

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

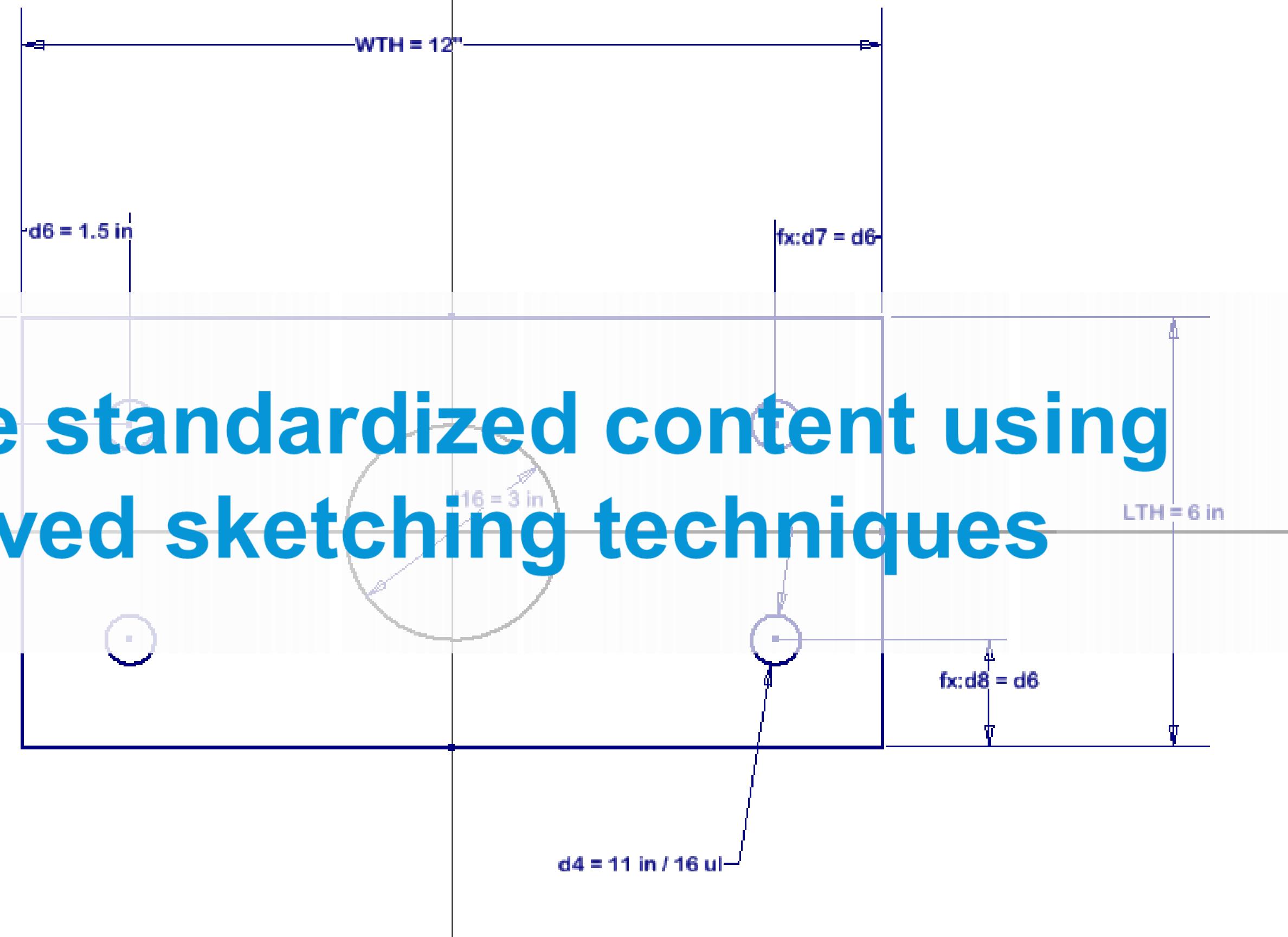
- 7 yrs. at NES
 - Previous to NES, 17 years' experience in manufacturing industry.
 - Use Autodesk Inventor to document substation designs. This includes field checking and using existing paper drawings then transferring this information into Inventor format.
 - Have used AutoCAD since 1989 and previous 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.

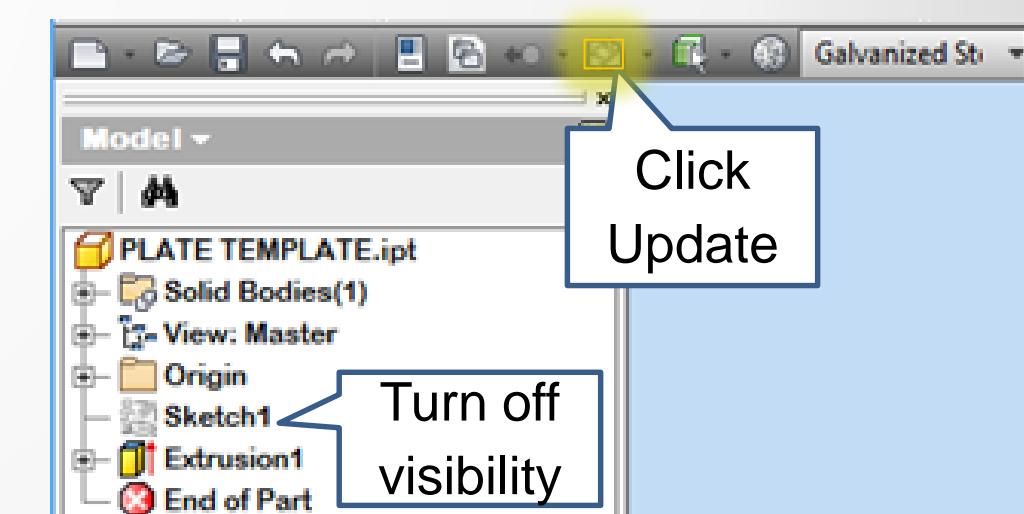
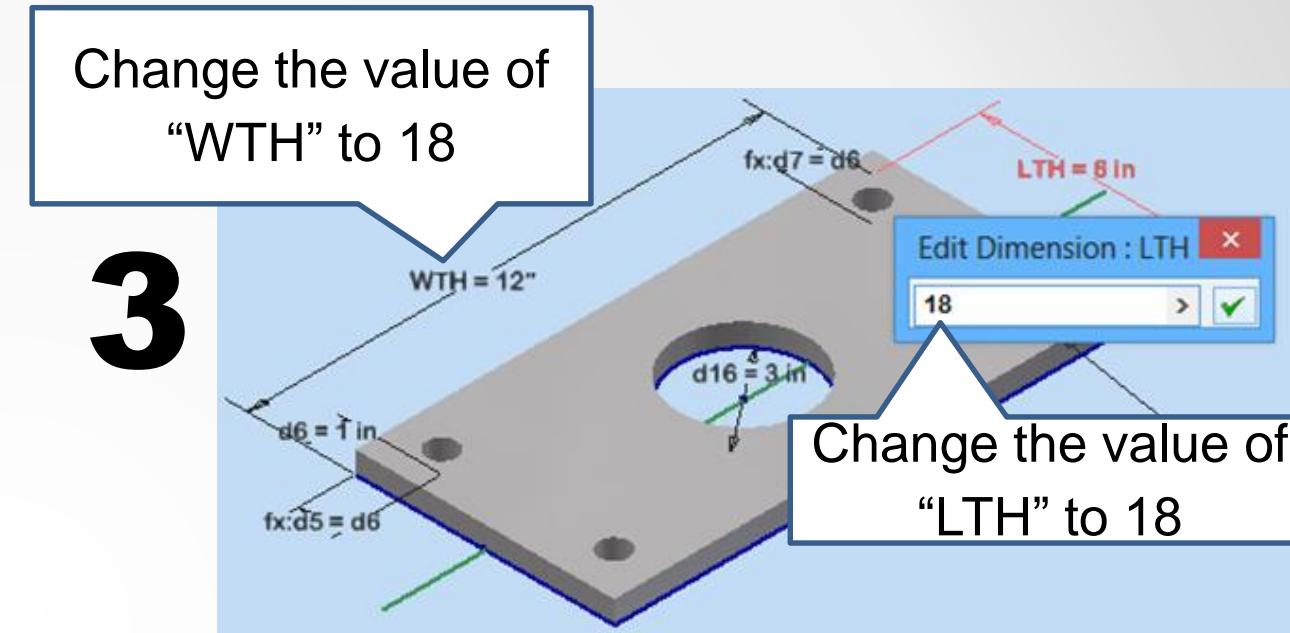
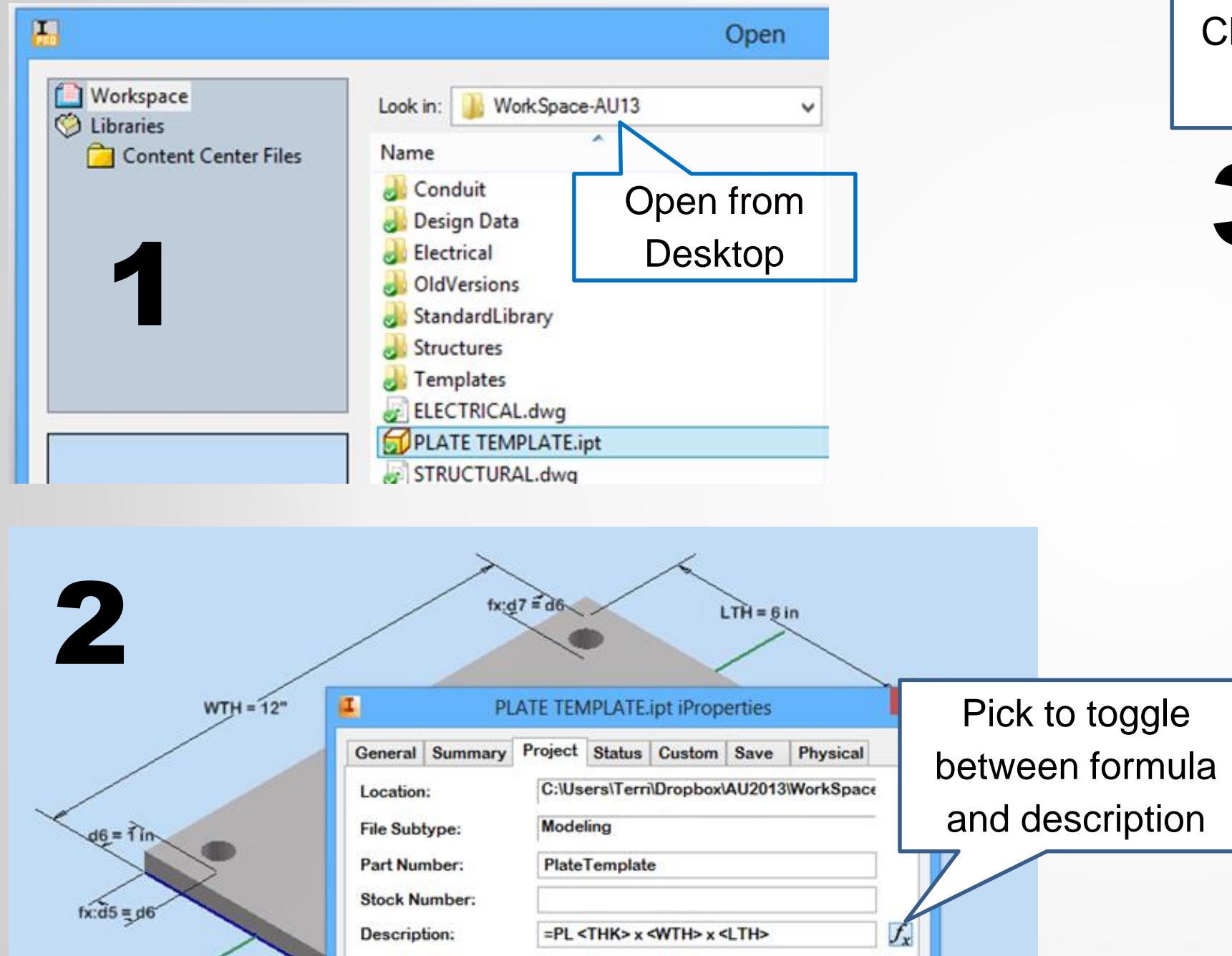
Create standardized content using improved sketching techniques



