Designing Substations Part by Part with Autodesk® Inventor®

Terri Humel & Chip Cullum

Principal Associate Engineer & Senior Associate Engineer – Nashville Electric Service

Class summary

- In the electric utility industry, it seems that everything we design is “just like that one, only different." Using Autodesk® Inventor® software we can easily alter standard content with intelligent model based design. These exercises show how the relationships between parameters, formulas, iProperties and dimensional constraints in sketches work together to ultimately auto update drawings and Parts List.

Key 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

Speaker Introductions

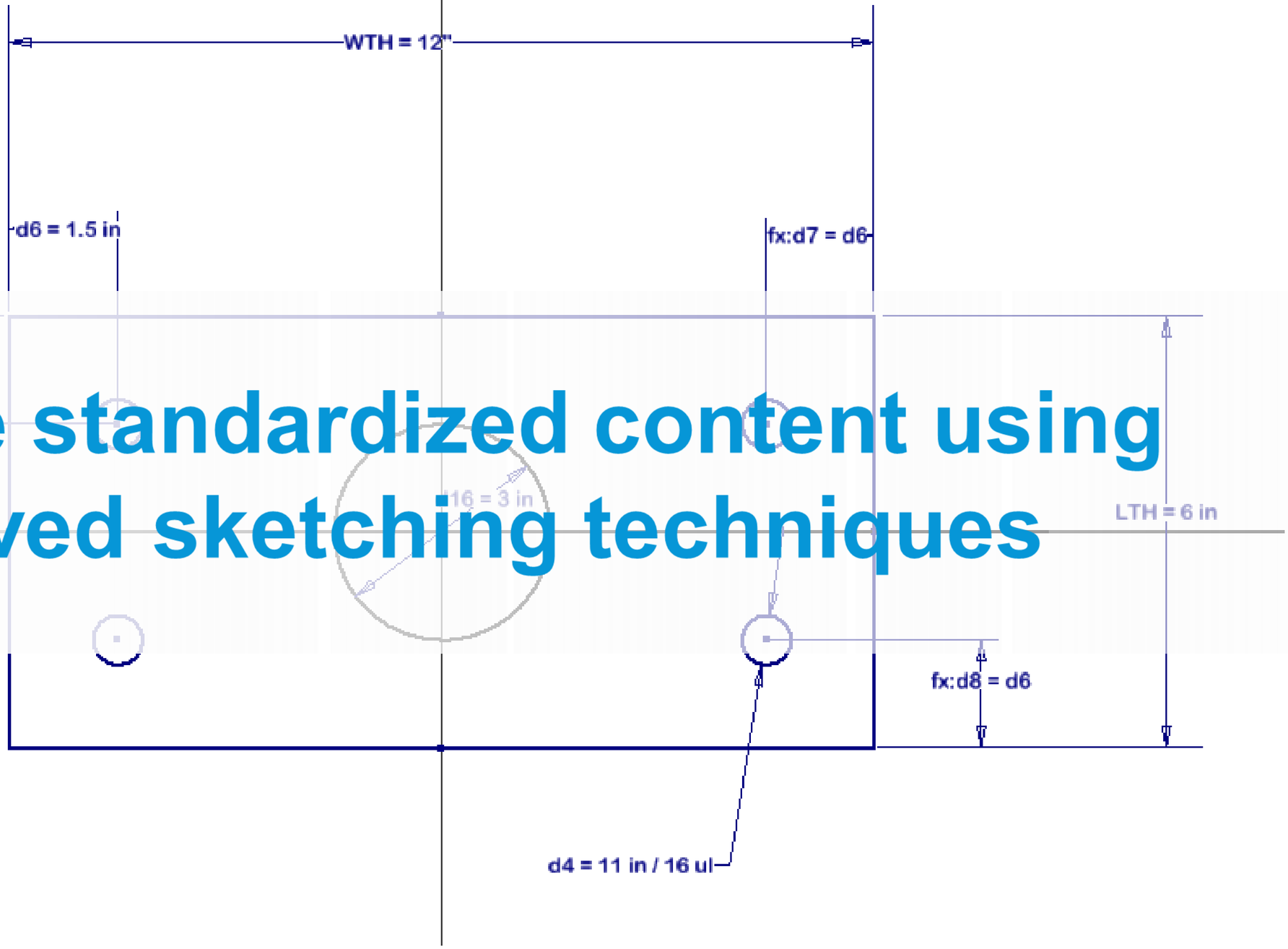
Chip Cullum
Senior Associate Engineer – Substation Design

- 7 yrs. at NES
  - Previous to NES, 17 years' experience in manufacturing industry.
  - Use Autodesk Inventor to document substation designs. This includes field checking and using existing paper drawings then transferring this information into Inventor format.
  - Have used AutoCAD since 1989 and previous to NES, has 8 years' experience using Pro-Engineer.
- About Substation Design
  - 3 Designers and 2 Engineers
  - 68 Primary Substations – 30 Customer Substations
  - Build 1 new Station every 2-3 years and work 15-25 Station upgrades per year
  - AutoCAD® Version 1.2 - 1985
  - AutoCAD® Map3D – 2007
  - Autodesk® Inventor® since 2008 & Substation Designer Suite since 2010

Terri Humel
Principal Associate Engineer – Substation Design

- 30 Years in Substation Design
  - Designing physical substation layouts including foundations, conduit, grounding and structures
  - Devise workflows and procedures
  - Managed the implementation of Inventor & Substation Designer to create intelligent substations models

- About Nashville Electric Service
  - Publicly Owned Utility – Distribution and Transmission
  - Purchase power from Tennessee Valley Authority at 23 feed points
  - Over 359,000 customers covering 700 sq. miles, including all of Davidson Co. and part of 6 surrounding counties
  - NES is one of the 12 largest public electric utilities in the nation
  - 2010 – One of 6 utilities in the nation awarded APPA's Reliable Public Power Providers (RP3) Diamond Status, the industry's highest designation for reliability and safety.

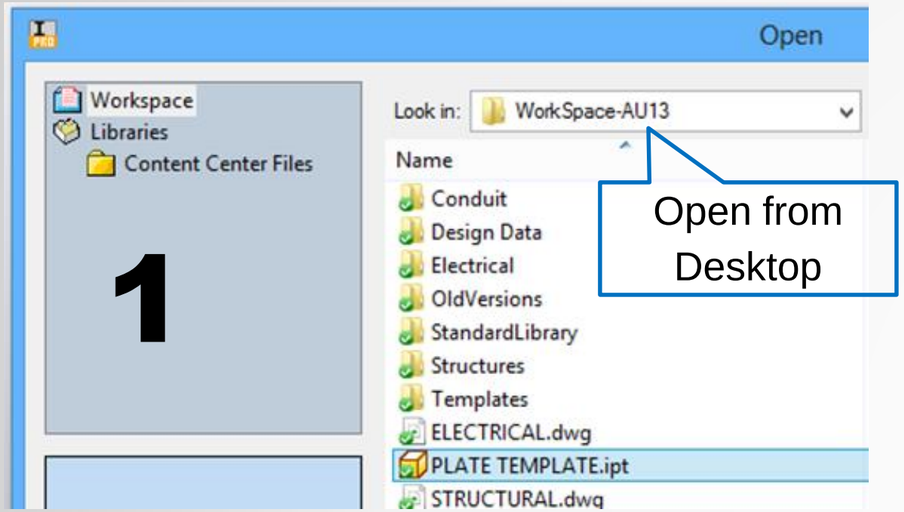


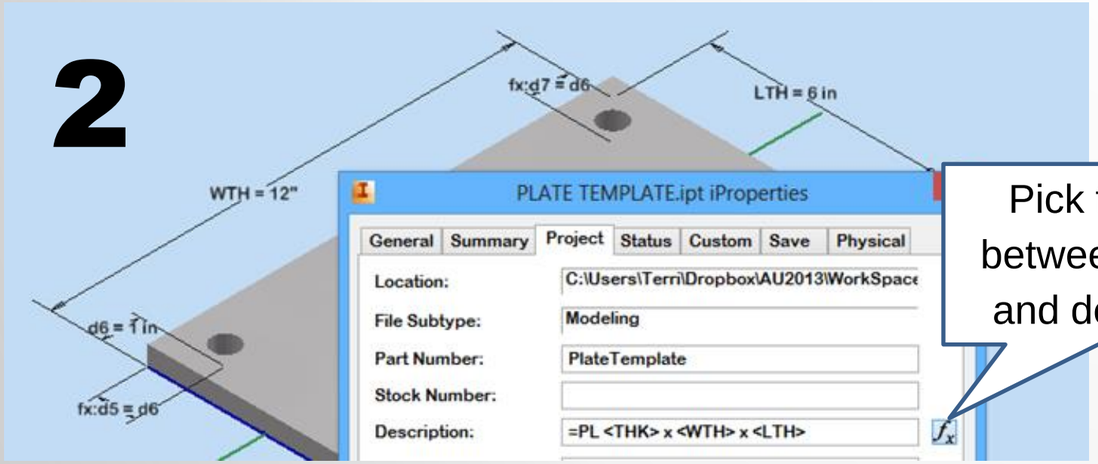
Create standardized content using improved sketching techniques

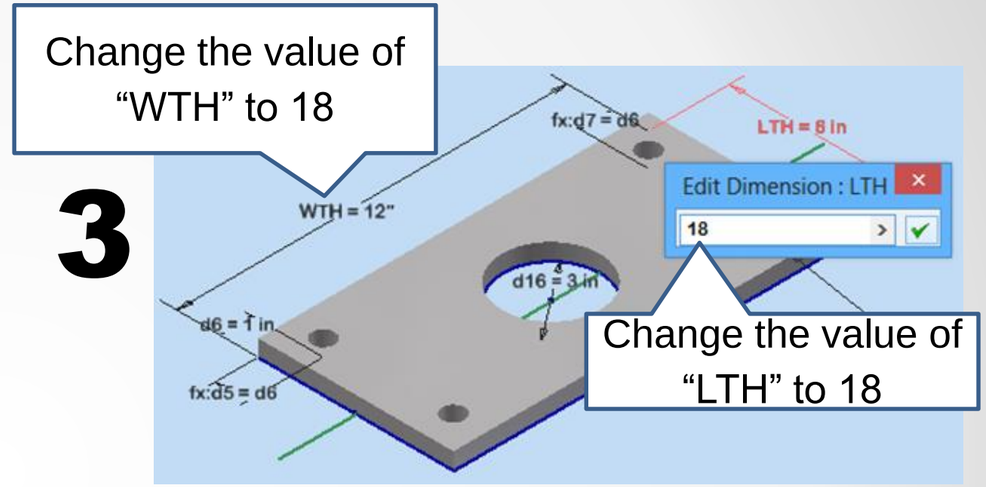
Where we begin

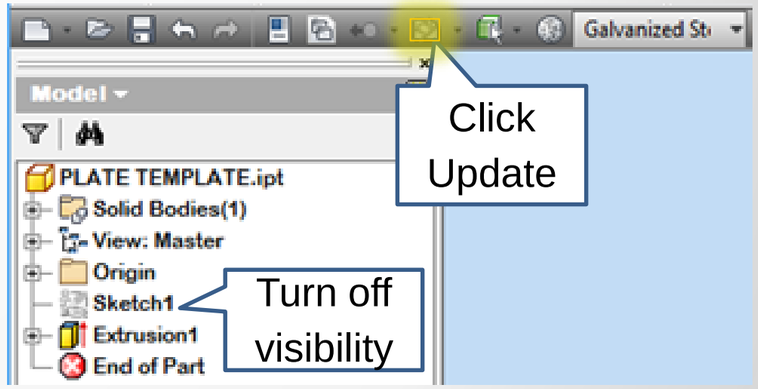
- Start with a PART TEMPLATE with the functionality to update the BOM information by using parameters, formulas and dimensional sketch constraints
- Alter a library part of a typical circuit breaker by editing the dimensional values in the sketch. One library part can be used for several different circuit breakers
- There are several more ways to use standard library parts in specific installations just by altering the sketch

Part Template

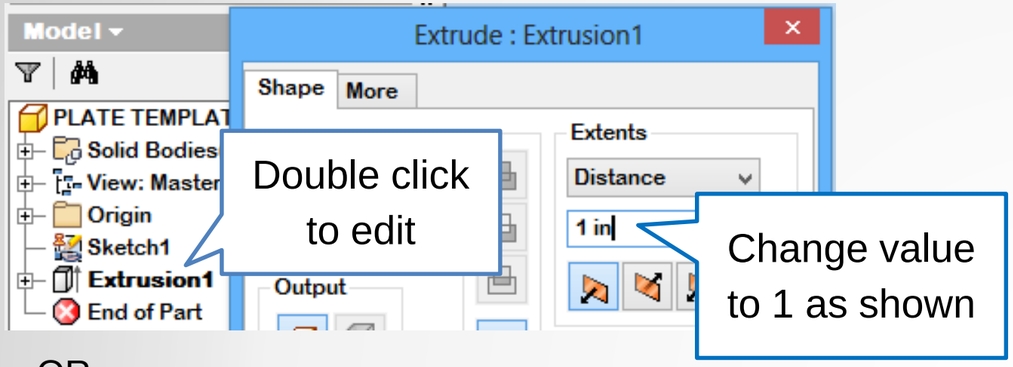








Part Template



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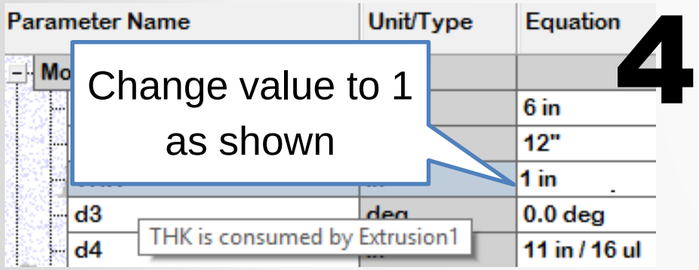
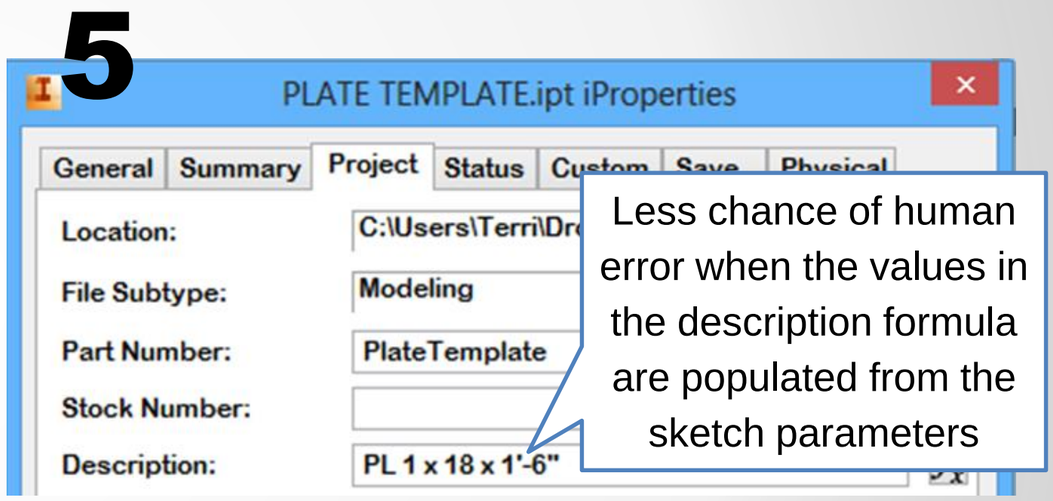
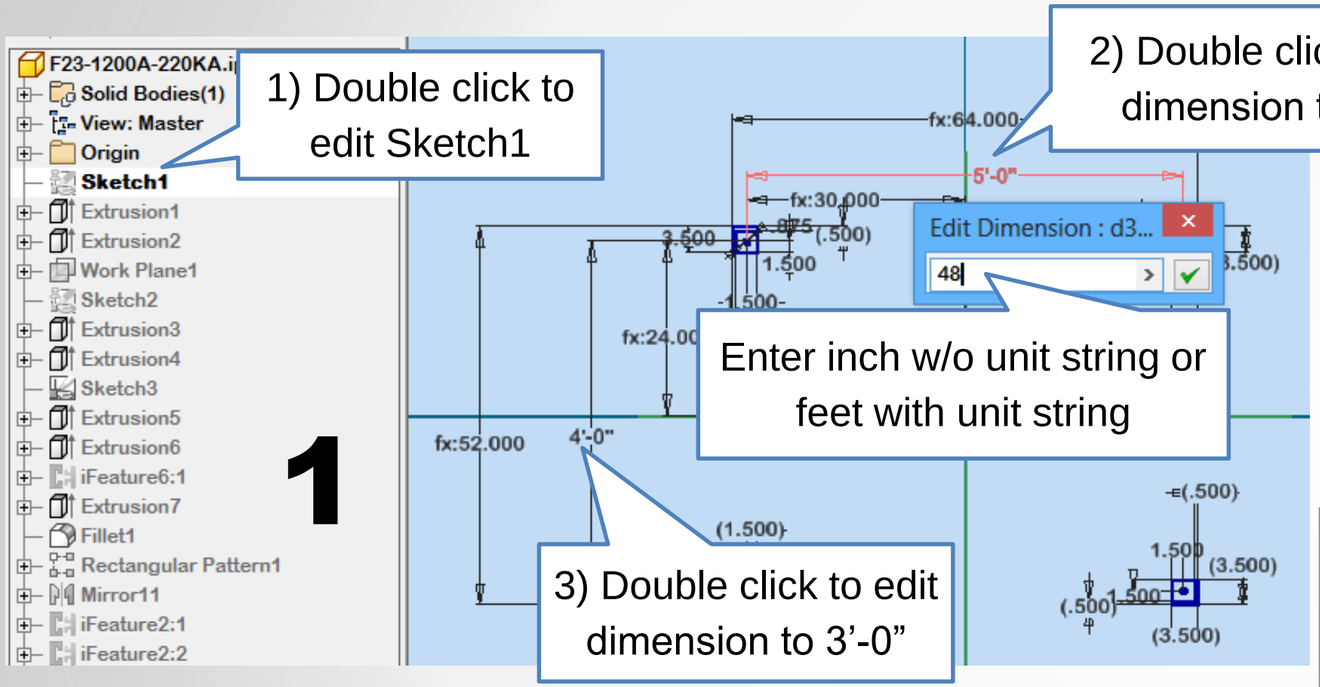
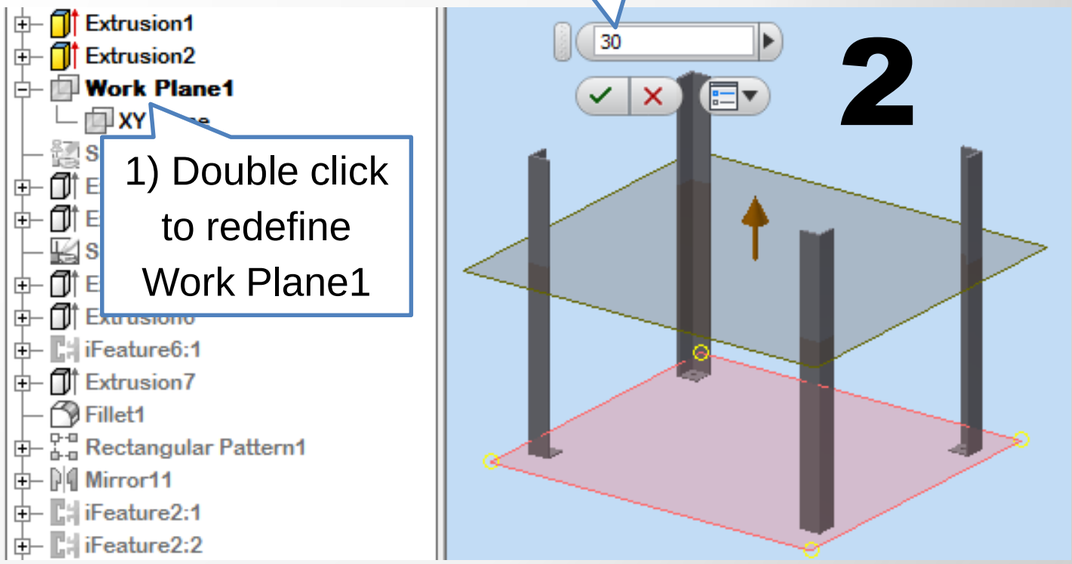




