Designing Substations Part by Part with Autodesk® Inventor®

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UT2388-L

In the electric utility industry, it seems that everything we design is “just like that one, only different." If you can relate to this statement, then this hands-on lab is for you. You will gain the ability to increase accuracy, quality, and productivity while improving Building Information Modeling (BIM) workflows when designing electric utility substations using Autodesk® Inventor® software. We demonstrate sketching techniques you can use to easily alter standard content. We show examples of creating, copying, and using standard 3D models to fit any unique situation. Finally, we take you through the procedures to create and update an accurate parts list and quality drawings in a matter of minutes.

Learning Objectives

At the end of this class, you will be able to:

- Create standardized content using improved sketching techniques
- Alter standard models to fit any unique application
- Quickly generate quality construction drawings
- Create an accurate parts list using intelligent 3D models

About the Speaker

Terri Humel has an Associate’s Degree in Mechanical Engineering from Nashville State Technical Institute. She is employed as the Principal Associate Engineer in Substation Design at Nashville Electric Service. She has 30 years of experience in the electric utility industry and 28 years of experience designing substations with AutoCAD®. Currently she is using Autodesk® Inventor® and the Substation Designer to produce intelligent 3D substation models. She’s presented at AU for the past 3 years. Other accomplishments include authoring an article in the March 2013 issue of Electricity Today.
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About the Co-Speaker

Chip Cullum is a Senior Associate Engineer in the Substation Design group at Nashville Electric Service (NES). He has an Associate’s Degree in Electrical Engineering Technology from Nashville State Technical Institute. He has been using Autodesk® products since 1989 starting with AutoCAD® Release 10 and has been using Autodesk® Inventor® Professional since 2010. He currently uses Autodesk® Inventor® and Substation Designer to produce 3D models and drawings of substations. He has been with NES since 2006 and been in substation design since 2010. Previous to NES, he has 8 years’ experience in electrical control panel design using AutoCAD products and 8 years’ experience in mechanical design using Pro-Engineer®.wcullum@nespower.com

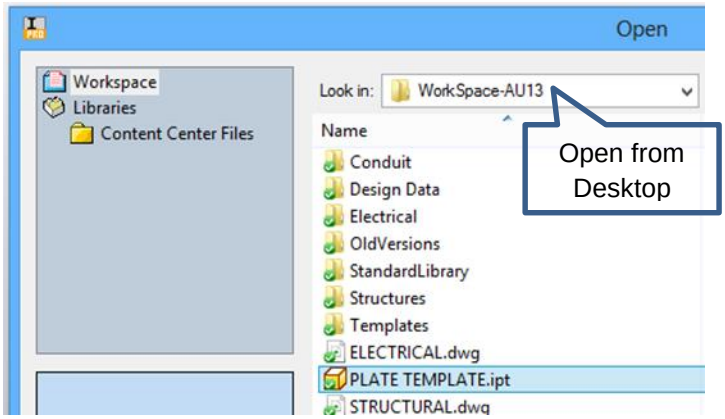
- **Create standardized content using improved sketching techniques**

Where to begin?

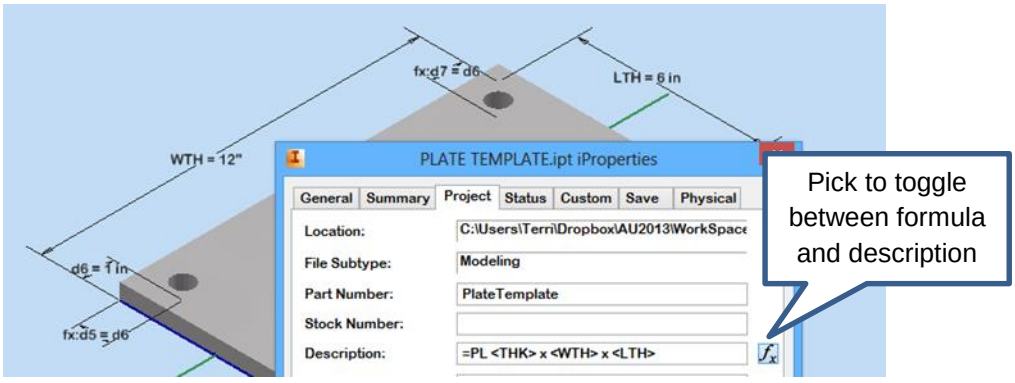
It all starts with a sketch that becomes a part and that part is placed in an assembly. The first exercise involves using a specialized template to create a structural part. The iProperties are set in the template to populate the Bill of Material with the information required. By using parameters in a formula, the description in the iProperties automatically changes as the sketch dimensions are modified. The next exercise uses the dimensional constraints in the sketches for a typical circuit breaker to change the critical dimensions. This allows one library part to be used for several types of breakers.

Part Template

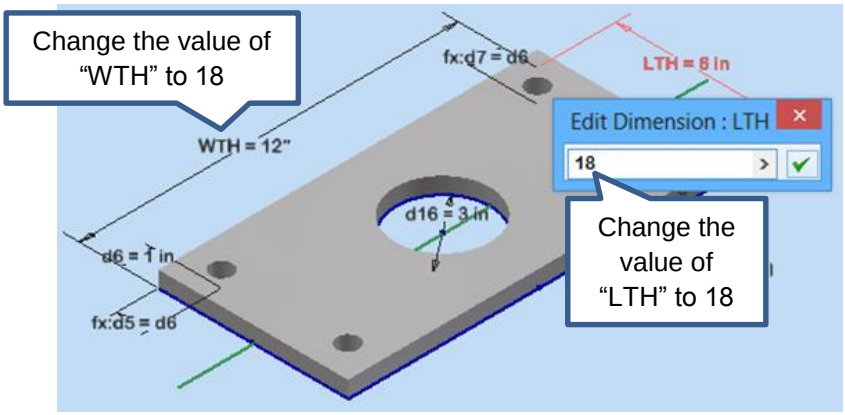
1. Open the Folder "WorkSpaceAU13" from the Desktop. Open the file PLATE TEMPLATE.

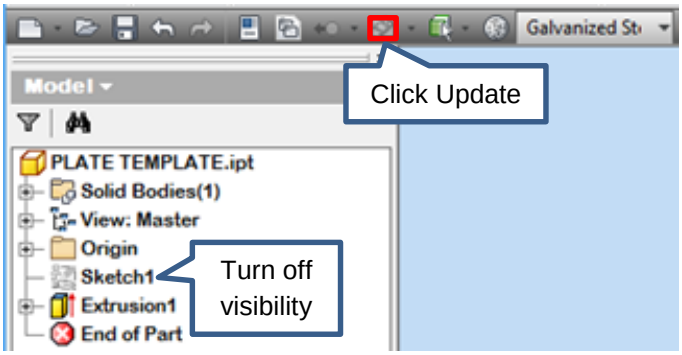


2. Open the iProperties dialog box and click on the Project Tab. The parameter symbol to the right of the description property indicates the description is a formula. Close the iProperties.

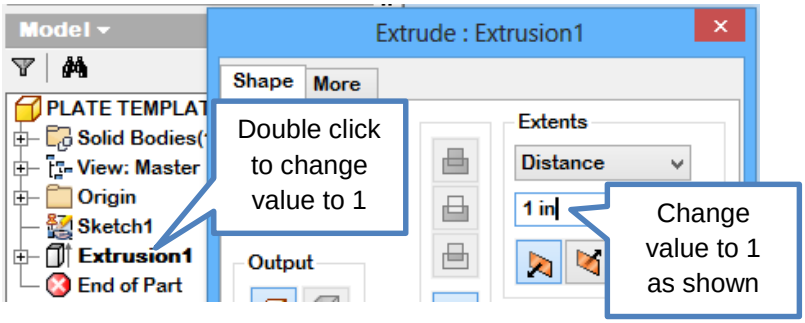


3. Change the value of the “LTH” and “WTH” dimensions to 18. Click the Update icon to implement the new dimension values. Turn off the visibility of Sketch1.

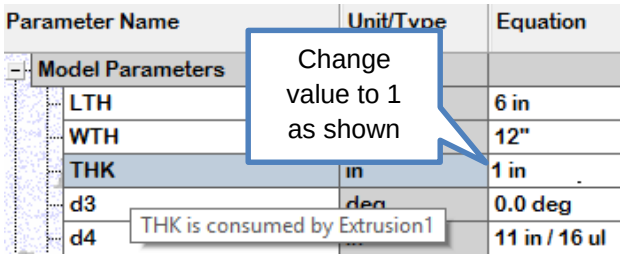




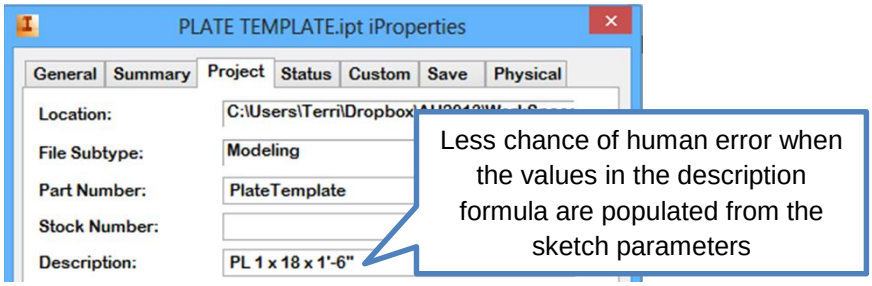
4. Change the value of the “THK” parameter to 1” either by opening the Parameter dialog box or double click on Extrusion1.



OR



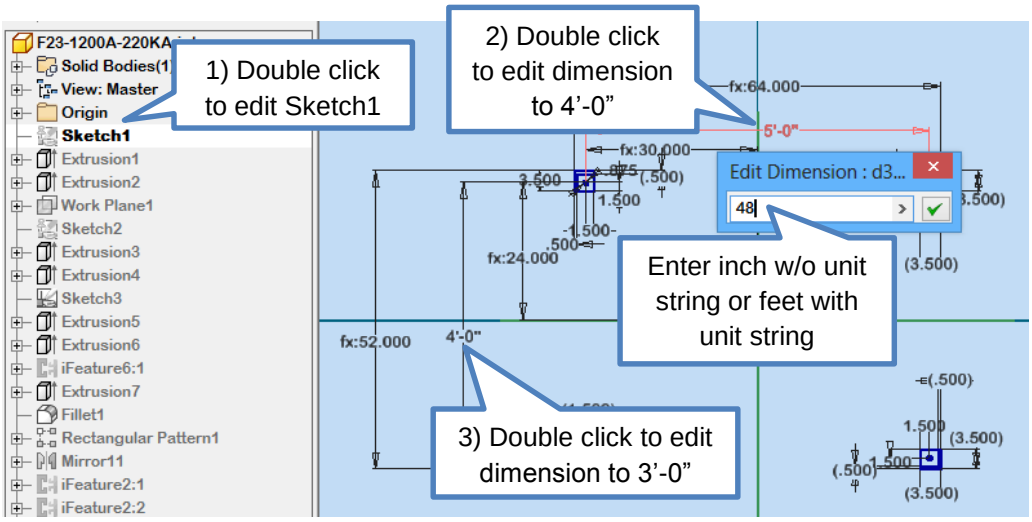
5. Open iProperties and click on the Project Tab. Notice the description has automatically been updated by the parameters in the formula.



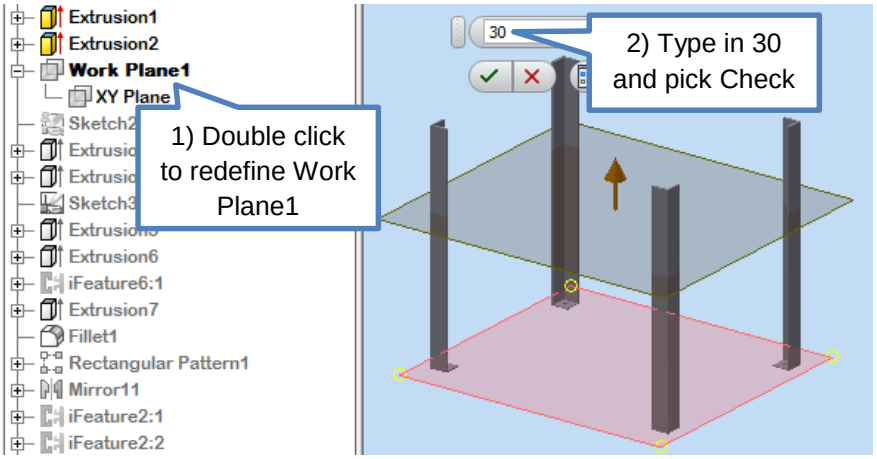
6. Save and close the PLATE TEMPLATE.

Typical Circuit Breaker

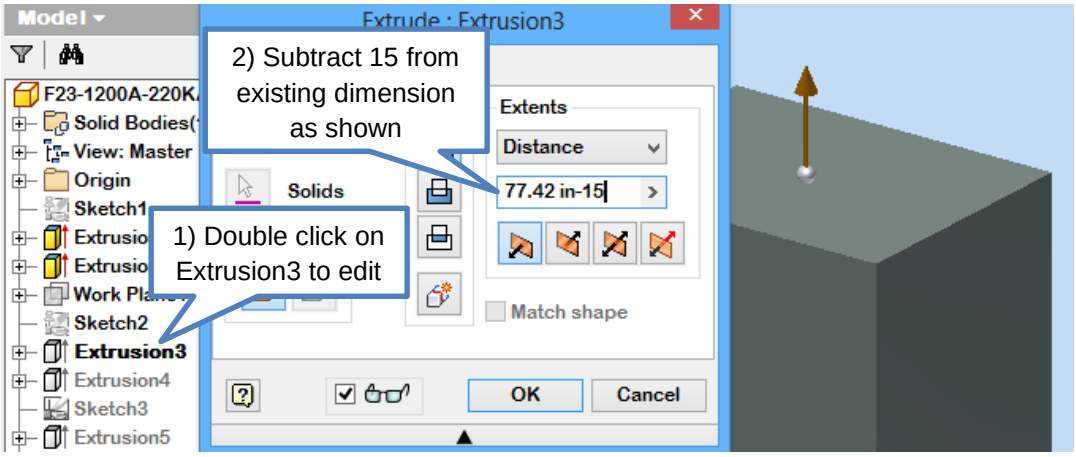
1. Open the file F23-1200A-22KA.ipt. To modify the anchor bolt pattern, edit Sketch1. Replace the 5'-0" dimension with 4'-0". Replace the 4'-0" dimension with 3'-0". Finish Sketch.



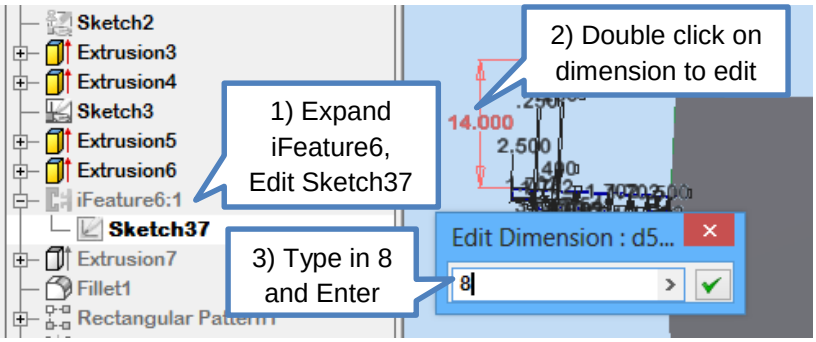
2. Double click on Work Plane1 to redefine. Change the distance to 30" and enter.