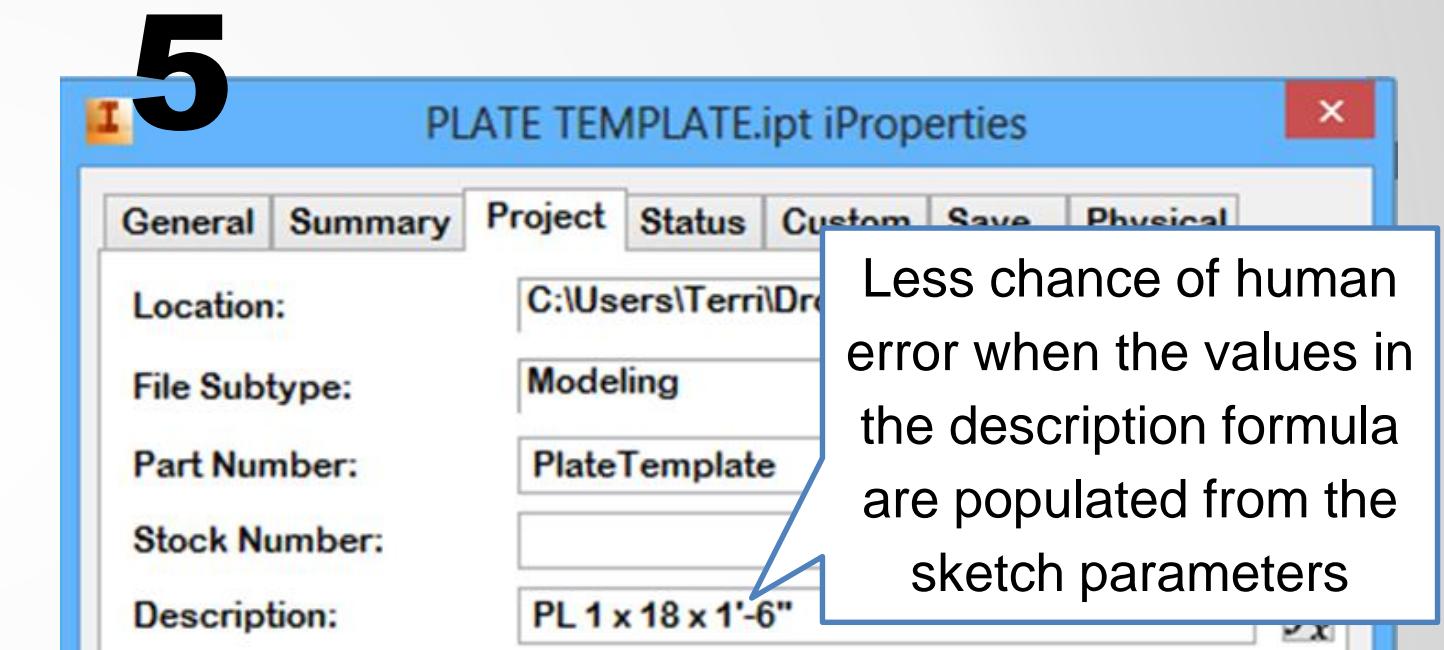
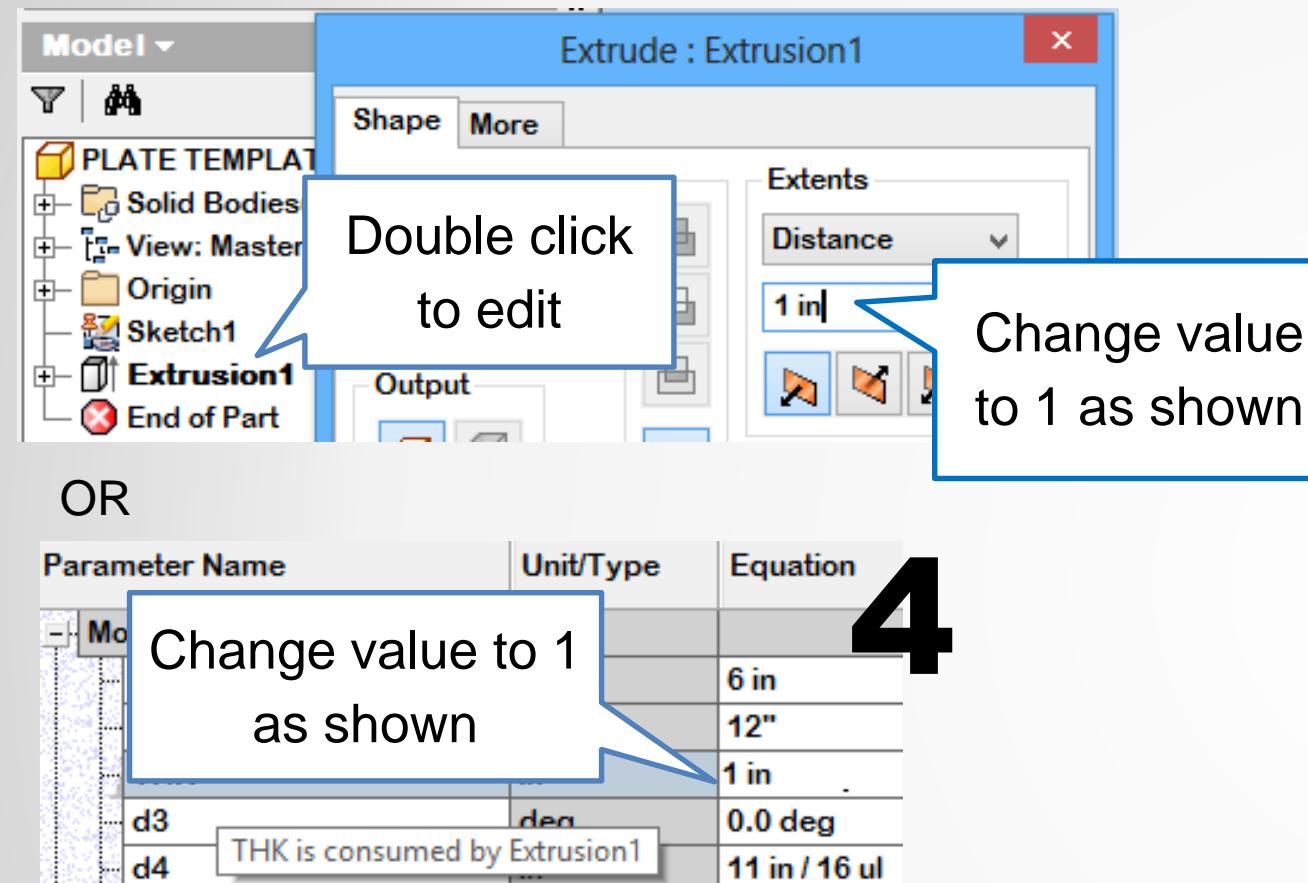
Where we begin