6 Save and close the PLATE TEMPLATE

Typical Circuit Breaker





Typical Circuit Breaker

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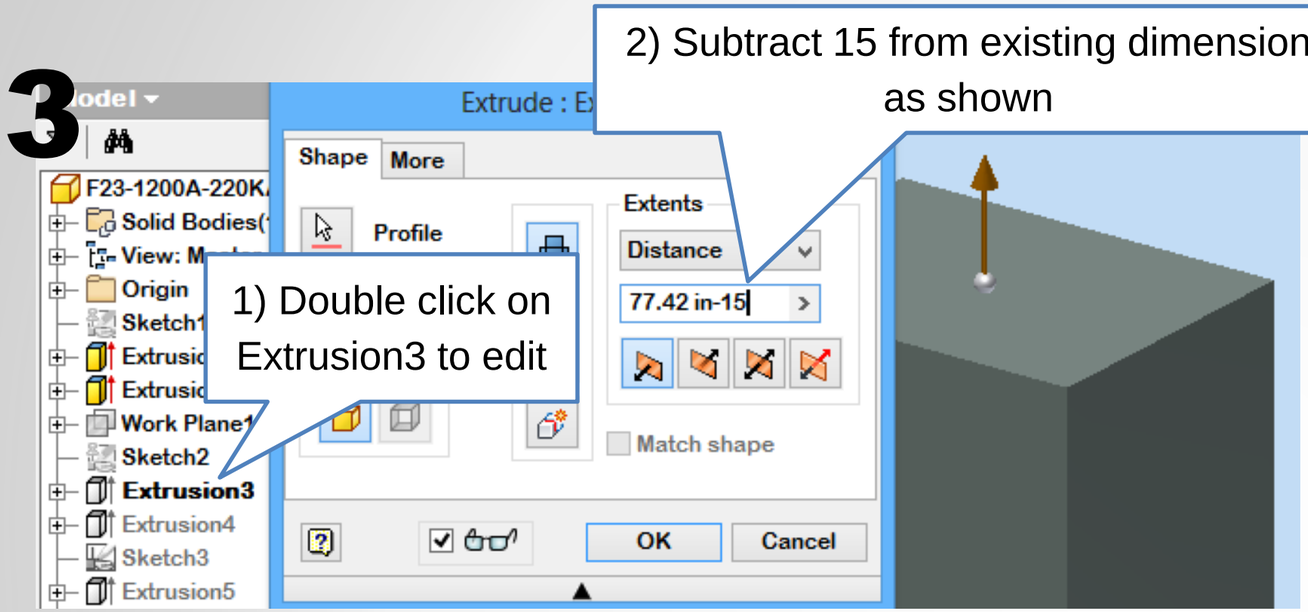

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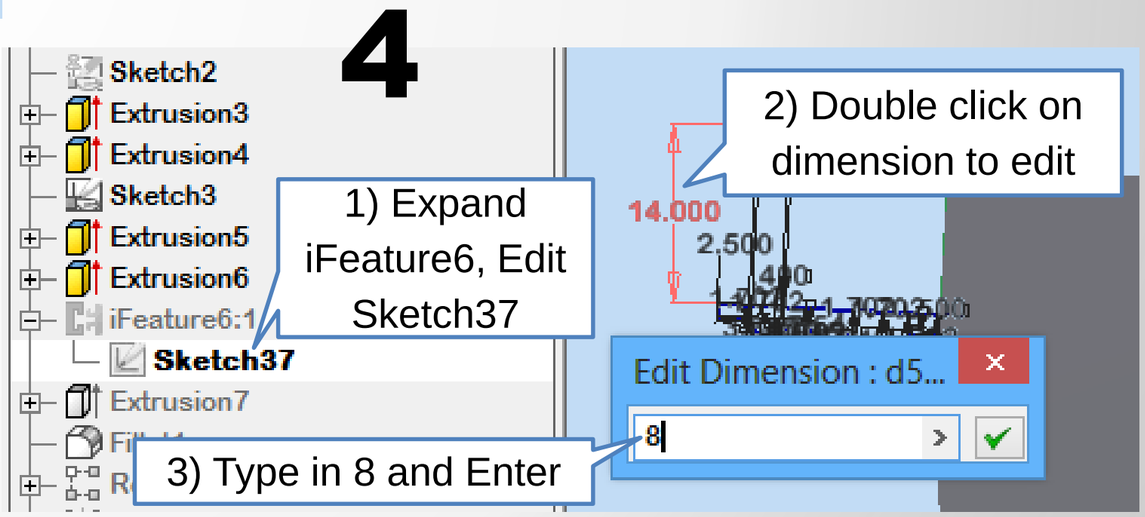
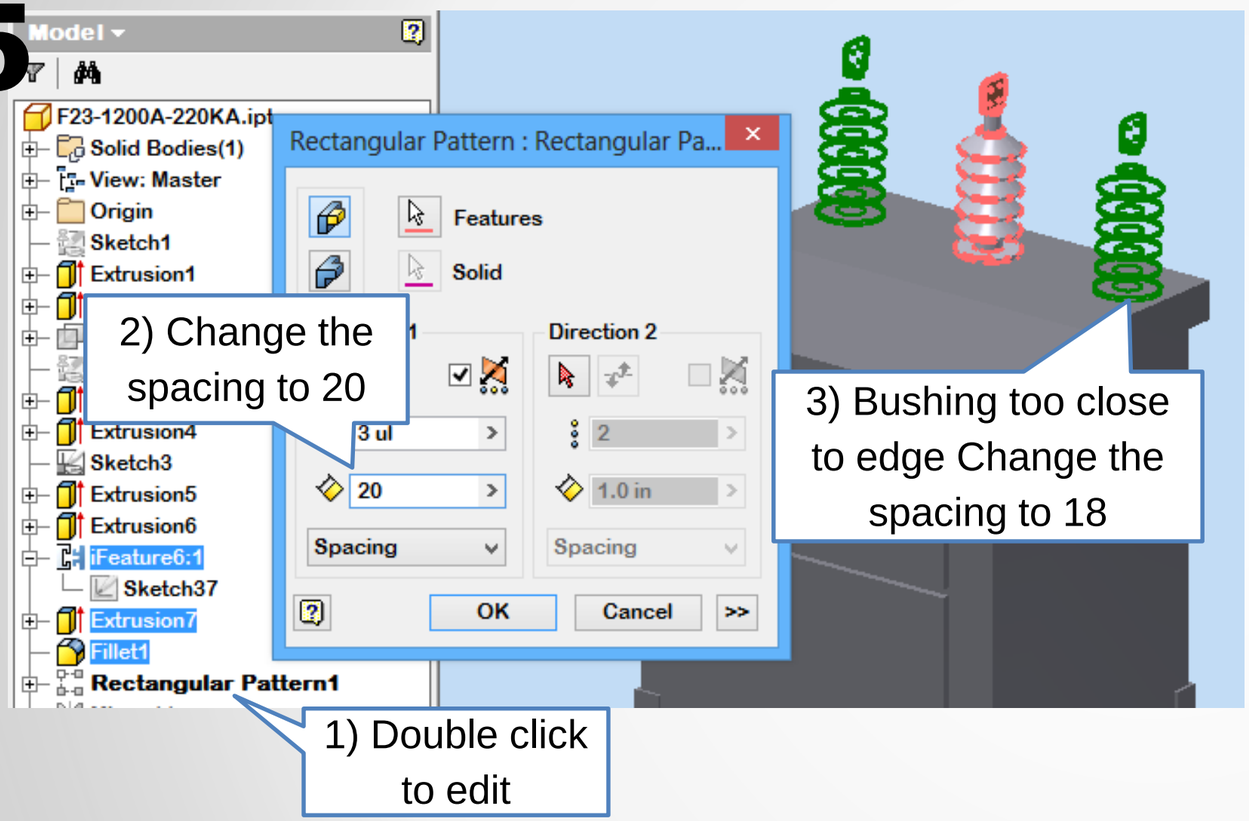


Typical Circuit Breaker

5



7 Save and close the file

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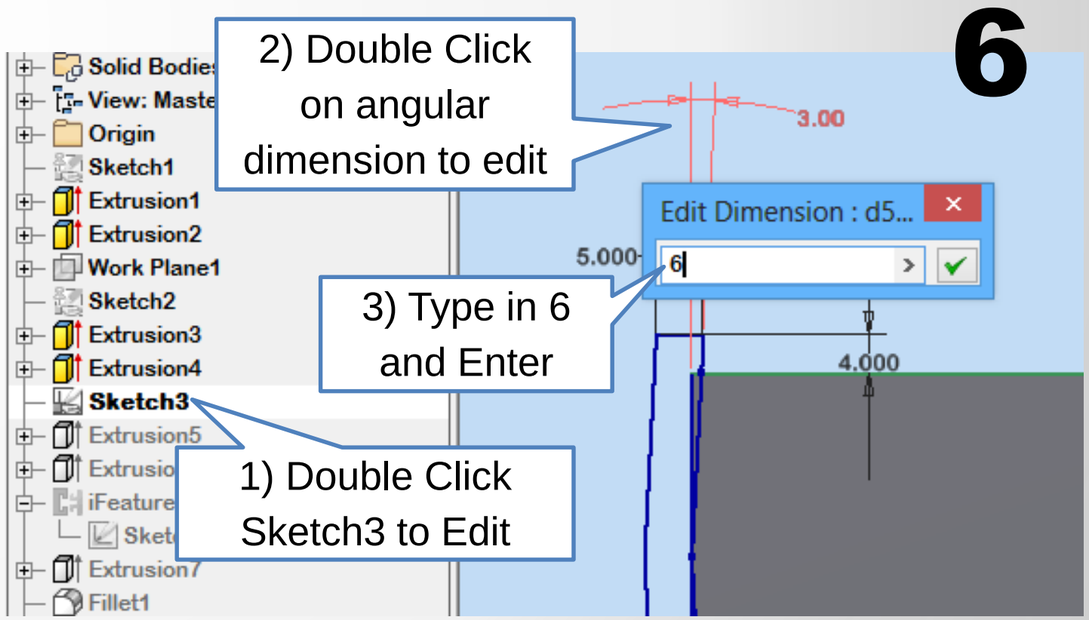


Alter standard models to fit any unique application

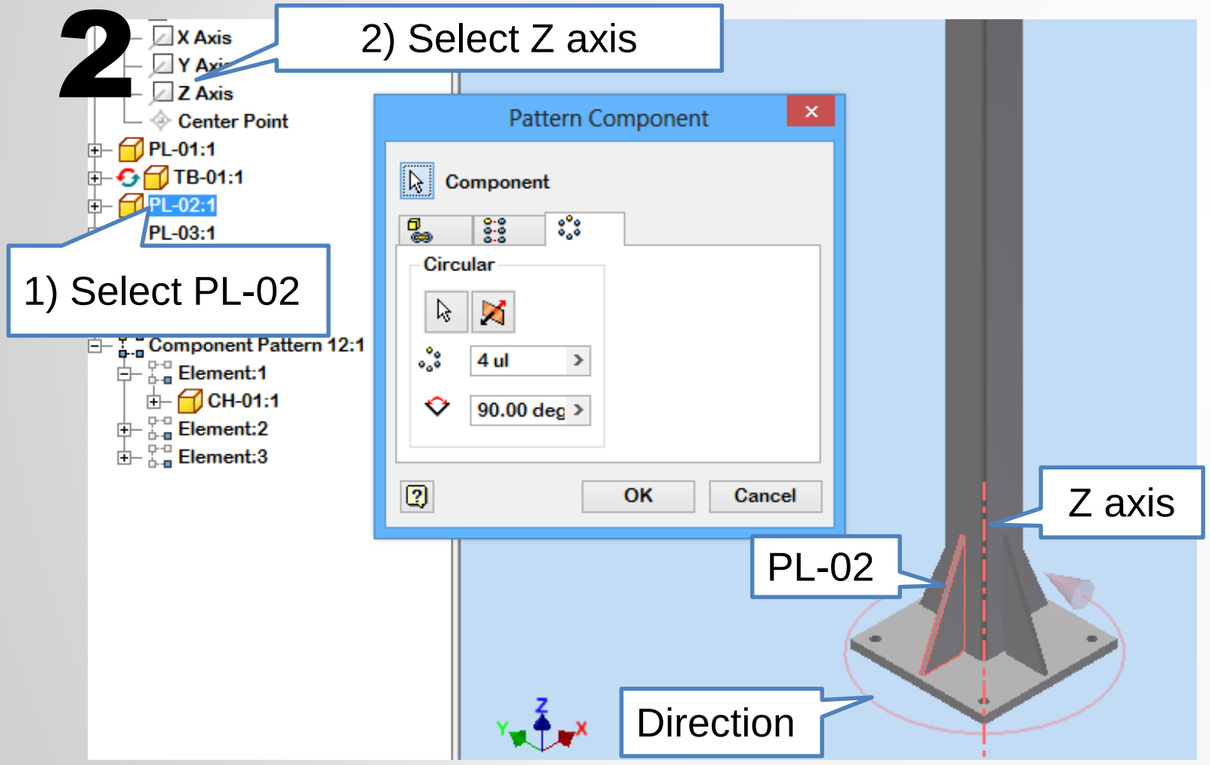
Standard Sub-Assembly

- Use one Standard Sub-Assembly for multiple applications
- The constraint relationships between the parts allows the model to adapt to dimensional changes
- Use pattern spacing and constraints to make a standard model for a specific installation
- The assembly and drawing will automatically update as the model is altered.

Standard Bus Support Model

1 Open the file STANDARD-BUS-SUP.iam

2



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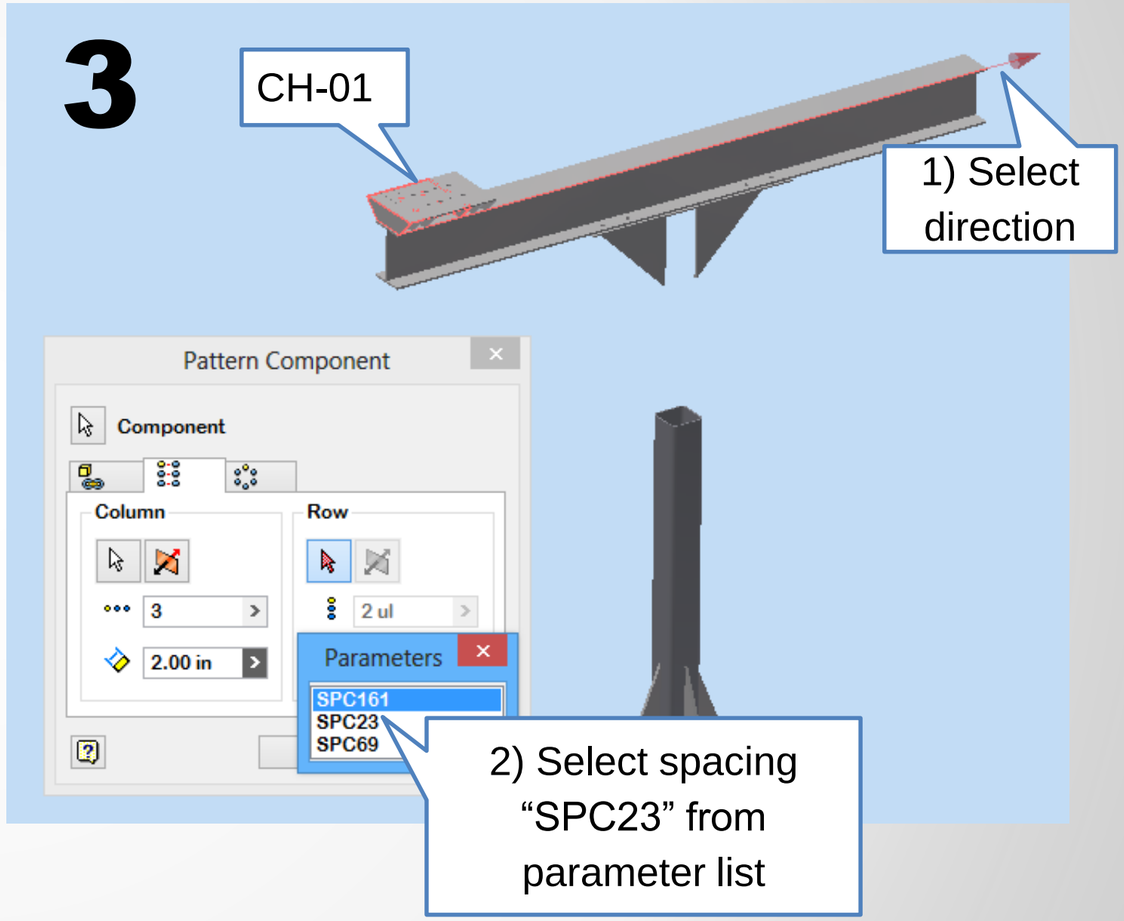


Standard Bus Support Model

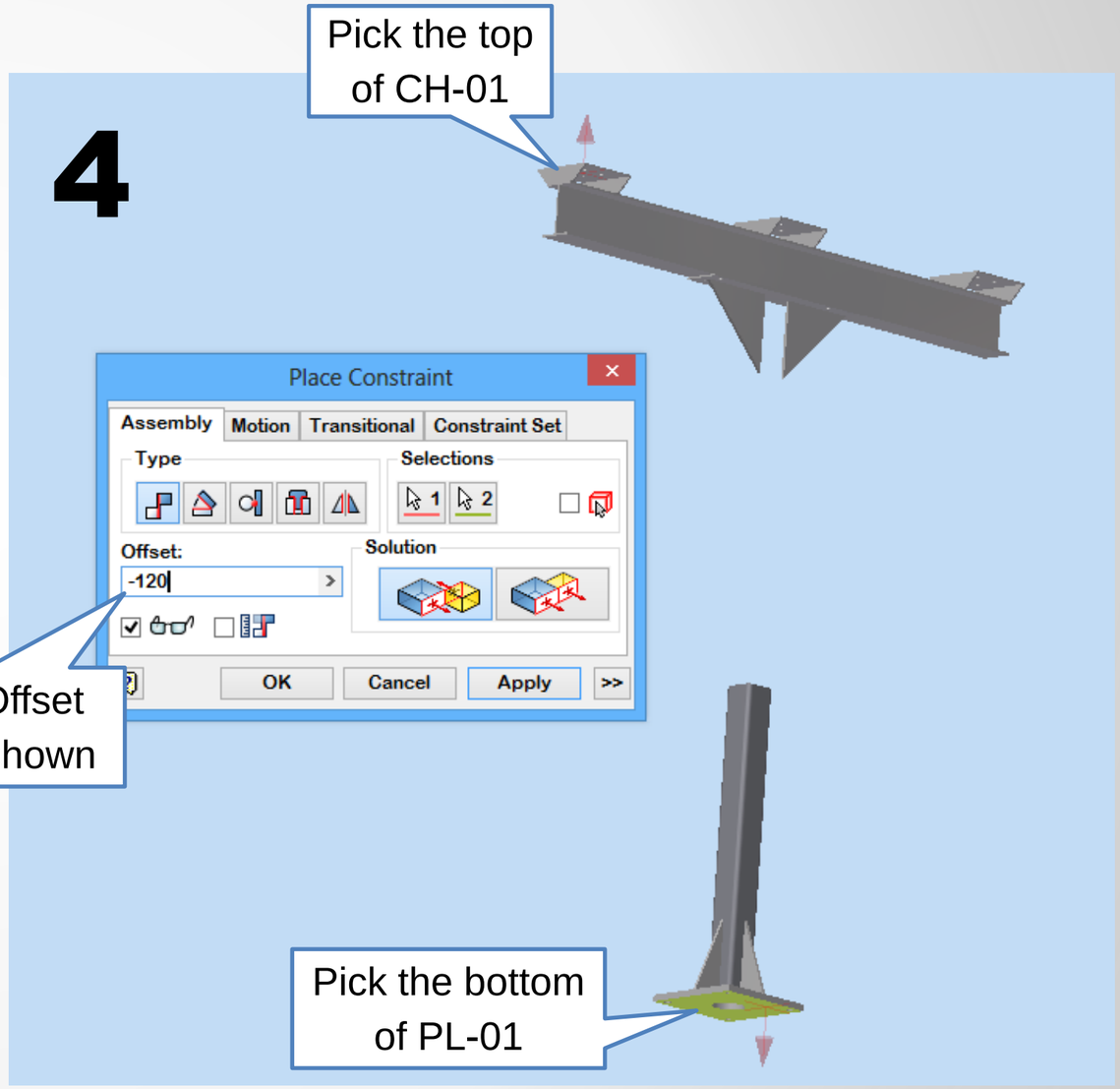
TYPICAL PHASE TO PHASE SPACING
User Parameters are set up to correspond to the phase to phase spacing for different voltages as shown below.