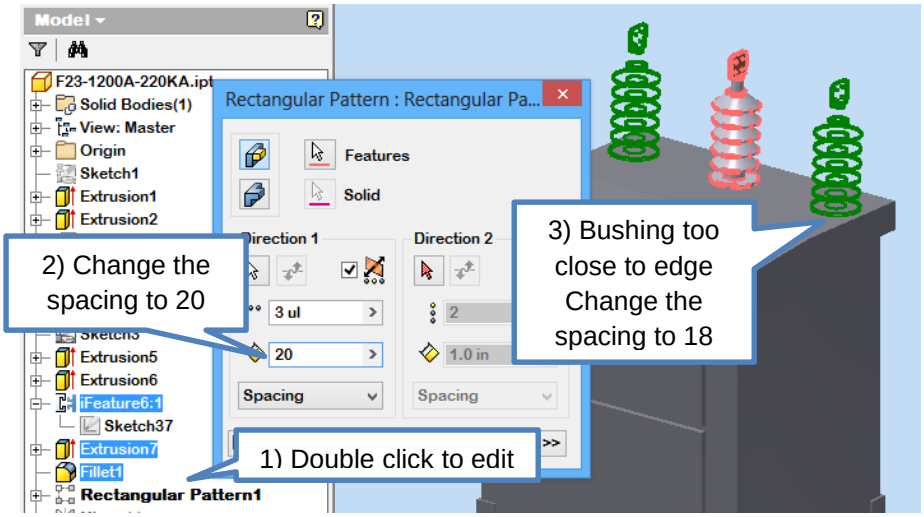
3. Edit Extrusion3. Subtract 15 from existing Distance dimension.



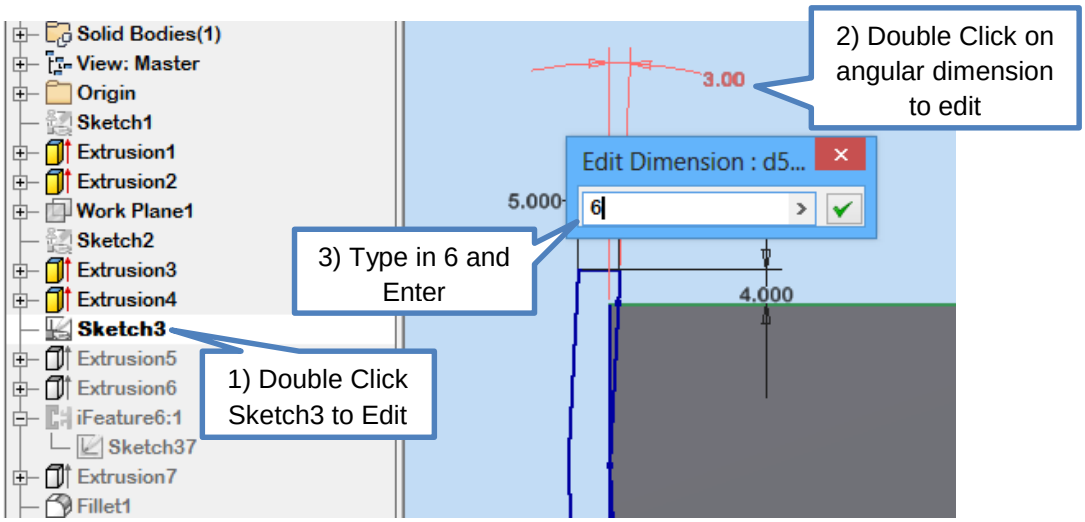
4. Set the View Cube to right. Expand “iFeature6 to edit Sketch37. Change the value of the distance from edge to center point of bushing from 14” to 8”. Finish Sketch.



5. Change the View Cube to Home. Edit Rectangular Patteren1. Change the value of the spacing from 16” to 20”. From the preview we can tell that the bushings are too close to the edge of the breaker. Change the spacing to 18” and enter.



6. Set the View Cube to the Right. Edit Sketch3. Change the slope from 3 deg to 6 deg. Finish sketch.



7. Save and close the file.

There are several more adjustments that can be made such as relocating the conduit entrance and relocating the cabinet door by redefining their sketch.

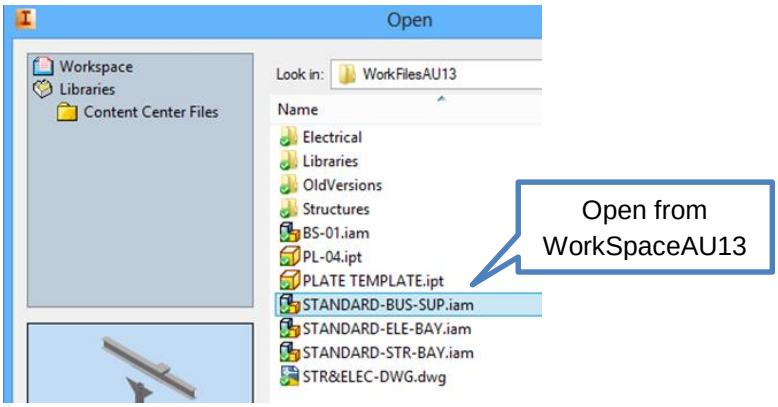
▪ Alter standard models to fit any unique application

Standard Sub-Assembly

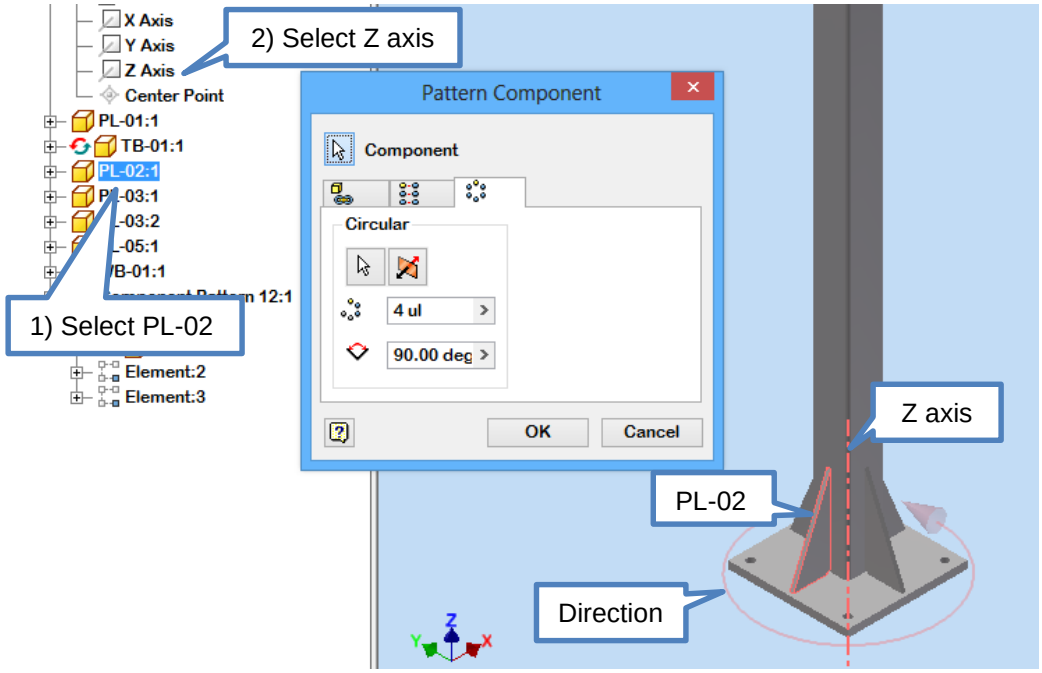
This example shows how to use one Standard Sub-Assembly for multiple applications. The constraint relationships between the parts allows the model to adapt to dimensional changes. In the first exercise we'll finish constraining a standard bus support assembly. In the second exercise we'll convert the standard bus support assembly to a 161kV bus support structure. In the third exercise we'll finish an electrical assembly by adding cabling, sizing the switches and completing the three phases.

Standard Bus Support Model

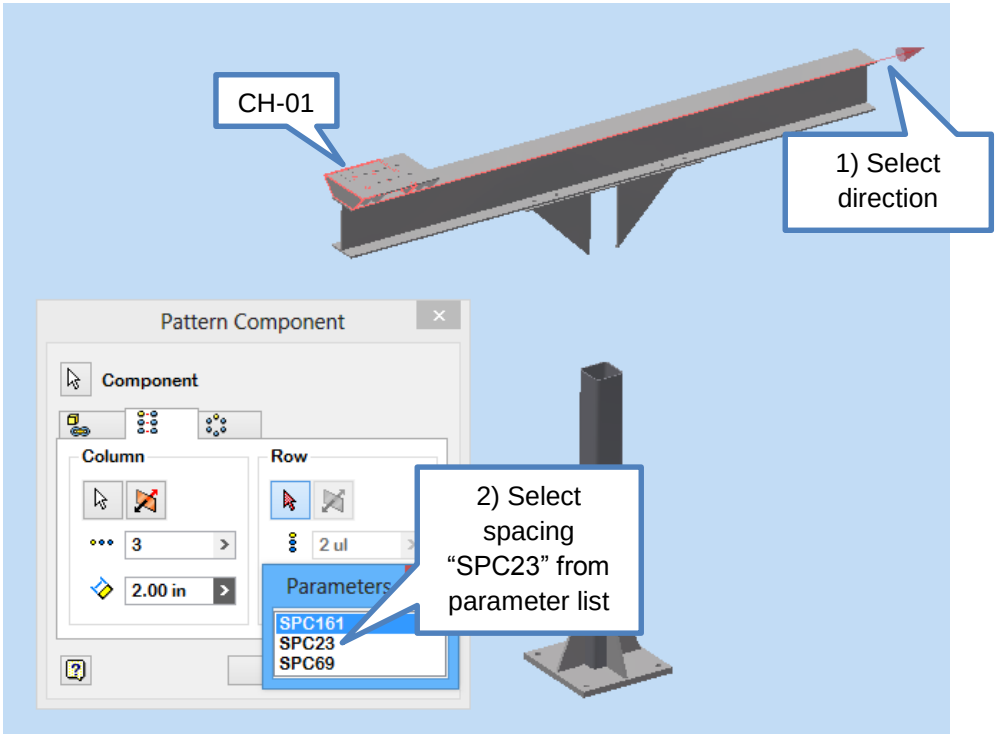
1. Open the file STANDARD-BUS-SUP.iam.



2. Create a Circular Pattern of support plate “PL-02” around the Z axis.

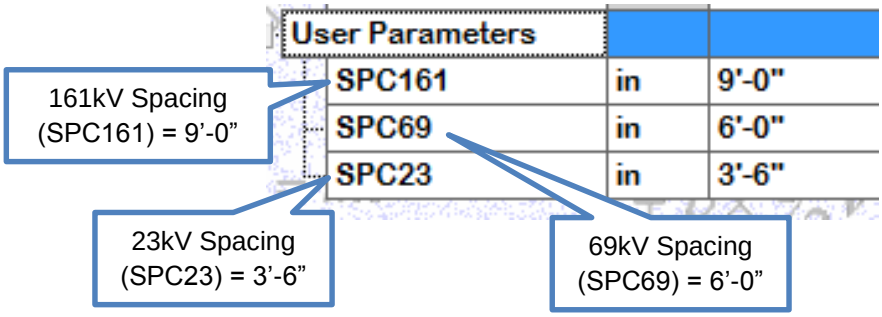


3. Create a Rectangular Pattern of channel CH-01. Pick the direction by picking an edge. Highlight the spacing value, right click, pick List Parameters and choose “SPC23”.

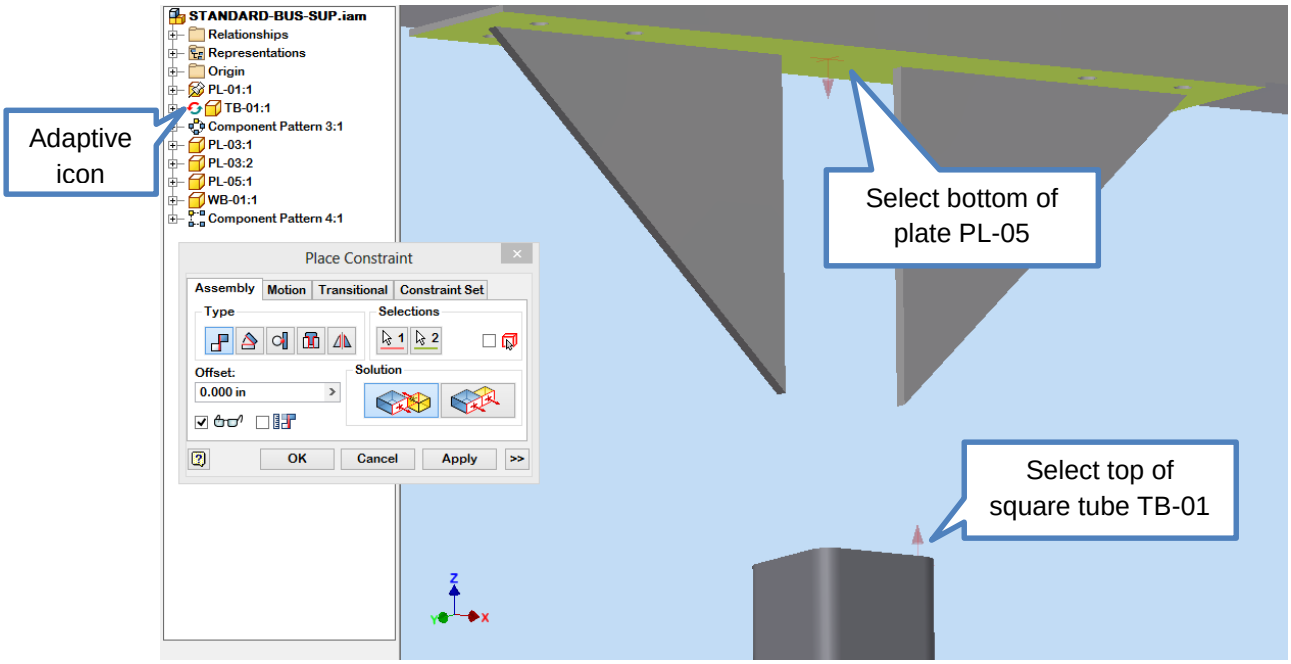


TYPICAL PHASE TO PHASE SPACING

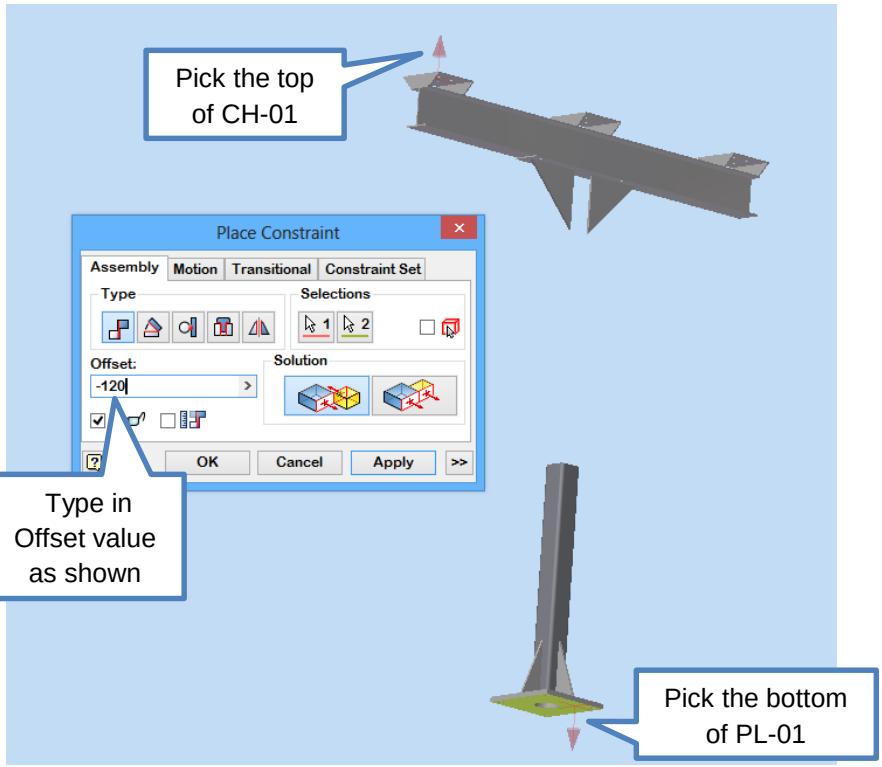
User Parameters are set up to correspond to the phase to phase spacing for different voltages as shown below.