- 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

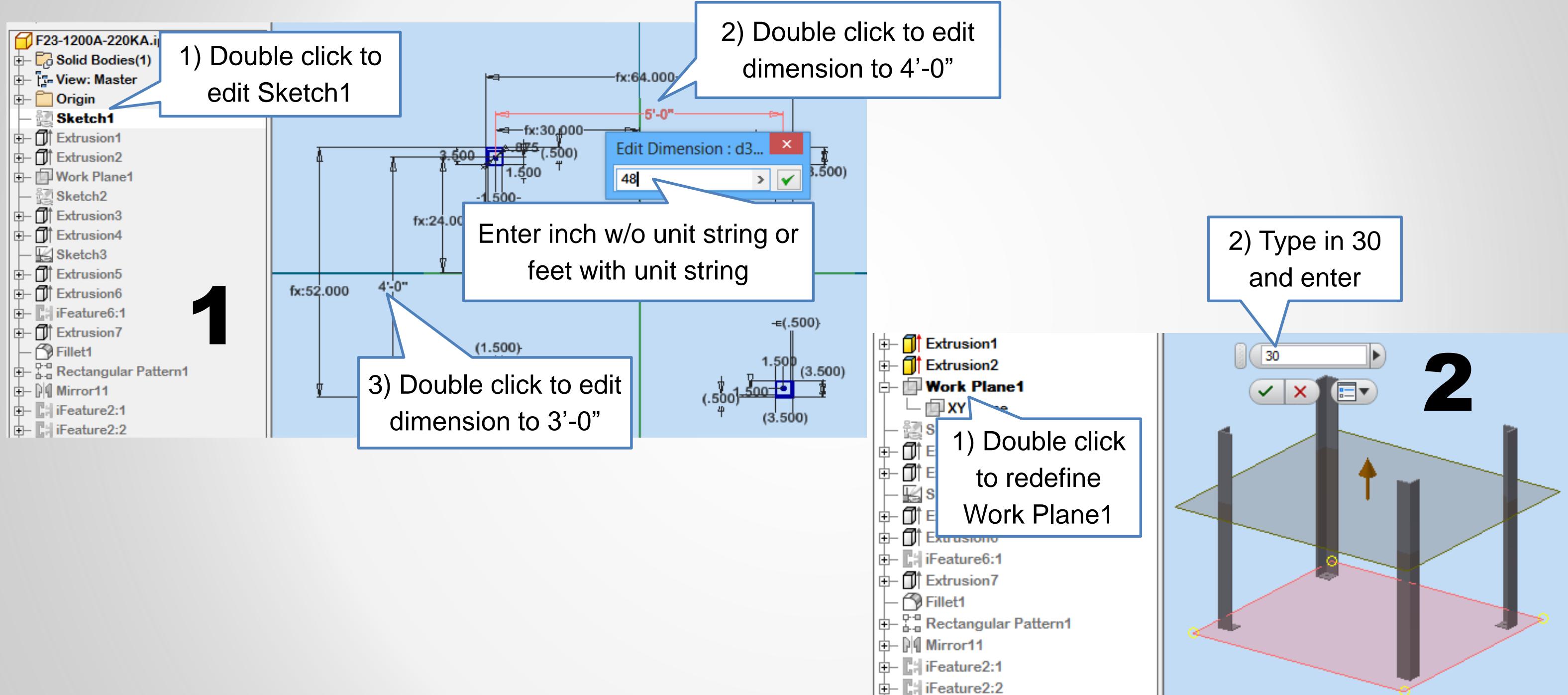


Part Template



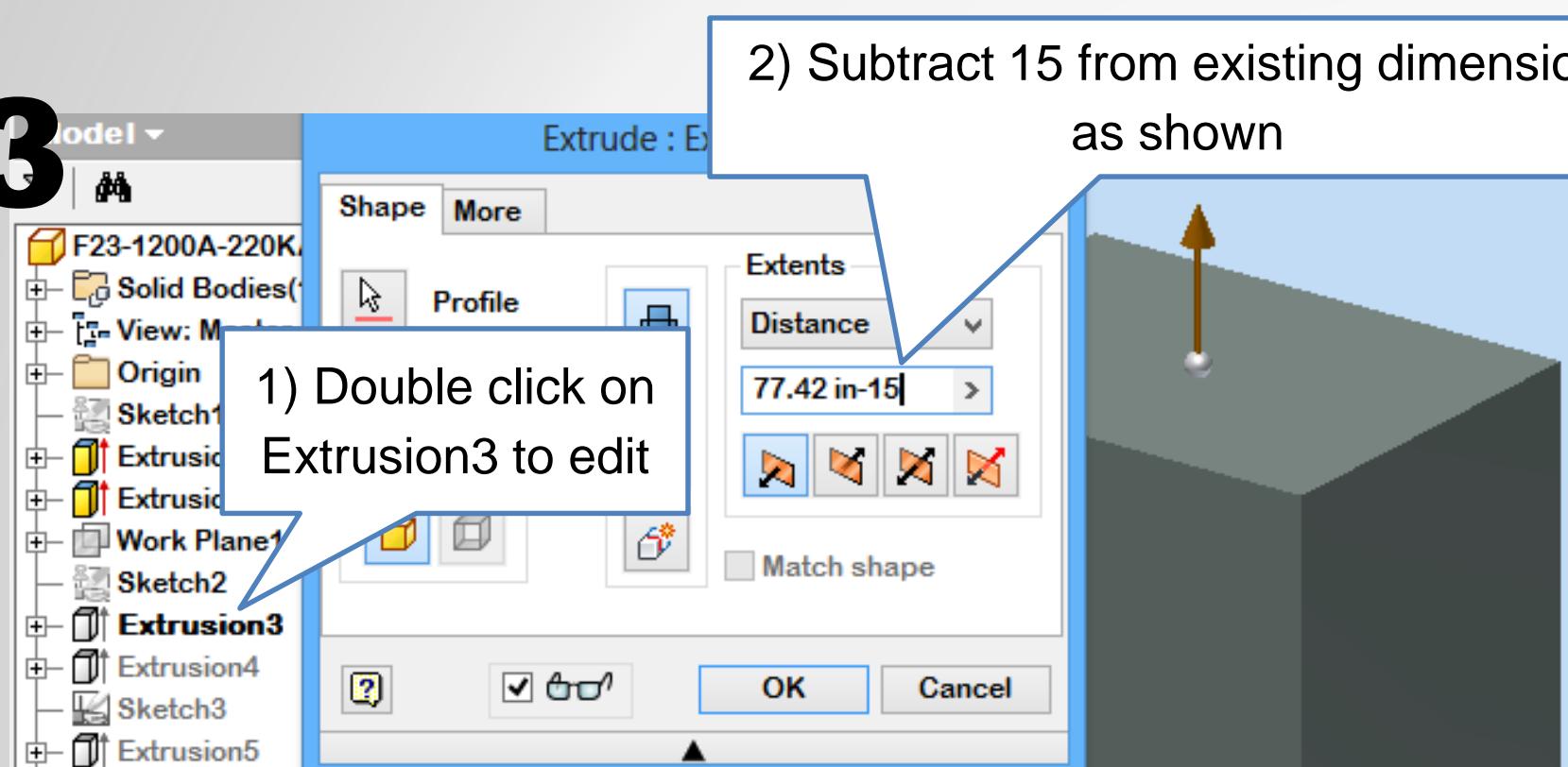
6 Save and close the PLATE TEMPLATE