User Parameters		
SPC161	in	9'-0"
SPC69	in	6'-0"
SPC23	in	3'-6"

161kV Spacing (SPC161) = 9’-0”

69kV Spacing (SPC69) = 6’-0”

23kV Spacing (SPC23) = 3’-6”



Standard Bus Support Model

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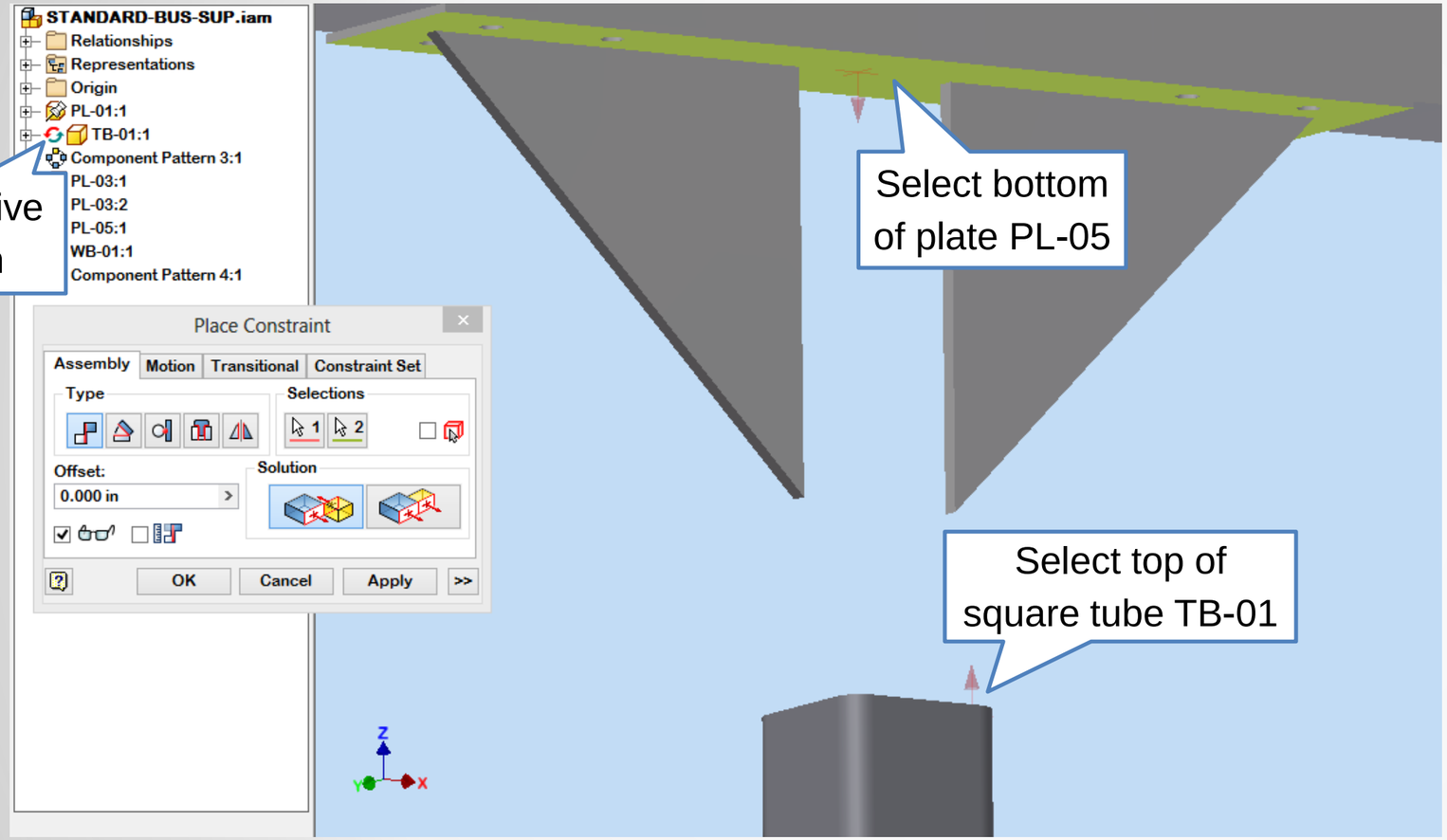
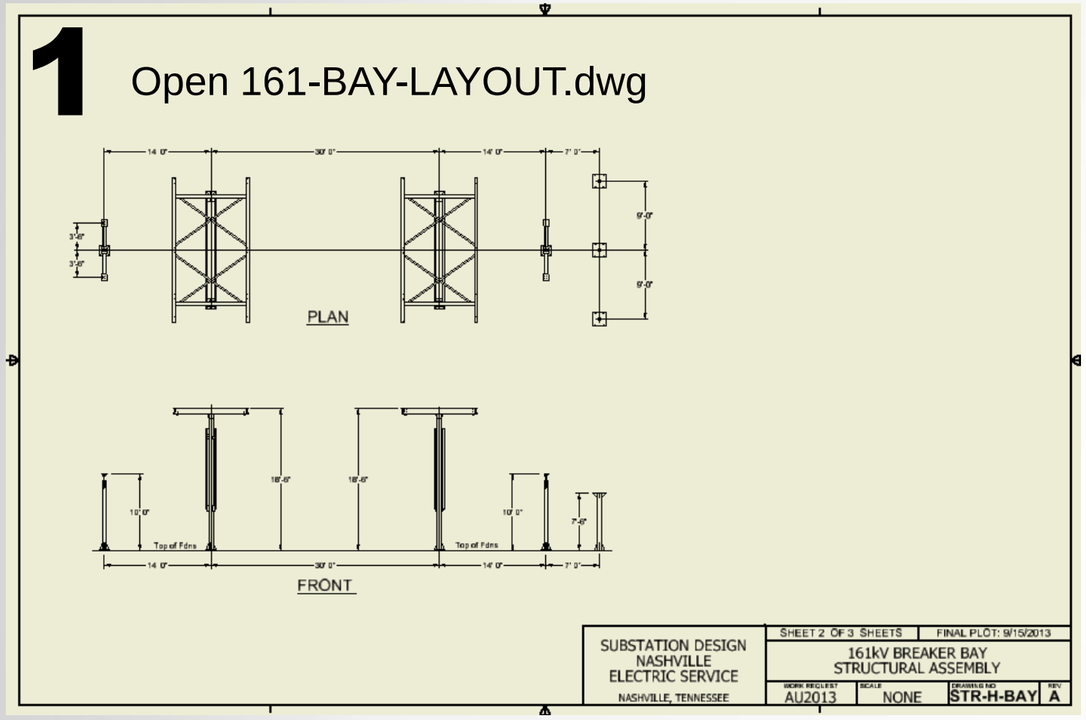


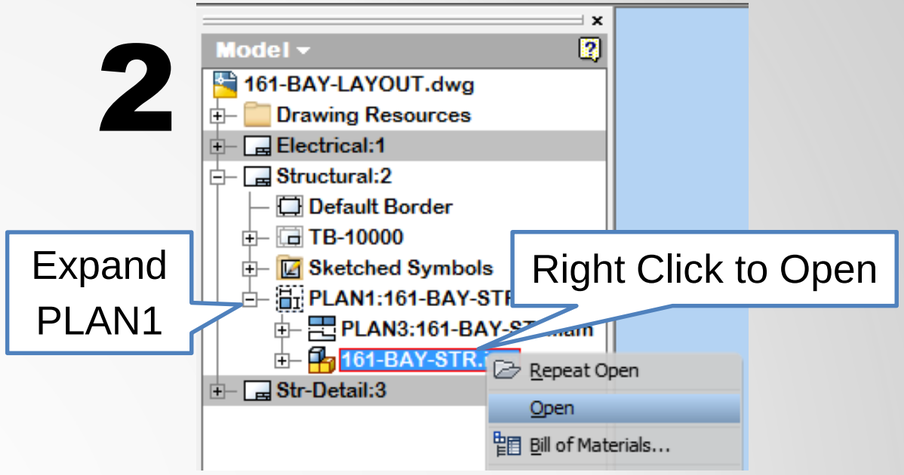
6

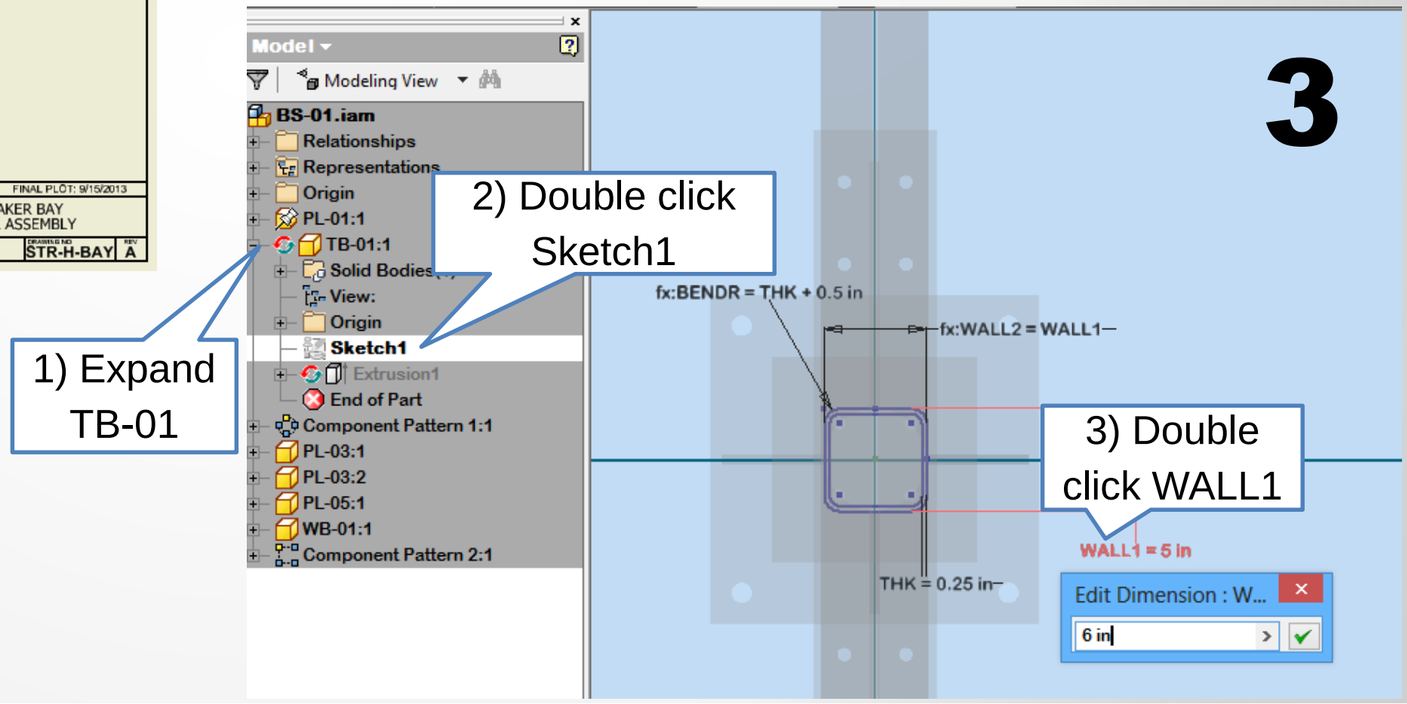
The Standard Bus Support Assembly is complete. Save as BS-01 to keep the Standard Assembly pristine. (Select “Yes” to replace existing BS-01 file.)

7 DO NOT CLOSE

Standard Structural Models



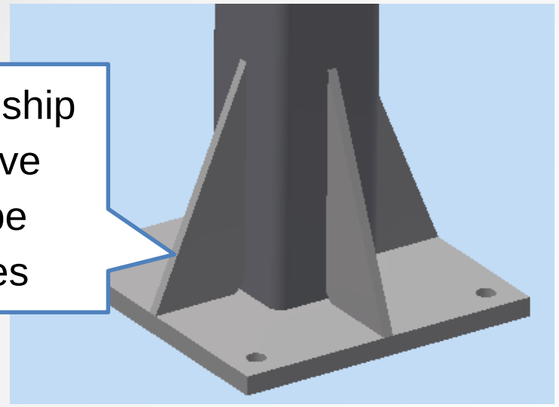




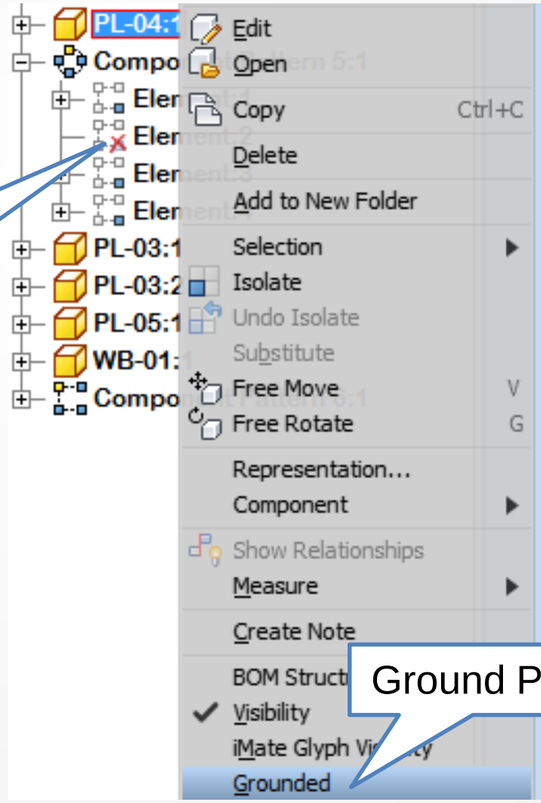
Standard Structural Models

4

The constraint relationship causes the plate move according to the tube dimensional changes