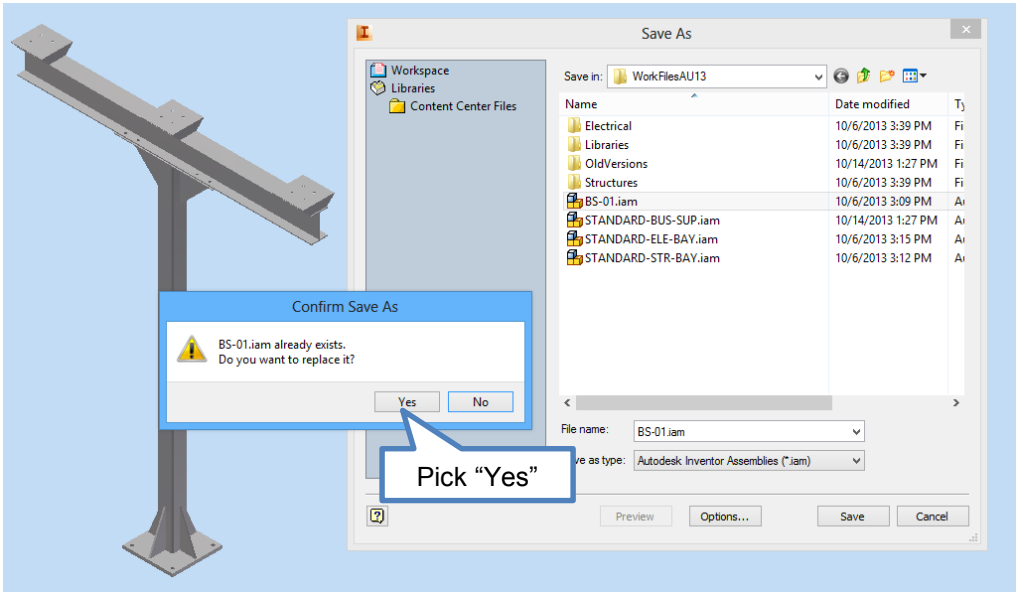
4. Constrain top of square tube "TB-01" to bottom of plate "PL-05". The adaptivity of the square tube allows the length to adjust according to the constraints



5. Use the mate constraint to constrain the top of channel CH-01 to the bottom of plate PL-01. Change the offset value to “-120” or “-10ft” then click “Apply”



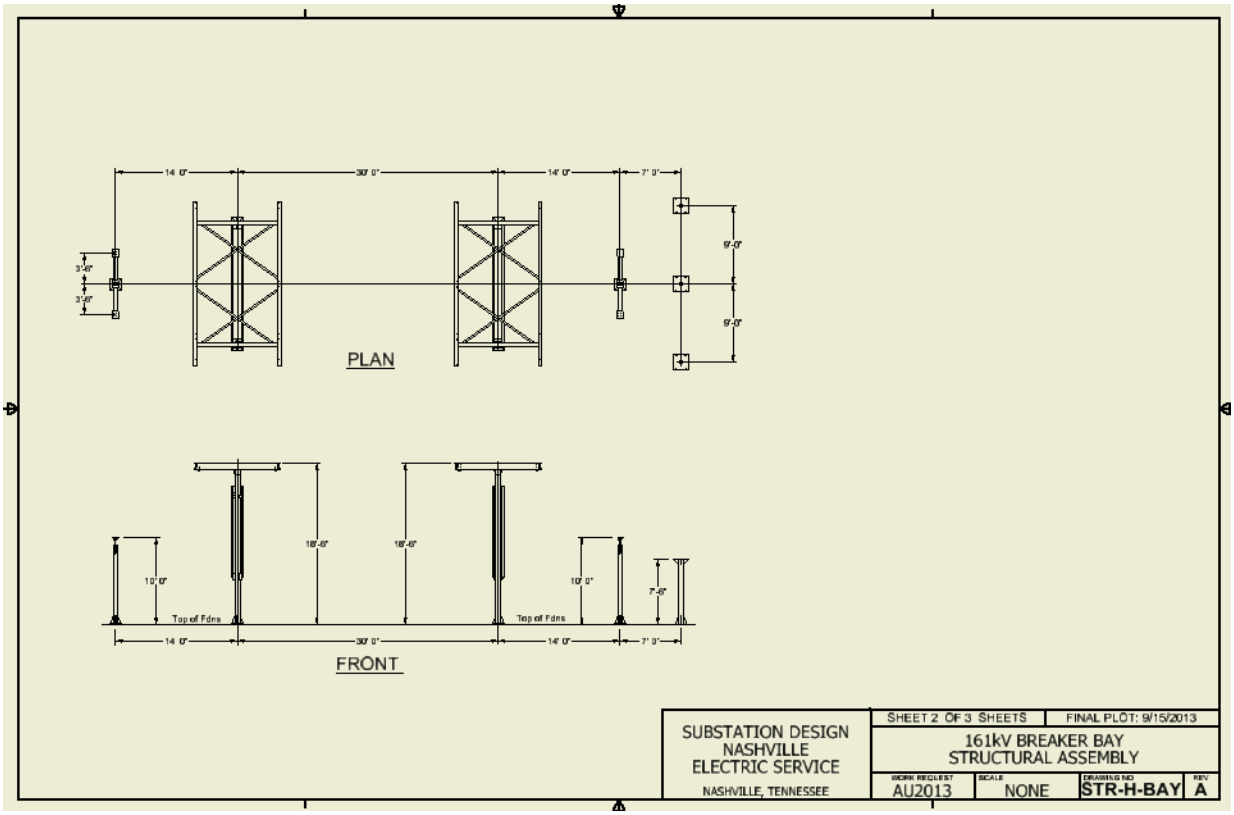
6. The Standard Bus Support Assembly is complete. Save as BS-01 to keep the Standard Assembly pristine. (Select “Yes” to replace existing BS-01 file.)



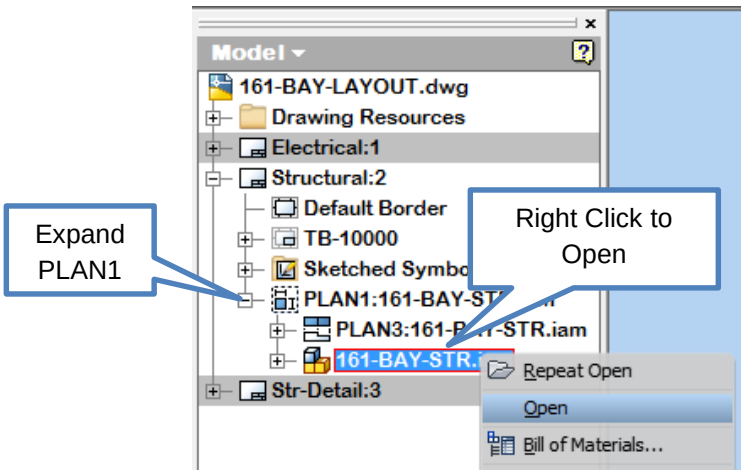
7. DO NOT CLOSE

Standard Structural Models

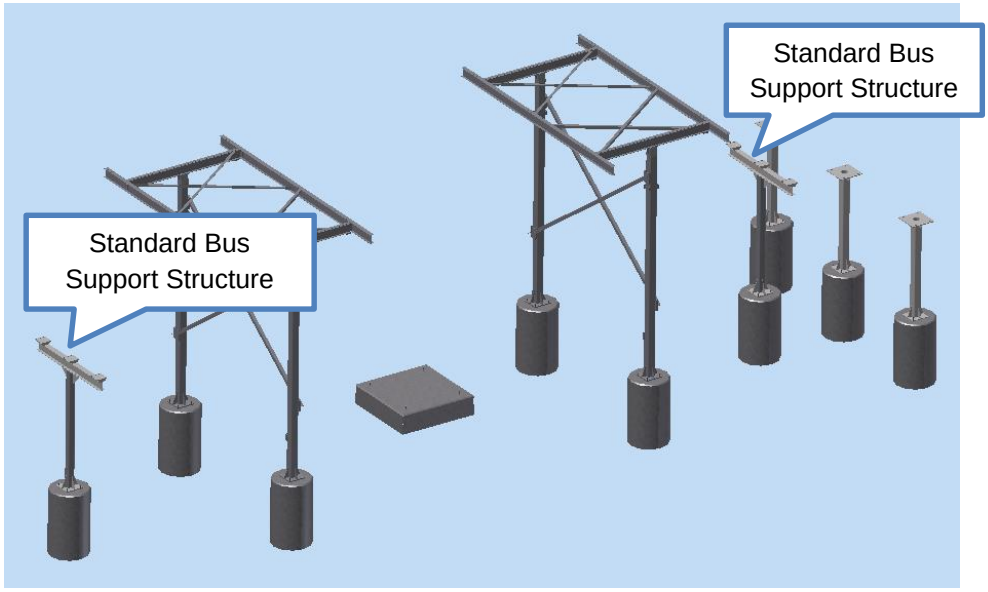
1. Open 161-BAY-LAYOUT.dwg



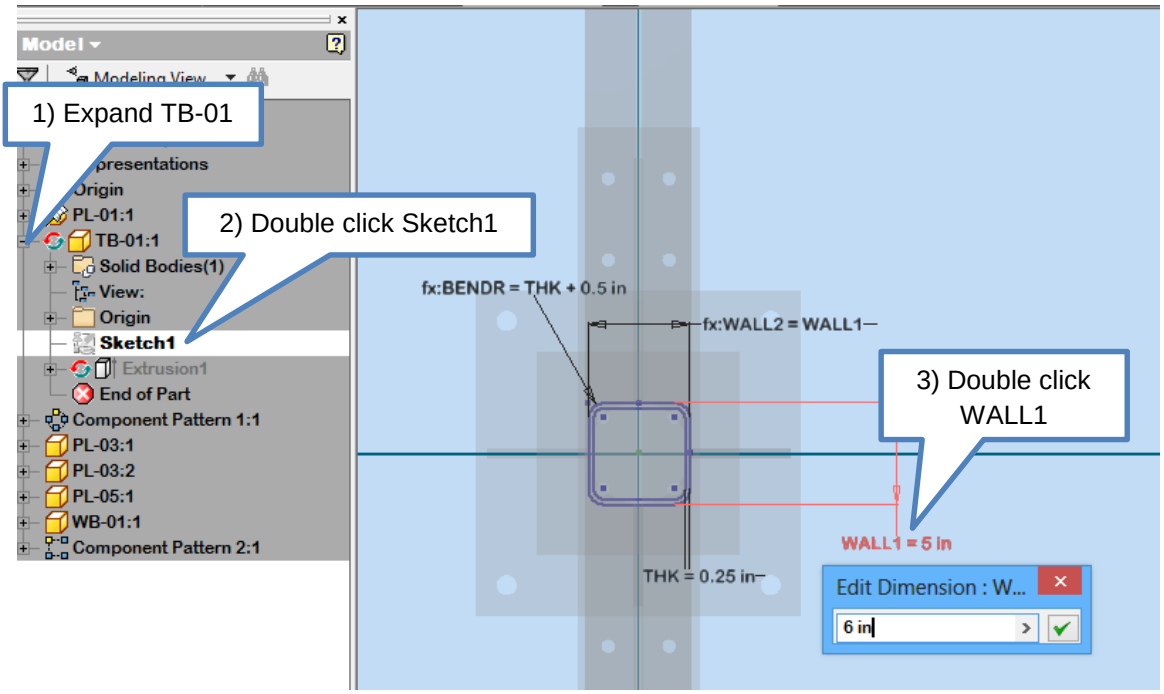
2. Open 161-BAY-STR.iam.from the browser under the “Structural” sheet and PLAN1.



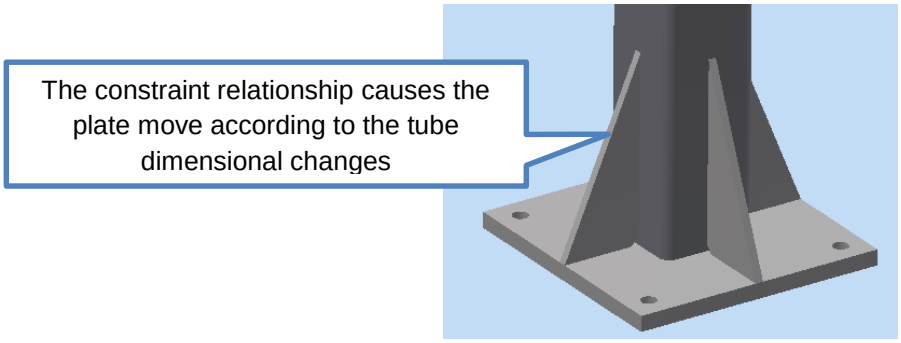
This is the foundations and structures of a Standard Structural Bay Assembly. In these next steps we will convert the Standard Bus Support to a 161kV structure. The assembly and drawing will automatically update as the Bus Support is altered.



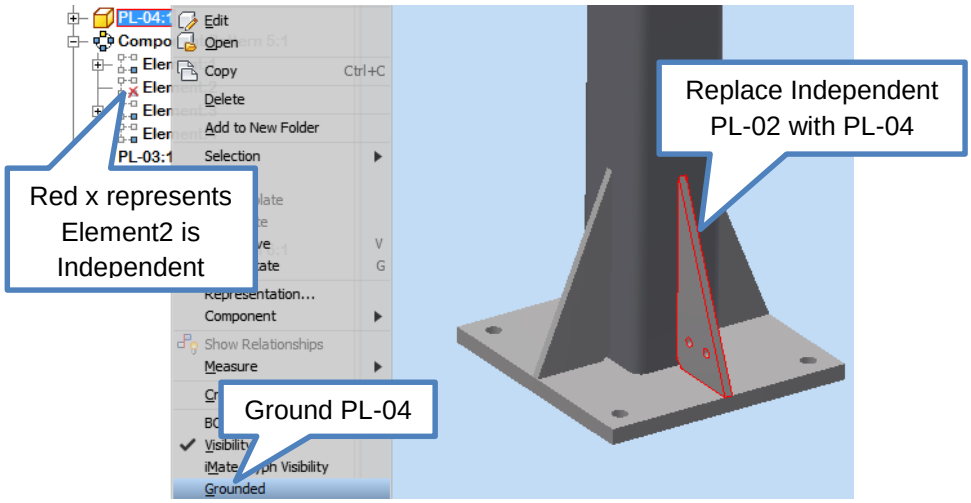
3. Make BS-01 tab current. Expand TB-01 in the browser. Double click on the shared Sketch1 to edit from assembly. Double click on the parameter “WALL1”. Change the value in the Edit Dimension box to 6 in.



