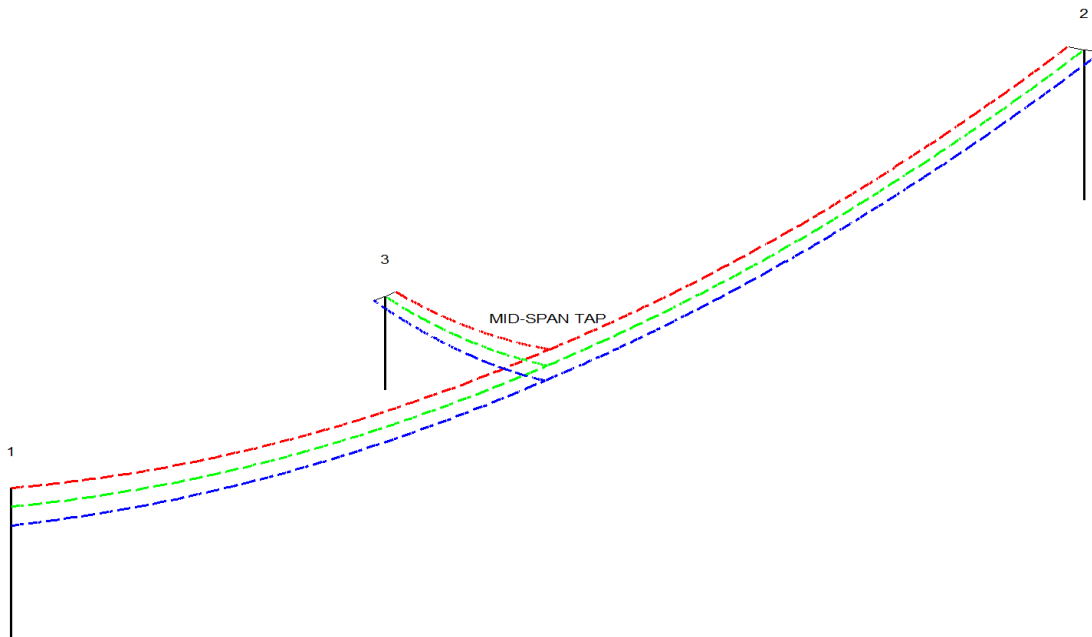


Modeling mid-Span taps, mid-span phase transpositions and phase spacers

Mid-Span taps (Flying taps), mid-span phase transpositions and phase spacers are able to be modeled in PLS-CADD. To do so PLS-CADD, SAPS and either PLS-POLE or TOWER is required. To model all of these scenarios structure models are created in PLS-POLE or TOWER that have joints defined that are free to move and rotate. When insulators are attached to these joints it is possible to create Method 4 structures to represent various taps or phase transpositions that happen along a span between structures. These Method 4 structures consist of joints and insulators that can be spotted in a PLS-CADD model and sections can be attached to the insulators of these Method 4 structure models. To display the interaction between these free joints in the structure models and the sections in the PLS-CADD model Level 4 SAPS Finite Element assumptions will have to be used. This can be selected in PLS-CADD within the menu command **Criteria/SAPS Finite Element Sag-Tension**. None of the other levels will be able to appropriately display the wire with the interaction between the sections. Please note that convergence of these specialty scenarios is not guaranteed and can be dependent on the other spans and structures in the sections and how flexible they are in L4 analysis.

Attached in this technical note is a PLS-CADD model that uses either a PLS-POLE or TOWER model to show mid-span tap examples, phase transposition examples and interphase spacers. You can switch between the different examples in PLS-CADD by using the **Lines/Edit** command..

Mid-Span Taps



Mid-Span taps (Flying taps) are possible in PLS-CADD with the use of PLS-POLE or TOWER structures and Level 4 SAPS analysis. The procedure below describes how Mid-Span tap structures can be created and spotted in a

PLS-CADD model. Structure models created in PLS-POLE or TOWER can be added to a PLS-CADD model with clamps for the through section of the span and strain insulators for the taps.

1. The first step in creating this structure is to create joints in the model using **Geometry/Joints** in PLS-POLE or **Geometry/Primary Joints...** in TOWER and setting the displacement and rotations to *Free* for the X, Y & Z direction.

Joints Geometry
 Joints need only be specified for complex structures such as A-Frames. Do NOT input joints here for single poles or for the joints that lie along an element. Instead, these joints can be specified as "relative joints" in the pole or arm tables below.

	Joint Label	Symmetry Code	X Coord. (ft)	Y Coord. (ft)	Z Coord. (ft)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
1	11	None	0	10	0	Free	Free	Free	Free	Free	Free
2	12	None	0	0	0	Free	Free	Free	Free	Free	Free
3	13	None	0	-10	0	Free	Free	Free	Free	Free	Free