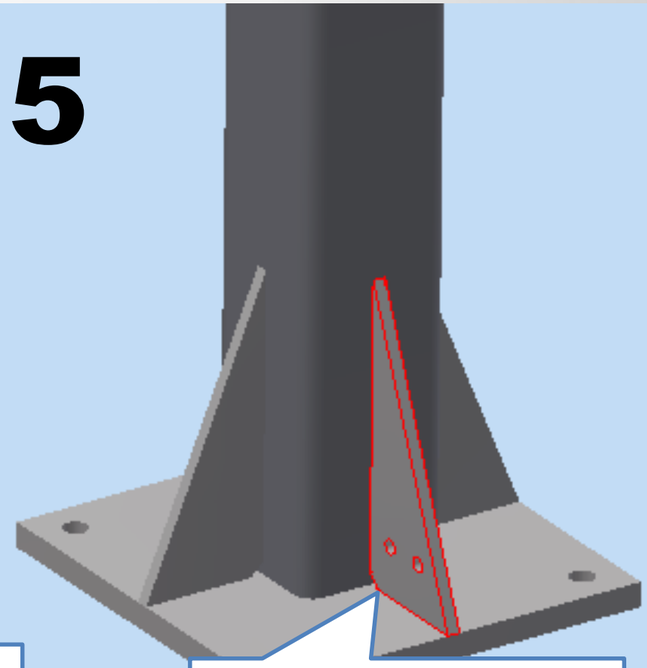


Red x represents Element2 is Independent Element



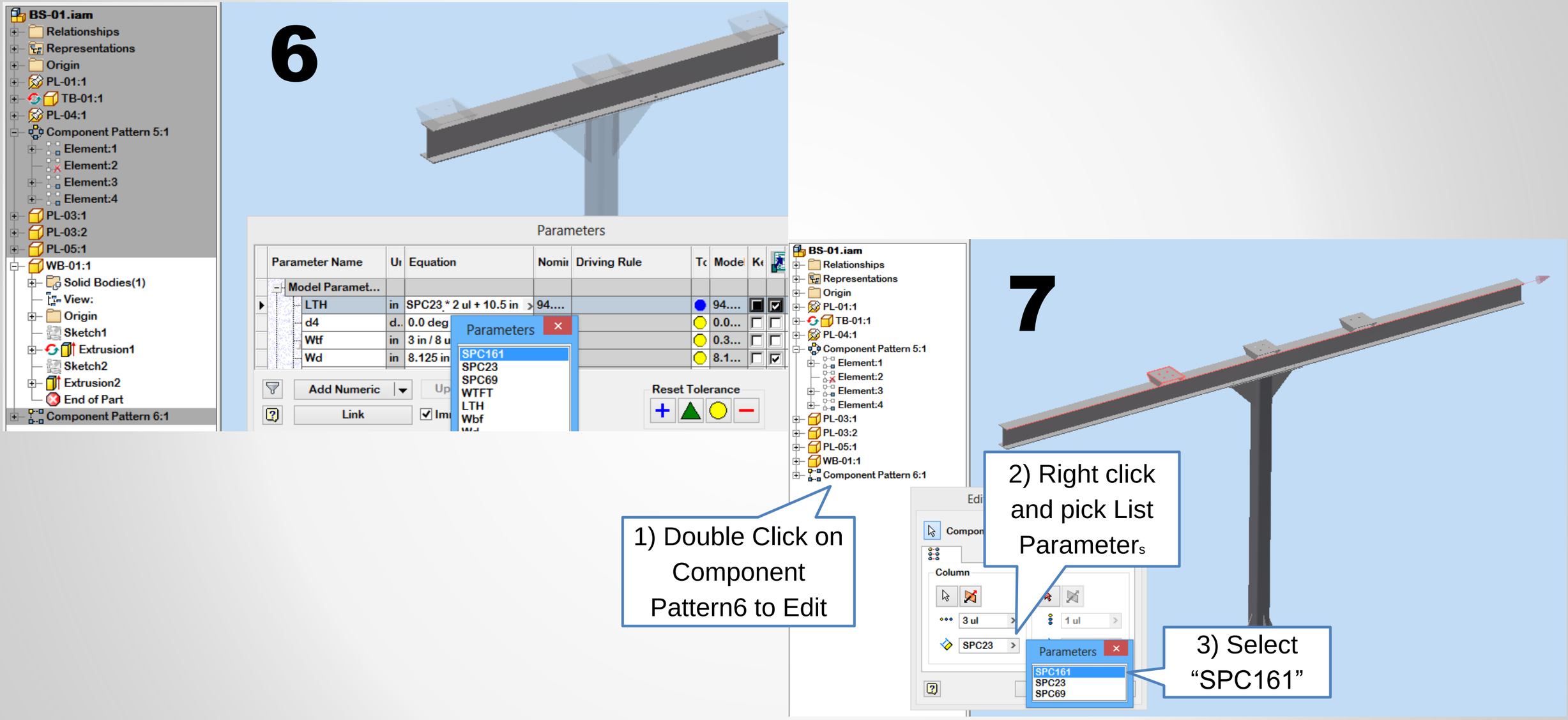
Ground PL-04

5

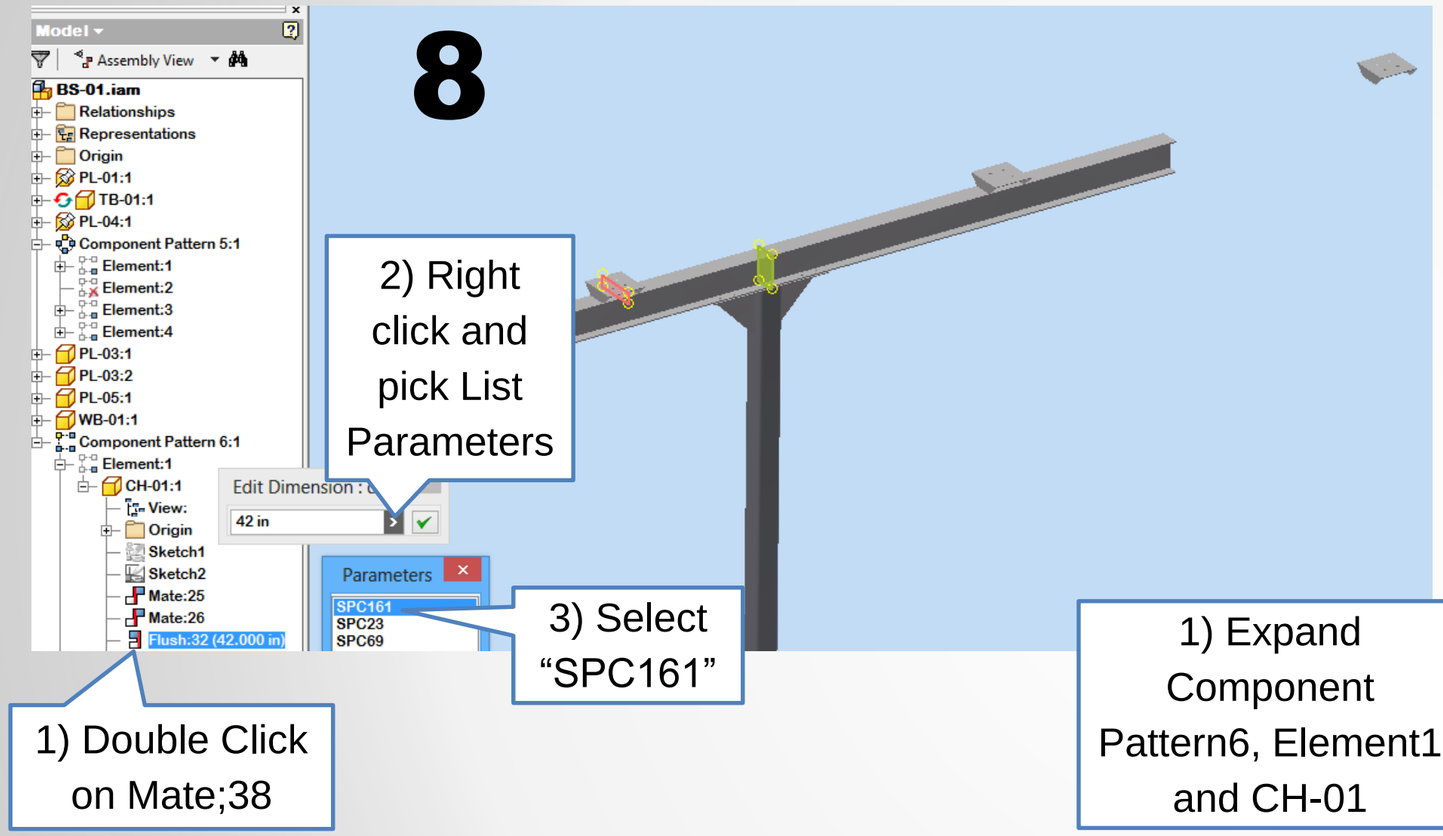


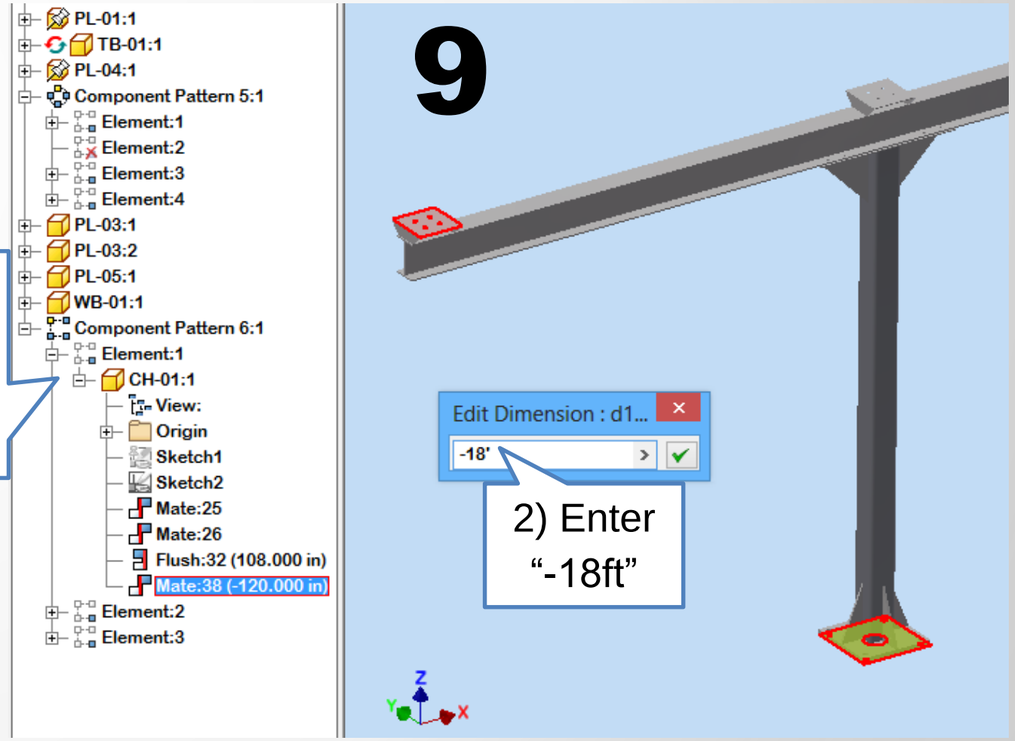
Replace Independent PL-02 with PL-04

Standard Structural Models

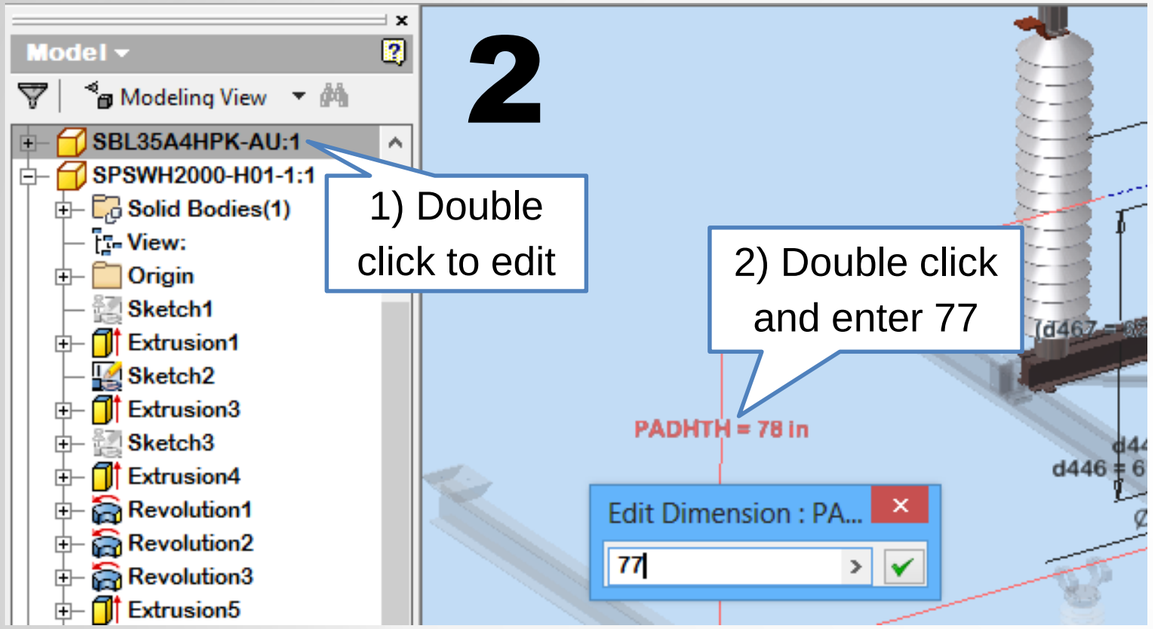


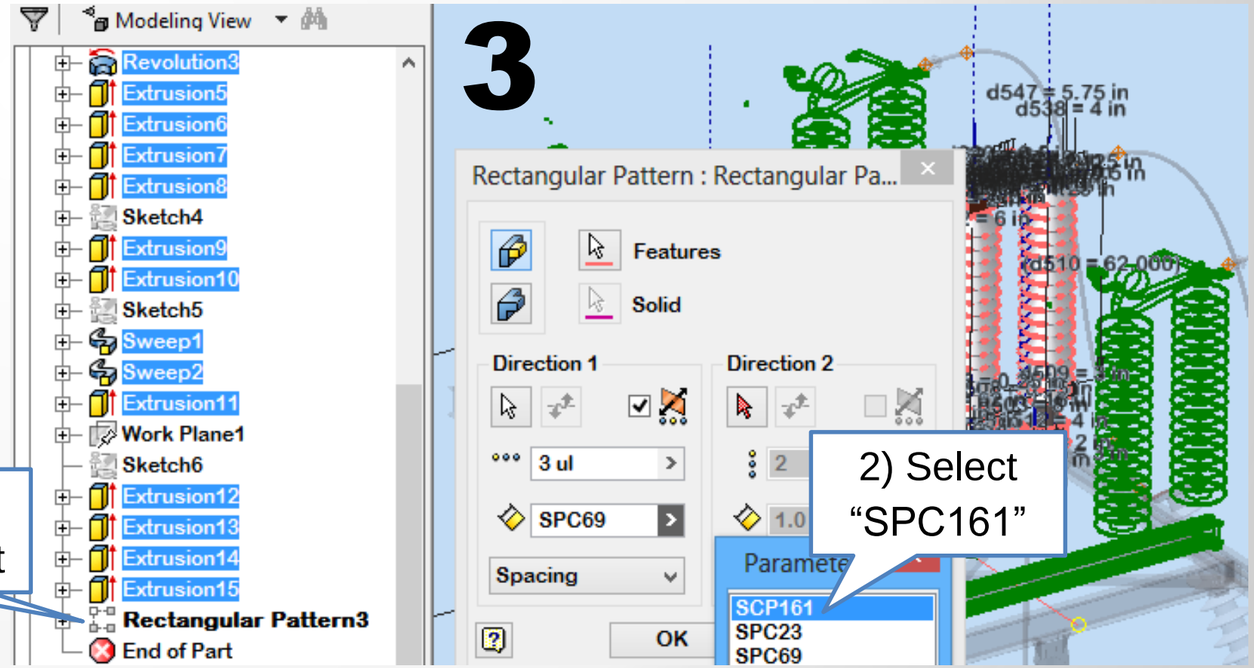
Standard Structural Models





Standard Electrical Models





Standard Electrical Models

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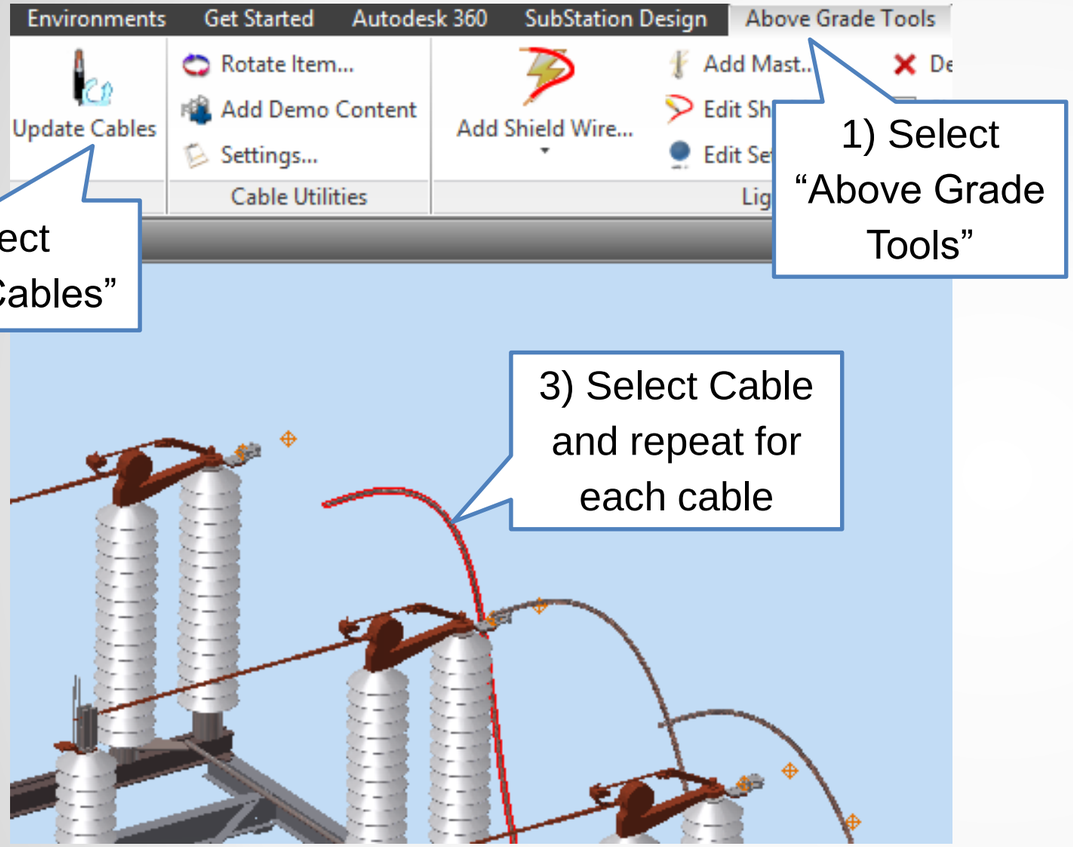

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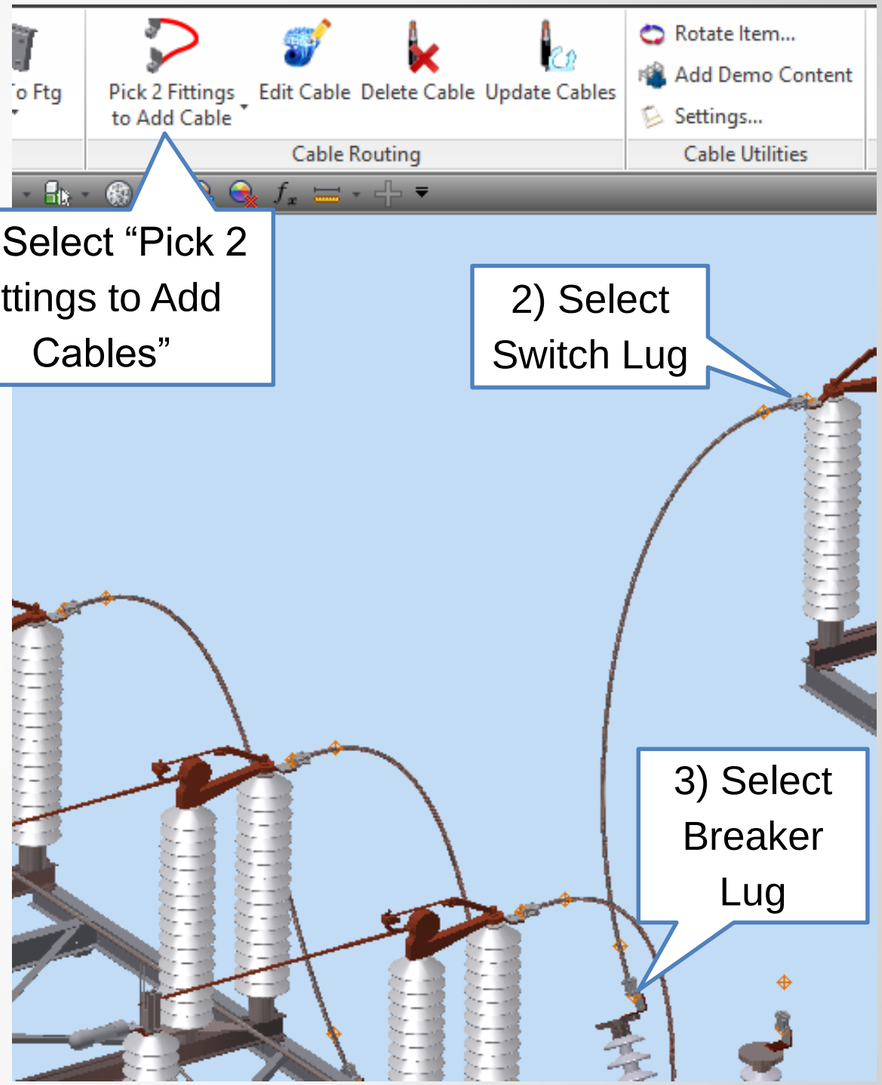