Typical Circuit Breaker

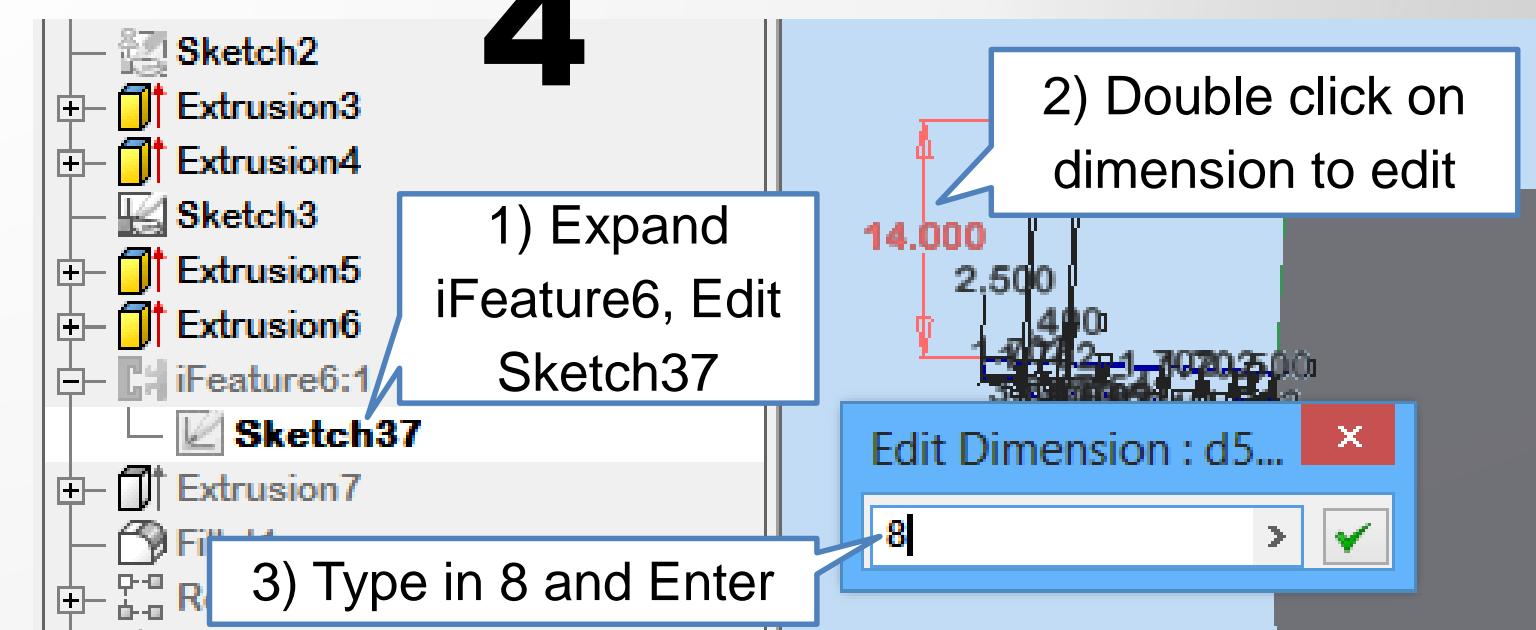


Typical Circuit Breaker

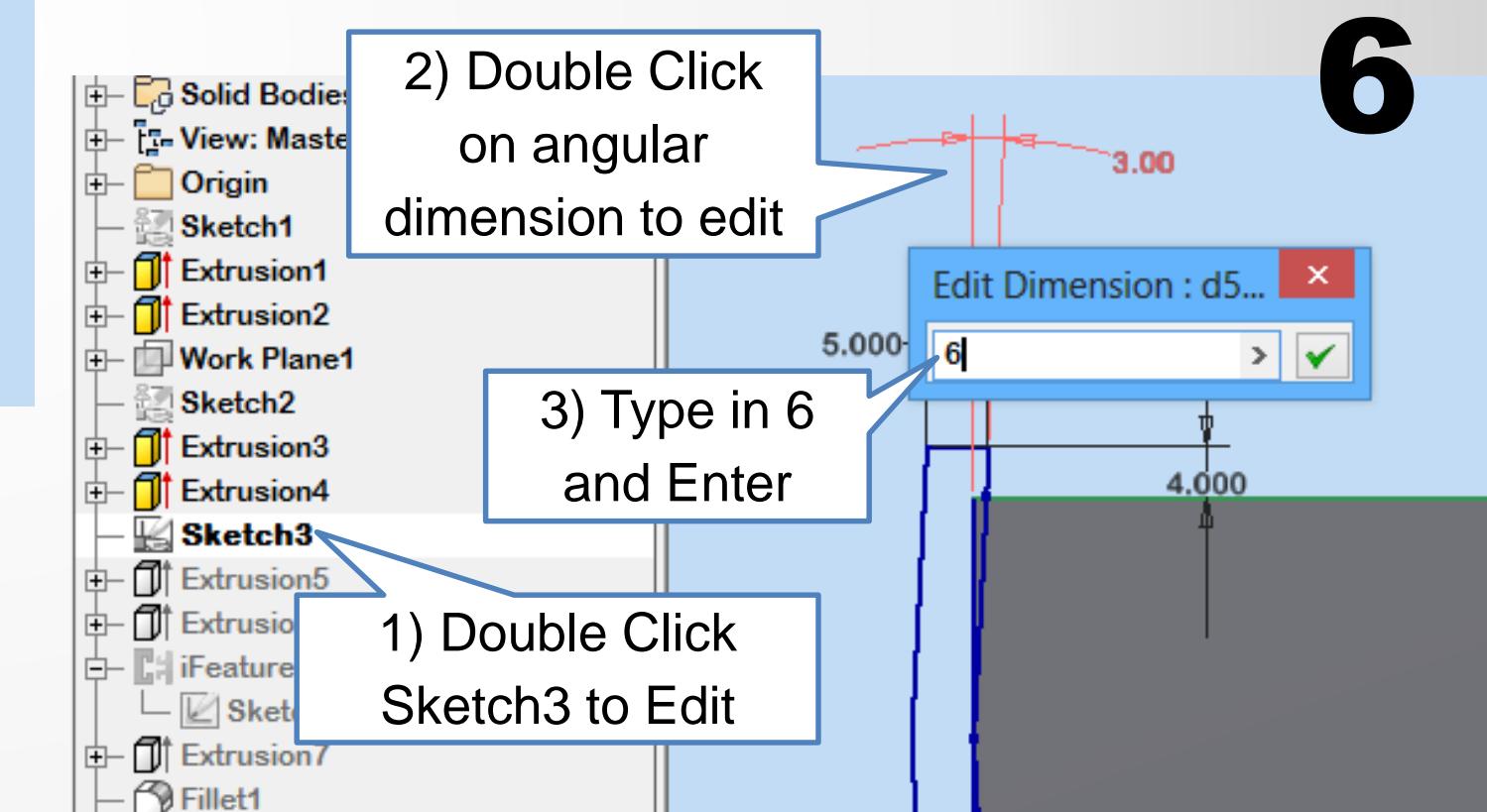
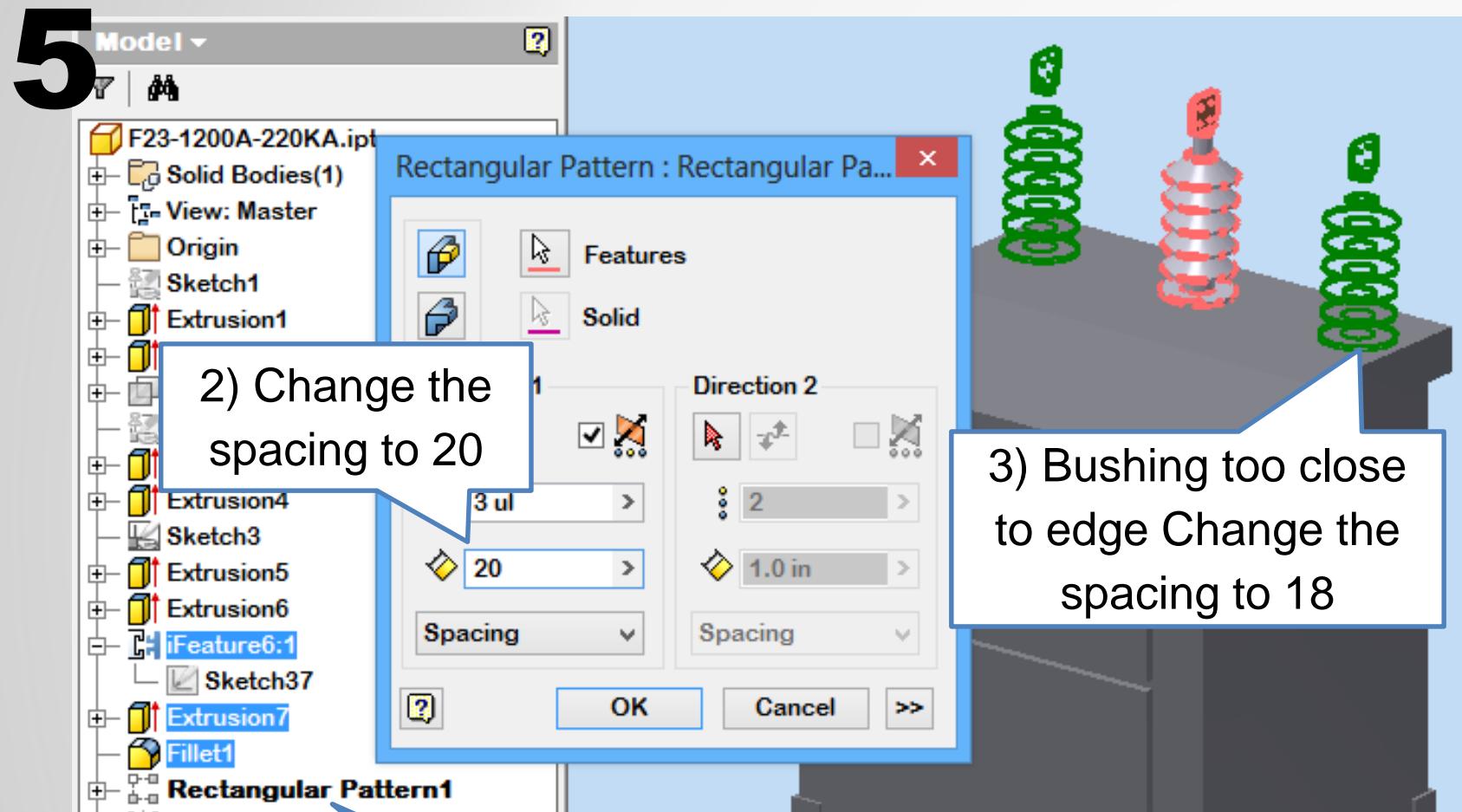
3