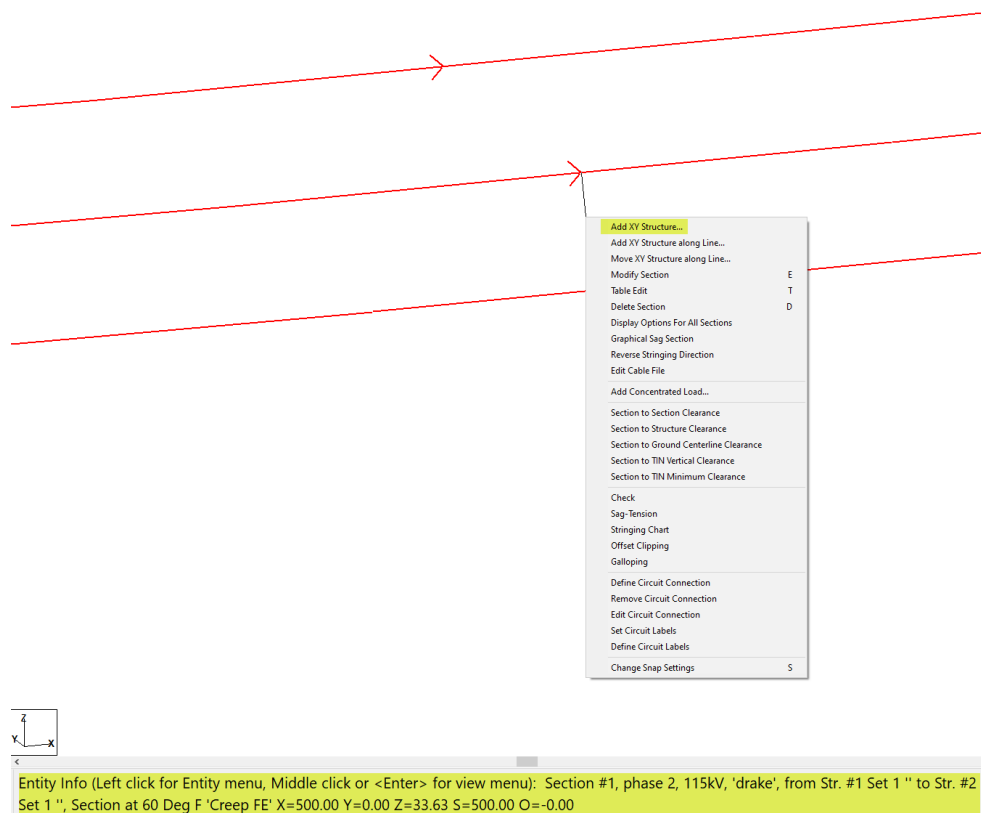
2. Next the clamp and strain insulators are attached to the joints created in the previous step by assigning them to the *Structure Attach* column within the respective Insulator Connectivity tables. The strain insulator can have length and/or weight or could be just a point like a clamp insulator.

Strain Insulator Connectivity
 Model Check Report
 No errors or relevant warnings detected.

Attach insulators to "Free" Joints

	Strain Label	Structure Attach	Tip Label	Property Set	Azimuth (deg)	Min. Required Vertical Load (uplift) (lbs)
1	STRAIN1A	11P	1	STRAIN	90	No Limit
2	STRAIN1B	12P	2	STRAIN	90	No Limit
3	STRAIN1C	13P	3	STRAIN	90	No Limit

3. The set and phase numbers will need to be assigned for each of the insulators within PLS-POLE or TOWER with the menu command **Geometry/PLS-CADD/Insulator Link...**
4. In PLS-CADD determine the wire condition and temperature at which you want to model the mid-span tap and display the span at this condition.
5. Add the mid-span structure to the model. This can be done by both snapping to the section at the location where you want the tap inserted (see 5a) or with the use of survey points created along the section (see 5b). When inserting the mid-span tap structure into the PLS-CADD model care should be taken so that the cable attachment points for all phases align with the sections where the tap will occur. The menu command **Drafting/Show Cable Attachment Points** can graphically show the attachment points of the structure.
 - a. When inserting a mid-tap span structure into a PLS-CADD model it may be helpful to update the entity snap settings so that the cursor just snaps to wires. This is done with the menu command **View/Entity Info Snap Settings...** in PLS-CADD. When the cursor is snapped to a wire the status bar at the bottom of the screen can be viewed to verify the phase and location. When the desired location for the mid-span tap is located the user can left-click the mouse and select **Add XY structure...**



- b. An alternative method is to create survey points along the span where the tap is being modeled so that the conductor attachment points for the mid-span tap structure can be positioned at the correct location. To do so use the **Sections/ Table** and use the *Create Survey Points Along Wire* command in the Command to Apply column of the table for the section in question.

Section Table

Sort Sections by:

- ☒ Section number
- ☐ Structure number section starts upon
- ☐ Attachment set section starts upon
- ☐ Voltage
- ☐ Cable file name

Displayed Color. Displayed Phase will not take effect until override in Section/Display Options is disabled.

Sec #	Start Str # Set #	End Str # Set #	Ruling Span (ft)	Insul. Clipped	Sec Notes	Cable File Name	Voltage (kV)	Bundle Shape	Bundle Spacing (ft)	Wires Per Phase	Sag Condition	Sag Temp. (deg F)	Sag Horiz. Ten. (lbs)	Display Weather Case	Display Condition	Disp. Wind From	Disp. Phase	Disp. Color	Command To Apply
1	1	111	211	490	Yes	drake	115			0	1	Initial RS	60.0	2085.8	60 Deg F	Initial FE	Left	1	Create Point...
2	2	Span Tap:111	311	90	Yes	drake	115			0	1	Initial RS	60.0	500.0	60 Deg F	Initial FE	Left		