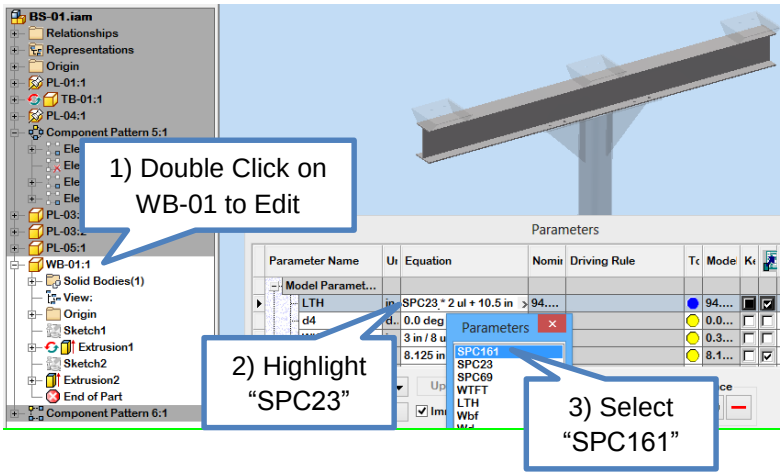
4. Finish the sketch and notice the tube enlarges. Click “Return” and notice the plates adjust to the larger tube.



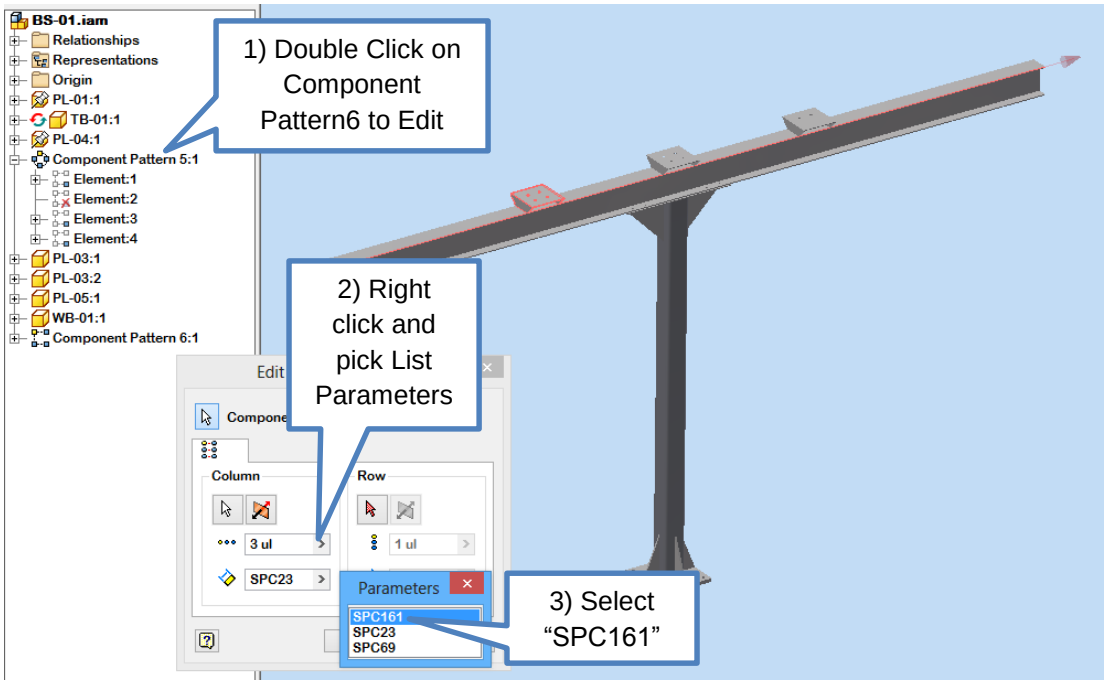
5. Expand “Component Pattern 5”. Right click on Element;2 and pick “Independent”. Replace the Independent PL-02 with PL-04 and ground. (an Independent Element loses its constraints)



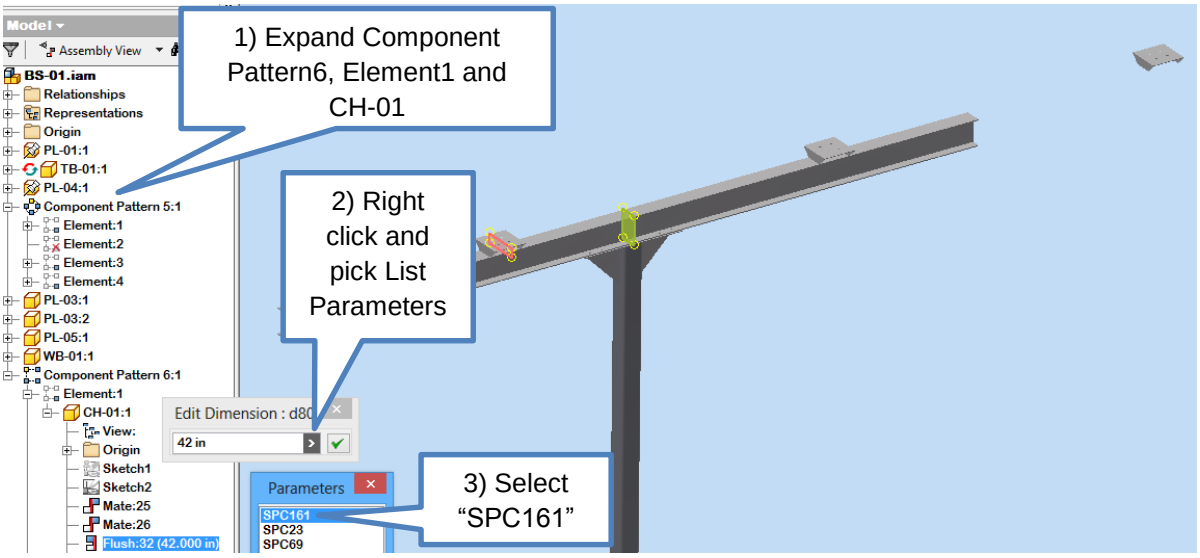
6. Double click on WB-01 to edit the beam. Open the Parameter dialog box. Highlight only “SPC23” of the Equation in the “LTH” parameter, right click, and click List Parameters then select “SPC161”. Return to the main assembly.



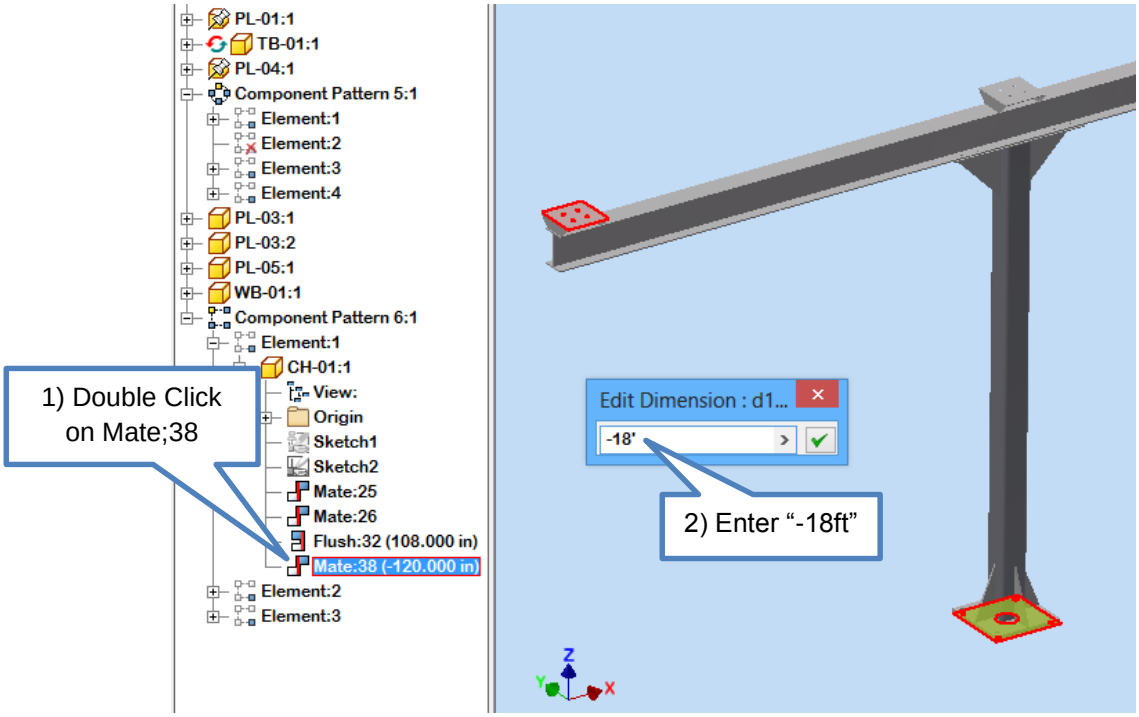
7. Double click on “Component Pattern 6” to edit. To change the spacing of the pattern, click on the arrow in the Edit Dimension box and pick List Parameters then select “SPC161”.



8. Expand “Component Pattern 6, Element;1 and CH-01. Double click on Flush;32, click on the arrow in the Edit Dimension box, List Parameters and pick “SPC161” then enter.



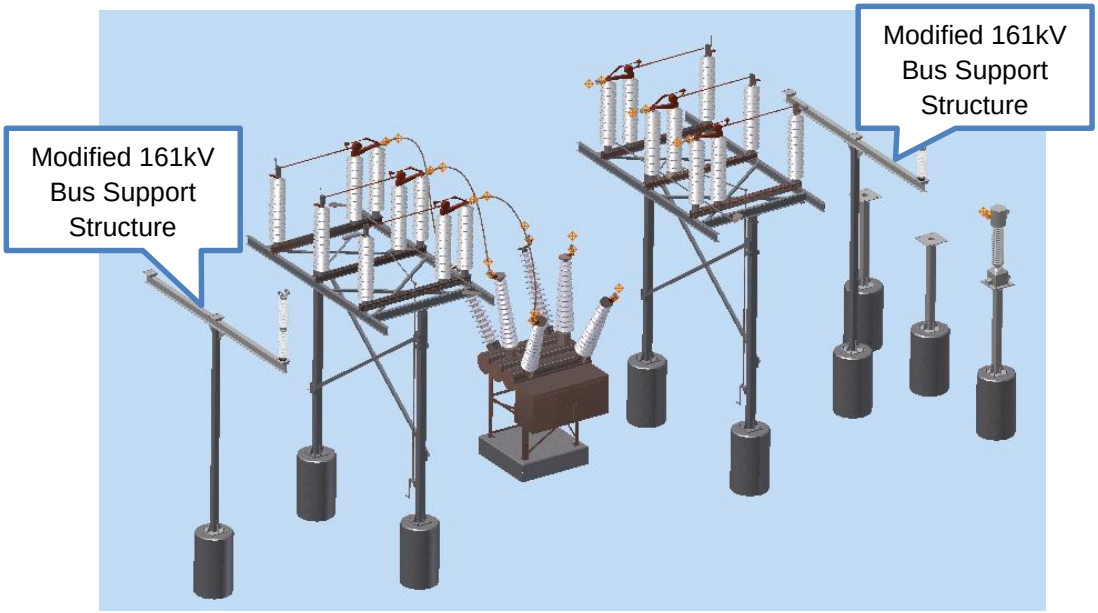
9. Double click on Mate;39. (This constraint was set in the standard bus support assembly in steps 4 and 5) Type in "-18ft" and enter. Save and Close.



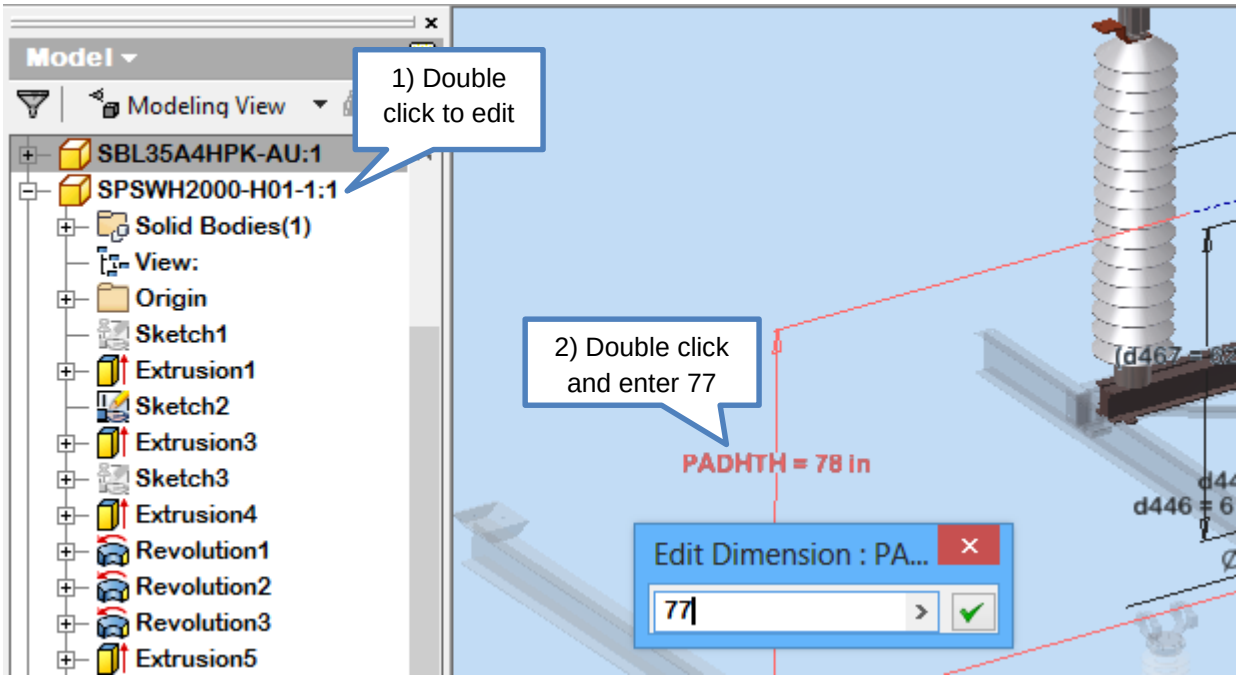
Standard Electrical Models

The structure assembly is modified to a 161kV structure. Now we will complete the electrical assembly.