4



Typical Circuit Breaker



7 Save and close the file



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.

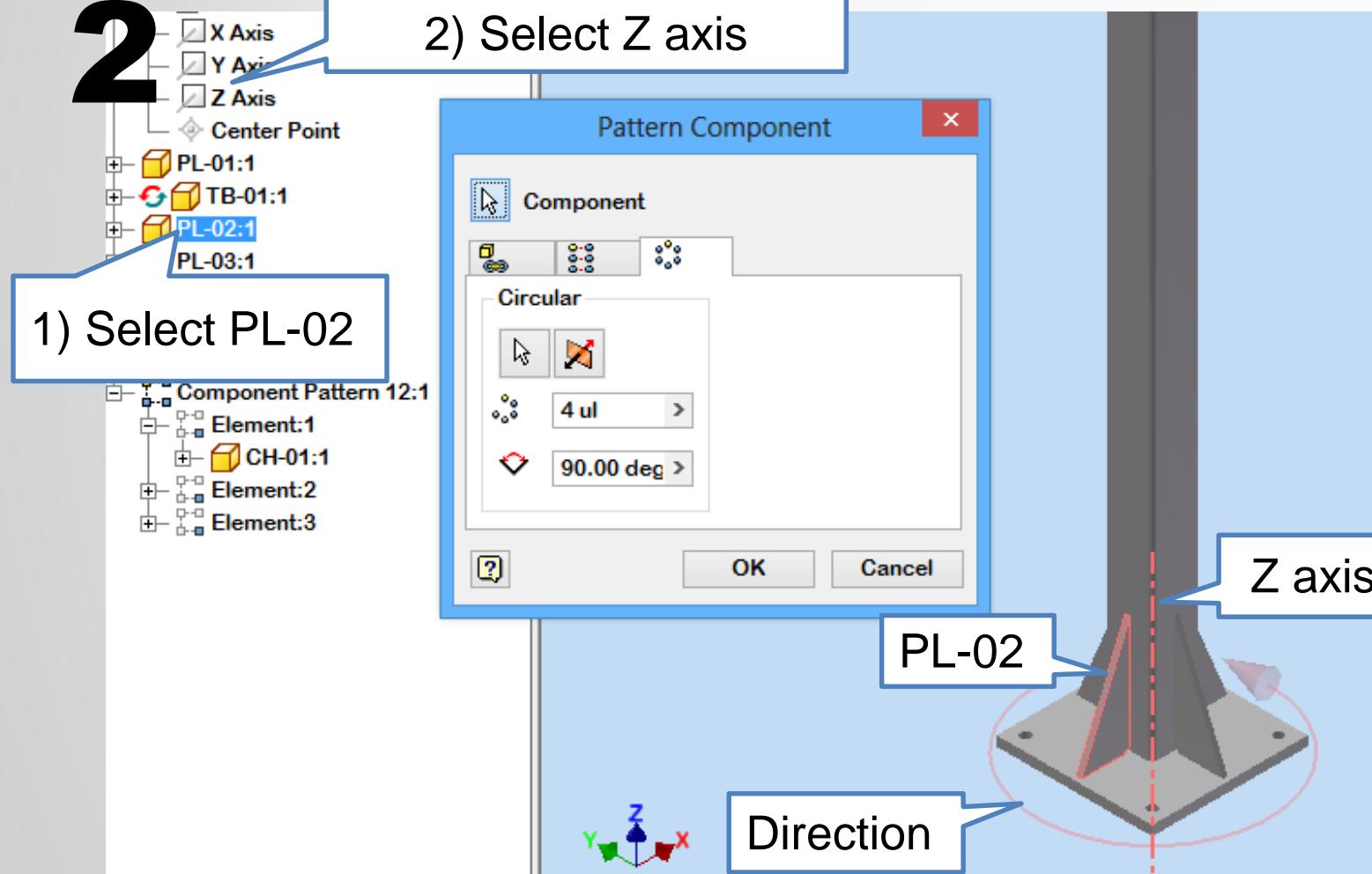
Standard Bus Support Model

1

Open the file STANDARD-BUS-SUP.iam

2

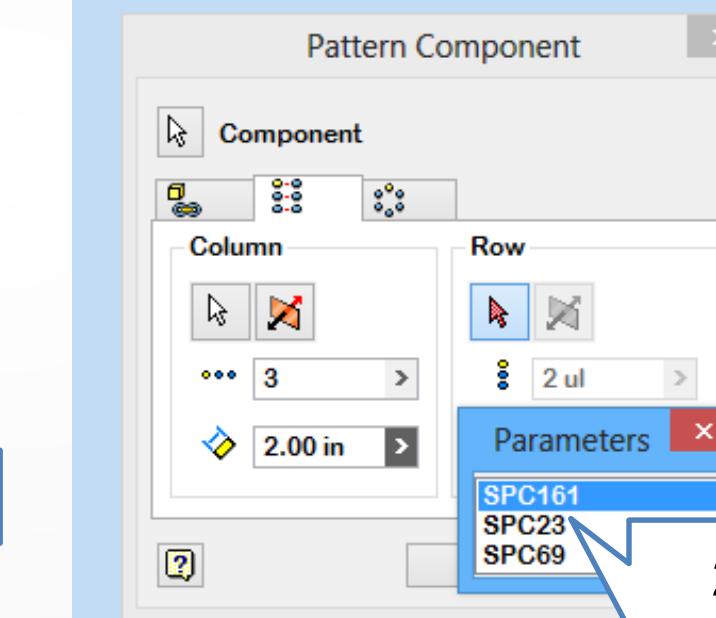
2) Select Z axis



3

CH-01

1) Select direction



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.