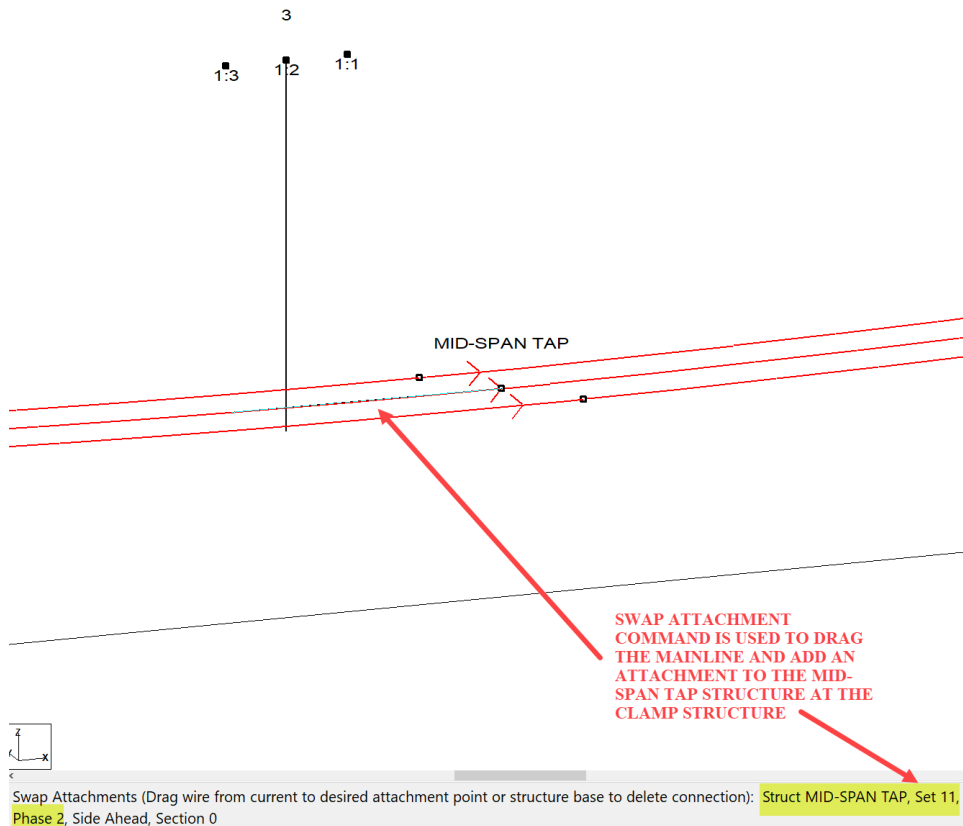
OK Cancel Apply

Clip
Unclip
Delete
Modify
Autosag
Reverse Stringing
Auto RS
Manual RS
Adjust Sag Temp.
Find Graph Sag Fit Points...
Graph Sag Fit to Points...
Create Points Along Wires...
Delete Concentrated Loads
Clear length adjust
Merge length adjust
Set Surveyed Temp
Find Surveyed Temp
Pretension

Then the menu command **Structures/Add/XY Structure/At Survey Point** can be used to add a structure to this survey point along the wire. It is also possible to use alignment based structures which can be added with the menu command **Structures/Add/Along Alignment** and then move the structure to the correct survey point with the command **Structures/Move/On Snap....**

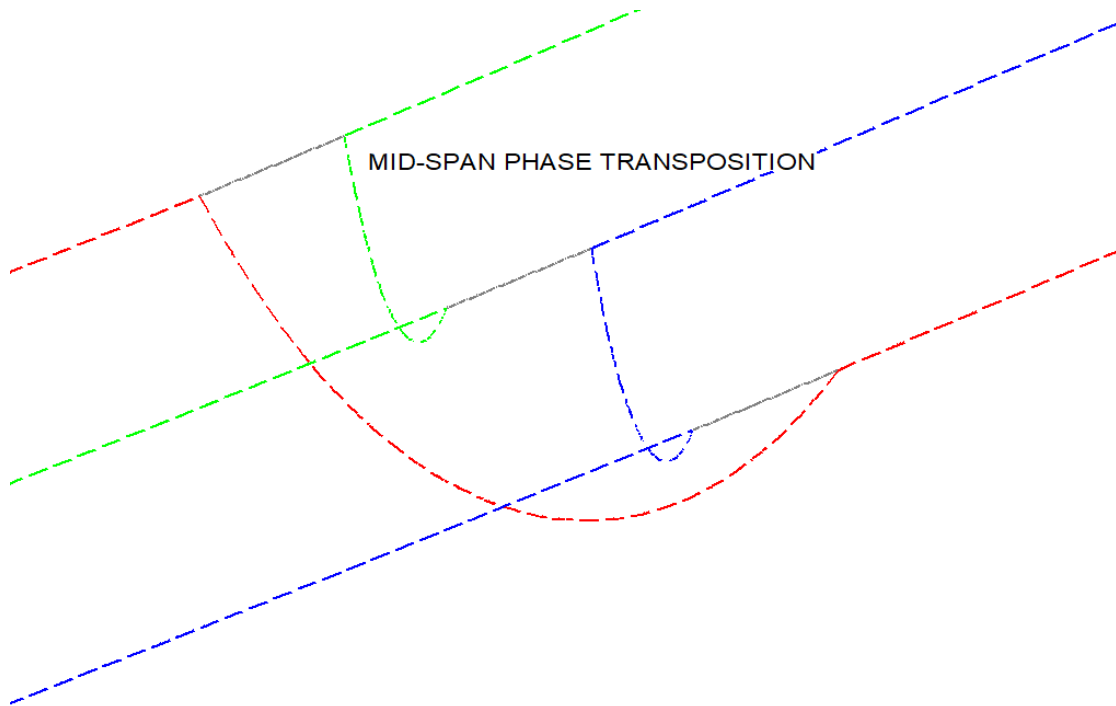
6. After inserting the mid-span tap structure into the PLS-CADD model the mainline sections will need to be attached to the clamp insulators. The command **Sections/ Swap Attachments** will allow the selection of a wire and allow the user to drag the wire to an attachment point on the mid-span structure. The

