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Loading Methods in PLS-CADD

Introduction

Version 7 of PLS-CADD restructures criteria related to wire and structure loading and introduces several new methods for calculating structure loads. Projects created in any previous version of PLS-CADD can still be opened, their criteria will automatically be migrated and by default PLS-CADD will calculate the same loads it did in version 6.

The changes to weather criteria include new options under "Wire Wind Height Adjust Model" and "Wire Gust Response Factor" for adjusting wind and ice according to the following codes: ASCE 74-2006 (draft), EN 50341-1:2001 (CENELEC), EN 50341-3-9:2001 (UK NNA), EN 50341-3-17 (Portugal NNA), IEC 60826:2003, REE (Spain), Russia 7th Edition, Statnett, TPNZ (New Zealand) and ESAA C(b)1-2003 (Australia).

The structure loads changes include new columns for "Structure Area Factor", "Structure Ice Thickness" and "Structure Wind Load Model". The load model column replaces the "Structure Gust Response Factor" found in earlier versions and also provides new methods for applying wind to structures according to the following codes: ASCE 74-2006 (draft), EN 50341-1:2001 (CENELEC), EN 50341-3-9:2001 (UK NNA), EN 50341-3-17 (Portugal NNA), IEC 60826:2003, REE (Spain), TPNZ (New Zealand) and ESAA C(b)1-2003 (Australia). It also provides improved options for ASCE 74-1991 and NESC 2002 as well as new options for SAPS Wind, Wind on Face, Wind on All, RTE Hyp1 and RTE Hyp2.

With these changes we have greatly expanded our support for international codes, provided better control over the application of wind on structures and simplified the criteria through a more logical grouping of items affecting wire loads and wind/ice on structure.

Revisions

Version 7.34:

ASCE 74-2006 (draft) made available (replaces **ASCE 2002** draft)
IEC 60826:2001 now adjusts ice for wire diameter and height above ground
Russia 1 revised and renamed to **Russia 7th Edition**
Statnett (Norway) *Wire Gust Response Factor* option added

Version 8.10:

NESC 2007 made available (effectively identical to **NESC 2002**)

Notes for Users of Previous Versions

The criteria changes occurred in three places in PLS-CADD: *Criteria/ASCE Terrain Type, Criteria/Weather Cases* and *Criteria/Structure Loads.* The *ASCE Terrain Type* menu has been made a submenu of *Code Specific Wind and Terrain Parameters* which now has options for *SAPS Wind (also used for RTE), EN 50341-1:2001(CENELEC), EN 50341-3-9:2001 (UK NNA*), *EN 50341-3-17:2001 (Portugal NNA), IEC 60826:2003, TPNZ (New Zealand), ESAA C(b)1-2003 (Australia), Statnett (Norway)* and *Russia 7th Edition.* You only need to enter data for those codes that you plan on using. The *Weather Cases* table has been simplified so that the adjustments in it apply only to wires; all structure related items including the structure component of the *Wind Height Adjust* column (now called *Structure Wind Load Model*) and the *GRF Structure* column have been moved to *Criteria/Structure Loads*. A *Wire Wind Height Adjust Model* column has been added that includes the wire component of the adjustment previously specified by the *Wind Height Adjust* column and that adds options for EN 50341-1:2001 (CENELEC), IEC 60826:2003, EN 50341-3-9:2001 (UK NNA), EN 50341-3-17 (Portugal NNA), REE (Spain), Russia 7th Edition, TPNZ (New Zealand) and ESAA C(b)1-2003 (Australia). The *Wire Gust Response Factor* also adds these options (and Statnett, but not REE) and unless you have a very good reason not to, you should make sure that you select the same code in both columns. Finally, *Criteria/Structure Loads* has a number of additional columns. *Structure Wind Area Factor* can be used to factor the structure wind area whether to approximate the increase in wind area of the structure caused by icing or for any other reason (UK NNA users should input K_{COM} in this column or leave it zero to have K_{COM} calculated automatically). The *Structure Wind Load Model* combines the structure component of the old *Weather Cases Wind Height Adjust* and GRF *Structure* columns and has a large number of options which are described in detail below. The *Structure Ice Thickness* and *Structure Ice Density* columns allow you to apply ice on a structure. While this is required by CENELEC, UK NNA and IEC 60826, neither ASCE 74 nor NESC 2002 requires it so most US users will leave these columns blank. Non-zero values will result in ice being applied on the surface of your structures. If you use method 4 structures and elect to take advantage of any of the new criteria options introduced in PLS-CADD version 7, you will also need to use PLS-POLE and TOWER version 7. Even if you do not use the new criteria options we recommend that you upgrade to version 7 of PLS-POLE and TOWER as many of the new features in PLS-CADD version 7 require them.