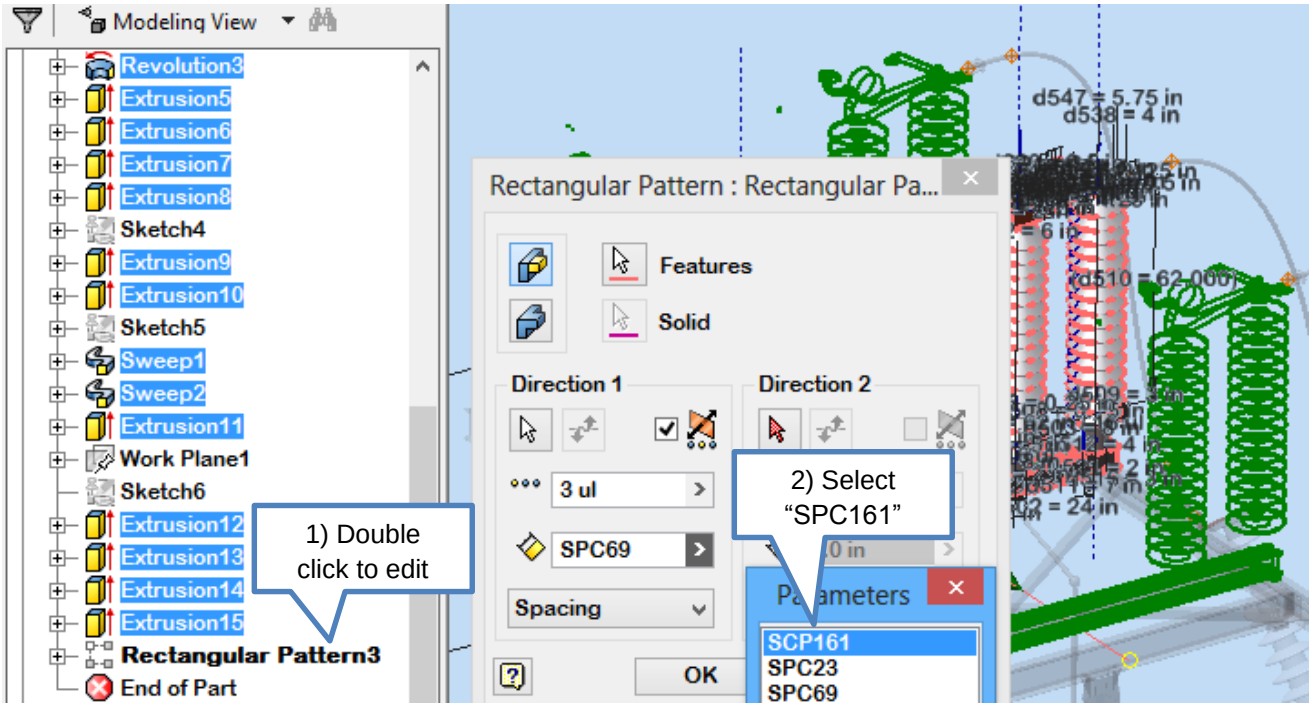
1. Make drawing 161-BAY-LAYOUT.dwg current. Activate the Electrical sheet, expand PLAN1 and right click on 161-BAY-ELE.iam to open assembly.



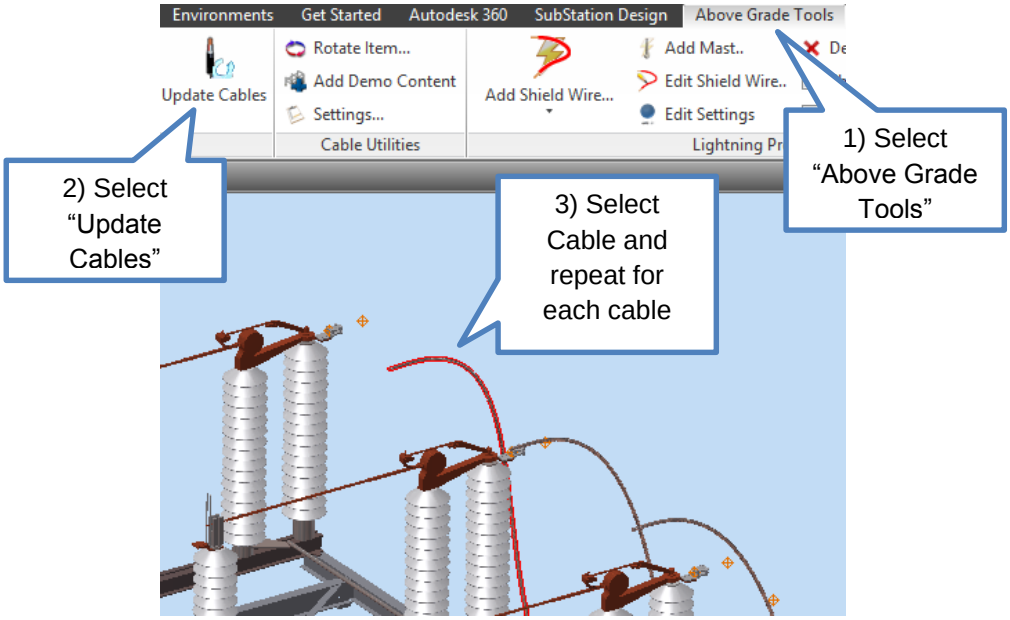
2. Double click on the switch “SPSWH2000-H01;1 to edit. Double click on Sketch2. Double Click on dimension “PADHTH” and type in a new value of 77 then enter.



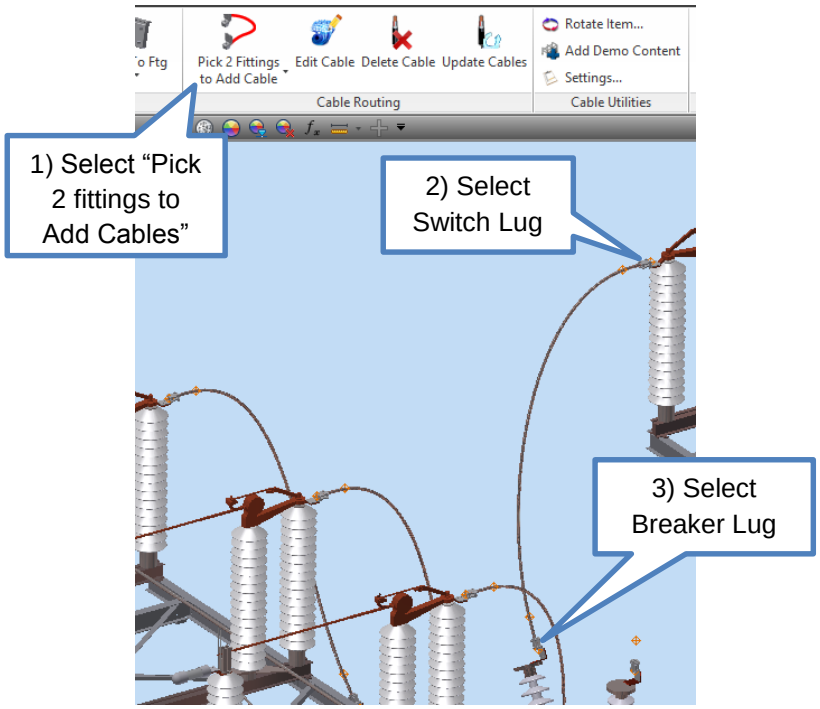
3. Edit Rectangular Pattern3. Change the spacing by using the parameter “SPC161”. Click on OK and return to assembly.



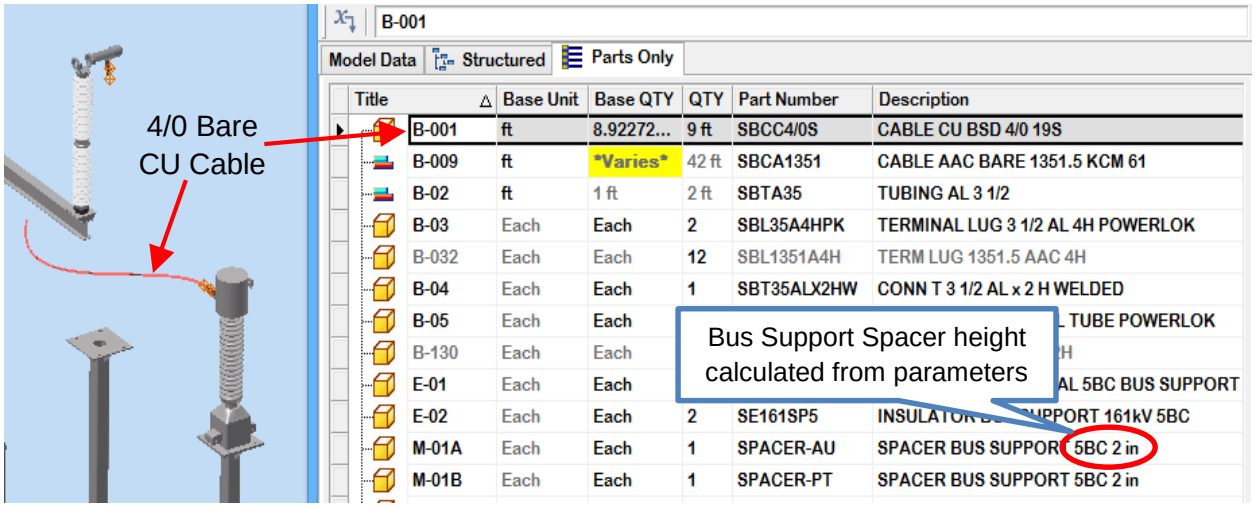
4. Next we will modify or add cabling as required. First we will re-attach the cabling that lost its connection when the switch was modified. We use the Substation Designer Suite by AutomationForce for our cabling. Go to the “Above Grade Tools” and pick the “Update Cable” icon. Pick the cable as shown. Notice the cables reconnect to their corresponding terminal lugs. Do this for each cable.



5. Pick the “Pick 2 Fittings to Add Cable” icon. Pick the lug on the switch pad then the lug on the breaker. The cable is generated. Do this for the other leads.

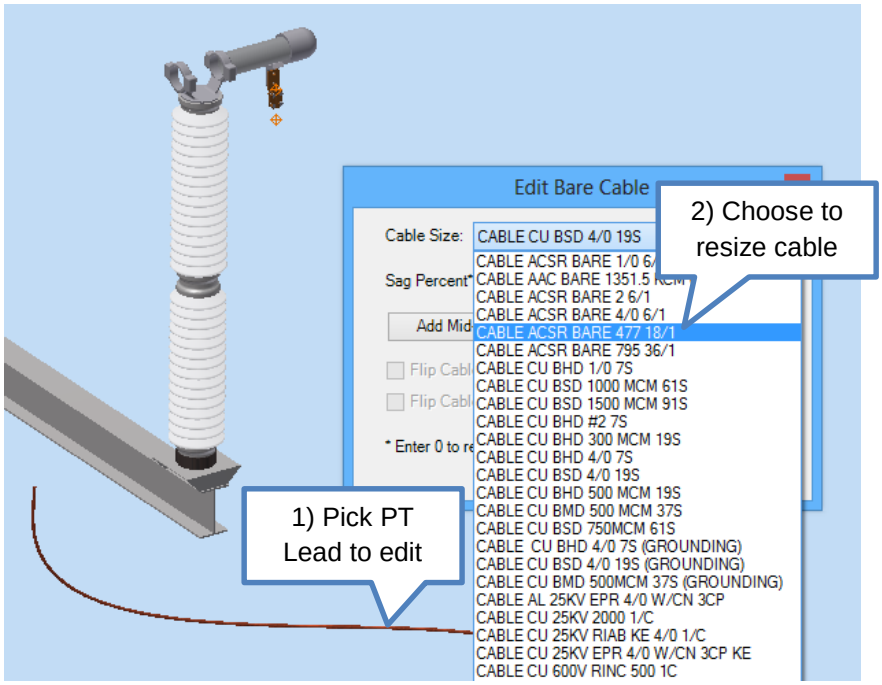


6. Open the BOM to see how the existing parts are listed.

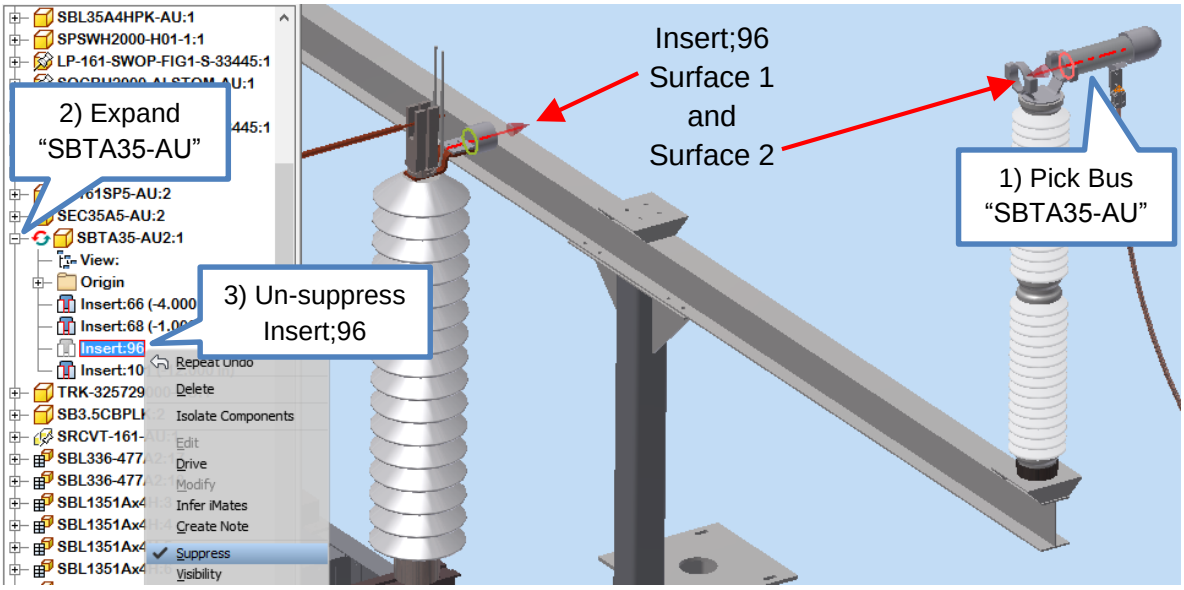


Title	Base Unit	Base QTY	QTY	Part Number	Description
B-001	ft	8.92272...	9 ft	SBCC4/0S	CABLE CU BSD 4/0 19S
B-009	ft	*Varies*	42 ft	SBCA1351	CABLE AAC BARE 1351.5 KCM 61
B-02	ft	1 ft	2 ft	SBTA35	TUBING AL 3 1/2
B-03	Each	Each	2	SBL35A4HPK	TERMINAL LUG 3 1/2 AL 4H POWERLOK
B-032	Each	Each	12	SBL1351A4H	TERM LUG 1351.5 AAC 4H
B-04	Each	Each	1	SBT35ALX2HW	CONN T 3 1/2 AL x 2 H WELDED
B-05	Each	Each			L TUBE POWERLOK
B-130	Each	Each			H
E-01	Each	Each			AL 5BC BUS SUPPORT
E-02	Each	Each	2	SE161SP5	INSULATOR ... UPPORT 161kV 5BC
M-01A	Each	Each	1	SPACER-AU	SPACER BUS SUPPORT 5BC 2 in
M-01B	Each	Each	1	SPACER-PT	SPACER BUS SUPPORT 5BC 2 in

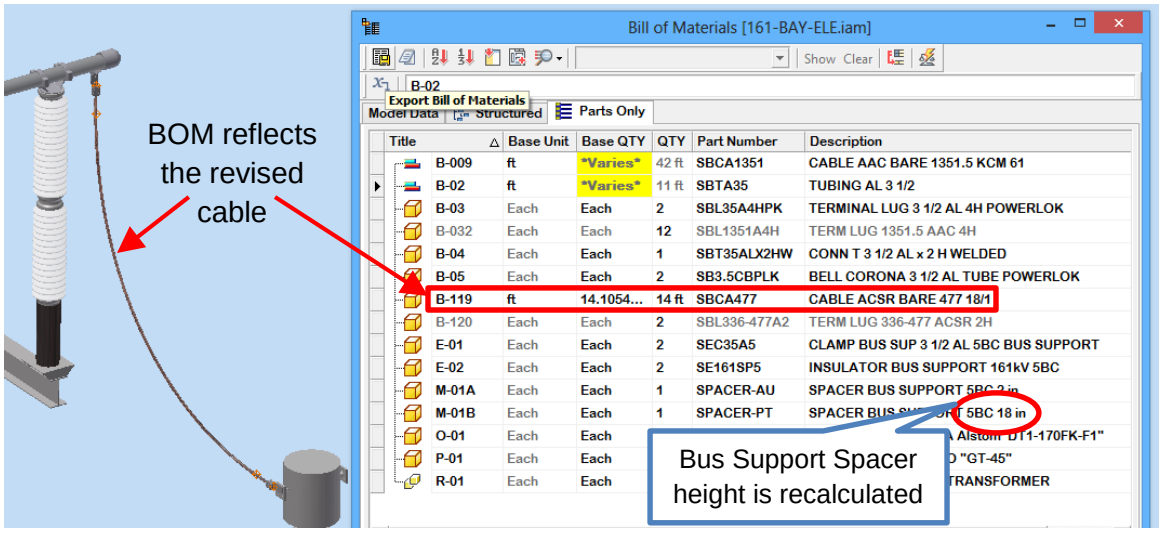
7. Relocate and revise the cable size by selecting “Edit Cable” in the “Above Grade Tools”, pick the PT lead. The Edit Bare Cable dialog box opens. Click on the arrow in the cable size box and pick “CABLE ACSR BARE 477 18/1”. Choose Apply then Done.