status bar can help the user to select the set:phase associated with the clamp insulators on the mid-span structure.



7. Then use the **Sections/ Add Graphical** to string between the mid-span structure and the structure the tap will connect to. This new section should attach to the strain insulators at the mid-span tap structure. When adding this tap the horizontal tension of the sections that make up the tap will need to be defined. PLS-CADD is not capable of stringing vertical wires, so if the tap is vertical a small offset is needed so the wire attachments are not in a vertical plane.
8. Then you can use the **Sections/ Table** to clip all the sections so they are displayed in FE cable condition.
9. Finally the only way to display the interaction between these sections is to go to the **Criteria/SAPS Finite Element Sag-Tension** and choose to display the sections in L4. None of the other levels will be able to appropriately display the wire with the interaction between the sections. Do not select *Use Level 2 modeling for display and insulator swing calculations* or the display weather conditions will not show L4 display options.

Phase Transpositions

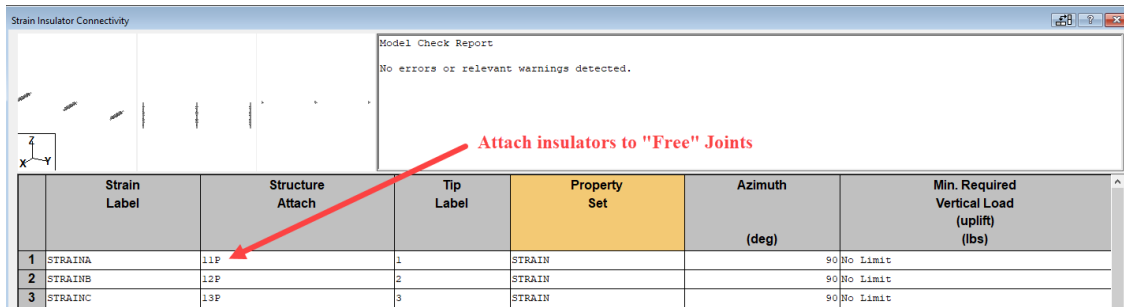


Phase transpositions can be modeled in PLS-CADD with the use of PLS-POLE or TOWER structures and jumpers in PLS-CADD. Modeling these transpositions requires SAPS for the finite element capabilities to model jumpers and Level 4 SAPS analysis to attach insulators to structure files with free joints. To model a phase transposition you can use the following method:

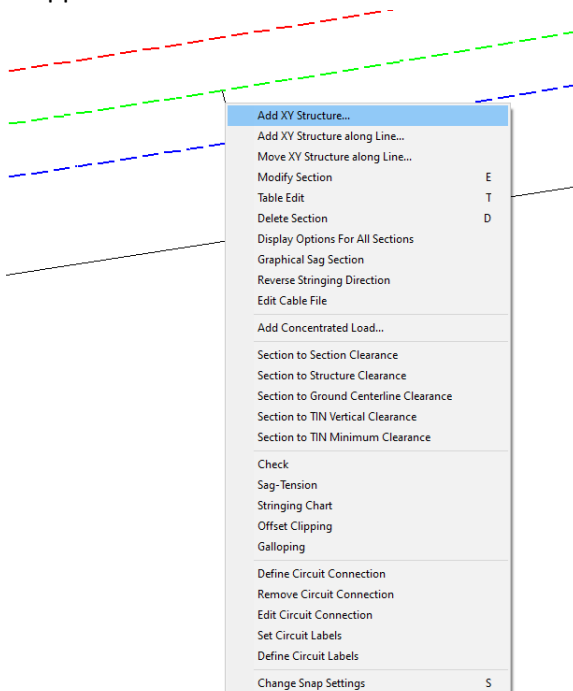
1. The first step in creating this phase transposition structure is to create joints in the model using **Geometry/Joints** in PLS-POLE or **Geometry/Primary Joints...** in TOWER. These joints will need to be positioned in such a way that they represent the distance between the phases of the overhead line. The displacement and rotations for these joints should be set to *Free* for the X, Y & Z direction.

Joints Geometry											
Joints need only be specified for complex structures such as A-Frames. Do NOT input joints here for single poles or for the joints that lie along an element. Instead, these joints can be specified as "relative joints" in the pole or arm tables below.											
	Joint Label	Symmetry Code	X Coord. (ft)	Y Coord. (ft)	Z Coord. (ft)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
1	11	None	0	10	0	Free	Free	Free	Free	Free	Free
2	12	None	0	0	0	Free	Free	Free	Free	Free	Free
3	13	None	0	-10	0	Free	Free	Free	Free	Free	Free

2. Properties for clamps and strain insulators need to be defined. For the strain insulators the length, weight and wind area will represent the insulators used to separate the phases at the transposition. The clamp and strain insulators are attached to the joint created in the previous step by assigning them to the *Structure Attach* column within the respective Insulator Connectivity tables.

