Tensions Tool Calculation Method

UNDER TESTING - NOT FOR USE

This note describes the calculation logic used by the Tensions tool for conductor unit loads, sag, tension, ruling span and shield wire checks. The method is intended as a calculation attachment and remains subject to project engineering verification.

1. Inputs and Weather Cases

The project defines the selected phase conductor, optional shield wires, attachment heights, required clearance, wind region and terrain category. Each weather case defines wind pressure, ice thickness, temperature, wind angle, drag coefficient, section length, height multiplier source, SRF, TSRF and allowable tension limits.

- Only one no-wind weather case may be marked Used for ruling span.
- Only one no-wind and no-ice weather case may be marked Used for shield wire sag.
- At least one phase tension limit is required for the phase solution; at least one applicable shield wire tension limit is required for each selected shield wire. Other limits may be blank.

2. Conductor Unit Weight and Ice Load

The bare conductor vertical load is derived from conductor mass. Ice thickness is entered in mm and is applied radially, so the iced diameter is D + 2t_ice. The percentage of ice load scales the calculated ice weight for the case.

```
W_c = mass_kg_per_km * g / 1000
D_ice = D + 2 * t_ice
W_ice_full = (pi / 4) * (D_ice^2 - D^2) * rho_ice * g
W_ice = W_ice_full * ice_percent / 100
```

Diameters are converted from mm to m before load calculation. Ice density is entered in kg/m3 and the resulting ice load is reported in N/m.

3. Wind Load

Wind pressure is entered by the user as site wind pressure in Pa, already including regional, direction, shielding and topographic effects. The wind load uses the iced conductor diameter, drag coefficient, wind height multiplier, span reduction factor and the square of the cosine of the wind angle to the conductor normal.

```
W_wind = q * D_ice * C_d * M_z,cat * SRF * cos^2(theta)
```

The resultant unit load is the vector combination of vertical load and wind load:

```
W_resultant = sqrt((W_c + W_ice)^2 + W_wind^2)
```

4. Wind Height Multiplier

The height multiplier may be entered directly as 1.0, selected from a named manual table, or calculated using the implemented standard options. AS/NZS 1170.2:2021 is specified for Synoptic Wind and AS/NZS 7000:2016 is specified for Downdraft Wind.

For manual tables, the wind height multiplier is interpolated by reference height. SRF and TSRF manual tables are interpolated by ruling span. The AS/NZS 7000:2016 option is implemented as defined for the selected wind model.

5. Reference Height of Conductor

Attachment heights are entered for the representative structure. The tool can use average attachment height, average conductor height, or lowest point. Average conductor height subtracts two thirds of the clearance sag from the attachment height. The clearance sag is taken from the weather case marked Used for ruling span.

```
s_clearance = min(phase_attachment_heights) - required_clearance
H_average_attachment = average(attachment_heights)
H_average_conductor = H_average_attachment - 2 * s_clearance / 3
H_lowest_point = H_average_attachment - s_clearance
```

6. SRF and TSRF

SRF and TSRF may be entered as 1.0, calculated using the implemented AS/NZS 7000 options, or read from named manual tables. Manual tables are stored once by name and selected inside each weather case. Values are interpolated by ruling span.

7. Clearance Sag and Ruling Span

The phase conductor control sag is derived from geometry and required clearance. This instruction is explicit in the calculation logic: use required clearance to derive ruling span sag. The weather case marked Used for ruling span must be no-wind; its calculated resultant load is used with the clearance sag to derive the governing span. The control sag is:

```
s_phase_control = min(phase_attachment_heights) - required_clearance
```

The tool evaluates each weather case with an entered phase tension limit as a candidate control condition. For a candidate, the initial control tension is the conductor breaking load multiplied by the allowable percentage after creep.

```
T_candidate = CBL * limit_percent / 100
```

Using the small-sag relation between resultant load, horizontal tension, sag and span, a trial ruling span is obtained from the candidate resultant load and the target clearance sag:

```
RS = sqrt(8 * T_candidate * s_phase_control / W_candidate)
```

The program then iterates. The ruling span gives sag and tension in the control case; the conductor state equation is used to recalculate tension in all weather cases considering load, temperature, modulus, area and thermal expansion:

```
T/(EA) - T0/(EA) + alpha*(temp - temp0) + RS^2*(W^2/T^2 - W0^2/T0^2)/24 = 0
```

Iteration continues until the sag/span residual is less than 1e-6 m and the state equation residual is less than 1e-6, or until the maximum iteration count of 80 is reached.

8. Governing Phase Case

Each candidate control case is checked against all entered phase tension limits. A candidate is rejected if it creates tension above the allowable limit in any weather case where such a limit is specified. Among feasible candidates, the governing case is the one that produces the critical admissible condition for the ruling span solution.

If no feasible candidate satisfies all entered limits, the tool reports that the phase ruling span cannot be solved for the specified geometry, loads and tension limits.

9. Shield Wire Sag

Shield wire sag is controlled separately from phase ruling span. One weather case may be marked Used for shield wire sag, and it must be a no-wind and no-ice case. The user enters the ratio of shield wire sag to phase conductor sag in that control case.

```
s_shield_control = s_phase_control_case * sag_ratio
```

For each selected shield wire, the tool uses the phase ruling span and shield wire resultant load in the shield control case to determine the control tension:

```
T_shield_control = W_shield_control * RS^2 / (8 * s_shield_control)
```

The shield wire state equation is then used to calculate shield wire tension and sag in every weather case, using the same state equation form as for the phase conductor.

10. Allowable Tension Limits

Allowable tension limits are entered separately for the phase conductor, shield wire 1 and shield wire 2 as percent of CBL after creep. At least one applicable limit is required for the phase conductor and for each selected shield wire. Blank limits are otherwise not used as constraints. Entered limits are used in two ways: first, to create candidate control tensions; second, to check calculated tensions across all weather cases.

- If a phase candidate causes another phase weather case to exceed its specified limit, that candidate is rejected.
- If shield wire sag ratio and shield wire limits cannot both be satisfied, the tool reports an infeasible shield wire solution.
- Results report unit loads, reference height, Mz,cat, SRF, TSRF, ruling span, tension, sag and percent CBL.