Additional information is available in the *Loading Methods Introduced in Version 7 of TOWER and PLS-POLE* document available at http://www.powline.com/products/version7_loads.pdf. You should carefully review this document and verify that your structure models have been appropriately modified prior to using any method other than a “Pre V7” one. In particular, for lattice towers it is imperative that you have input the appropriate factors in the *Geometry/Sections/Define* table in TOWER prior to using a new loading method.

Detailed Notes for Each Structure Wind Load Model

For each method available in the *Structure Wind Load Model* in *Criteria/Structure Loads* the following information will be given below: reference wind, method categorization, code calculations that are automated in PLS-CADD (PLS-CADD A.C.) and code calculations that are automated in PLS-POLE and TOWER (Structure A.C.). The options can be divided into three categories: those that existed in previous versions of PLS-CADD (referred to as Legacy), those that existed in previous versions of the structure programs, but which could not be selected from PLS-CADD (referred to as V7-Selectable) and those that are new to version 7 (referred to as V7-New). As you develop new criteria in the future we encourage you to only use the non-legacy methods (V7-Selectable and V7-New) for generating loads. However, it is not necessary and in many cases will not be desirable, to modify existing criteria and structures for projects that have already been completed or that are in progress.

Note that the wind pressures printed in the PLS-CADD Structure Loads report include the factors described in PLS-CADD A.C. These wind pressures become the basic wind pressure for PLS-POLE and TOWER which can be found in the *Loads/Vector Loads* table. They are then further modified as described in Structure A.C. before being applied to the structure. The final pressures used are printed in the *Detailed Pole Loading Data for Load Case* tables in PLS-POLE and the *Section Load Case Information* tables in TOWER. You should verify your understanding of the application of all the factors involved in calculating loads by calculating one of these pressures by hand and verifying that it matches what the program calculates. Modern codes are regrettably complicated, so this may be a long and tedious process, but it is the only way to assure yourself that your interpretation of the code matches the programs. To assist you with this process we have provided a “Show Graphs” button at the bottom of the code specific parameters dialog for many of the codes which will show you the quantities built into PLS-CADD. In addition, you can use the *Structures/Loads/Report Options* dialog to set the *Include extended diagnostic information on adjustments to input wind and ice* option which will provide intermediate results to assist you with your validation.

Structure Wind Load Model Options

Pre V7 Standard

Reference Wind	User defined
Method Category	Legacy
PLS-CADD A.C.	None
Structure A.C.	None. Will apply constant unadjusted wind pressure on all members unless Wind On Face was previously selected in TOWER.
Notes	This is the basic loading provided by PLS-CADD which does not adjust wind pressures, ice thicknesses or anything else.

Pre V7 ASCE 1991

Reference Wind	One minute (close to fastest mile)
Method Category	Legacy
PLS-CADD A.C.	Structure GRF Wind pressure adjusted for 2/3 of structure height
Structure A.C.	None. Will apply constant unadjusted wind pressure on all members unless Wind On Face was previously selected in TOWER.
Notes	Wind on wire adjusted for height only if **ASCE 1991** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire GRF is calculated only if **ASCE 1991** is selected in the *Wire Gust Response Factor* column in *Criteria/Weather Cases* ASCE Manual 74, 1991, Guidelines for Electrical Transmission Line Structural Loading

Pre V7 ASCE 1991 w/o GRF - same as **ASCE 1991**, but does not calculate Structure GRF

Pre V7 ASCE 2002

Reference Wind	Three second gust
Method Category	Legacy
PLS-CADD A.C.	Structure GRF Constant wind adjusted for 2/3 of structure height
Structure A.C.	None. Will apply constant wind pressure on all members unless Wind On Face was previously selected in TOWER.