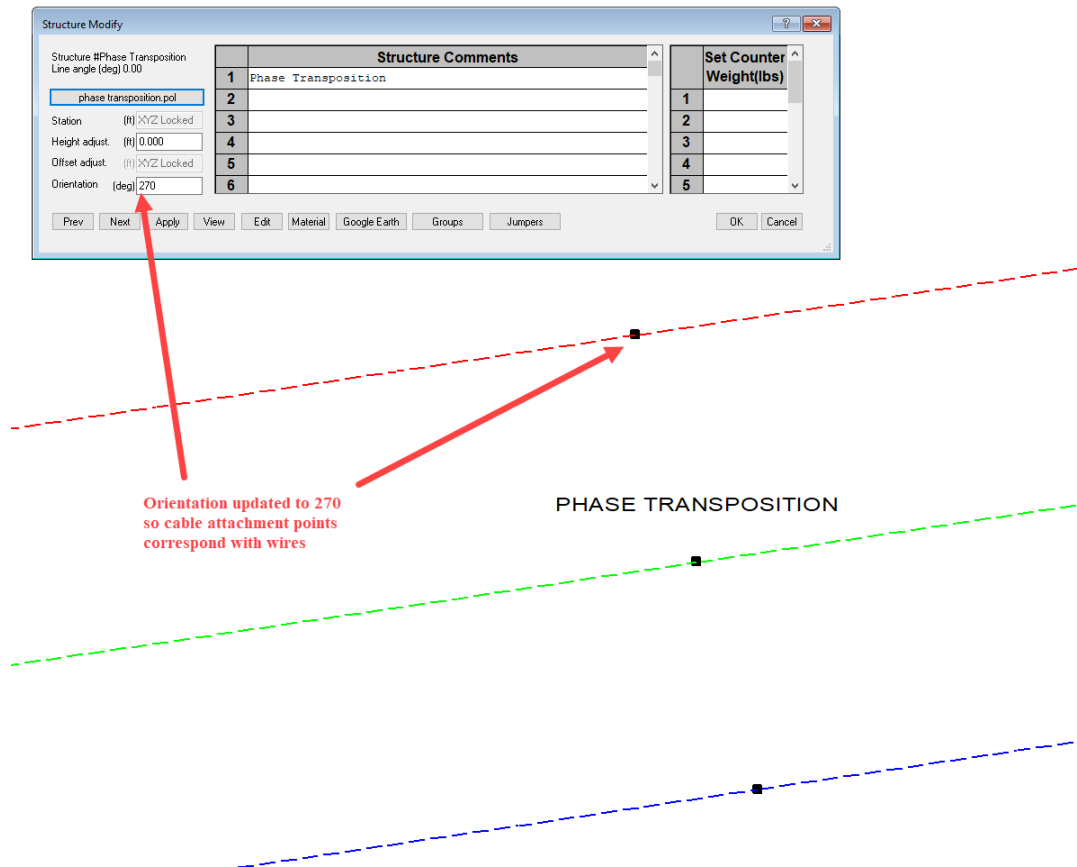


- Next, the set and phase will need to be assigned for each of the insulators with the command **Geometry/PLS-CADD/Insulator Link....** When assigning the set & phase for the clamps and strain insulators select YES for the Dead-End column. The insulators are required to be classified as Dead-End attachment points because to model jumpers they must begin and end on a dead-end attachment point. This mid-span transposition structure also needs to have all three phases included in a set and will not work with three individual mid-span structures compromised with one set: one phase for each structure.
- Save your phase transposition structure within PLS-POLE or TOWER.
- Insert the phase transposition structure into the PLS-CADD model. It is helpful to update the entity snap settings to just *Wires* using the menu command **View/Entity Info Snap Settings....** When your cursor is snapped to the correct location left-click on the mouse and select add **XY Structure...**

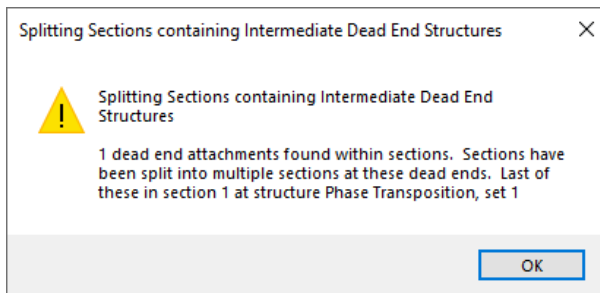


It is also possible to add this structure as an alignment based structure but the user will have to adjust the height of the structure so that is attached at the proper height of the wires.

