{M} \Delta \mathbf{\ddot{u}}_e
\]

with:

\[
\mathbf{M} = \int_{s_1}^{s_2} \mathbf{L}^T \mathbf{\rho} \mathbf{A} \mathbf{L} ds.
\]

\( \mathbf{M} \) is the mass matrix of the element. \( -\mathbf{M} \Delta \mathbf{\ddot{u}}_e \) is the variation \( \Delta F_{\text{iner}} \) of the inertia forces to the nodes due to the correction of acceleration \( \Delta \mathbf{\ddot{u}}_e \).
7 Typical case of the cable elements with two nodes

These elements are 1st degree: they are thus right in position of reference and remain right in deformed position.

No moment is applied in their ends and they are the seat only of one uniaxial stress. They are thus elements of bar.

In other words: to model a cable by elements with two nodes comes down comparing it to a character string whose links (cable elements) would be articulated perfectly between them.

On the other hand, the cable elements having more than two nodes in general have a variable curvature with the strain. One cannot thus treat them like elements of bar.
8 Use in Code_Aster

This paragraph indicates how one introduces the cables into the commands concerned of Code_Aster.

<table>
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<th>Key word</th>
<th>Argument</th>
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<td>CABLE</td>
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<td></td>
<td></td>
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<td>Ratio of the bulk modulus (very weak and being able to be null) on the modulus.</td>
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<td>GROUP_MA</td>
<td>Name of the mesh group supporting a cable.</td>
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<td></td>
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<td>COMP_ELAS</td>
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<td>Name of the mesh group supporting a cable.</td>
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9 Problem static

This problem is that of the search of the equilibrium of a structure of cables in position unspecified and subjected to a system of forces given.

9.1 Iterative algorithm

the balance equation, forms discretized [éq7] and [éq3] without the term of inertia, which must be satisfied in each node, is:

\[ F_{\text{int}} = F_{\text{ext}} \]  \[ \text{[10]} \]

Let us suppose that one has just calculated the field of displacement of the cables \( u^n \mid s_o \) , with the iteration \( n \) :

- if this field makes it possible to satisfy, except for a tolerance, with [éq 9.1-1], one considers that line:
  \[ x \mid s_o + u^n \mid s_o \]
  is the figure of equilibrium of the cables;
- if not, one calculates corrections of displacement \( \Delta u^{n+1} \) by the linearized system:
  \[ \left[ K_M^n + K_G^n \right] \Delta u^{n+1} = F_{\text{ext}} - F_{\text{int}}^n \]

One uses for that the quasi-static nonlinear algorithm describes in [R5.03.01], and which corresponds to command STAT_NON LINE. Displacement with the iteration \( (n+1) \) is:

\[ u^{n+1} = u^n + \Delta u^{n+1} \]

It is looked at if [éq10] is satisfied by the field \( u^{n+1} \) and so on.

9.2 Example

One wants to calculate the figure of equilibrium of a heavy cable [fig 9.2-a] whose end \( A \) is fixed and of which the other, \( B \) of level with \( A \), is subjected to a given horizontal force. With this problem is dealt in [feeding-bottle4], where he is regarded as highly nonlinear.

Figure 2: Balance of a heavy cable subjected to a horizontal tension

Extensional rigidity (E.A): 4,45 X 105 N, linear Weight: 1,46 N/m
At the beginning, the cable, modelled by 10 elements of the 1st degree, is supposed in weightlessness and has a horizontal rectilinear position $AB_o$. One simultaneously subjects it to the action of gravity and the horizontal force $F$ applied in $B_o$. The static equilibrium position $ACB$ is reached in 8 iterations only.
10 Dynamic problem

This problem is that of the computation of the evolution of a structure of cables.

10.1 Iterative algorithm of temporal integration

the form discretized of [eq7] and [eq3] supplements, which must be satisfied in each node and at every moment is:

\[ F_{\text{int}}(t) - F_{\text{iner}}(t) = F_{\text{ext}}(t) \] \[11\]

the algorithm of temporal integration is of Newmark type and . Let us suppose that the state of the cable (fields at nodes \( u, \dot{u} \text{ et } \ddot{u} \) ) is known at time \( t \) and that one has just calculated an approximate value of these fields to the nth iteration of time \( t + \Delta t \).

- If these values satisfy [eq13], except for a tolerance, one takes them for values of the fields at time \( t + \Delta t \).