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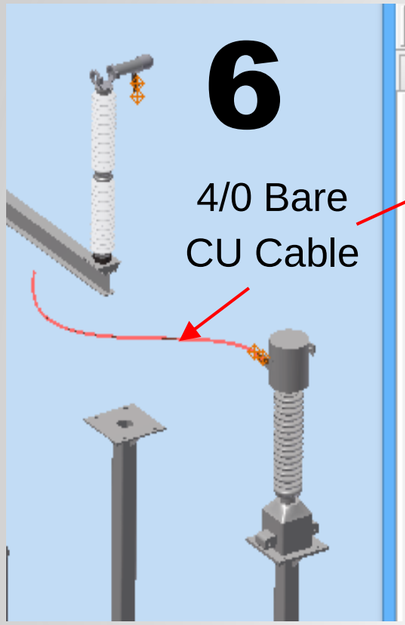
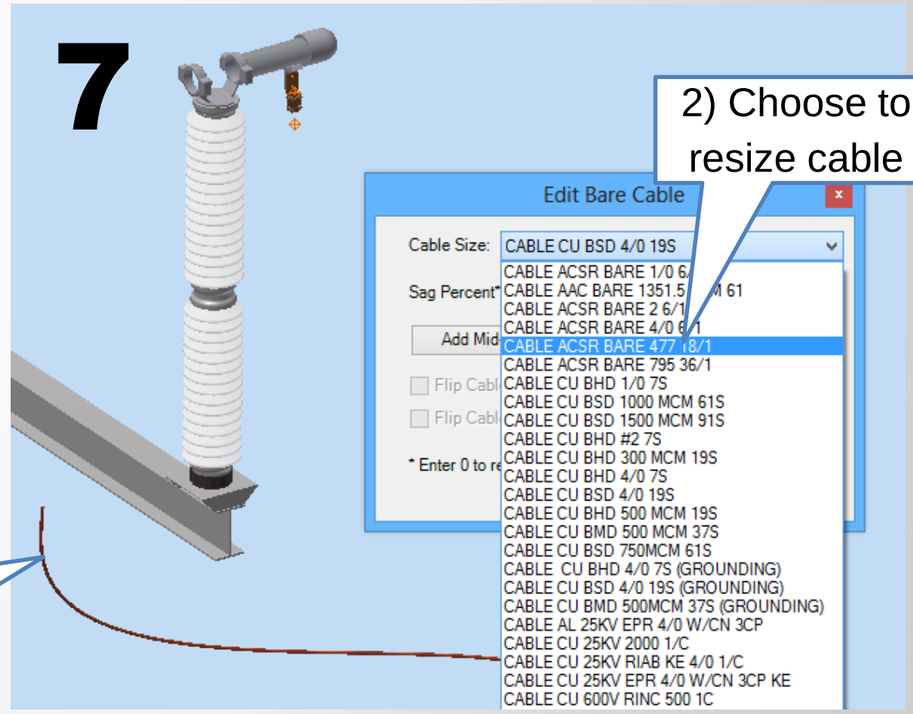


B-001

Model Data | Structured | Parts Only

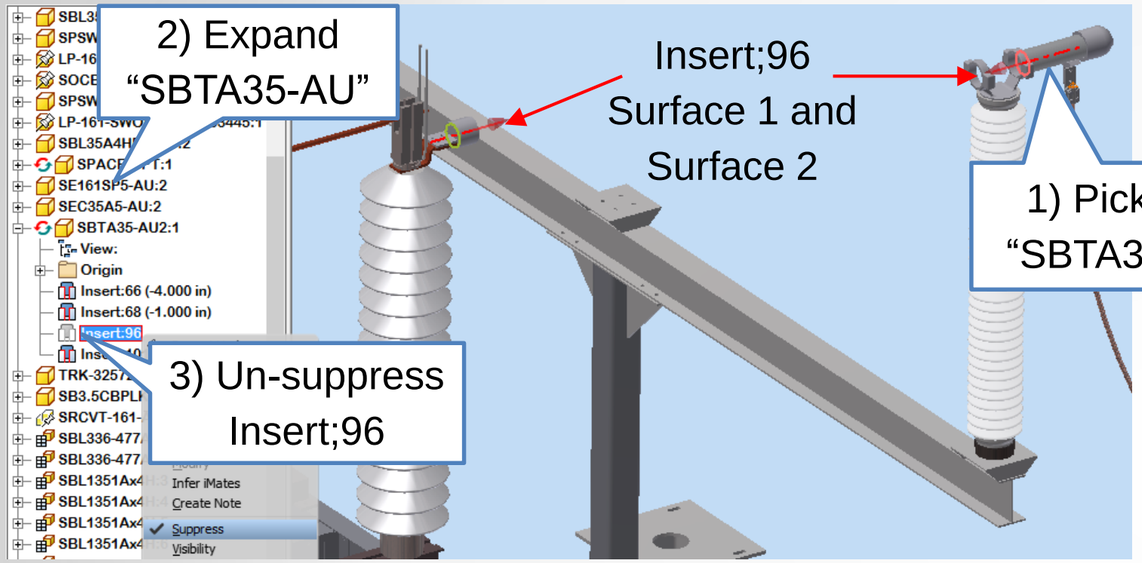
Title	Base Unit	Base QTY	QTY	Part Number	Description
B-001	ft	8.92272...	9 ft	SBCC4/0S	CABLE CU BSD 4/0 19S
B-009	ft	*Varies*	42 ft	SBCA1351	CABLE AAC BARE 1351.5 KCM 61
B-02	ft	1 ft	2 ft	SBTA35	TUBING AL 3 1/2
B-03	Each	Each	2	SBL35A4HPK	TERMINAL LUG 3 1/2 AL 4H POWERLOK
B-032	Each	Each	12	SBL1351A4H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

Bus Support Spacer height calculated from parameters



1) Pick PT Lead to edit

Standard Electrical Models



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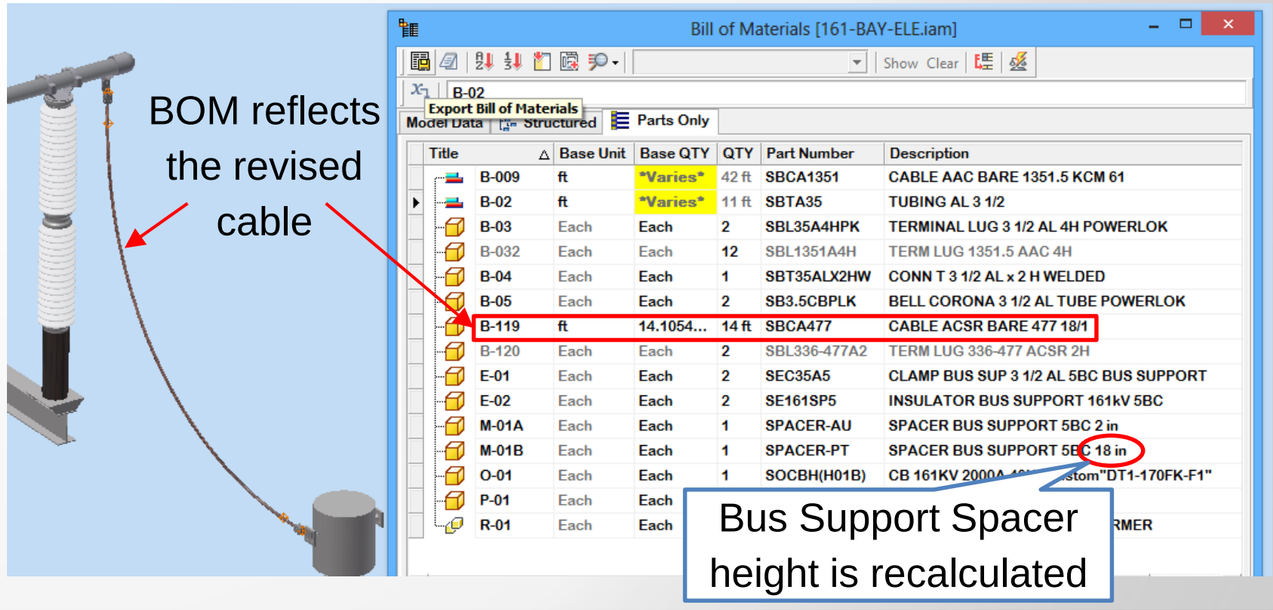
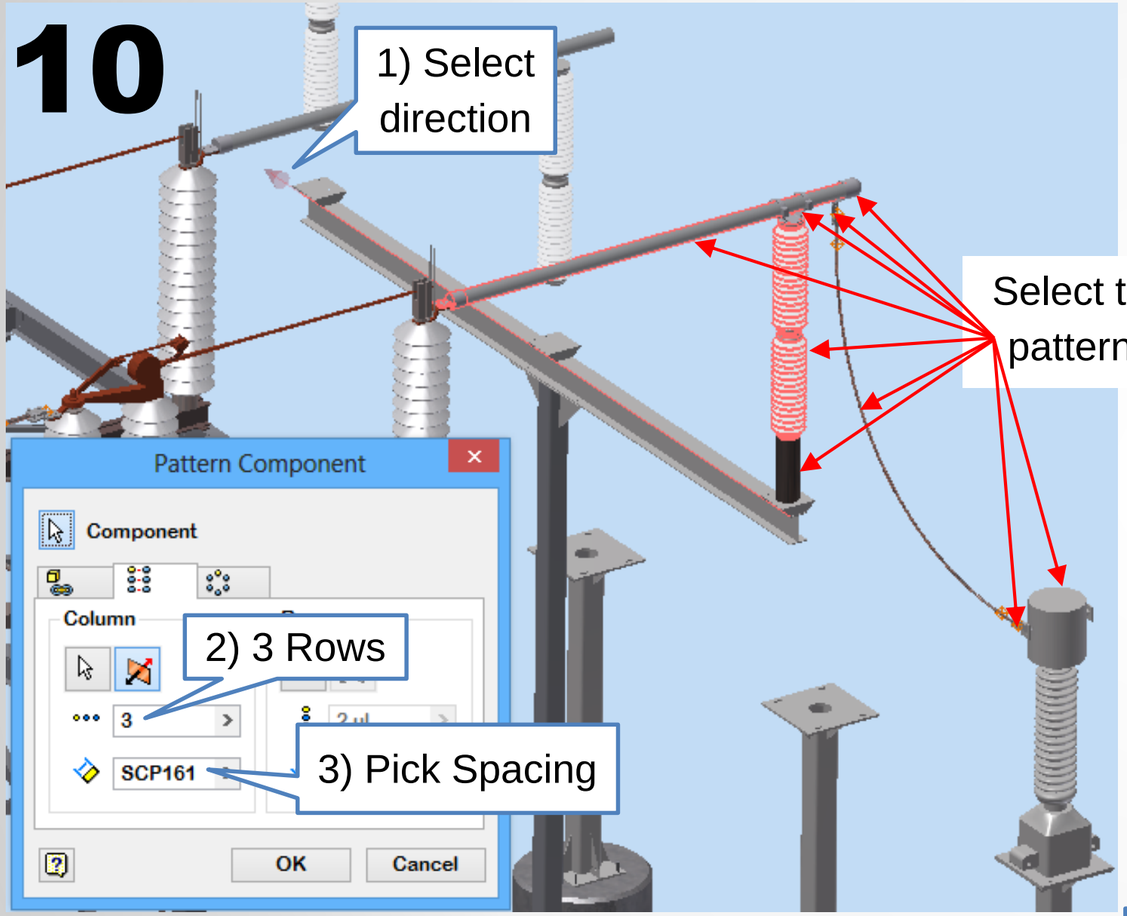
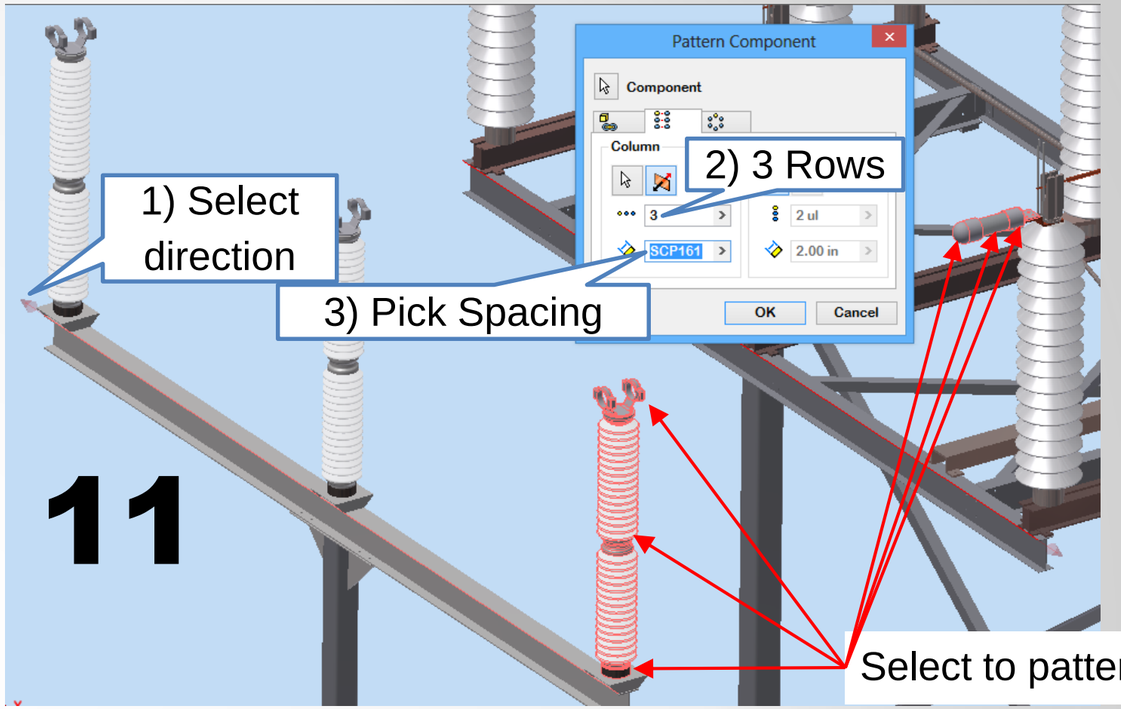
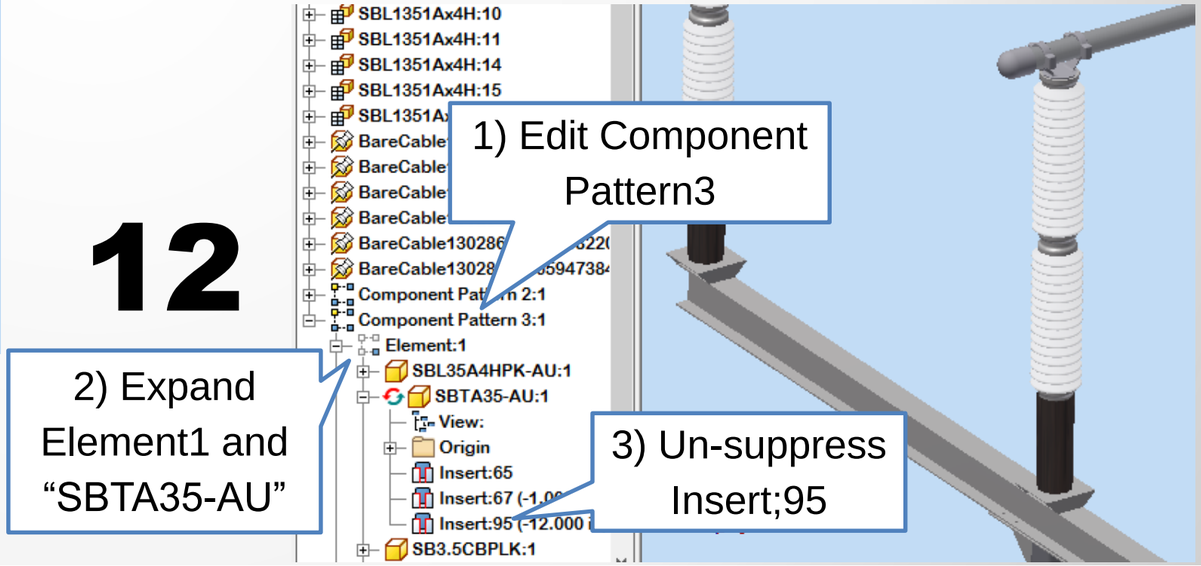
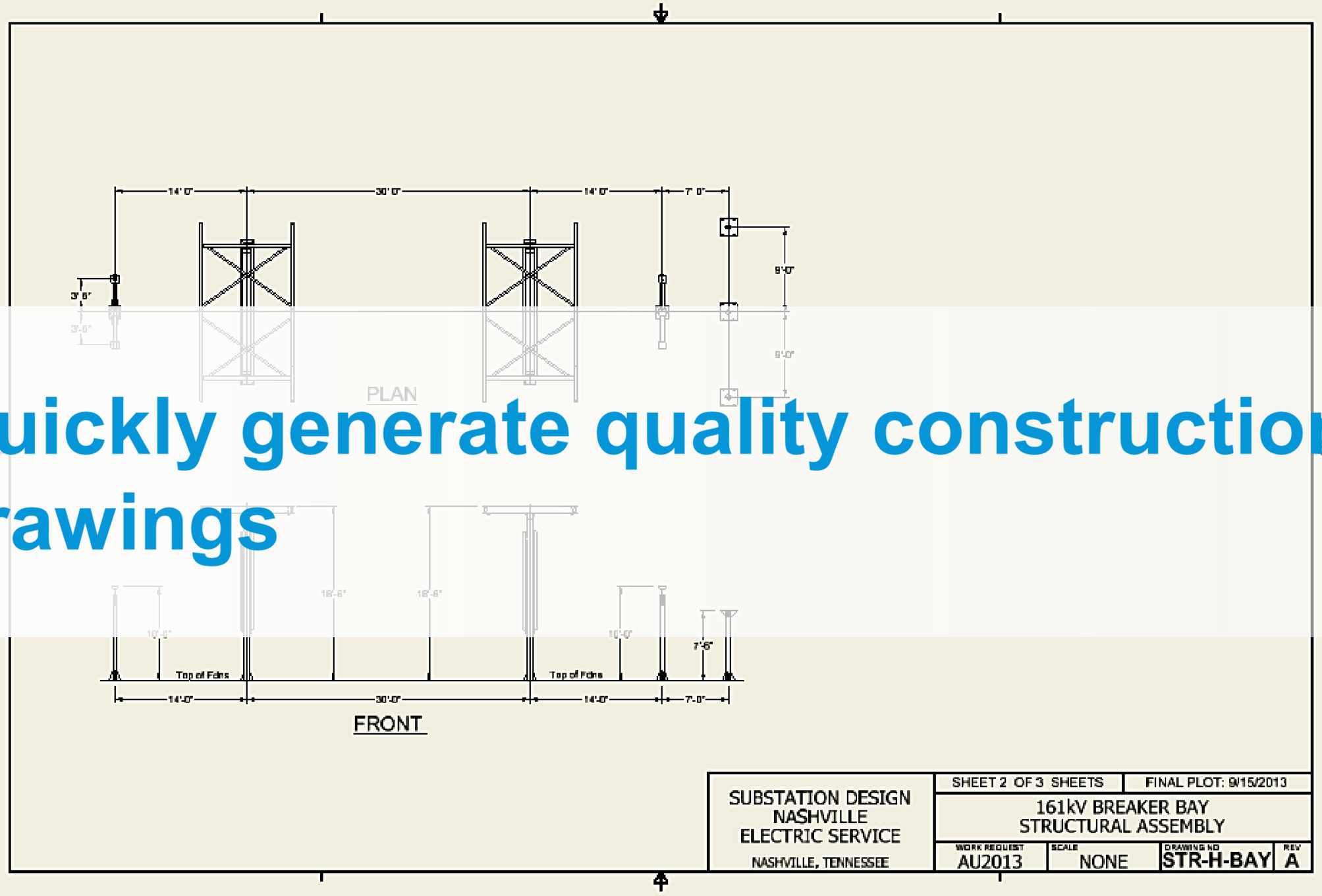