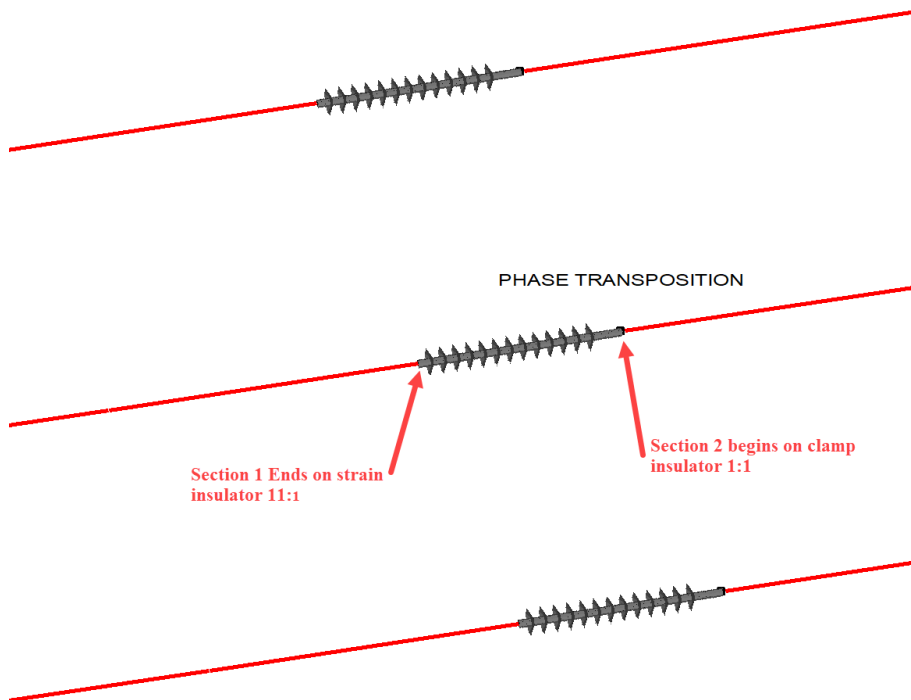
- When an XY structure is inserted its orientation angle is zero. Verify the orientation and location of the phase transposition structure after it has been inserted so that the attachment points correspond and update if necessary. The command **Drafting/Show Cable Attachment Points** can help graphically show the location of the phase transposition structure attachment points. For the screenshot below the orientation angle had to be updated.



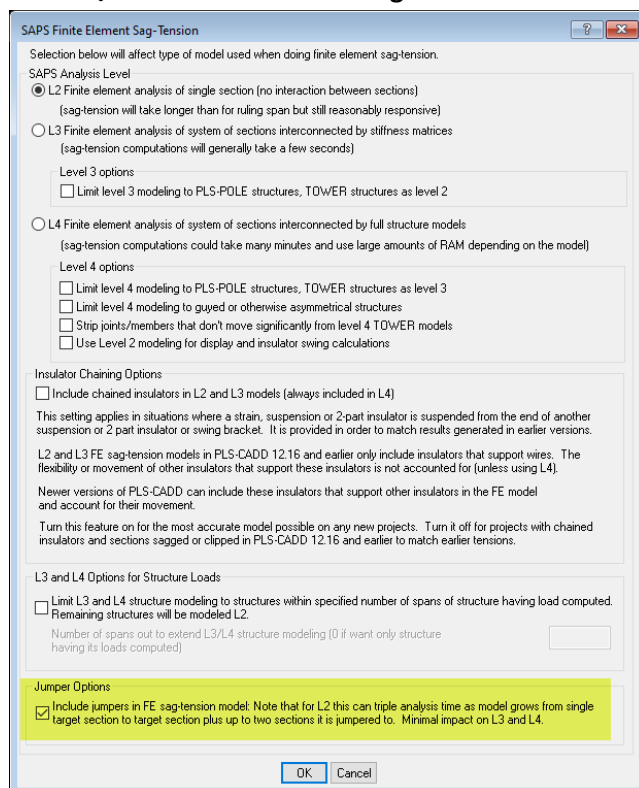
- Attach the sections to the phase transposition structure with the command **Sections/Swap Attachments** and left-click on a wire and drag it to the appropriate attachment point on the structure. You should receive the warning below telling you the software will now split the sections to attach to the dead-end attachment points on the phase transposition structure.



- Next update the stringing so that the sections attach to the set:phases associated with the strain insulators on one side of the phase transposition structure and the clamp insulators on the other side of the phase transposition structure. The menu command **Sections/Modify** and using the *Edit Stringing* button or menu command **Sections/Swap Attachments** can help achieve this stringing configuration shown below.



9. The next step is to add jumpers to model the phase transposition. First activate the jumpers within **Criteria/SAPS Finite Element Sag-Tension....**