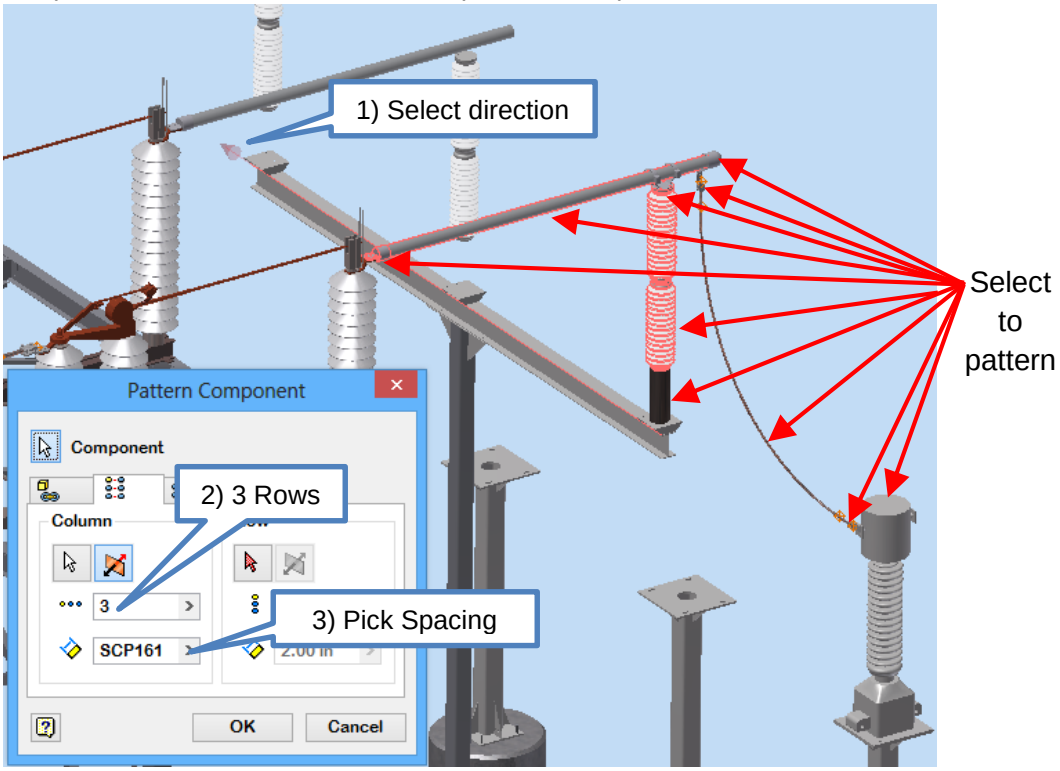
8. Click on the bus to which the PT lead is attached. Find the highlighted part (SBTA35-AU) in the browser and expand. Right click on the greyed out (suppressed) Insert;96. The bus is constrained to the switch terminal lug. Click on “Suppress” to unsuppressed the constraint and watch what happens.



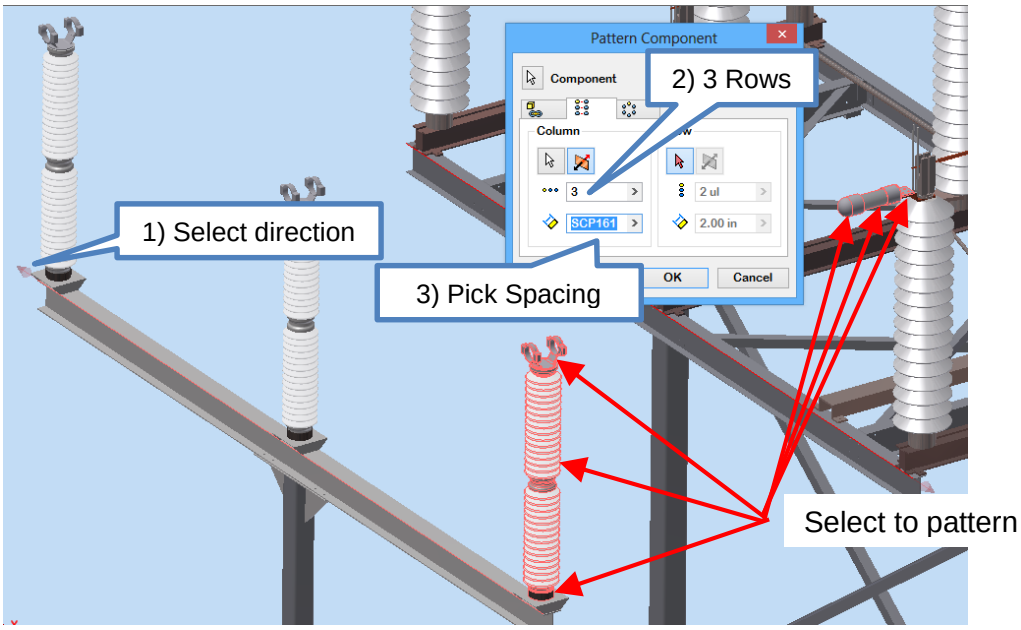
9. Reopen the BOM to see how the changes affected the listed parts.



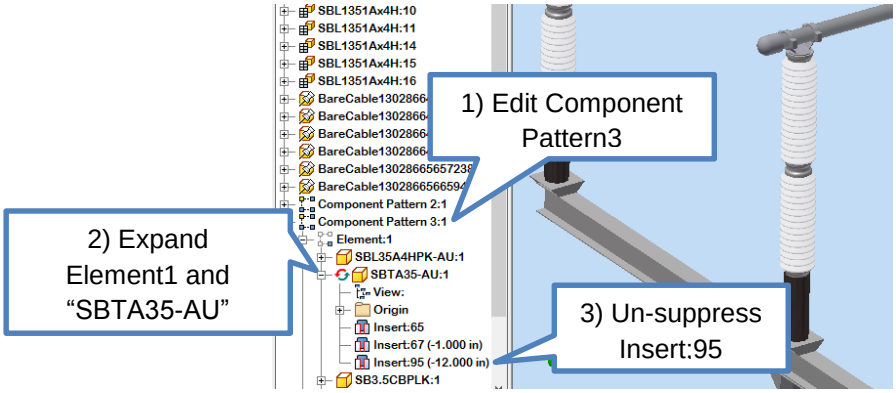
10. Update the PT lead using the SDS “Above Grade Tool”. Create a Rectangular Pattern. Click on the direction arrow and pick an edge. Make 3 rows and pick the “SPC161” spacing. Pick the component arrow and select each component to be patterned as shown below.



11. Repeat patterned component. Select the components as shown below. Select the correct direction choose 3 rows and “SPC161” then click OK.



12. The last step in this section is to extend the bus. Edit Patteren3, expand Element 1, and unsuppressed Insert; 95.



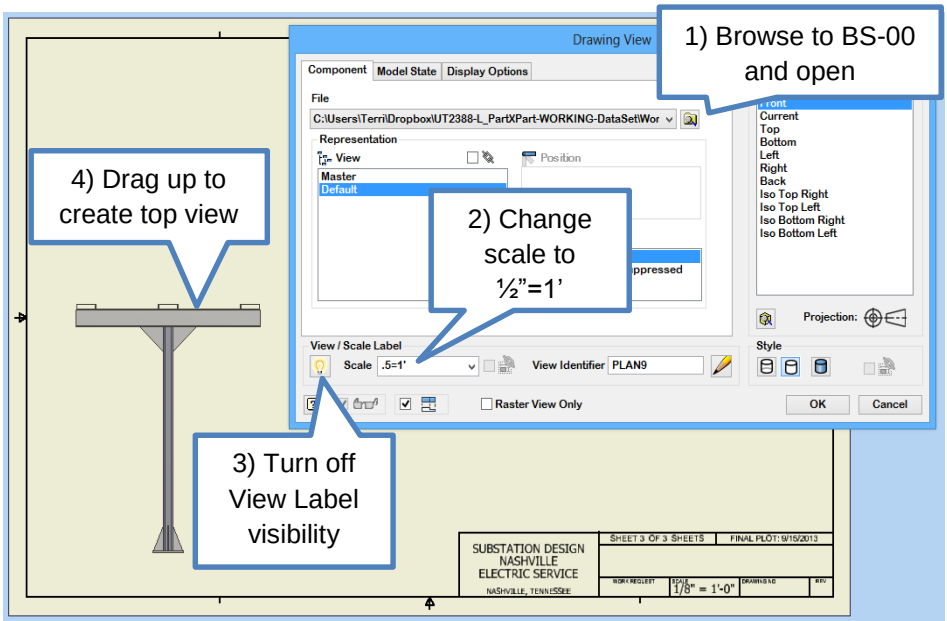
- **Quickly generate quality construction drawings**

Generate Drawings

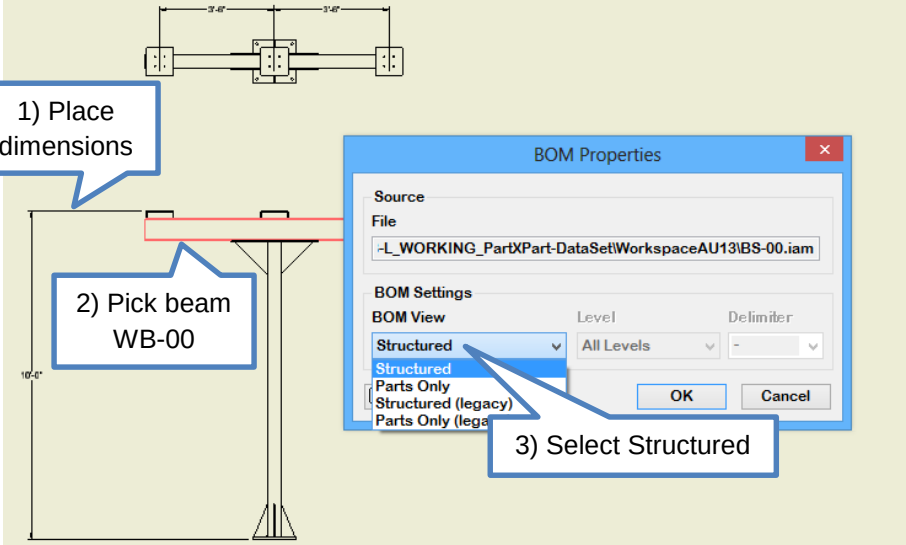
This exercise creates a standard drawing. When the Base View is placed, the Title Block is populated. Next, the Views are annotated by placing Dimensions, Balloons and the Parts List. Now replace the standard model using the Replace Model Reference tool. The Views, Dimensions, Balloons, Title Block and Parts List all update to the values of the new model automatically. Some clean-up is usually required, such as moving dimensions, changing scale, sorting the Parts List, etc.

Standard Drawings

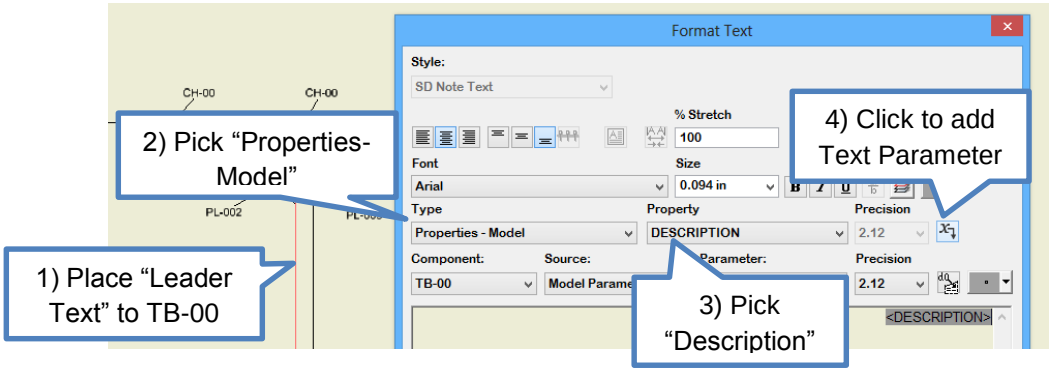
1. Make the 161-BAY-LAYOUT.dwg current. Activate the "Structure-Det" sheet. Open the Base View dialog box. Browse to open "BS-00". In the Base View dialog box, change the scale to ½"=1 and turn off the View Label visibility. Place the front view, drag up to place the top view, right click then pick "Create".



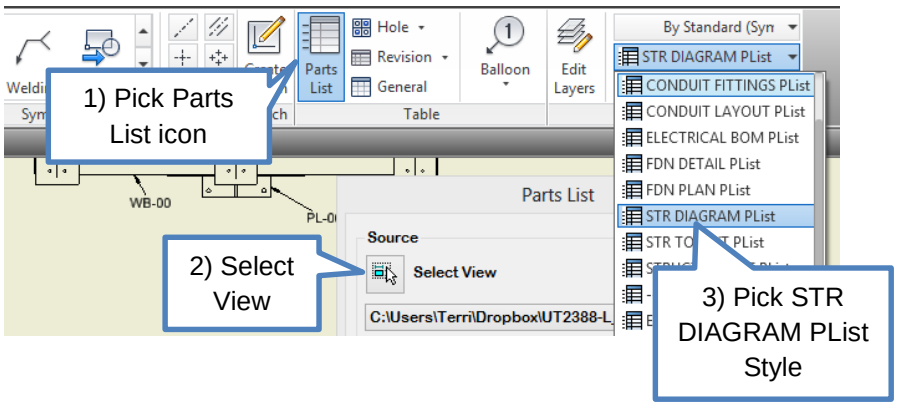
2. Place Dimensions as shown. To place Balloons, right click and select the Balloon button. Pick the beam WB-00 in the structure as shown. In the BOM Properties dialog box, click on the arrow in the "BOM View" box and select "Structured". Click OK, place the Balloon, right click, pick "Continue" and repeat.