Standard Electrical Models









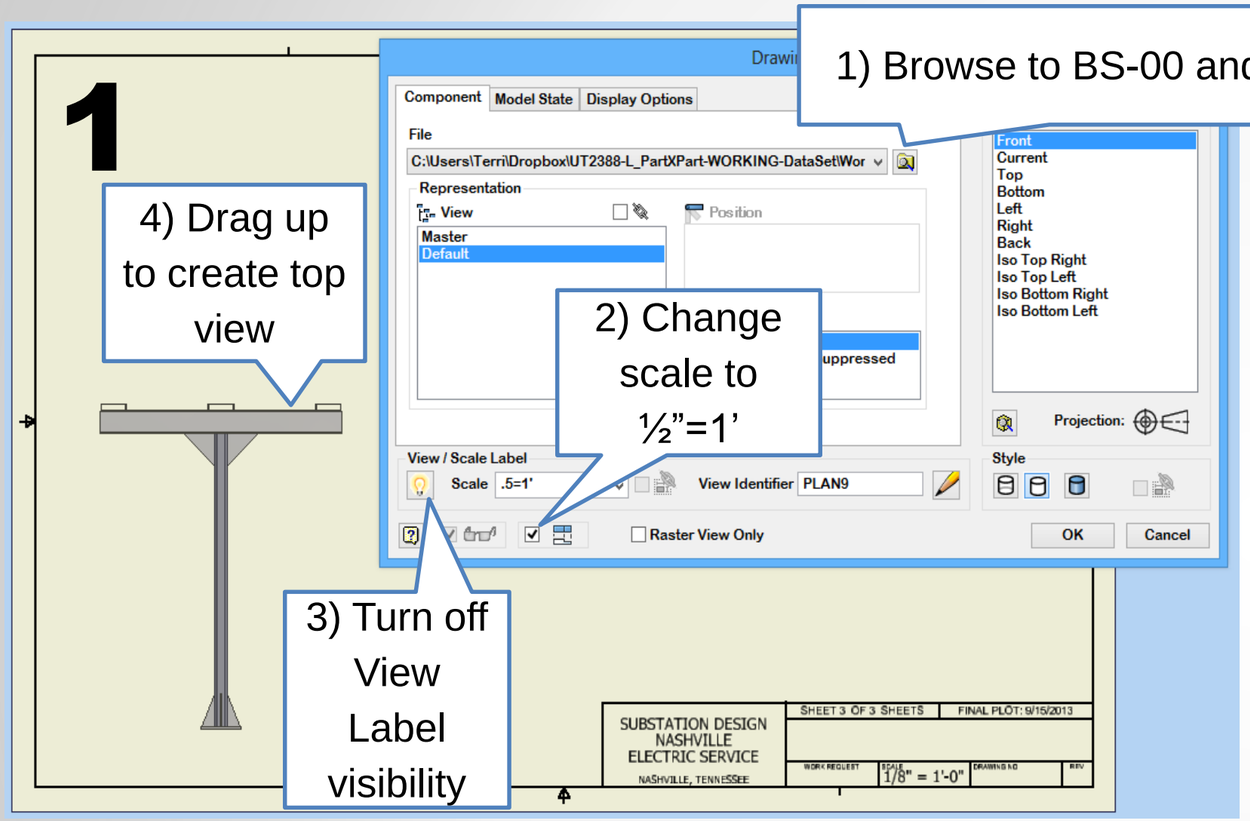
Quickly generate quality construction drawings

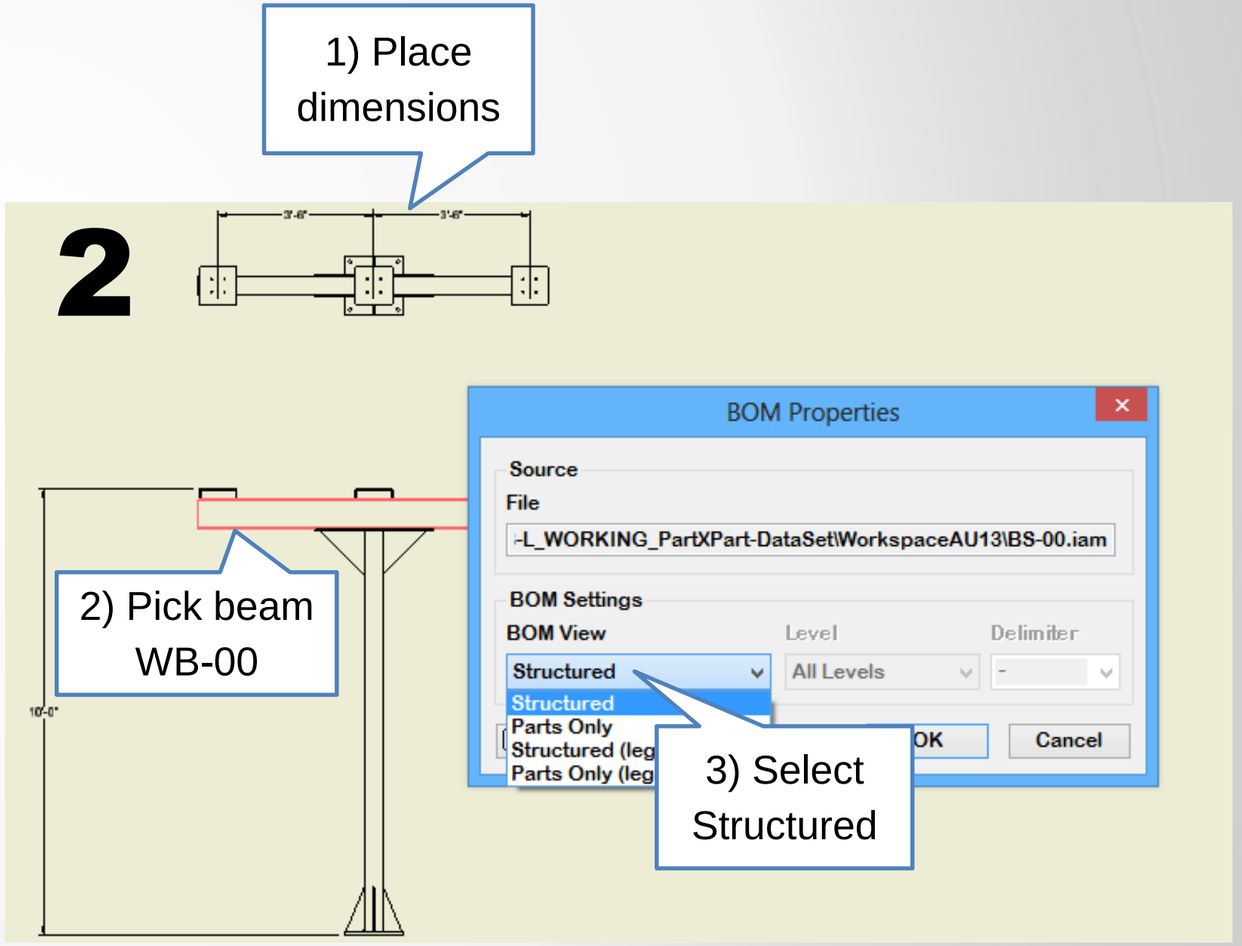
Generate Drawings

- Use a standard assembly to place Views, populate the Title Block, place Dimensions, Balloons and the Parts List.

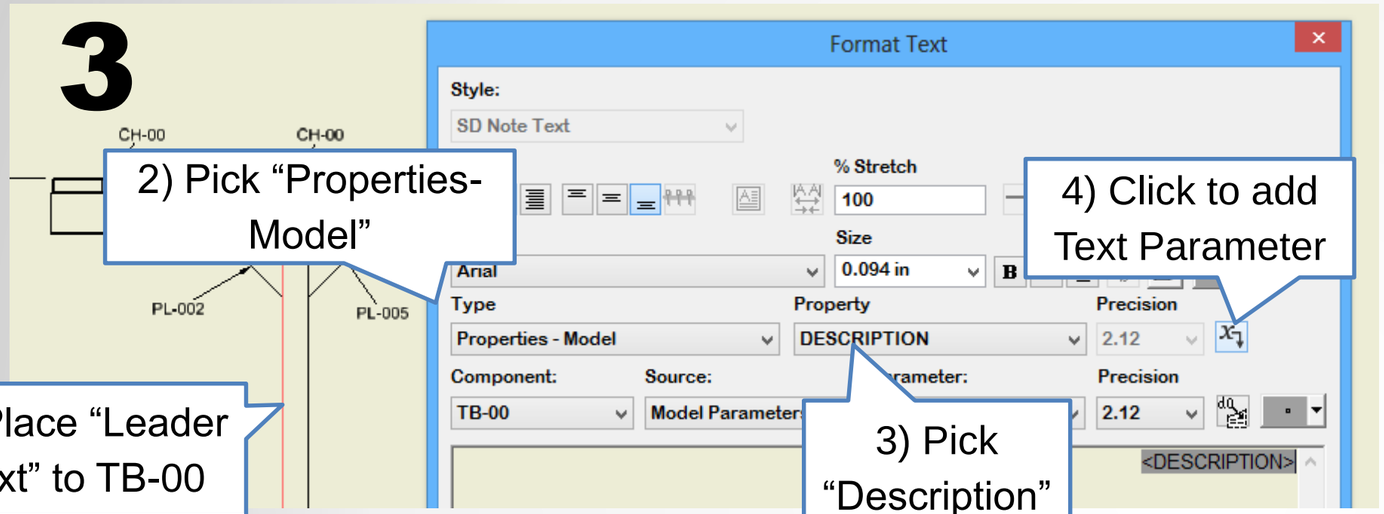
- Replace the standard assembly using the Replace Model Reference tool. The Views, Title Block, Dimensions, Balloons and Parts List update to the values of the new model automatically

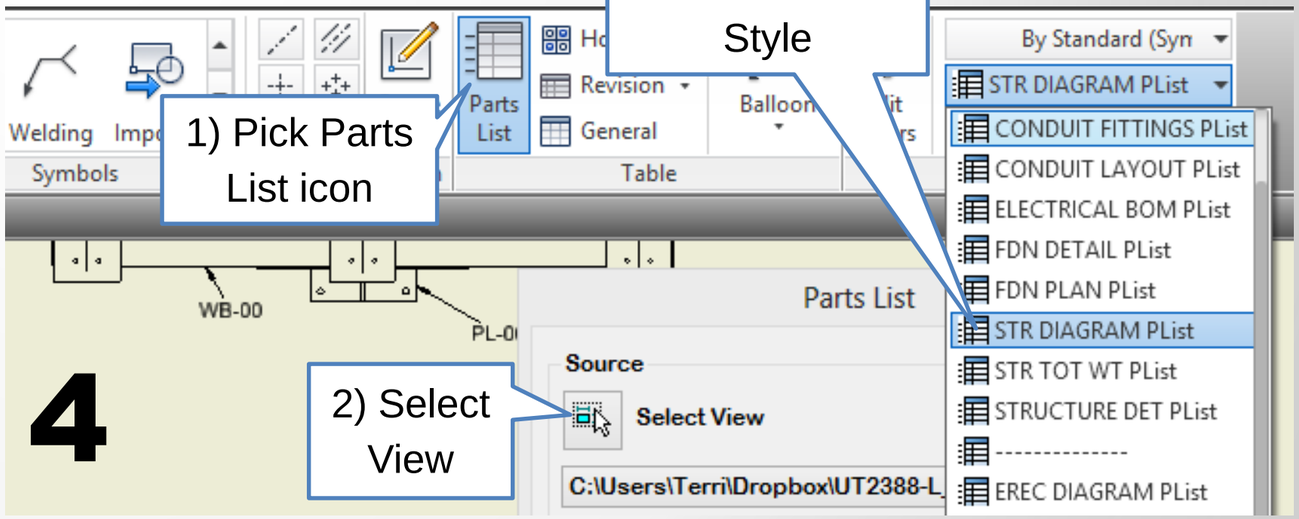
Standard Drawings



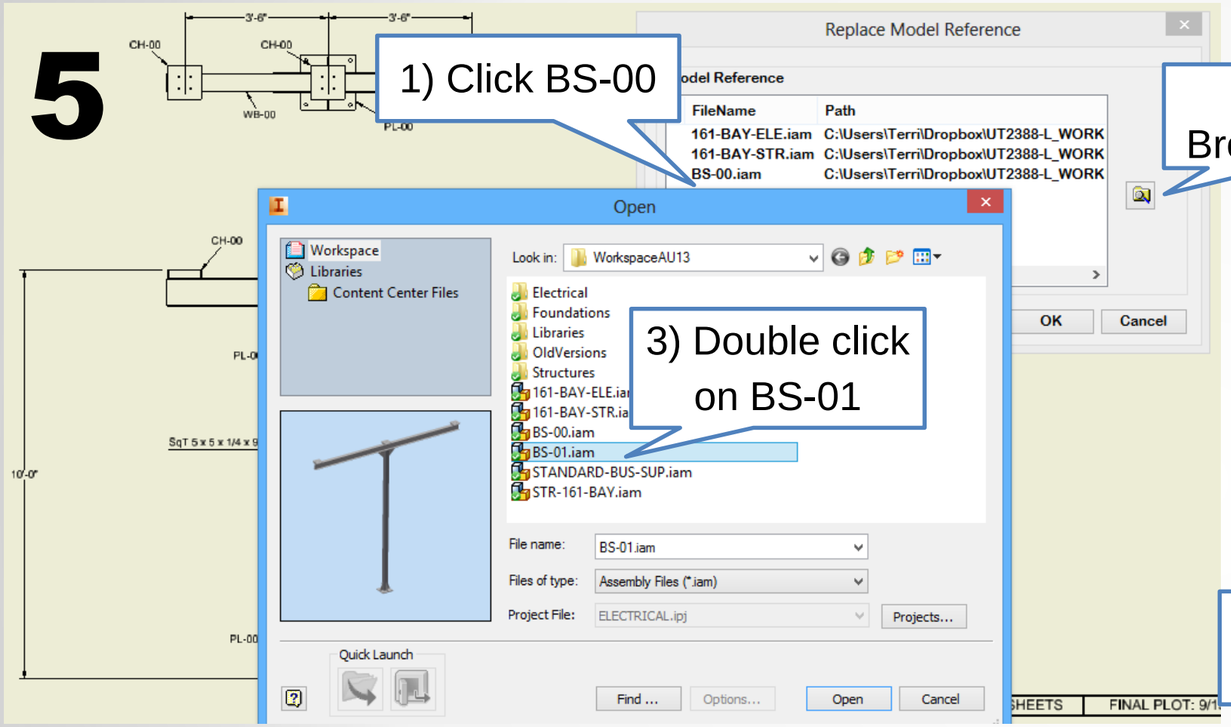


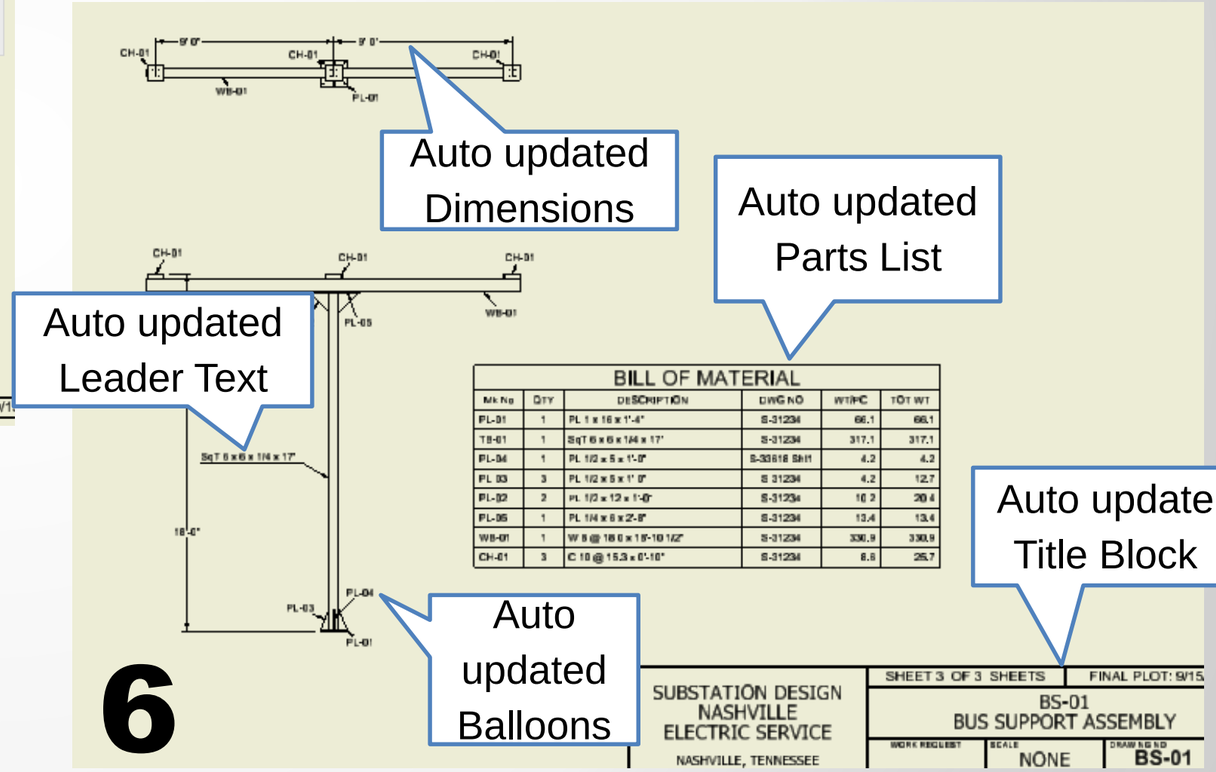
Standard Drawings





Standard Drawings

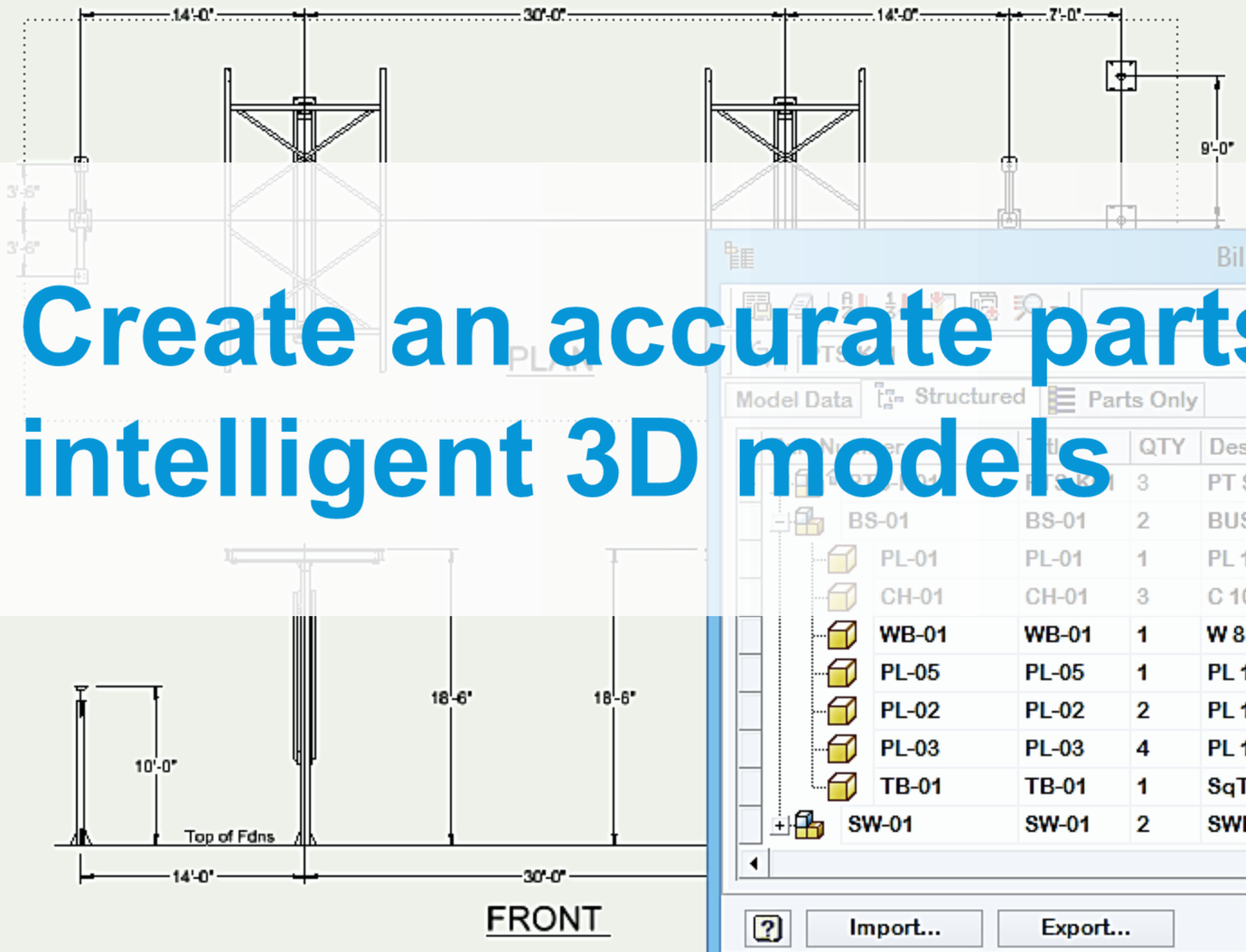




Create an accurate parts list using intelligent 3D models

BILL OF MATERIAL

Mk No	QTY	DESCRIPTION	DWG NO	WT/PC	TOT WT
PL-01	1	PL 1 x 16 x 1'-4"	S-31234	66.1	66.1
CH-01	3	C 10 @ 15.3 x 0'-10"	S-31234	8.6	25.7
WB-01	1	W 8 @ 18.0 x 7'-10 1/2"	S-31234	137.9	137.9
PL-05	1	PL 1/4 x 6 x 2'-8"	S-31234	13.4	13.4
PL-02	2	PL 1/2 x 12 x 1'-0"	S-31234	10.2	20.4
PL-03	4	PL 1/2 x 5 x 1'-0"	S-31234	4.2	16.9
TB-01	1	SqT 5 x 5 x 1/4 x 9'	S-31234	137.3	137.3