Notes **ASCE 2002** has been inexplicably delayed in committee and has not been ratified, but as of the last draft was equivalent to **NESC 2002** in terrain category C for the purposes of developing structure loads.
The **ASCE 2002** option was provided for research and testing purposes of committee members.
This method is identical to **Pre V7 NESC 2002** except that it uses the input ASCE terrain exposure category in the calculation of wind where the NESC assumes terrain category 'C'

Pre V7 NESC 2002

Reference Wind 3 second gust

Method Category Legacy

PLS-CADD A.C. Structure GRF
Constant wind adjusted as per Rule 250C

Structure A.C. None. Will apply constant wind pressure on all members unless Wind On Face was previously selected in TOWER.

Notes This method is identical to **Pre V7 ASCE 2002** except that it always uses terrain category 'C'.

NESC (2002), National Electric Safety Code, ANSI C2-2002, IEEE, New York, N.Y.

Pre V7 ASCE 2002 w/o GRF - same as **ASCE 2002**, but does not calculate Structure GRF

Pre V7 NESC 2002 w/o GRF - same as **NESC 2002**, but does not calculate Structure GRF

SAPS Wind also
RTE Hyp1 (France) also
RTE Hyp2 (France)

Reference Wind	User defined
Method Category	V7-Selectable
PLS-CADD A.C.	None
Structure A.C.	Adjusts wind with height according to a user defined power law assuming no shielding.
Notes	The **RTE** options use **SAPS** wind which is based on the principles of fluid mechanics. It was previously available only to users designing for EDF/RTE, but can now be selected by all PLS-CADD users. Due to its basis in physics, this method can be helpful when faced with odd and otherwise intractable problems. It is the national standard for France. Selecting either **RTE Hyp1** or **RTE Hyp2** has implications beyond the scope of this document and should only be done by users designing according to the EDF/RTE standards.

Wind on Face

Reference Wind	User defined
Method Category	V7-Selectable
PLS-CADD A.C.	None
Structure A.C.	TOWER: Wind is applied only on members in the face.
Notes	This was previously selected in the **General/General Data** dialog in TOWER, but can now be selected from PLS-CADD so that it can be combined with other methods in a single structure check without having to edit the structure file. This is equivalent to **Wind on All** for PLS-POLE structures.

Wind on All

Reference Wind	User defined
Method Category	V7-Selectable
PLS-CADD A.C.	None
Structure A.C.	None
Notes	This was previously selected in the **General/General Data** dialog in TOWER, but can now be selected from PLS-CADD so that it can be combined with other methods in a single structure check without having to edit the structure file.

ASCE 74-1991

Reference Wind	One minute (close to fastest mile)
Method Category	V7-New
PLS-CADD A.C.	None
Structure A.C.	Structure GRF Wind pressure is adjusted panel by panel for height. TOWER: wind incidence factor (K_θ) is applied. TOWER: wind on face with drag coefficient a function of solidity ratio. PLS-POLE: wind on all with drag coefficient a function of # of sides.
Notes	Identical to Pre-V7 ASCE 1991 except that the wind adjustment with height is performed in the structure program which can adjust the wind panel by panel as opposed to a constant wind at 2/3 the height of the structure. This is required for structures that exceed 200ft in height. The Structure GRF is also calculated in the structure program instead of in PLS-CADD. Wind on wire adjusted for height only if **ASCE 2002** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire GRF is calculated only if ASCE 1991 is selected in the *Wire Gust Response Factor* column in *Criteria/Weather Cases* ASCE Manual 74, 1991, Guidelines for Electrical Transmission Line Structural Loading

ASCE 74-2006 (both the F and M options) (draft)

Reference Wind Three second gust

Method Category V7-New

PLS-CADD A.C. None

Structure A.C. Structure GRF

ASCE 74-2006F (Face based loading) applies wind to the face of a lattice tower with the drag coefficient a function of solidity ratio. Wind pressure is adjusted panel by panel for height.

ASCE 74-2006M (Member based loading) applies wind to each member individually assuming no shielding. You must input the drag coefficient of 1.6 for angles and 1.0 for rounds in *Geometry/Sections/Define* in TOWER. The wind is adjusted at the mid-height (average elevation) of each individual member.

PLS-POLE: wind on all with drag coefficient a function of # of sides (**ASCE 74-2006F** and **ASCE 74-2006M** are identical for PLS-POLE).