- If not, the correction of displacement is sought \( \Delta u^{n+1} \), to which correspond, according to the algorithm of Newmark, corrections velocity and acceleration:

\[ \Delta u^{n+1} = \frac{\gamma}{\beta} \Delta u^n + \Delta u^{n+1} \]

and

\[ \Delta \dot{u}^{n+1} = \frac{1}{\beta} \Delta t^2 \Delta u^{n+1}, \]

such as:

\[ \left[ K^n_M + K^n_G + \frac{1}{\beta} \Delta t^2 M \right] \Delta u^{n+1} = F_{\text{ext}}(t + \Delta t) - F_{\text{int}}(t + \Delta t) + F_{\text{iner}}(t + \Delta t). \]

In the analysis of the motion of the cables, the algorithm of Newmark can be unstable. This is why we use the algorithm says HHT, defined in [bib7], in which the two parameters of Newmark are functions of a third parameter \( \delta \):

\[ \gamma = \frac{1}{2} - \delta \]
\[ \beta = \frac{(1 - \delta)^2}{4} \]
\[ \delta \leq 0. \]

For \( \delta = 0 \), the algorithm is that of Newmark, known as “trapezoidal rule”. But for \( \delta \) slightly negative \( \delta \geq -0.3 \), it appears numerical damping which stabilizes computation.

The determination of initial acceleration and the initialization of the fields at the beginning again time step are indicated in [feeding-bottle5].

10.2 Comparison of computations and tests of short-circuits

to validate this modelization of the cables, we compared dynamic computations by Code_Aster with test results of short-circuits [bib8]. Those were carried out at the Laboratory of Electronic engineering of EDF on an experimental structure representative of the configurations of station [Figure3]. Three cables tended between two distant gantries of 102 m are short - circuities, with the foreground, by a shunt laid out on insulating columns.
On the level of the other gantry, they are fed by a three-phase current of \( 35 \text{ kA} \) during \( 250 \text{ ms} \). The evolution was recorded:

- tension of the cables to their anchorage on the gantries, using dynamometers;
- displacement of the points mediums of the ranges, located by spheres of indication, using fast cameras. One sees the cage of glass of the one of these cameras assembled on a gantry, on the left of [Figure 3].

![Figure 3: General sight of the testing facility of short-circuits](image-url)
It [Figure 4] gives the comparison for a tension of anchorage and the displacement of the medium of a cable.

**Figure 4**: Comparisons of computations by *Code_Aster* and tests of short-circuits

### 11 Conclusion

The modelization of the cables presented above is powerful (reasonable number of iterations by time step or to reach a static equilibrium) and precise: it is adapted to the analysis of the long cables. For the short cables, on the other hand, the flexional stiffness is not negligible, especially with the anchorages, and the modelization must be done by beam elements in large displacements and large rotations [R5.03.40].

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12 Bibliography


[8] F: Range of line three-phase (102 m) for stations VHV. Ratio of tests. EDF (1990). History
Annexe 1 conducting computation of the forces of Laplace between drivers traversed by a flow creates a magnetic field in its vicinity. This magnetic field, acting on the flow conveyed by another driver, induced on this one a force known as of Laplace. Figure 5.

![Diagram of two close drivers](image)

Let us take a driver traversed \(i_1(t)\) by the flow [Figure], located in the vicinity of the driver traversed \(i_2(t)\) by flow. At \(P\), the point \(P\) of the driver, where the unit tangent directed in the meaning of flow is, the linear force of Laplace induced by the driver is \(f(P)\).

\[
f(P) = 10^{-7} i_1(t) i_2(t) e_1 \times \int e_2 \times \frac{r}{r^3} ds_2
\]

is interested only in the forces due to very intense flows of short-circuit, the forces of Laplace in normal circumstances being negligible. can

\[
f(P)
\]

obviously put itself in the shape of the product of a function of time by a function of space.

A1.1 Function of the time of the forces of Laplace

This function, is \(g(t)\), except for a factor, the product of the intensities in the conducteurset: \(i_1(t)\) and \(i_2(t)\).

\[
g(t) = 2 \cdot 10^{-7} i_1(t) i_2(t)
\]

where

\[
i_j(t) = \sqrt{2} I_{ij} [\cos (\omega t + \phi_j) - e^{-j\tau} \cos \phi_j]
\]

\[\text{with}
\]

\(I_{ij}\) intensity of flow \(J\); \(\omega\) pulsation of flow (for \(\omega = 100\pi\) a flow of 50 Hz); \(\phi_j\) phase depending on time when the short-circuit occurs; \(\tau\) time-constant of line shorted-circuit dependant on its electric characteristics (coil, capacity and strength).