Bill of Materials [161-BAY-STR.iam]

Model Data | Structured | Parts Only

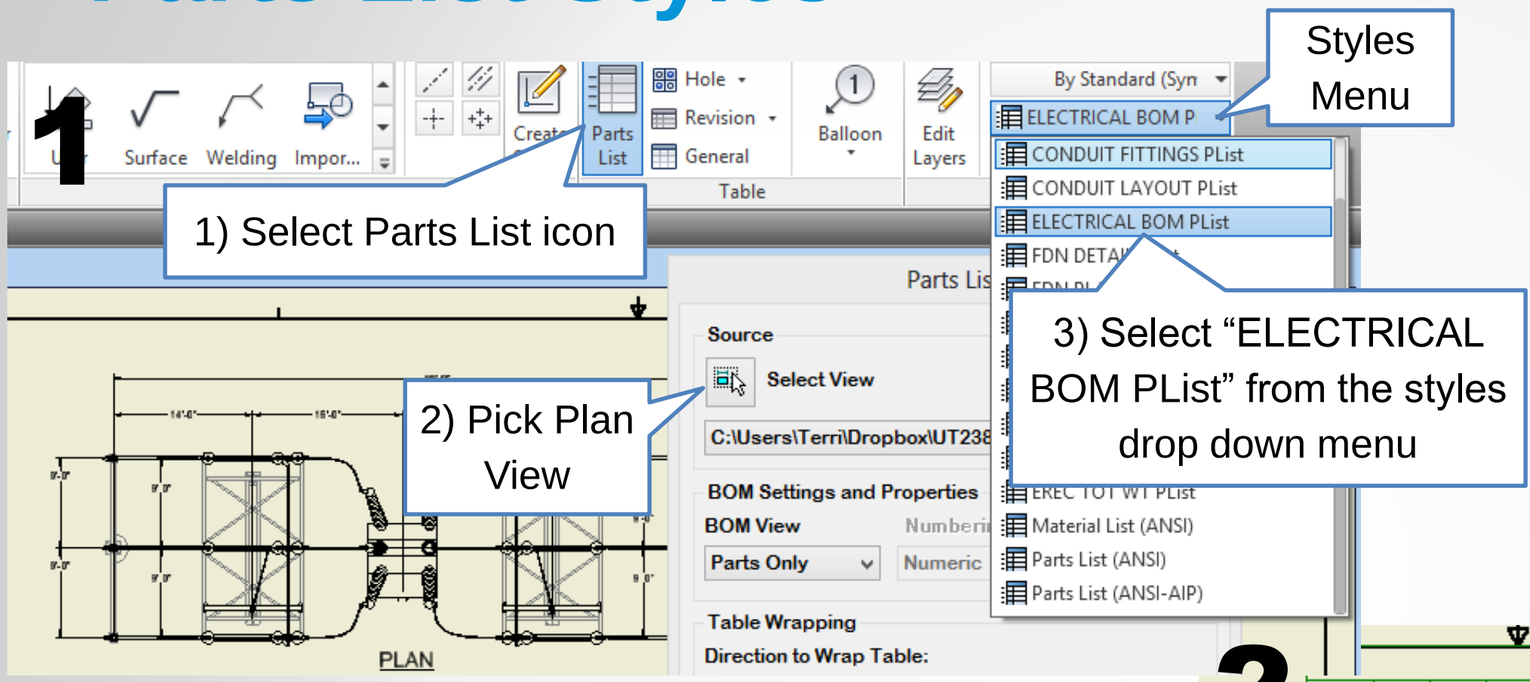
		QTY	Description	Mass	Total	Dwg#
		3	PT STRUCTURE	302.220 lbmass	Total	S-22712
BS-01	BS-01	2	BUS SUPPORT ASSEMBLY	417.781 lbmass	Total	S-31234
PL-01	PL-01	1	PL 1 x 16 x 1'-4"	66.142 lbmass	Total	S-31234
CH-01	CH-01	3	C 10 @ 15.3 x 0'-10"	8.559 lbmass	Total	S-31234
WB-01	WB-01	1	W 8 @ 18.0 x 7'-10 1/2"	137.925 lbmass	Total	S-31234
PL-05	PL-05	1	PL 1/4 x 6 x 2'-8"	13.402 lbmass	Total	S-31234
PL-02	PL-02	2	PL 1/2 x 12 x 1'-0"	10.210 lbmass	Total	S-31234
PL-03	PL-03	4	PL 1/2 x 5 x 1'-0"	4.236 lbmass	Total	S-31234
TB-01	TB-01	1	SqT 5 x 5 x 1/4 x 9'	137.270 lbmass	Total	S-31234
SW-01	SW-01	2	SWITCH STRUCTURE ASSEMBLY	1853.66005 lbmass	Total	S-33432

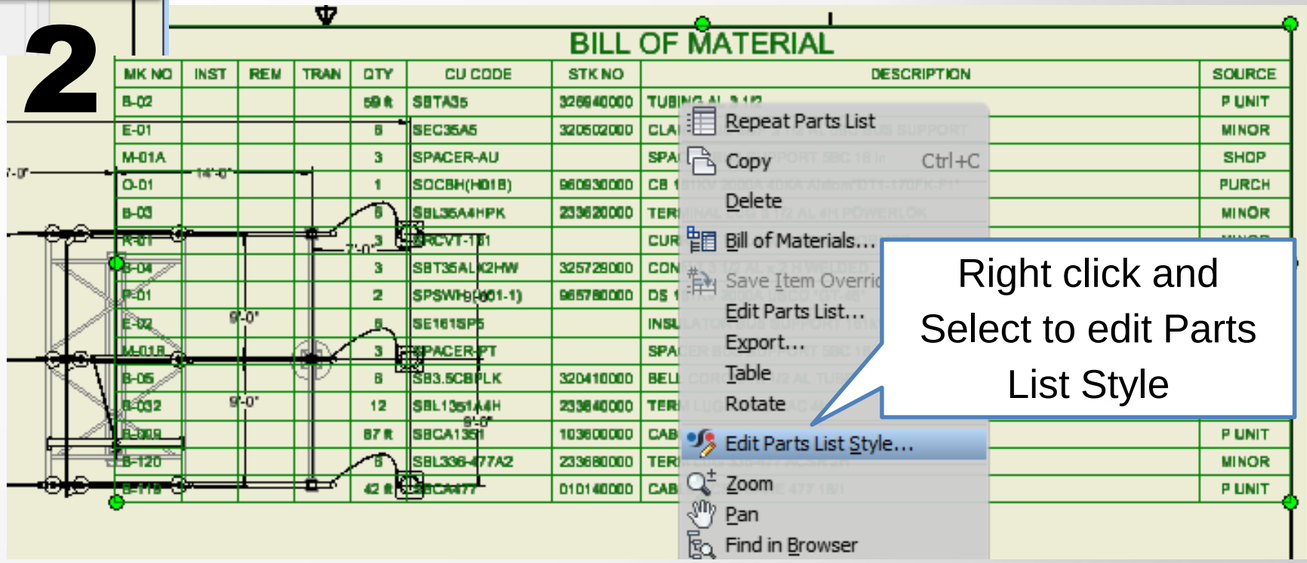
Import... Export... Done

3D Model to BOM to Parts List

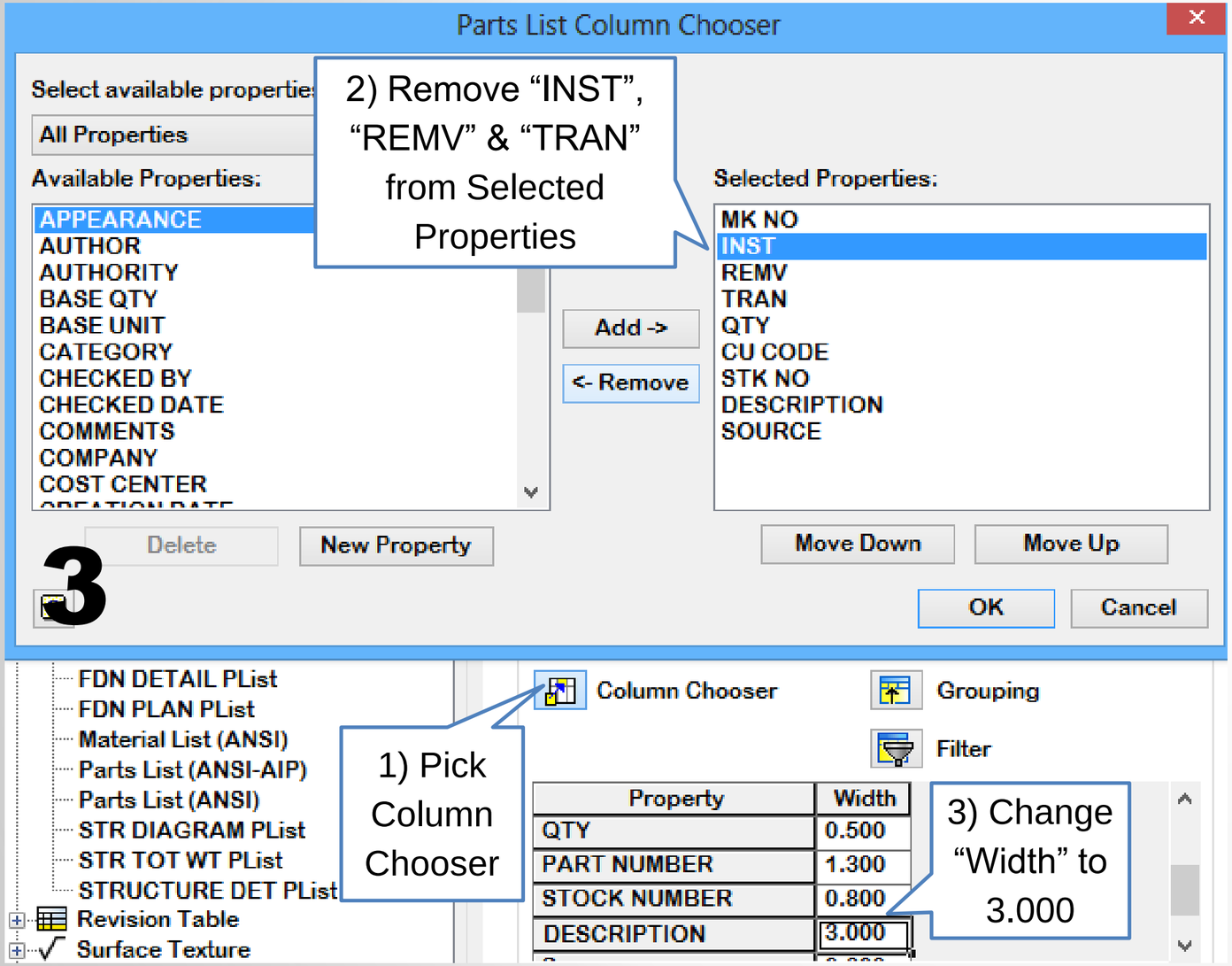
- Balloons, Parts List Styles, Bill of Material (BOM) and Parts List work together to present the information about the parts contained in an assembly
- Customize the display of data in the Parts List using Parts List Styles
- The BOM Structure affects the display of data
- Correct information in the BOM vs. correcting information in the Parts List.