Notes Wind on wire adjusted for height only if **ASCE 2006** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.*

Wire GRF is calculated only if **ASCE 2006** is selected in the *Wire Gust Response Factor* column in *Criteria/Weather Cases*

ASCE Manual 74, 2006 (draft), Guidelines for Electrical Transmission Line Structural Loading

NESC 2002 and 2007

Reference Wind Three second gust

Method Category V7-New

PLS-CADD A.C. None

Structure A.C. Structure GRF as per Rule 250C.
Constant wind on face adjusted as per Rule 250C
The 60ft exemption is not automated.
Drag coefficients applied to angle members in the face of a lattice tower are 3.2 and 2.0 for rounds independent of the solidity ratio of the section as per Rule 252B2c. Drag coefficients for poles are calculated as per Rule 252B2 with 1.0 being used for all but rectangular poles (which use 1.6).
NESC 2002 does not define a Wind Incidence Angle Factor; therefore, for applying wind on lattice towers from other than the transverse direction we use the Wind Incidence Angle factor defined in **ASCE 74-1991** (which is identical to that in **IEC 60826** and **EN 50341-1**).

Notes Wind on wire adjusted for height only if **NESC 2002** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.*
Wire GRF is calculated only if **NESC 2002** is selected in the *Wire Gust Response Factor* column in *Criteria/Weather Cases.*

NESC (2002), National Electric Safety Code, ANSI C2-2002, IEEE, New York, N.Y.

NESC (2007), National Electric Safety Code, ANSI C2-2007, IEEE, New York, N.Y.

EN50341-1:2001 (CENELEC)

Reference Wind	Two second gust for terrain category 2 at 10m User should input V_g Users opting for the 10 minute average must manually convert to a 2 second gust
Method Category	V7-New
PLS-CADD A.C.	None
Structure A.C.	Wind increased with height logarithmically. TOWER: wind incidence factor (K_θ) is applied. G_t is assumed to always be 1.05 even for structures in excess of 60m. G_{pol} is assumed to always be 1.15 for all materials (wood, steel, concrete and modular mast). TOWER: wind on face with drag coefficient a function of solidity ratio. PLS-POLE: wind on all with drag coefficient a function of # of sides and Reynolds number. CENELEC did not provide for drag coefficients for poles. Therefore, drag coefficients for poles are selected from ENV 1991-2-4:1997 and IEC 60826:2003.
Notes	This is the generic version of the common European code. Wind on wire adjusted for height only if **EN50341-1** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* If **EN50341-1** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases* and ice density and ice load are nonzero then equivalent ice thickness is calculated and added to wire diameter. Wire GRF is calculated only if **EN50341-1** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.* Ice drag factor (coefficient) C_{CI} is calculated only if ice density is input and **EN50341-1** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.*

EN50341-3-9:2001 (UK NNA)

Reference Wind	One hour average User should input V_B K_d as wind pressure.
Method Category	V7-New
PLS-CADD A.C.	Terrain type adjustment (K_R) based on input terrain type.
Structure A.C.	Wind increased with height logarithmically. TOWER: wind incidence factor (K_θ) is applied. Gust Response Factor calculated as ($1+K_{COM}G_B$). TOWER: wind on face with drag coefficient a function of solidity ratio. PLS-POLE: wind on all with drag coefficient a function of # of sides as per ASCE 74 1991.
Notes	This is the National Normative Aspects of generic CENELEC for The United Kingdom and Northern Ireland as interpreted by National Grid. The calculated structure gust response factor will includes effects from K_{COM}. K_{COM} should be input in the *Structure Wind Area Factor* column in *Criteria/Structure Loads*. The input structure ice thickness must already include any necessary adjustment. Wind on wire adjusted for height only if **EN50341-3-9:2001** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire GRF is calculated only if **EN50341-3-9:2001** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.*

EN50341-3-17:2001 (Portugal NNA)