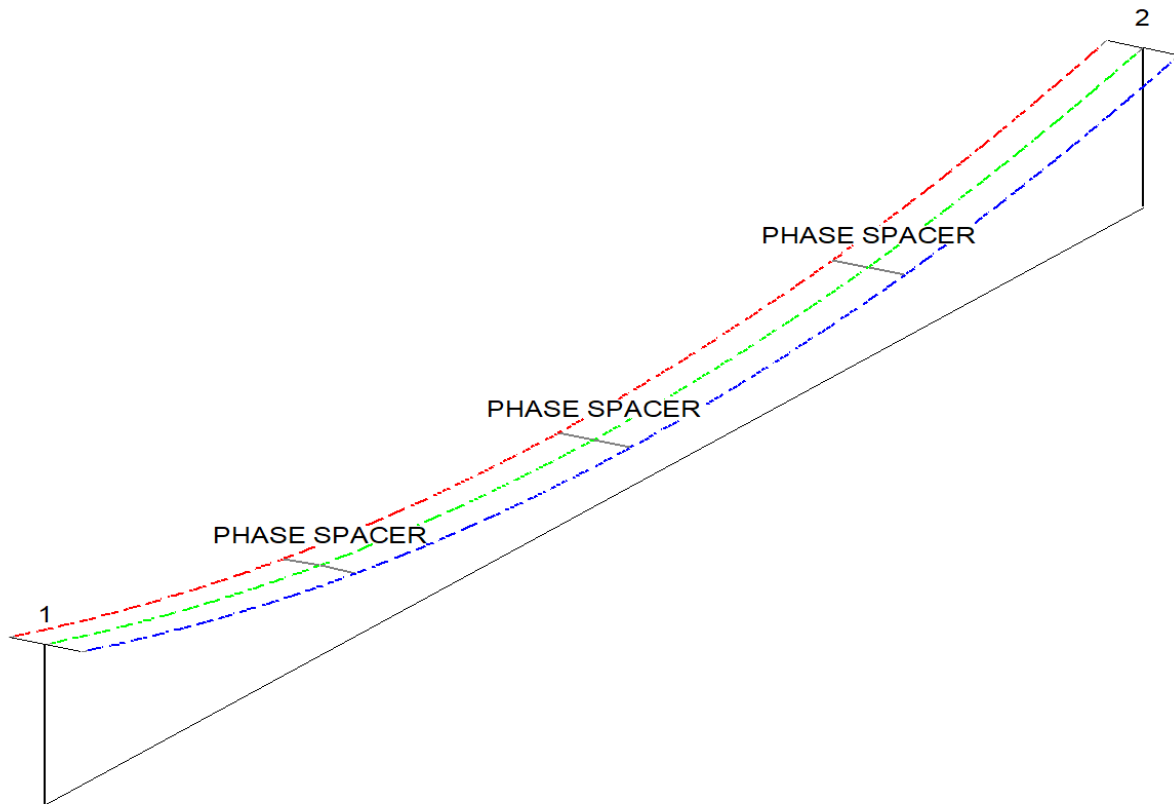
10. Next use the menu command **Structures/Jumpers/Add** or the Jumpers button within the Structure Modify dialog. When creating the jumpers make sure to enter the proper sag or length for the jumper.

Structure Comments	
1	Phase Transposition
2	
3	
4	
5	
6	

Set Counter Weight(lbs)	
1	
2	
3	
4	
5	

11. Finally the circuits and phases can be updated. To do so the graphical methods with the menu command **Sections/Electric/Edit Circuit Connection** or tabular method **Sections/Electric/Define Circuits and Phases/Table...** can be used to update the circuit and phase. The jumpers will help link the phase labels between the back and ahead spans at the phase transposition structure.

Phase Spacers



Phase spacers can be modeled in PLS-CADD using two methods. A simplistic approach is to add concentrated loads at the locations of the phase spacers to represent the weight and wind area of the phase spacers. This does not account for the interaction of the phases being tied together, but this simplification of the interphase spacers will be quicker to model, and allows the use of ruling span assumptions or L2 SAPS finite element analysis options.

Another method is with the use of PLS-POLE or TOWER structures and Level 4 SAPS Finite-Element analysis. This requires adding method 4 structures that consist of insulators tied to free joints within a PLS-POLE or TOWER file. The steps below describe the process to construct and add method 4 PLS-POLE or TOWER structures that represent the phase spacers and effectively tie phases together. The effect of tying the phases of a circuit together can be graphically seen by toggling between different display weather cases and the weight of the spacers are accounted for in sag-tension calculations and in clearance checks. However, one report where these spacers cannot account for the effect of the phases being tied together is the galloping report. This is because the galloping ellipses that simulate the theoretical envelopes of a galloping conductor are based on nominal methods using span lengths and modeling the interphase spacers will effectively shorten span lengths between structures.

When creating a method 4 structure in PLS-POLE or TOWER there are two methods that can be used:

- a) The first method uses clamp insulators attached to joints that are free to move and rotate and then model the phase spacer as a brace in PLS-POLE or a member in TOWER. This will effectively tie the phases together for sag-tension calculations and clearance calculations. However, because PLS-CADD

defaults to displaying the undeformed geometry of structures and the brace and angle are structural members, so this type of phase spacer does not graphically move with the wires. The effective wire position will be shown correctly accounting for the spacer, but the brace will remain in its original position.

- b) The second method involves attaching a clamp and rigid suspension insulators to a single free joint that is free to move and rotate. The suspension insulators are used to represent the phase spacer. This will effectively tie the phases together for sag-tension calculations and clearance calculations. With this sort of structure the insulators will move with the wires and can be seen graphically when different weather cases are displayed. However, with this method there are some small differences in the unstressed lengths of cables between the phases. So the sag and tension values between the phases are similar but not exactly the same like they would be using the first method.

Both of these methods are described below and contained within the bak file associated with the technical note. The method using braces will be under the a. bullets and the suspension insulator method will be under the b. bullets.

- 1) The first step in creating this structure is to create joints in the model using **Geometry/Joints** in PLS-POLE or **Geometry/Primary Joints...** in TOWER and setting the displacement and rotations to *Free* for the X, Y & Z direction.
 - a) Three joints should be created so that they are spaced in the Y direction the same distance as the phases are separated.