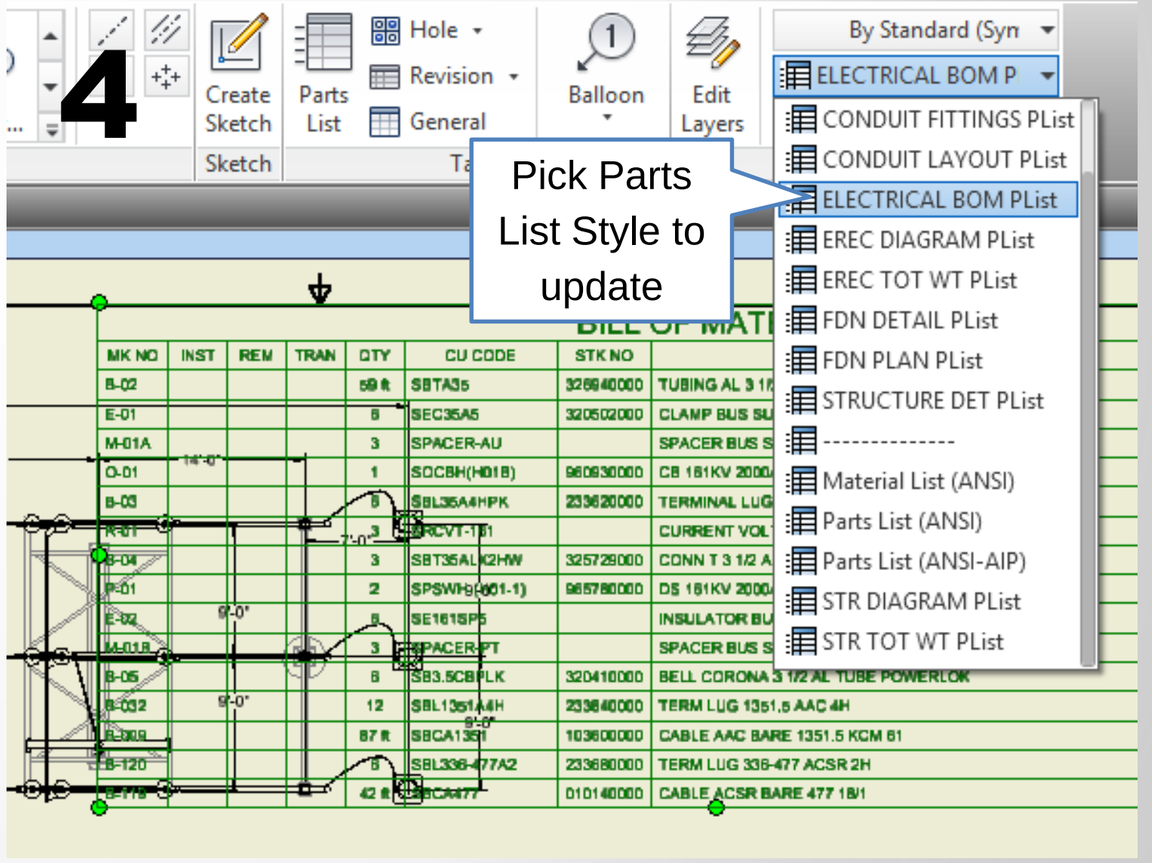
Parts List Styles



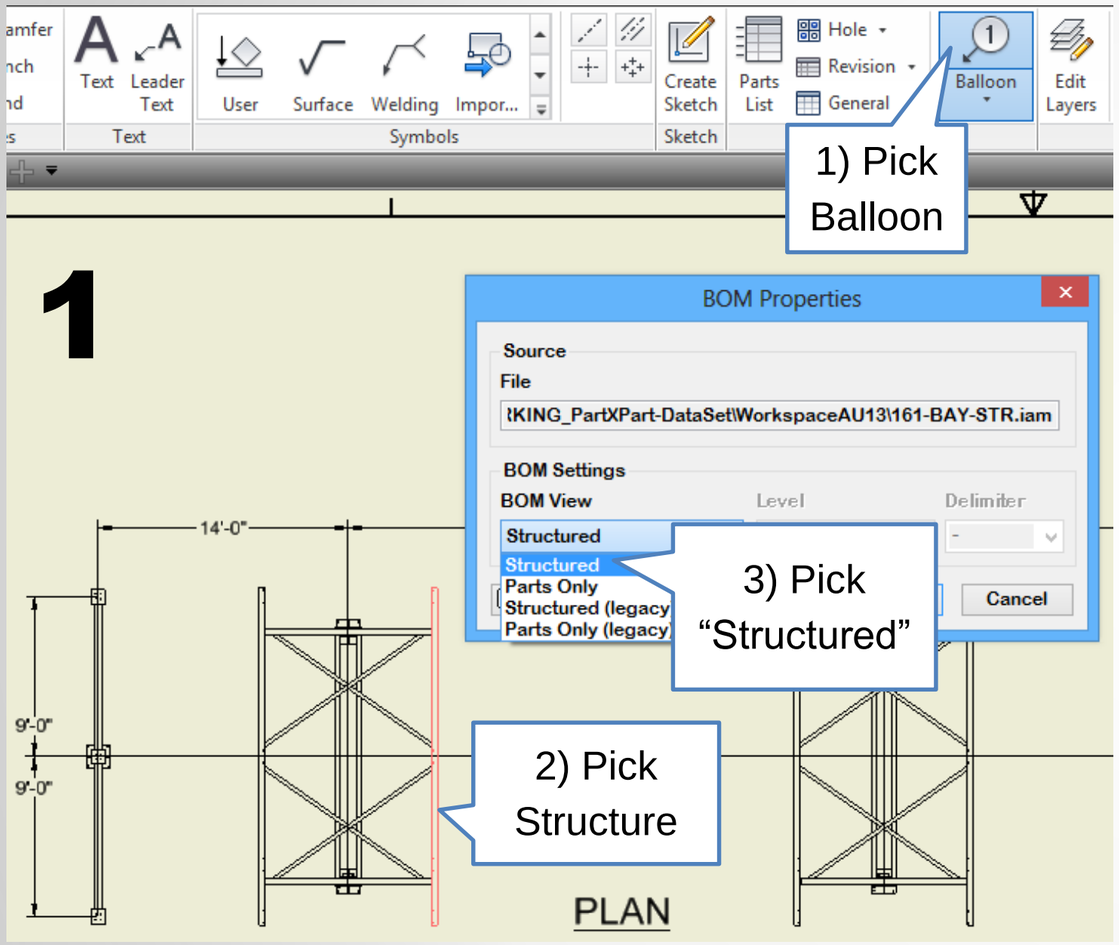


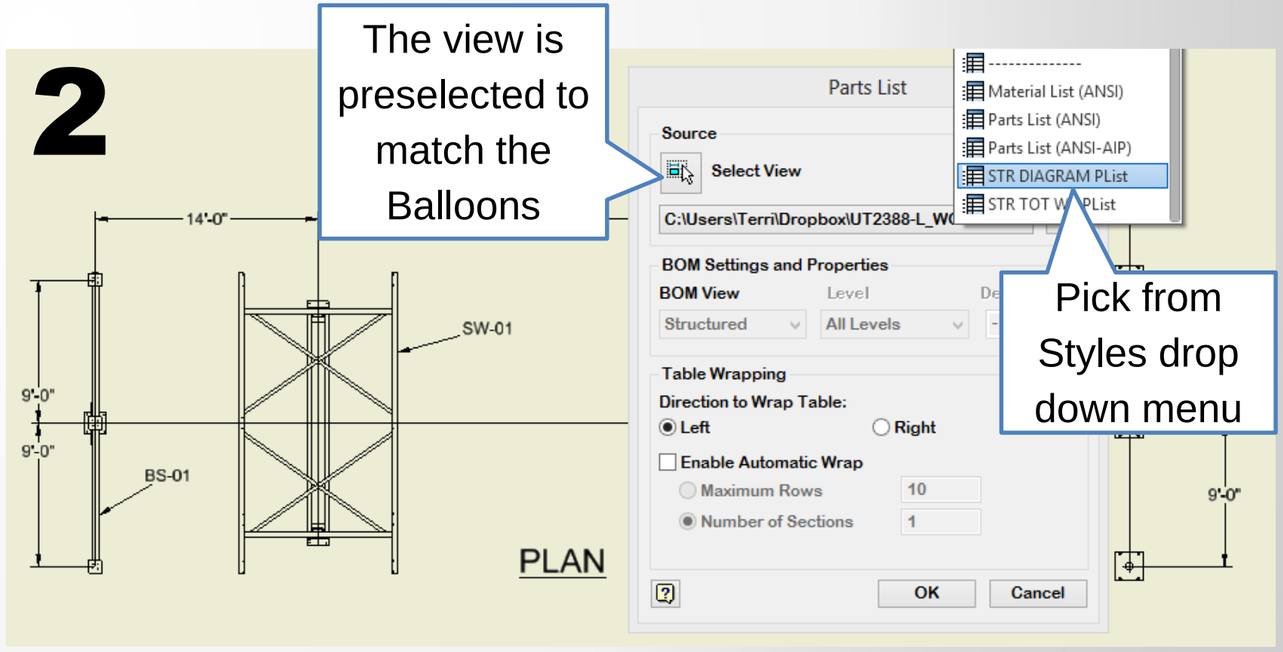
Parts List Styles



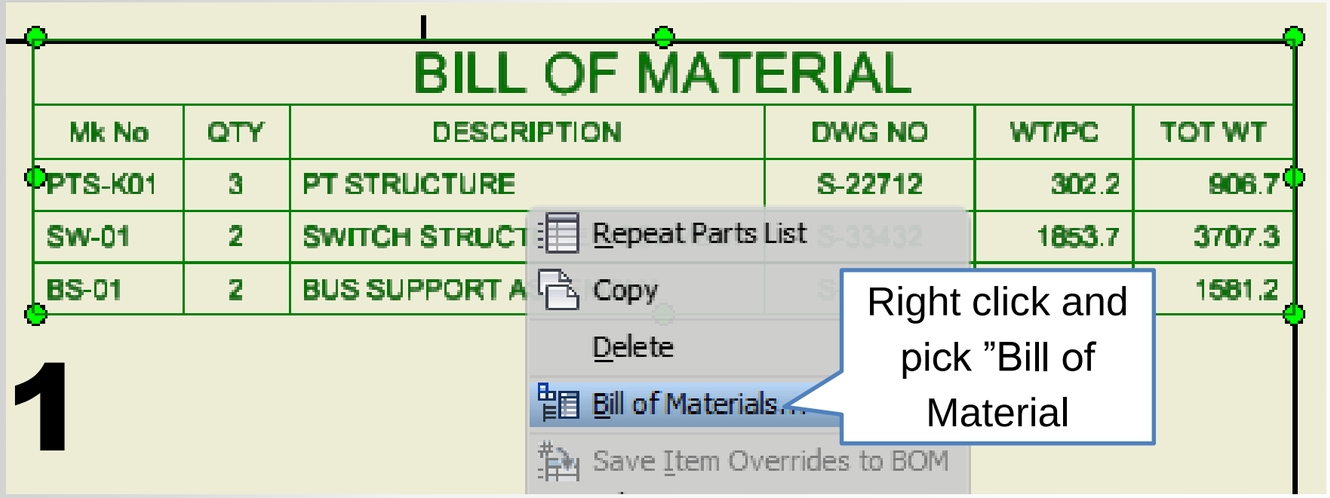


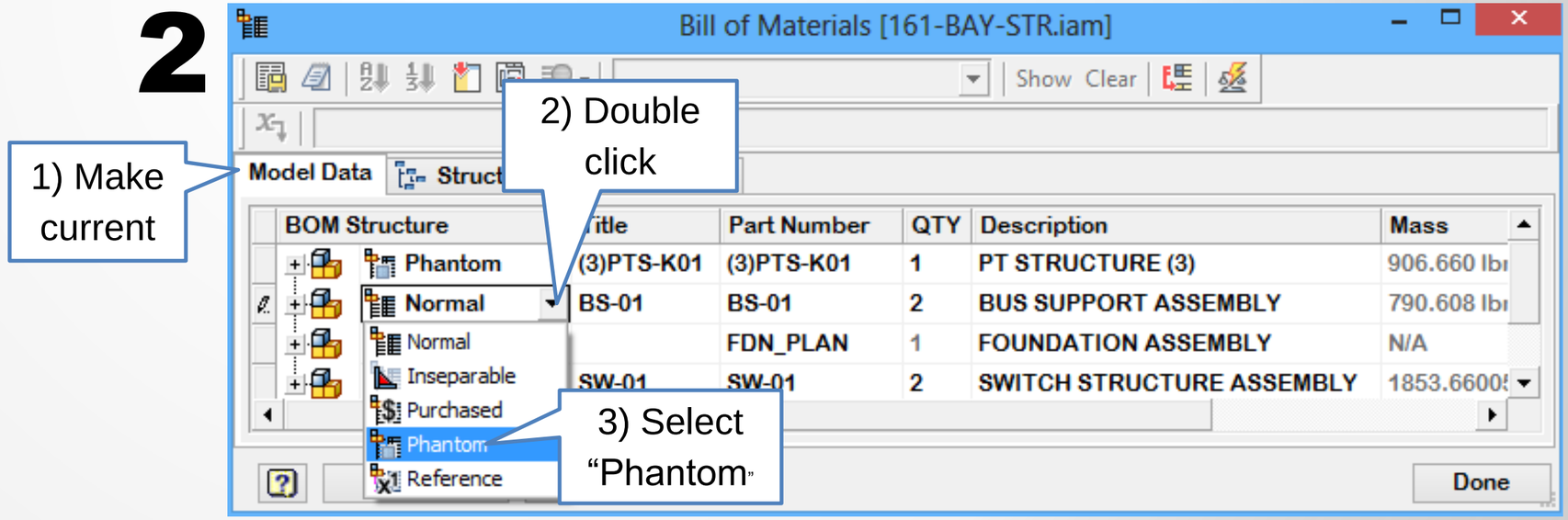
Balloons and the Parts List



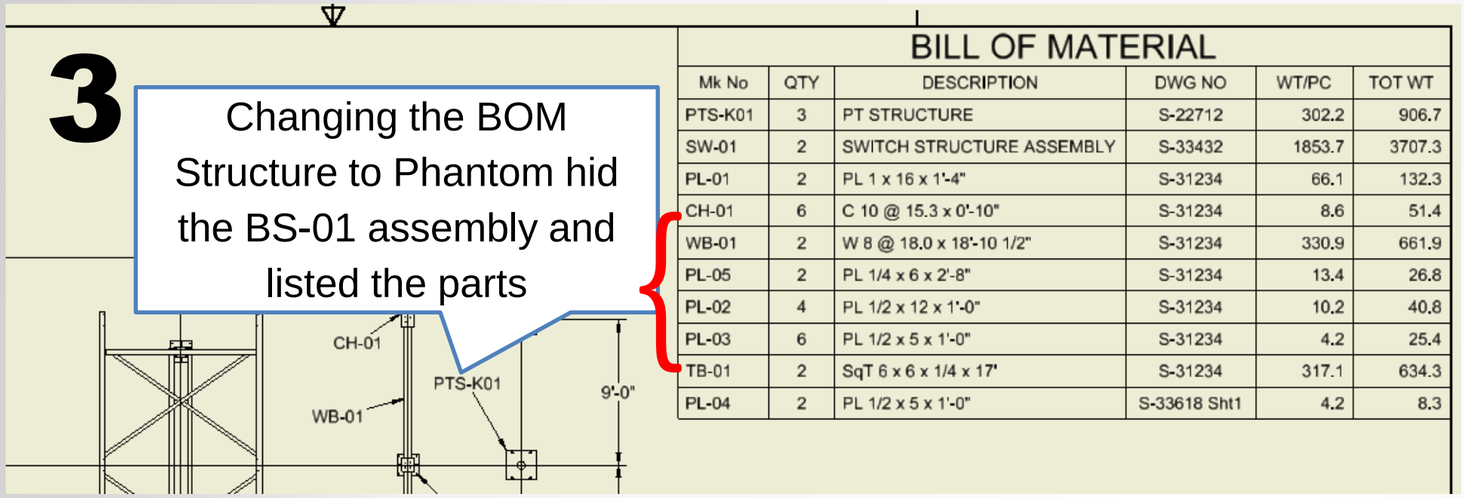


BOM vs. Parts List



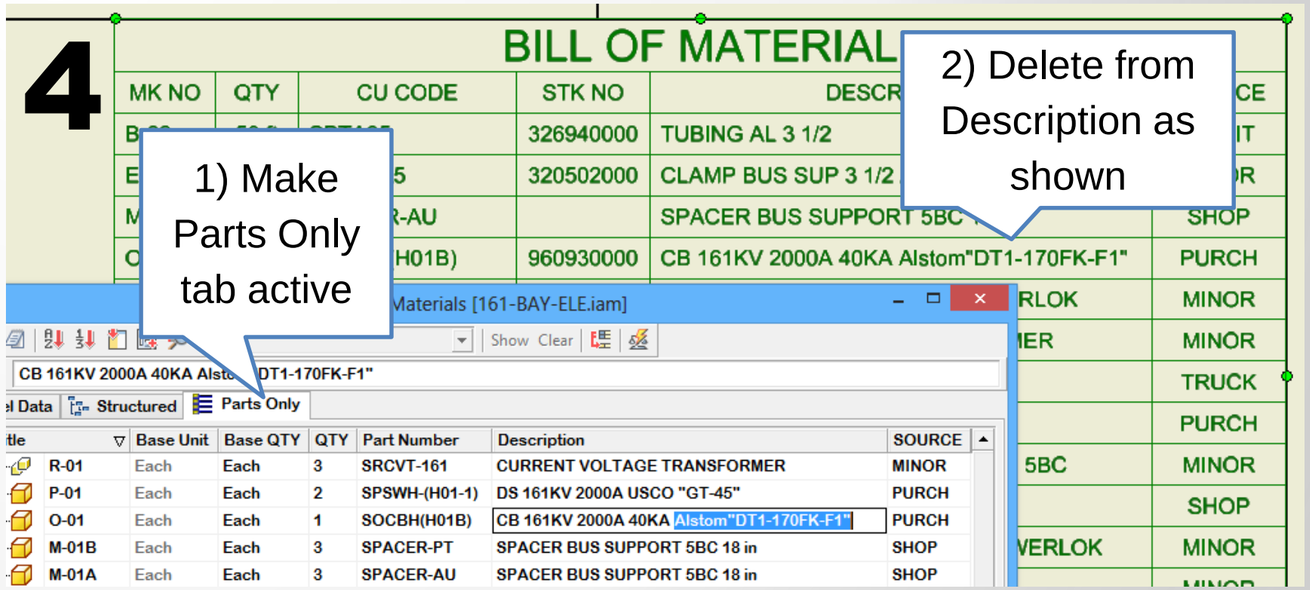


BOM vs. Parts List



BILL OF MATERIAL

Mk No	QTY	DESCRIPTION	DWG NO	WT/PC	TOT WT
PTS-K01	3	PT STRUCTURE	S-22712	302.2	906.7
SW-01	2	SWITCH STRUCTURE ASSEMBLY	S-33432	1853.7	3707.3
PL-01	2	PL 1 x 16 x 1'-4"	S-31234	66.1	132.3
CH-01	6	C 10 @ 15.3 x 0'-10"	S-31234	8.6	51.4
WB-01	2	W 8 @ 18.0 x 18'-10 1/2"	S-31234	330.9	661.9
PL-05	2	PL 1/4 x 6 x 2'-8"	S-31234	13.4	26.8
PL-02	4	PL 1/2 x 12 x 1'-0"	S-31234	10.2	40.8
PL-03	6	PL 1/2 x 5 x 1'-0"	S-31234	4.2	25.4
TB-01	2	SqT 6 x 6 x 1/4 x 17'	S-31234	317.1	634.3
PL-04	2	PL 1/2 x 5 x 1'-0"	S-33618 Sht1	4.2	8.3



BOM vs. Parts List

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BILL OF MATERIAL

MK NO	QTY	CU CODE	STK NO		
B-02	59 ft	SBTA35	326940000	TUBING AL 3 1/2	
E-01	6	SEC35A5	320502000	CLAMP BUS SU	
M-01A	3	SPACER-AU		SPACER BUS SUPPORT 5BC 18	SHOP
O-01	1	SOCBH(H01B)	960930000	CB 161KV 2000A 40KA	PURCH

Manufacturer is deleted from Description of Parts List

Parts List: 161-BAY-ELE.iam

Delete from Parts List

Manufacturer is deleted from Description of the BOM

MK NO			STK NO		
B-02	59 ft	A35	326940000	TUBI	
E-01	6	5A5	320502000	CLAMP BUS SUP 3 1/2 A	UPPORT MINOR
M-01A	3	SPA ER-AU		SPACER BUS SUPPORT 5BC	SHOP
O-01	1	SOCBH(H01B)	960930000	CB 161KV 2000A 40KA	PURCH
B-03	6	SBL35A4HPK	233620000	TERMINAL LUG 3 1/2 AL 4H POWERLOK	MINOR
R-01	3	SRCVT-161		CURRENT VOLTAGE TRANSFORMER	MINOR

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BILL OF MATERIAL

MK				DESCRIPTION	SOURCE
B-02				UBING AL 3 1/2	P UNIT
E-01				LAMP BUS SUP 3 1/2 AL 5BC BUS SUPPORT	MINOR
M-01A	3	ER-AU		SPACER BUS SUPPORT 5BC 18 in	SHOP
O-01	1		960930000	CB 161KV 2000A 40KA	PURCH

CU Code/Part Number is deleted from the Parts List

Bill of Materials [161-BAY-ELE.iam]

CU Code/Part Number is still populated in the BOM

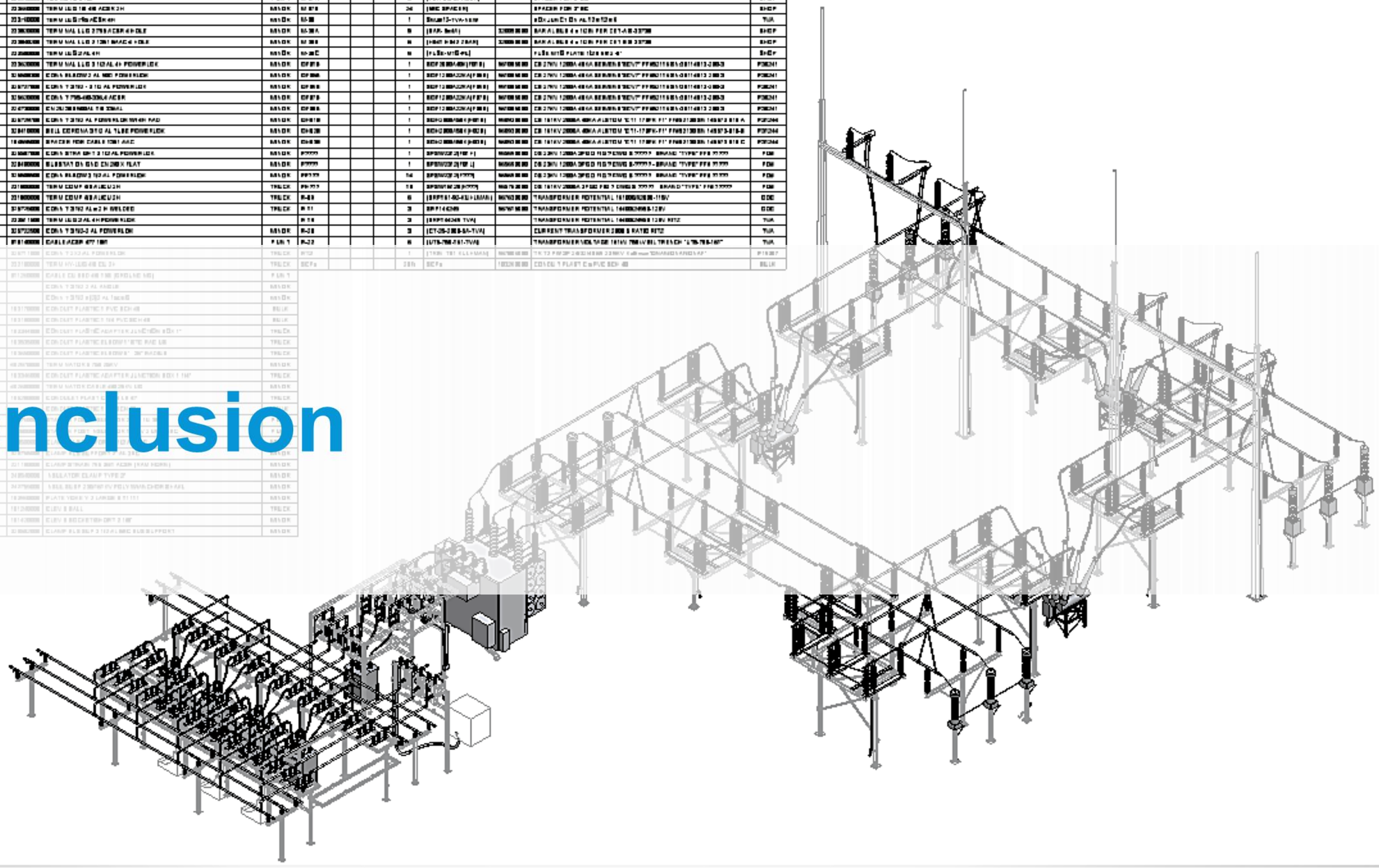
Show Clear

SOCBH(H01B)

Model Data | Structured

Title	Base Unit					SOURCE
R-01	Each	Each			CURRENT VOLTAGE TRANSFORMER	MINOR
P-01	Each	Each	2	-(H01-1)	DS 161KV 2000A USCO "GT-45"	PURCH
O-01	Each	Each	1	SOCBH(H01B)	CB 161KV 2000A 40KA	PURCH
M-01B	Each	Each	3	SPACER-PT	SPACER BUS SUPPORT 5BC 18 in	SHOP
M-01A	Each	Each	3	SPACER-AU	SPACER BUS SUPPORT 5BC 18 in	SHOP

In Conclusion



The Same but Different

- Inventor is perfect for Substation Design because it seems each job is the same as the last job except...different
- It all starts with a sketch in a template that uses parameters and dimensional constraints adjust the part and information for the Parts List
- 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.