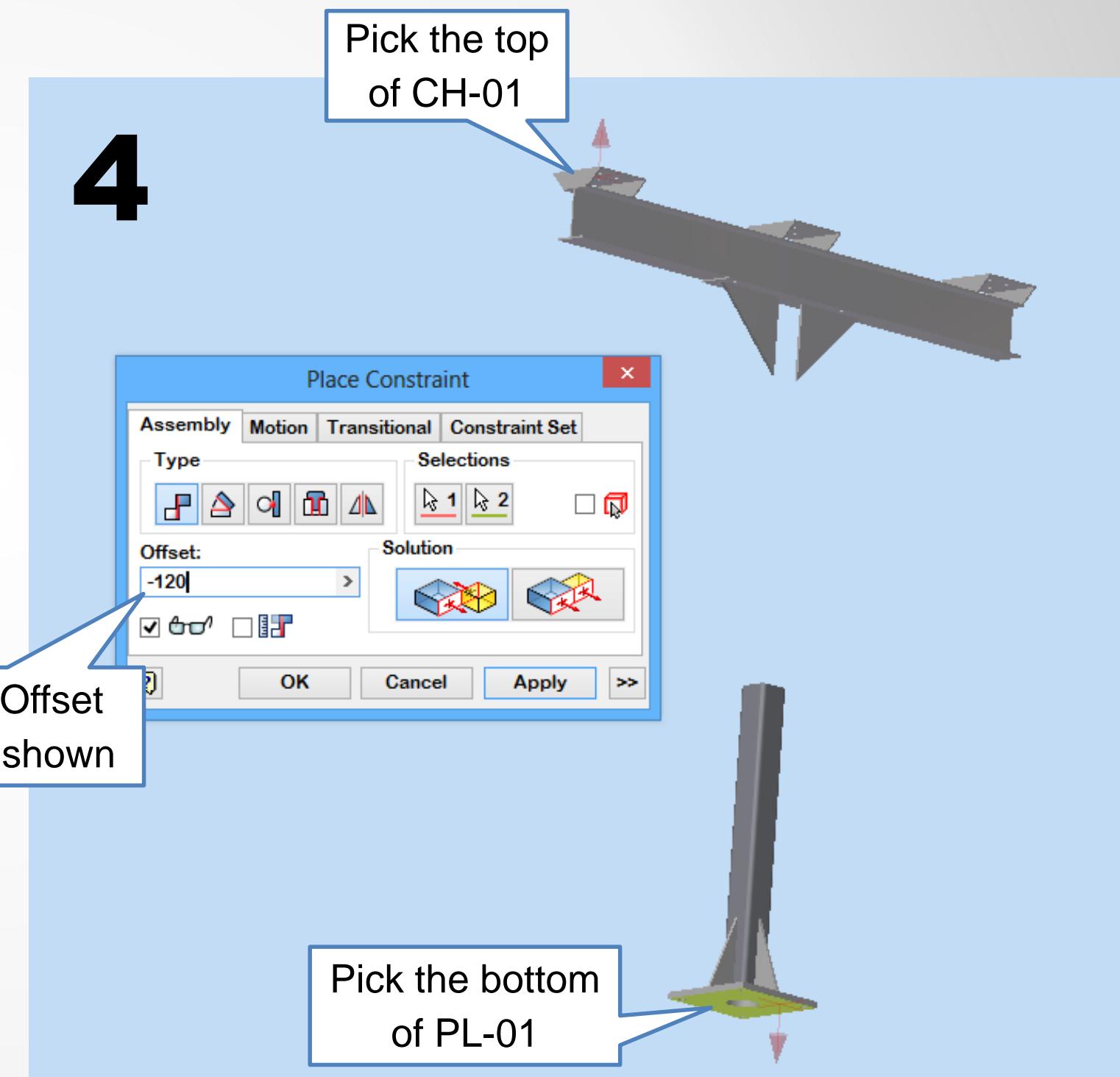
User Parameters			
SPC161	in	9'-0"	
SPC69	in	6'-0"	
SPC23	in	3'-6"	

161kV Spacing
(SPC161) = 9'-0"

69kV Spacing
(SPC69) = 6'-0"

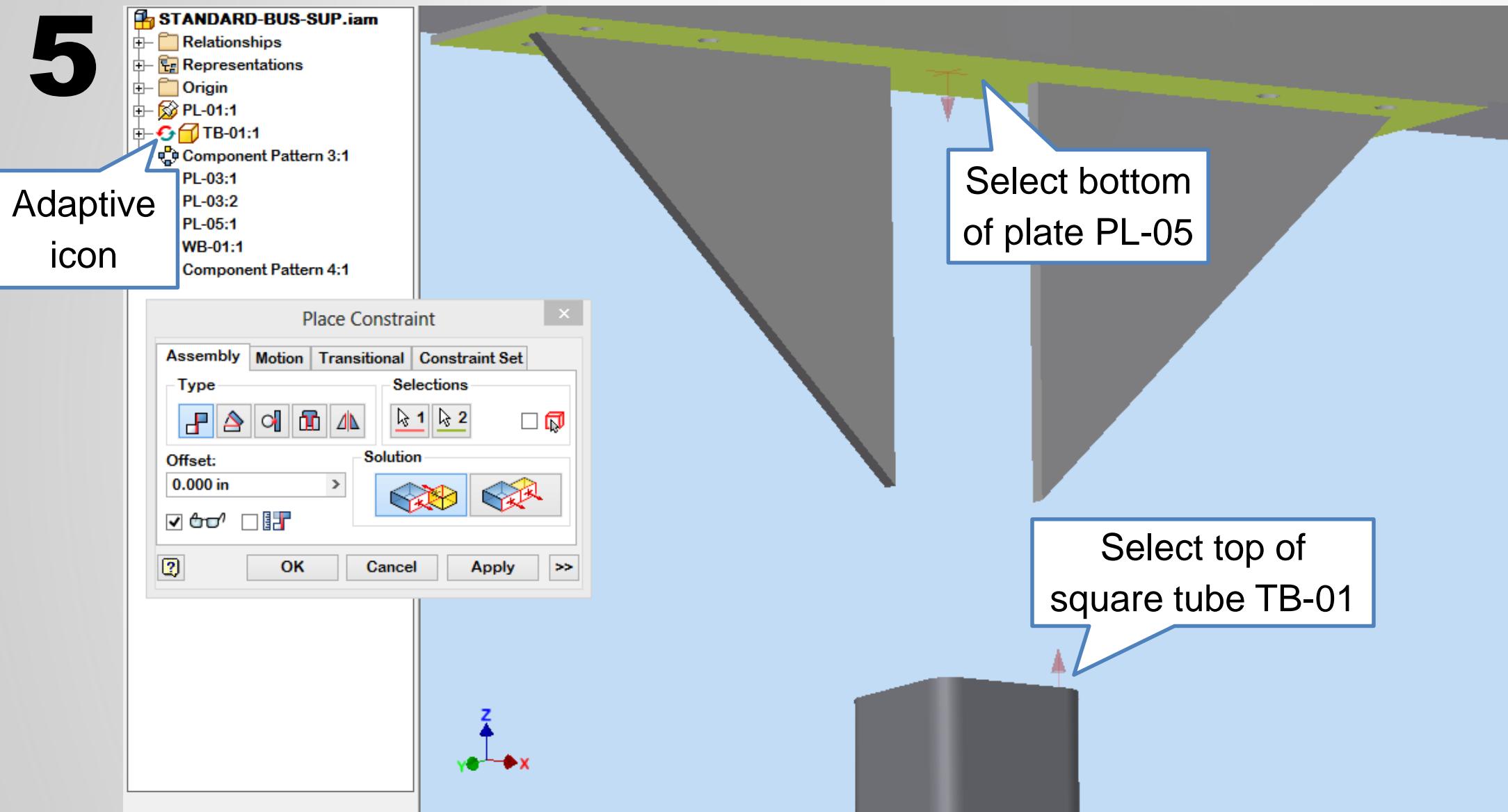
23kV Spacing
(SPC23) = 3'-6"