	Joint Label	Symmetry Code	X Coord. (ft)	Y Coord. (ft)	Z Coord. (ft)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
1	11	None	0	10	0	Free	Free	Free	Free	Free	Free
2	12	None	0	0	0	Free	Free	Free	Free	Free	Free
3	13	None	0	-10	0	Free	Free	Free	Free	Free	Free

- b) One joint should be created.

	Joint Label	Symmetry Code	X Coord. (ft)	Y Coord. (ft)	Z Coord. (ft)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
1	12	None	0	0	0	Free	Free	Free	Free	Free	Free

- 2) Attach insulators to the joints created in the previous step by assigning them to the *Structure Attach* column within the respective Insulator Connectivity tables.
 - a) Create properties for a clamp insulator. Attach a clamp insulator at each of the three joints created in the previous step. Next, for a model using PLS-POLE create a brace with a length, weight and dimensions representing a phase spacer.

Brace Properties (From file "C:\Support\midspantap\archive\midspantap\default.brc")

Brace Property Label	spacer
Stock Number	
Cross Section Area (in ²)	4
Length (ft)	20
Depth (in)	2
Width (in)	2
Weight (lbs)	30
Unit Wt. (If Length Unknown) (lbs/ft)	0
Modulus of Elasticity (ksi)	26000
Drag Coef.	1
Strength Check Type	Nominal
Use Steel S.F.	Yes
Tension Capacity (lbs)	50000
Compres. Capacity (lbs)	50000
Net Area (in ²)	NA
Design Normal Stress (ksi)	NA
X-Moment Of Inertia (in ⁴)	NA
Z-Moment Of Inertia (in ⁴)	NA
Unbraced Length Ratio-X	NA
Unbraced Length Ratio-Z	NA
Texture	

Save Save As Merge Report Cancel

Attach the brace between the joints created in the previous step.

In TOWER a member representing the phase spacer will need to be created. The Steel Material and Angle Properties will need to be completed in the Components menu.

Angle Properties (From file "c:\users\public\documents\pls\tower\examples\new.ang")

Angle Type	spacer
Angle Size	spacer
Long Leg (in)	2
Short Leg (in)	0
Thick. (in)	0
Unit Weight (lbs/ft)	0.6667
Gross Area (in ²)	3.14
w/t Ratio	0
Radius of Gyration Rx (in)	50
Radius of Gyration Ry (in)	50
Radius of Gyration Rz (in)	50
Angle Cross Section	Round
Wind Width (in)	0
Short Edge Dist. (in)	0
Long Edge Dist. (in)	0
Optimize Cost Factor	0
Section Modulus (in ³)	0

Save Save As Merge Report Cancel

Next add members between the joints created in the previous steps with the menu command **Geometry/Members/Add...**

	Member Label	Group Label	Section Label	Symmetry Code	Origin Joint	End Joint
1	g1	spacer		None	12P	11P
2	g2	spacer		None	12P	13P

- b) Create properties for a clamp insulator and a suspension insulator. The suspension insulator will represent the phase spacer and the length, weight, and wind area will represent the physical characteristics of the spacer. The suspension insulator should also be defined as a rigid insulator.

Suspension Properties (From file "C:\Support\midspantap\archive\midspantap\default.ini")

Label	spacer
Stock Number	
Length (ft)	20
Weight (lbs)	30
Wind Area (ft^2)	0.0277
Tension Capacity (lbs)	50000
Top Rect Width (ft)	0
Top Rect Height (ft)	0
Bot. Rect Width (ft)	0
Bot. Rect Height (ft)	0
Vert. Rect Width (ft)	0
Vert. Rect Height (ft)	0
Hardware Capacity (lbs)	30000
Notes	
Draw	Shedless
Rigid	Yes

Save Save As Report Cancel

Attach all three insulators to the single joint created in the previous step.

- Next, the set and phase will need to be assigned for each of the insulators with the command **Geometry/PLS-CADD/Insulator Link....** When assigning the set & phase for the clamps and suspension insulators select NO for the Dead-End column. For a reference see the example structures named interphase spacer for both PLS-POLE and TOWER for the within the bak file associated with the technical note.
- In PLS-CADD determine the wire condition and temperature at which you want to tap the span and display the span at this condition.
- Go to the **Sections/ Table** and clip the insulators.
- Add the interphase structures to the model on sections and locations where interphase spacers are required.
 - It also may be helpful to go to the **Sections/ Table** use the *Create Survey Points Along Wire* command in the Command to Apply column of the table for the sections in question. Then add interphase spacers with the menu command **Structures/Add/XY Structure/At Survey Point**.

- b) Insert the phase spacer structure into the PLS-CADD model. It is helpful to update the entity snap settings to just Wires using the menu command **View/Entity Info Snap Settings...**. When your cursor is snapped to the correct location left-click on the mouse and select **add XY Structure...**
 - c) It's also possible to use alignment based structures to represent interphase spacers which can be added with the menu command **Structures/Add/Along Alignment**.
- 7) After inserting the interphase spacer structures into the PLS-CADD model the menu command **Sections/Swap Attachments** can be used to connect the sections to the proper set:phase of the phase spacer.
- 8) Finally the only way to display the interaction between these sections is to go to the **Criteria/SAPS Finite Element Sag-Tension** and choose to display the sections in L4. None of the other levels will be able to appropriately display the wire with the interaction between the sections and structures. Do not select *Use Level 2 modeling for display and insulator swing calculations* or the display weather conditions will not show L4 analysis results.