Very often, one replaces the complete function [\(g(t)\) \(\text{[12]}\) and \(\text{[13]}\) by its average - that one calls the part continues - by neglecting the terms and \(\cos(\omega t + \ldots) - \cos(2\omega t + \ldots)\) The taking into
account of these terms would require one time step very small and the corresponding forces, with and
50 Hz, are 100 Hz almost without effect on the cables of which the frequency of oscillation is
about the hertz. Thus

A1.2

\[
g_{\text{continue}}(t) = 2 I_1 I_2 \left[ \frac{1}{2} \cos(\varphi_1 - \varphi_2) + e^{-\frac{t}{\tau_1 + \tau_2}} \cos \varphi_1 \cos \varphi_2 \right]
\]

**Function of space**

This function is: The integral

\[
h(P) = \frac{1}{2} e_1 \times \int e_2 \times \frac{r}{r^2} ds_2,
\]

is calculated analytically when one cuts out the driver \( K \) in rectilinear elements. Along such an
element [A1.2-a \( M_1 M_2 \) Figure], one has an effect: Figure

\[
r^3 = (y^2 + r_m^2)^{3/2}
\]

\[
e_2 \times r = e_2 \times r_m
\]

\[
ds_2 = dy
\]

6: 6 of Laplace induced by a rectilinear element of driver Like

\[
\int_{y_1}^{y_2} \frac{dy}{(y^2 + r_m^2)^{3/2}} = \frac{1}{r_m^2} \left[ \frac{y}{\left(y^2 + r_m^2\right)^{1/2}} \right]_{y_1}^{y_2}
\]
the hook
\[
\frac{1}{2} e_1 \times \int_{M_1} e_2 \times \frac{r}{r^3} dy = \frac{1}{2r_m} e_1 \times e_2 \times r_m \left[ \frac{y}{\left(y^2 + r_m^2\right)^{1/2}} \right]_{y_1}^{y_2}
\]
of the second member is also equal to: . A1.3
\[
\sin \alpha_2 - \sin \alpha_1
\]

Realization in Code_Aster the function

of space précédent D emment definite is calculated by an elementary routine which evaluates for each element of the driver, (1) the contribution of all the elements of the driver which (2) act on him. This contribution is evaluated to Gauss points (1 only for the elements with 2 nodes) of the element of the driver, by the key word (1) INTE_ELEC of the command AFFE_CHAR_MECA . The elementary routine has 2 parameters of entry: the load card
- of the element of the driver including (1) the list of meshes driver acting (2) on him; the name of the geometry, variable in the course of the time, which at every moment makes it possible to evaluate the quantities. \( r_m, \sin \alpha_1, \sin \alpha_2 \). The function

of time \( g(t) \) is calculated by the operator DEFI_FONC_ELEC which produces a concept of type function. A1.4

Use in Code_Aster Definition

• of the function of time Orders \( g(t) \)

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<td></td>
<td>INST_CC_FIN</td>
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• of the function of space Orders \( h(P) \)

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- into account of the forces of Laplace Orders

<table>
<thead>
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<td></td>
<td>of: Computation $g(t)$</td>
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Annexe 2 of the force exerted by the wind A3.1

Formulation

One admits that a wind velocity exerts \( V \) in the vicinity of the point of \( P \) a cable [Figure 7] an aerodynamic linear force having \( f \) the following characteristics: has

- \( f \) the direction and the meaning of the component \( V_n \) velocity of the wind in the normal plan of the cable. a modulus
- \( f \) proportional squared of that has of. Figure \( V_n \)

![Diagram showing the force exerted by the wind](image)

7: 7 of the wind in the vicinity of a cable

the regulations of computation of the lines define the force of a wind by the pressure which he \( p \) exerts on a normal plane surface with his direction. For a cable, placed normally at the direction of the wind, these regulations prescribe to take for linear force: , being \( f \) the diameter of the cable. That amounts considering that the cable offers to the wind a plane surface equal to its Master-couple. An increase of the force thus is obtained because the cable, cylindrical, has a less strength with the air than a plane surface. If the velocity of the wind \( V \) forms an angle with \( \theta \) the cable, its component in the plane perpendicular to the cable has as a modulus: . Therefore \( \|V_n\| = \|V\| \cdot |\sin \theta| \)

\( f \) the linear force: , Of course \( f = p \phi \sin^2 \theta \)

, the linear force exerted by the wind depends on the position of the cable: it is “following”. A3.2

Use in Code_Aster

Here how one introduces the force of the wind into Code_Aster. The unit vector having the direction and the meaning velocity of the wind has as components. Order \( v_x, v_y, v_z \)

<table>
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</table>

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Annexe 3 of the installation of the cables a cable

in the course of installation in a canton (several ranges between columns) [Figure 8] is fixed at the one of the supports of stop. It rests on pulleys placed at the bottom of the insulators suspension and it is retained by a force on the level of the second support of stop. Figure

8: 8 of a cable in a canton with two ranges While exploiting this force - or by moving its point of application - one adjusts the deflection of the one of the ranges, that which is subjected to stresses of environment. Then one removes the pulleys and one fixes the cable at the insulators: the length of the cable in the various ranges is then built-in. It is on this configuration that one mounts possibly additional components: spacers, descents on equipment, point masses,… to give to the canton its final form. This

modelization is described in the documentation of reference of elements CABLE_POUILLE [R3.08 .05].

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