Type in Offset
value as shown



Standard Bus Support Model

5



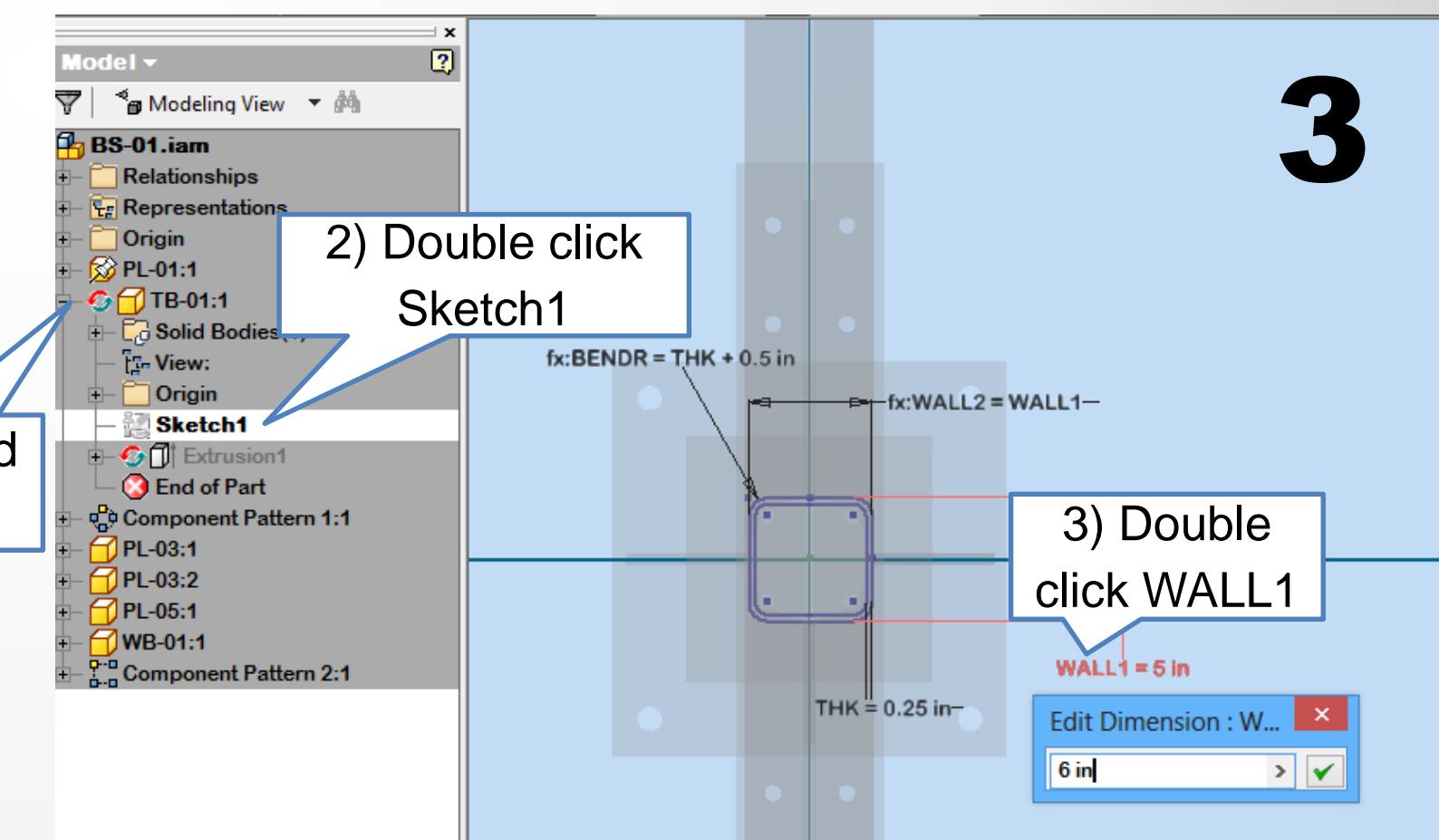
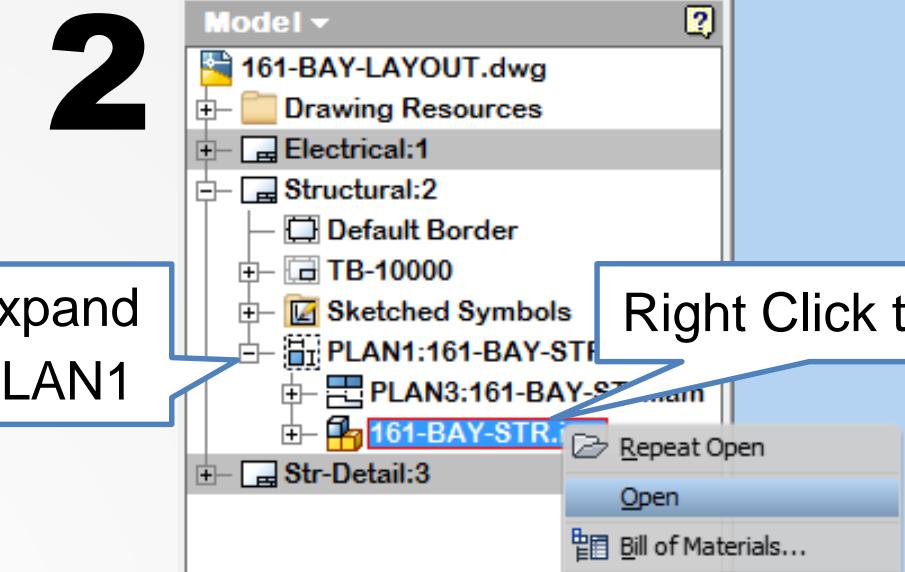
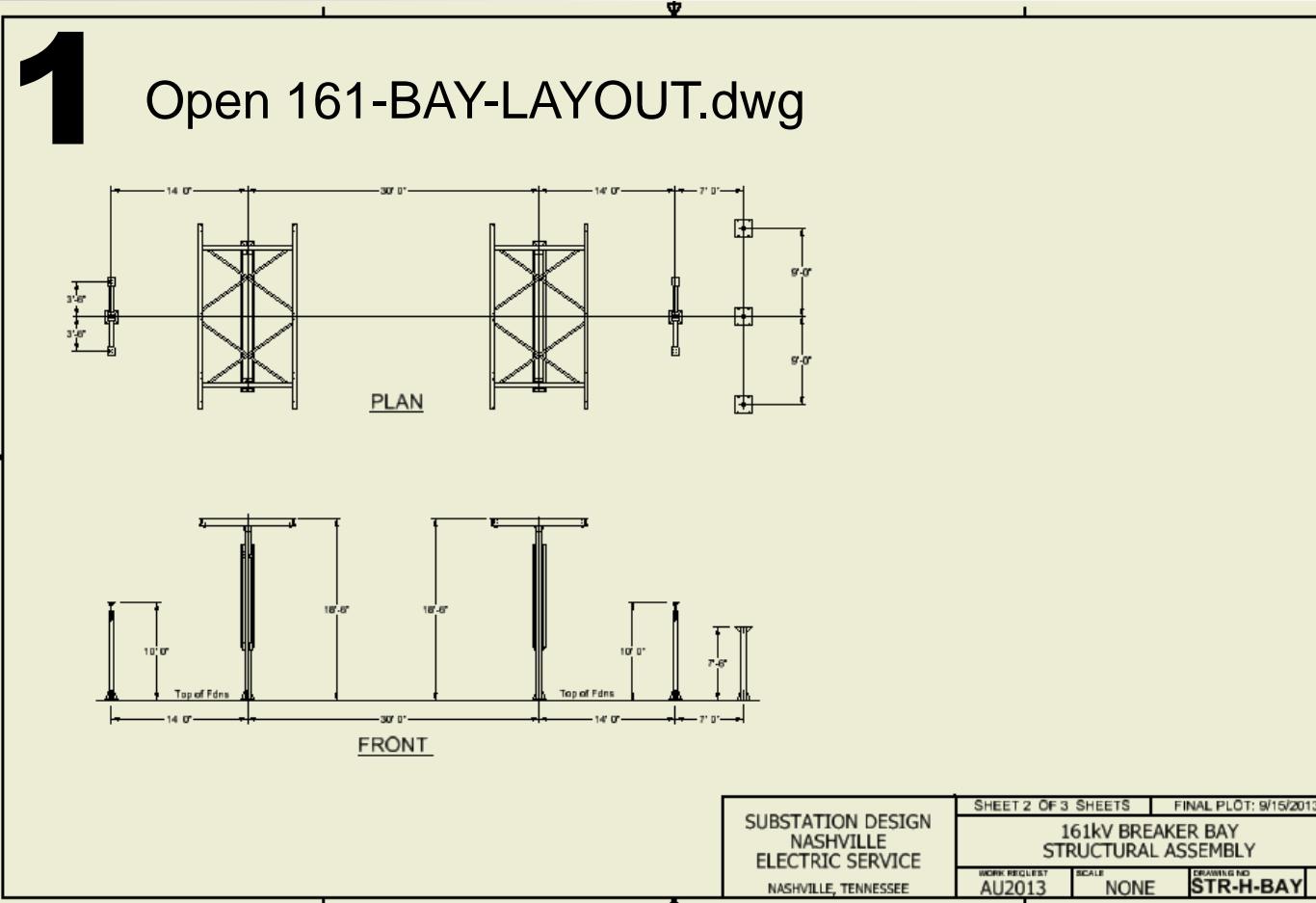
6