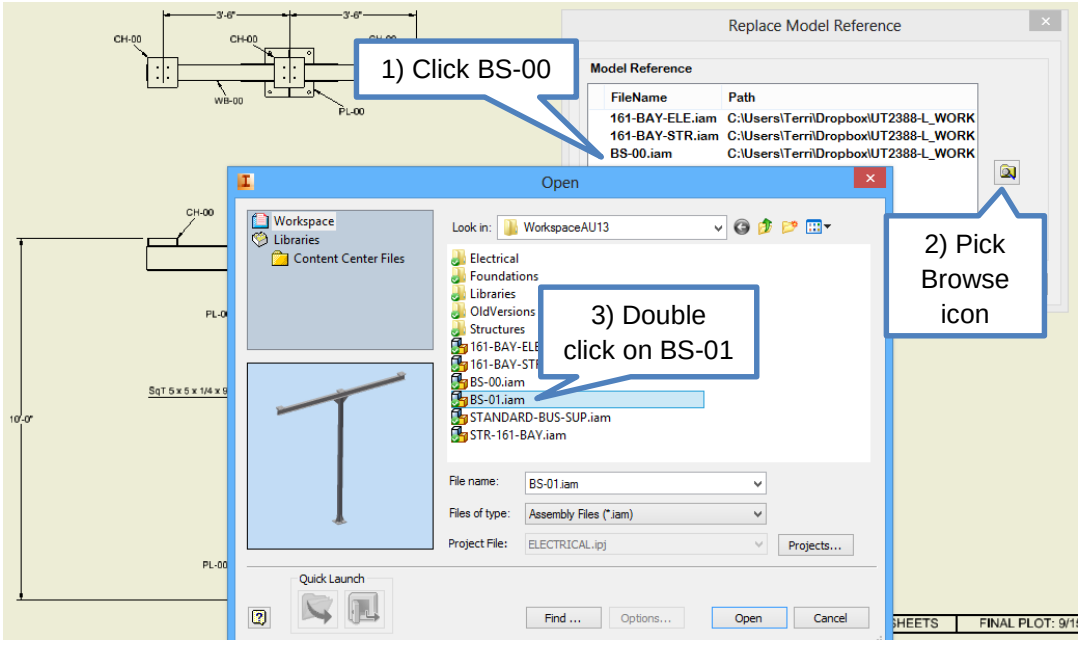
3. Place "Leader Text" pointing to the column TB-00. In the Format Text dialog box, pick "Properties – Model" from the "Type" menu. Then from the "Properties" menu, pick "Description".



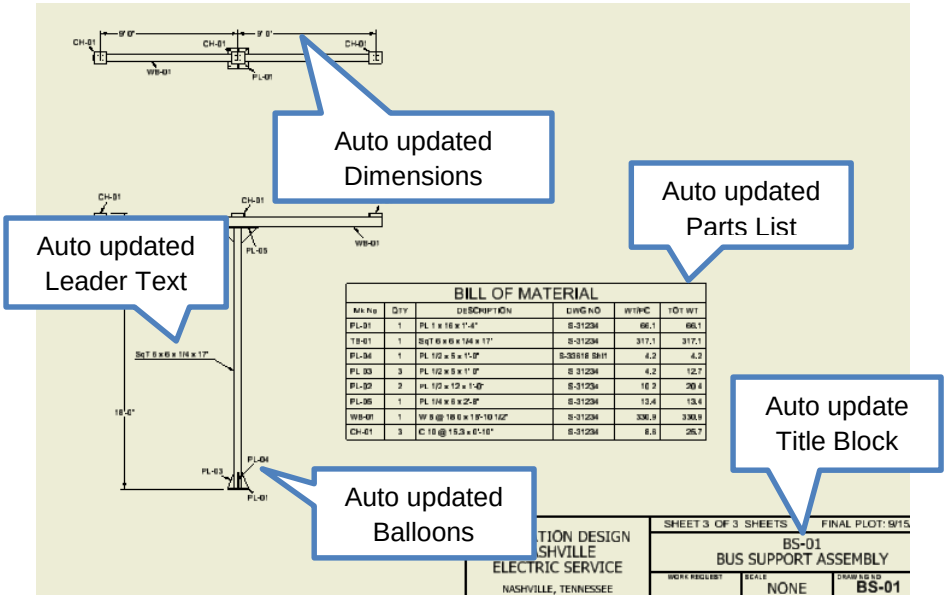
4. To place the Parts List, select the icon from the Annotate tab. Select the view. Pick STR DIAGRAM PList from the style drop down menu. Click OK and place the Parts List.



5. The standard drawing is complete. To quickly create the detail drawing of BS-01, pick the "Replace Model Reference" icon on the "Manage" tab. When the Replace Model Reference dialog box opens, click on BS-00. Select the Browse icon, select BS-01 and double click to open. Pick yes at the prompt and click OK.



6. BS-00 is replaced by BS-01. Double click in the Base View. In the Drawing View dialog box, change the scale to ¼"=1' and enter. The dimensions and Mk No's updated automatically and retain their attachments.



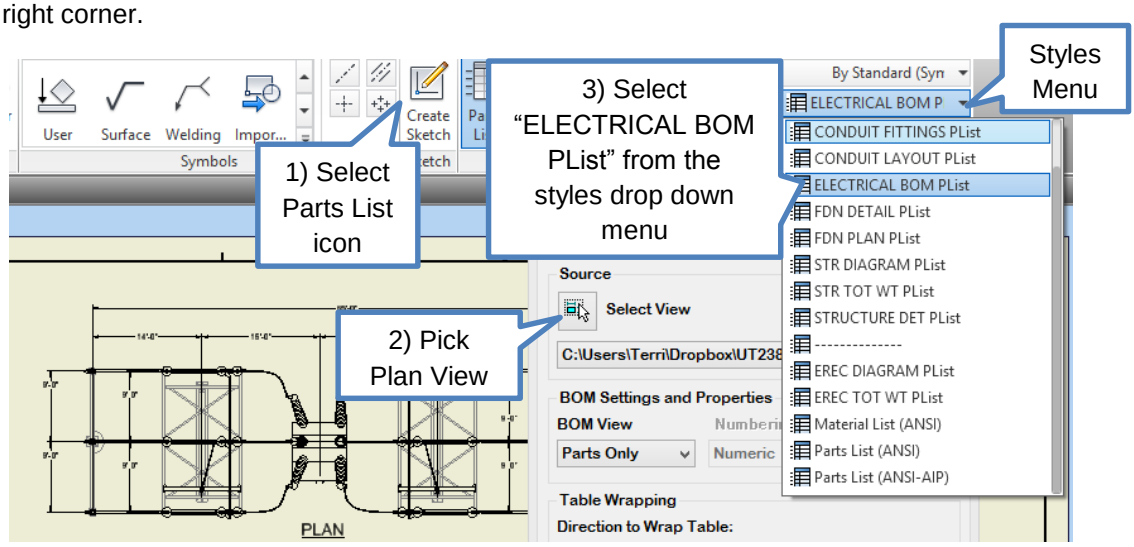
- **Create an accurate parts list using intelligent 3D models**

3D Model to BOM to Parts List

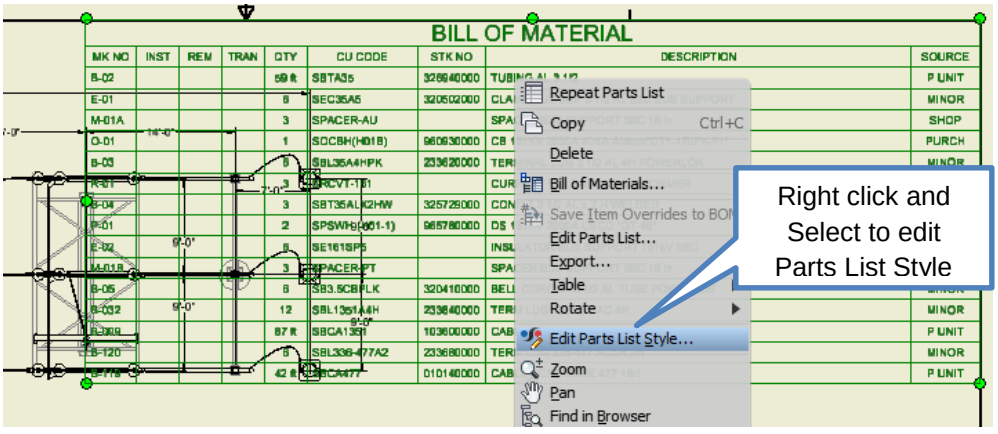
This last section shows how Balloons, Parts List Styles, Bill of Material (BOM) and Parts List work together to present the information about the parts contained in the assembly in a multitude of arrangements. The examples shown are a glimpse into the versatility of creating Bill of Materials. The first exercise shows how the Parts List Styles customizes the display of data in the Parts List. The second shows how the Balloons are related to the Parts List. Last we will look at correcting information in the BOM vs. correcting information in the Parts List.

Parts List Styles

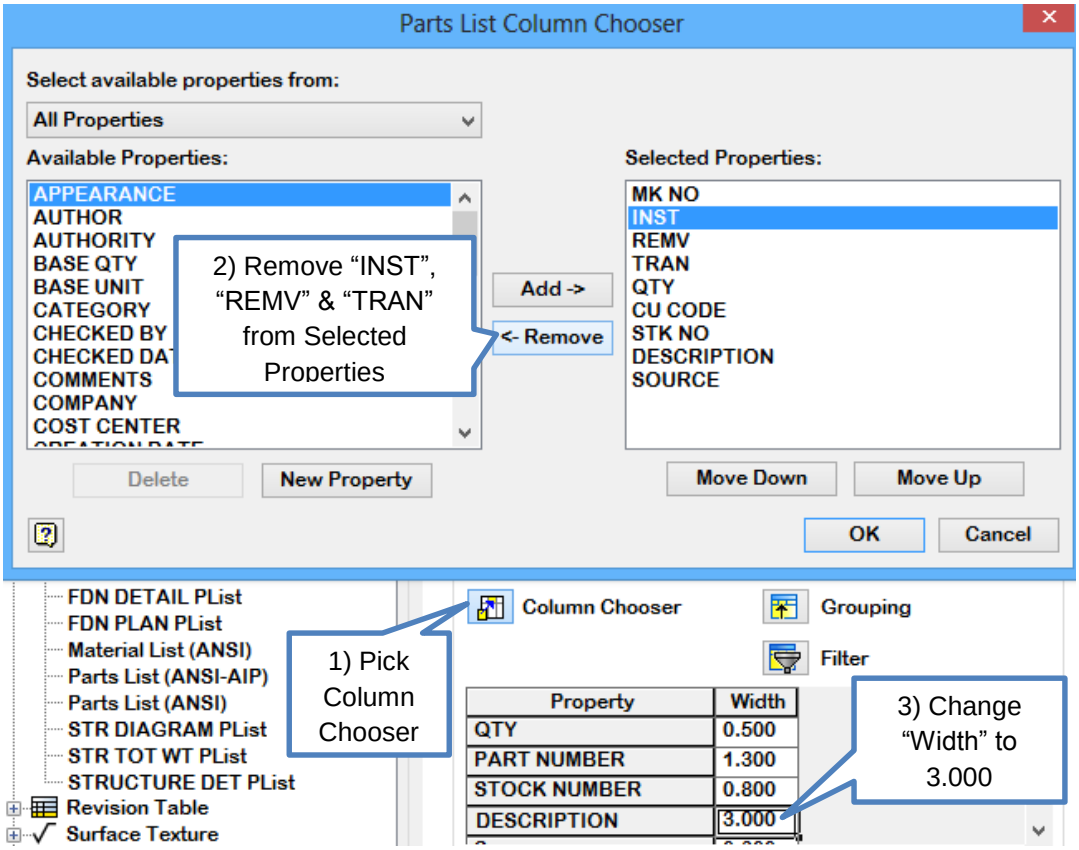
1. Make the drawing 161-BAY-LAYOUT.dwg current and activate the "Electrical" sheet. Select the Parts List icon. From the Parts List dialog box, select the PLAN view. Use the styles drop down menu to pick the "ELECTRICAL BOM PList" style. Click OK. Drop the Parts List in the upper right corner.



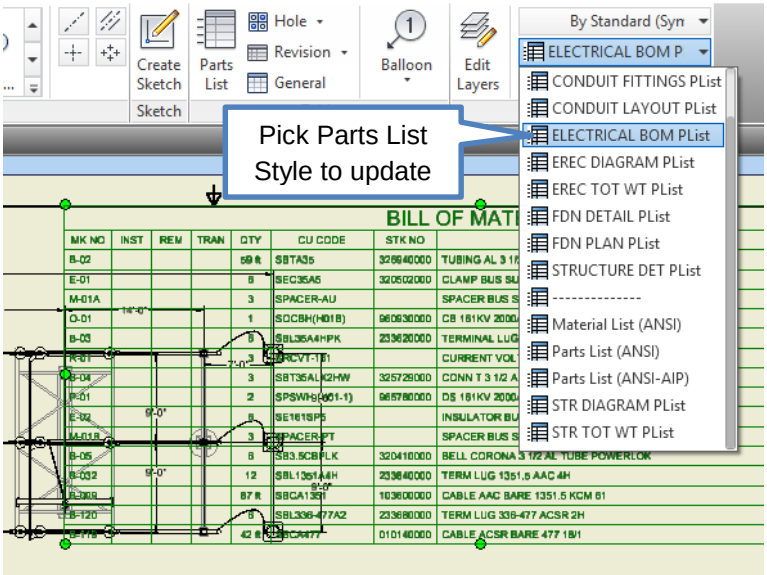
2. As you can see, we need to alter the display of the Parts List. To do this, right click and choose "Edit Parts List Style".



3. Pick the Column Chooser. Under Selected Properties, remove “INST”, “REMV” & “TRAN”. Click OK. Change the width of the “Description” column to 3.000. Click “Save” and then “Done”.

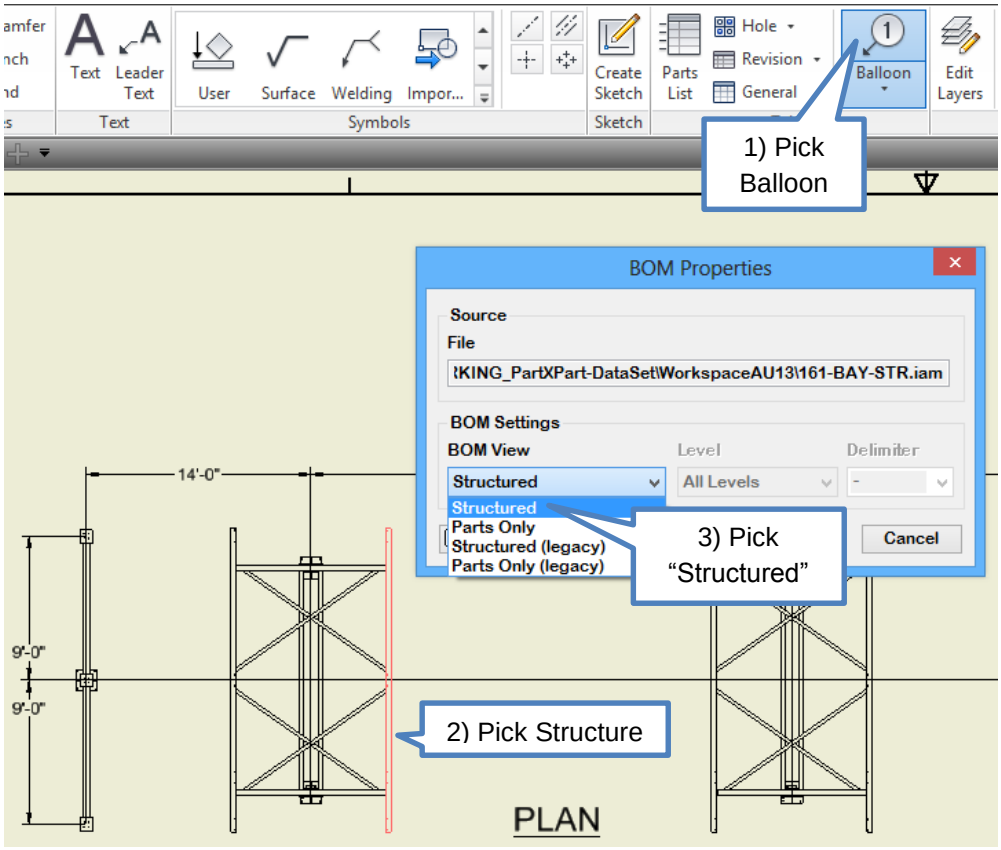


4. The Parts List must now be updated. Click on the Parts List and use the drop down styles menu to select “ELECTRICAL BOM PList”