Reference Wind	Ten minute average User should input V_{mean} for the zone the line is in
Method Category	V7-New
PLS-CADD A.C.	None
Structure A.C.	K_g applied to the input wind, V_{mean} to obtain V_R. TOWER: wind incidence factor (K_θ) from CENELEC is applied. TOWER: wind on face with drag coefficient a function of solidity ratio. PLS-POLE: wind on all with drag coefficients selected from ENV 1991-2-4:1997 and IEC 60826:2003. Portugal NNA did not provide for drag coefficients for poles. Therefore, drag coefficients for poles are selected from ENV 1991-2-4:1997 and IEC 60826:2003. Wind increased with height as per 4.2.2.1.6 PT.1
Notes	This is the National Normative Aspects of generic CENELEC for Portugal. Wind on wire adjusted for height only if **EN50341-3-17:2001** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire drag coefficient and span factor is calculated only if **EN50341-3-17:2001** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.*

IEC 60826:2003

Reference Wind	Ten minute average User should input V_{RB} for wind pressure.
Method Category	V7-New
PLS-CADD A.C.	Effects of altitude should be manually included in the *Air Density Factor* Terrain type adjustment (K_R) based on input terrain type. For wind on insulators G_t is calculated as per 6.2.6.3, but C_{xi} must be manually included in the input wind area.
Structure A.C.	Effects of wind increase with height and structure GRF modeled via a single quadratic equation. Ice contributes to vertical load, but not wind load. TOWER: wind incidence factor (K_θ) is applied. TOWER: wind on face with drag coefficient a function of solidity ratio. PLS-POLE: wind on all with drag coefficient a function of Reynolds number.
Notes	Wind on wire adjusted for height only if **IEC 60826** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire GRF is calculated only if **IEC 60826** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.*

REE (Spain)

Reference Wind	User defined
Method Category	V7-New
PLS-CADD A.C.	None
Structure A.C.	TOWER: Wind On Face with drag coefficients for round members based on CENELEC, angle members use 3*(1-solidity ratio). The input wind pressure should take this into account. PLS-POLE: wind on all with drag coefficients a function of # of sides and Reynolds number. TOWER: ASCE74/CENELEC/IEC wind incidence factor (K_θ) is applied.
Notes	This is the methodology used in Spain as provided by Red Eléctrica de España. Ice load on wire adjusted only if **REE (Spain)** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.*

TPNZ (New Zealand)

Reference Wind	Three second gust User should manually apply M_{lr} M_{ls} M_t M_s to input velocity.
Method Category	V7-New
PLS-CADD A.C.	None
Structure A.C.	TOWER: Wind On Face with drag coefficients taken from AS3995. PLS-POLE: Wind On All with TP.DL 12.01 drag coefficients. TOWER: ASCE74/CENELEC/IEC wind incidence factor (K_θ) is applied. $M_{z,cat}$ calculated as per the commentary of AS/NZS 1170 C4.2[7,8].
Notes	This is the methodology used in New Zealand as provided by Transpower and Maunsell. Wind on wire adjusted for height ($M_{z,cat}$) only if **TPNZ** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* User input drag coefficient applied to wire in presence of ice only if **TPNZ** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire GRF (SRF) is calculated only if **TPNZ** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.* Multi-span section wind reduction factor as per 7.2 of TP.DL 12.01 is only applied when **TPNZ** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.*

ESAA C(b)1-2003 (Australia)

Reference Wind	Three second gust User should use V_R M_d M_s M_t as the input velocity.
Method Category	V7-New
PLS-CADD A.C.	None
Structure A.C.	TOWER: Wind On Face with drag coefficients taken from BS8100. PLS-POLE: Wind On All with ASCE 74 drag coefficients. TOWER: BS8100 (UK NNA) wind incidence factor (K_θ) is applied. $M_{z,cat}$ calculated as per AS/NZS 1170.2:2002 table 4.1(A) and 4.1(B).
Notes	Wind on wire adjusted for height ($M_{z,cat}$) only if **ESAA C(b)1-2003** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* User input drag coefficient applied to wire in presence of ice only if **ESAA C(b)1-2003** is selected in the *Wire Wind Height Adjust Model* column in *Criteria/Weather Cases.* Wire GRF (SRF) is calculated only if **ESAA C(b)1-2003** is selected in *Wire Gust Response Factor* column in *Criteria/Weather Cases.* SRF calculated using formulas in ESAA C(b)1-2003 figures A1 and A2. Value for category 2.5 is average of values for category 2 and 3. SRF for regions A and B in category 1 and 4 are not specified so will use category 2 (instead of 1) and 3 (instead of 4).