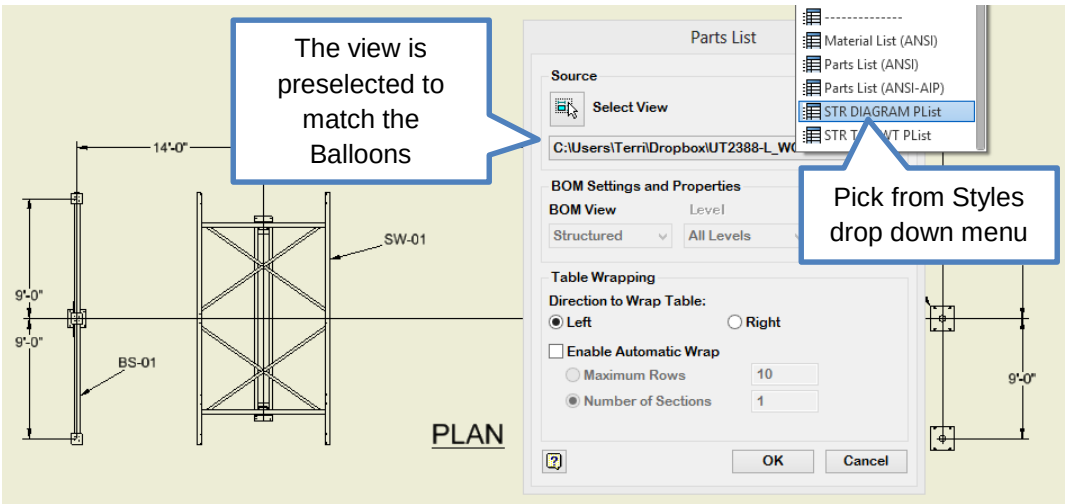


Balloons and the Parts List

1. Make the “Structural” sheet current. Click on the Balloon icon and pick a structural member. Expand the BOM View menu. Pick “Structured” to Balloon the sub-assemblies. (To Balloon the parts pick “Structured”) Click OK and place the Balloons.

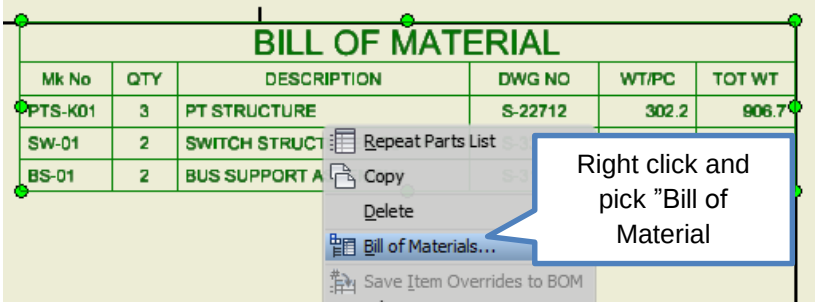


2. To place the Bill of Material, select the Parts List icon. Select the STR DIAGRAM PList from the styles menu. Place the Parts List in the upper right hand corner.

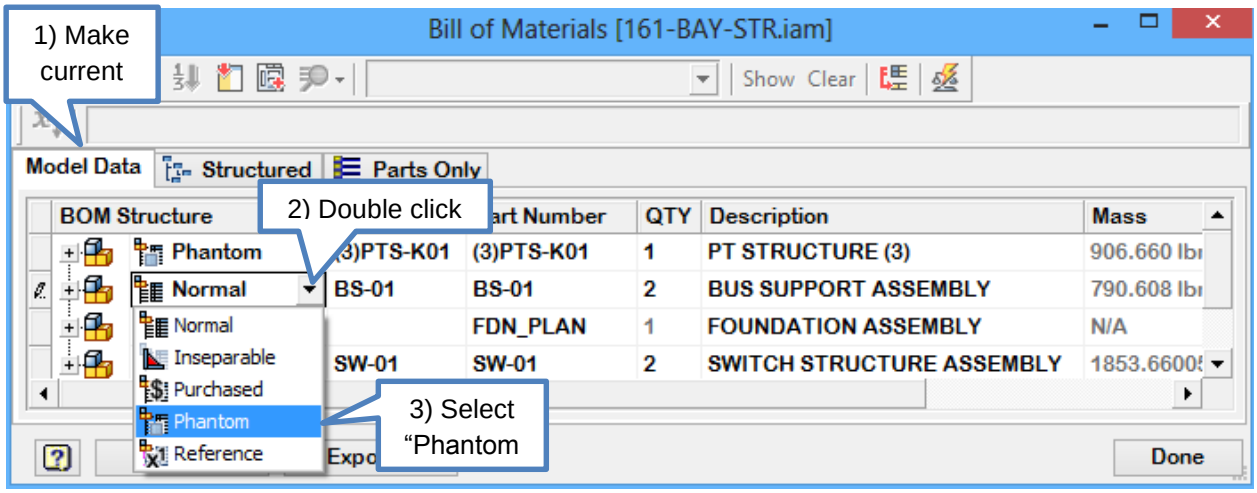


BOM vs. Parts List

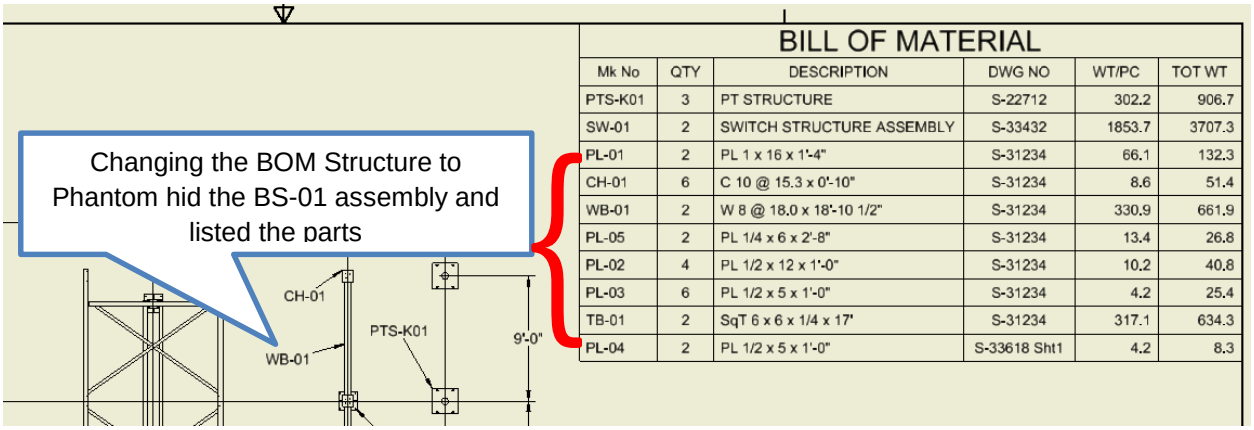
1. The Parts List is also controlled by the BOM Structure in the assembly Bill of Material. Right click on the Parts List and pick “Bill of Material”.



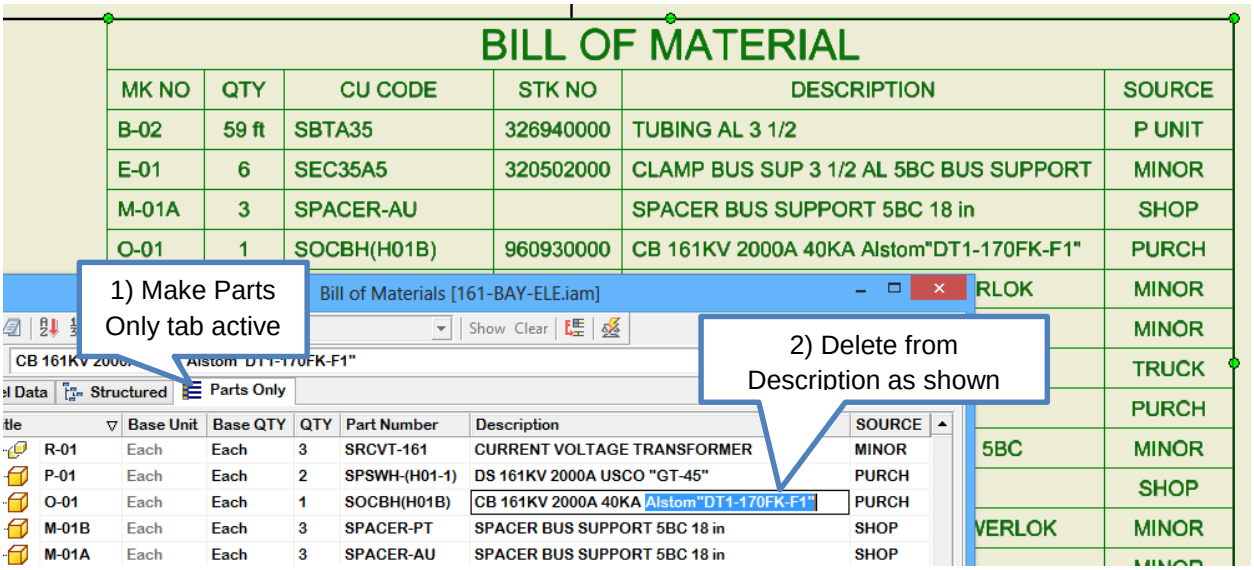
2. Make the Model Data tab current. In the BOM Structure cell next to BS-01, double click to the right side of the cell. Select “Phantom” and click “Done”.



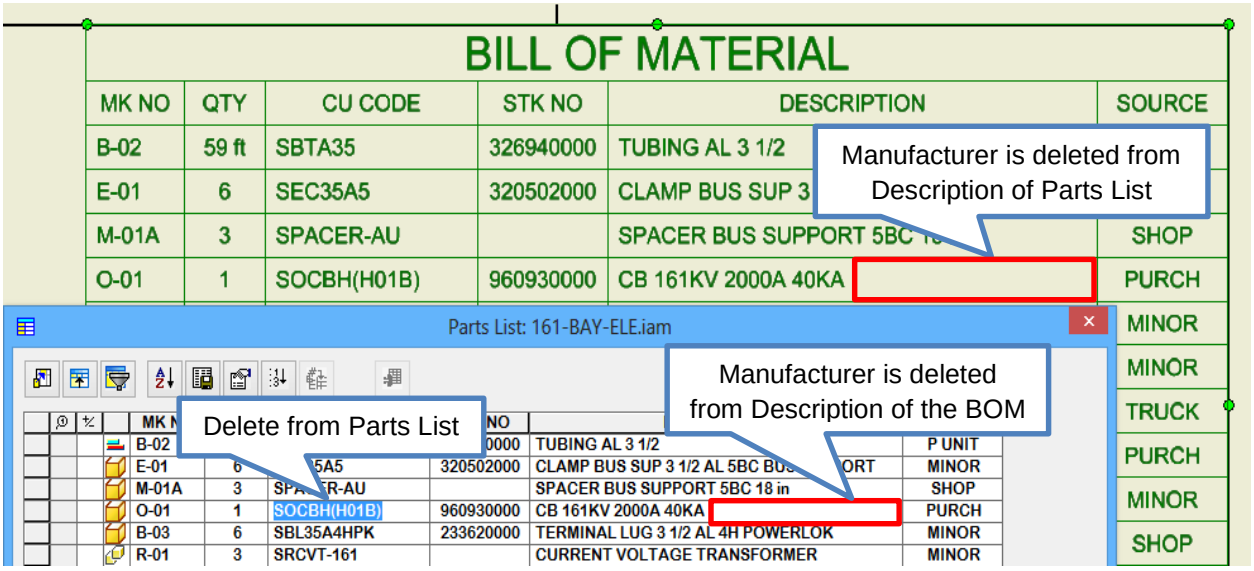
3. Notice the Balloons have changed to designate the parts of BS-01 and the parts are listed in the Parts List.



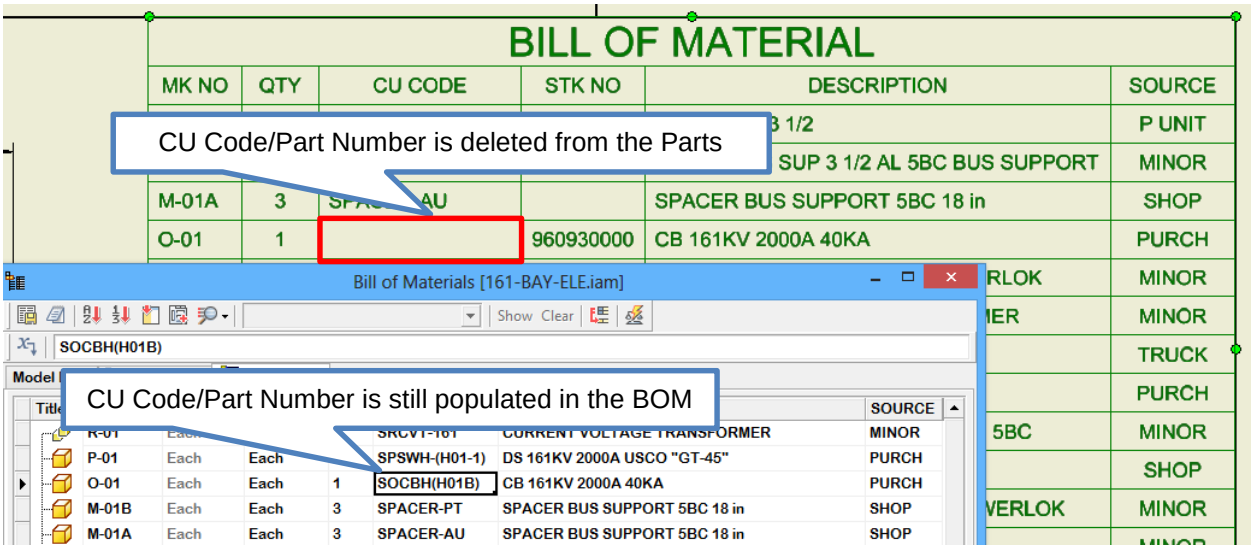
4. Make the “Electrical” sheet current. Right click on the Parts List, pick “Bill of Material” and make the Parts Only tab active. On the row beginning with “O-01”, delete the manufacturer from the description. Click “Done”



5. The Parts List is updated automatically. Right click on the Parts List to “Edit the Parts List”. On the row beginning with “O-01”, delete “SOCBH(H01B)” in the CU CODE column. Click OK.



6. Again, the Parts List is automatically updated. Open the “Bill of Material” to see that this last change to the Parts List did not affect it.



In Conclusion

In the Substation utility industry we use the same designs at multiple stations, except the designs are a little different for each station. Inventor’s adaptability make it a perfect design tool for creating standard parts and assemblies that can be easily modified for specific installations. It all starts with the part template and a sketch. Then parameters, constraints and iProperties are used to dimensionally adjust the part and the Parts List data. When the parts are modeled correctly, the assemblies, drawings and Parts List carry the intelligence to automatically update themselves as design changes to the model are made.

We’ve only scraped the surface of the capabilities of Inventor and SDS.

Thank you for taking the time to participate in this class. Feel free to contact Chip Cullum *wcullum@nespower.com* or Terri Humel thumel@nespower.com with any questions, suggestions or ideas.