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

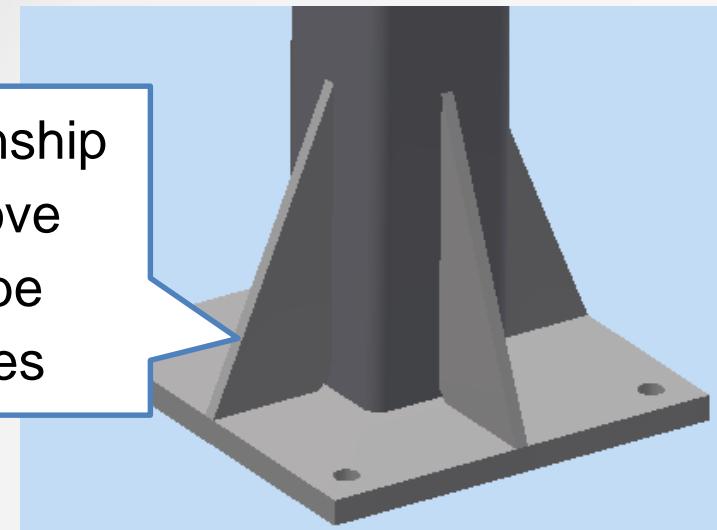
Standard Structural Models



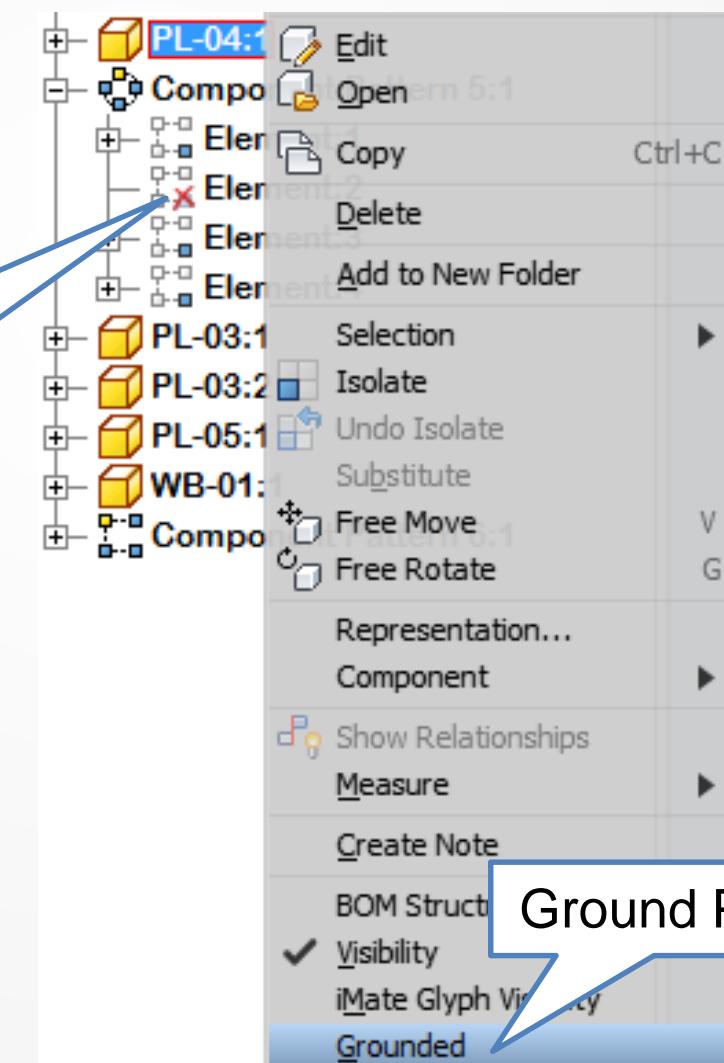
Standard Structural Models

4

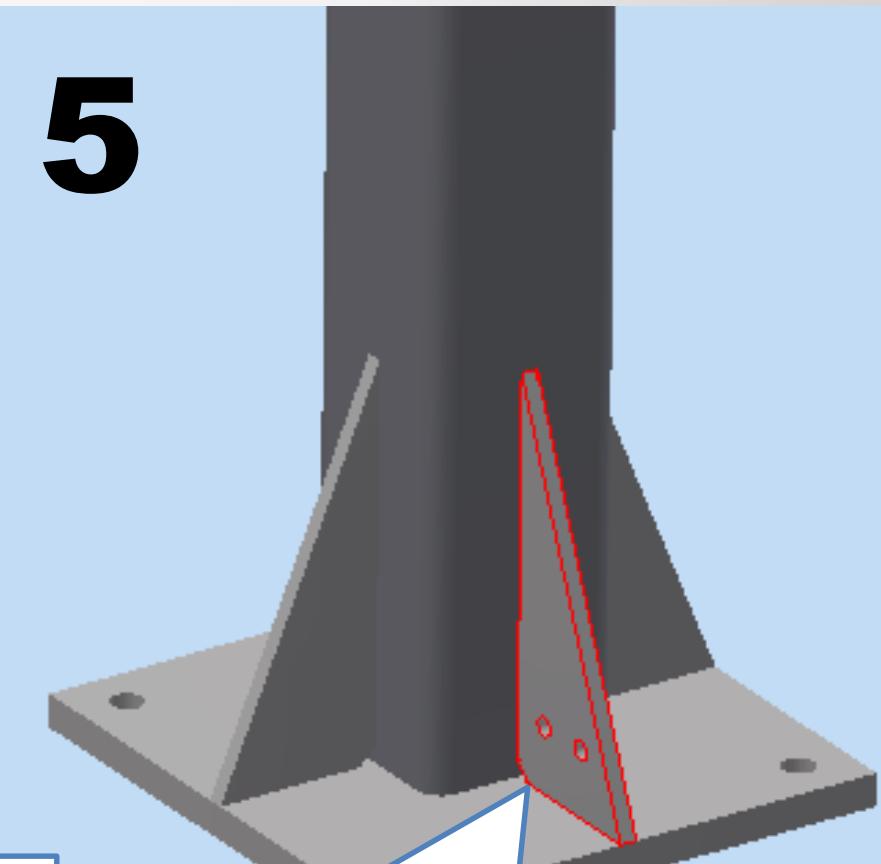
The constraint relationship causes the plate move according to the tube dimensional changes



Red x represents
Element2 is
Independent Element

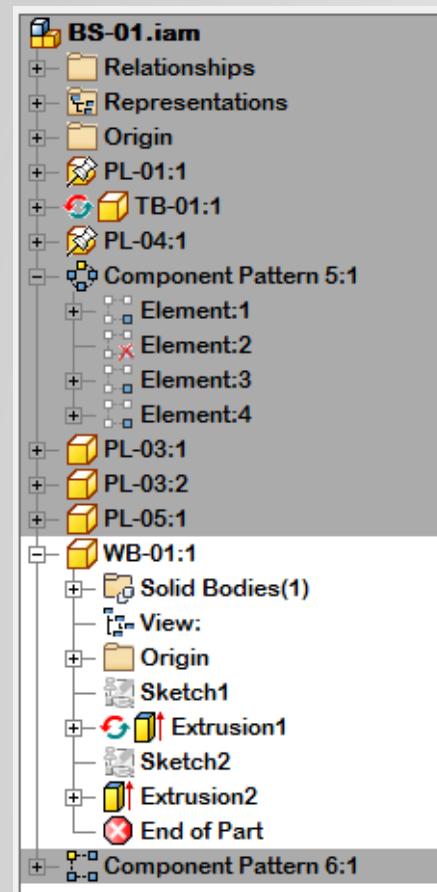


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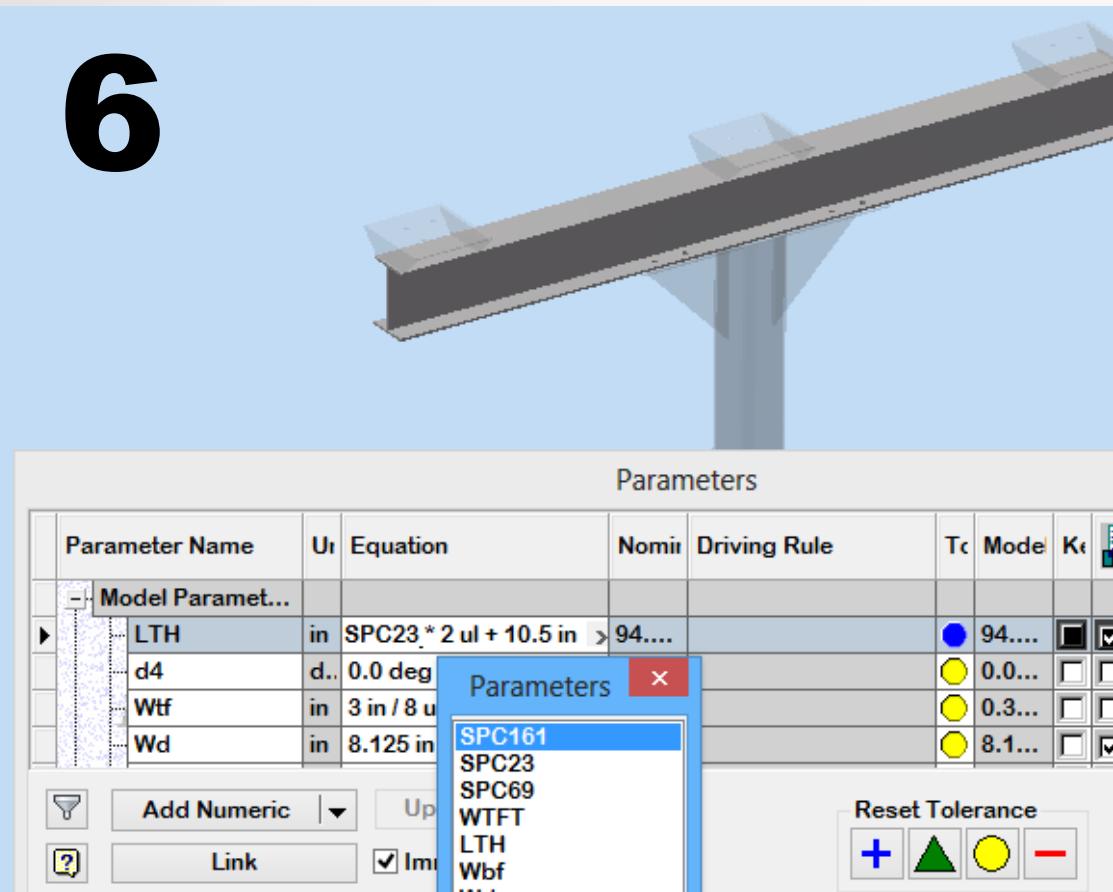


Replace Independent
PL-02 with PL-04

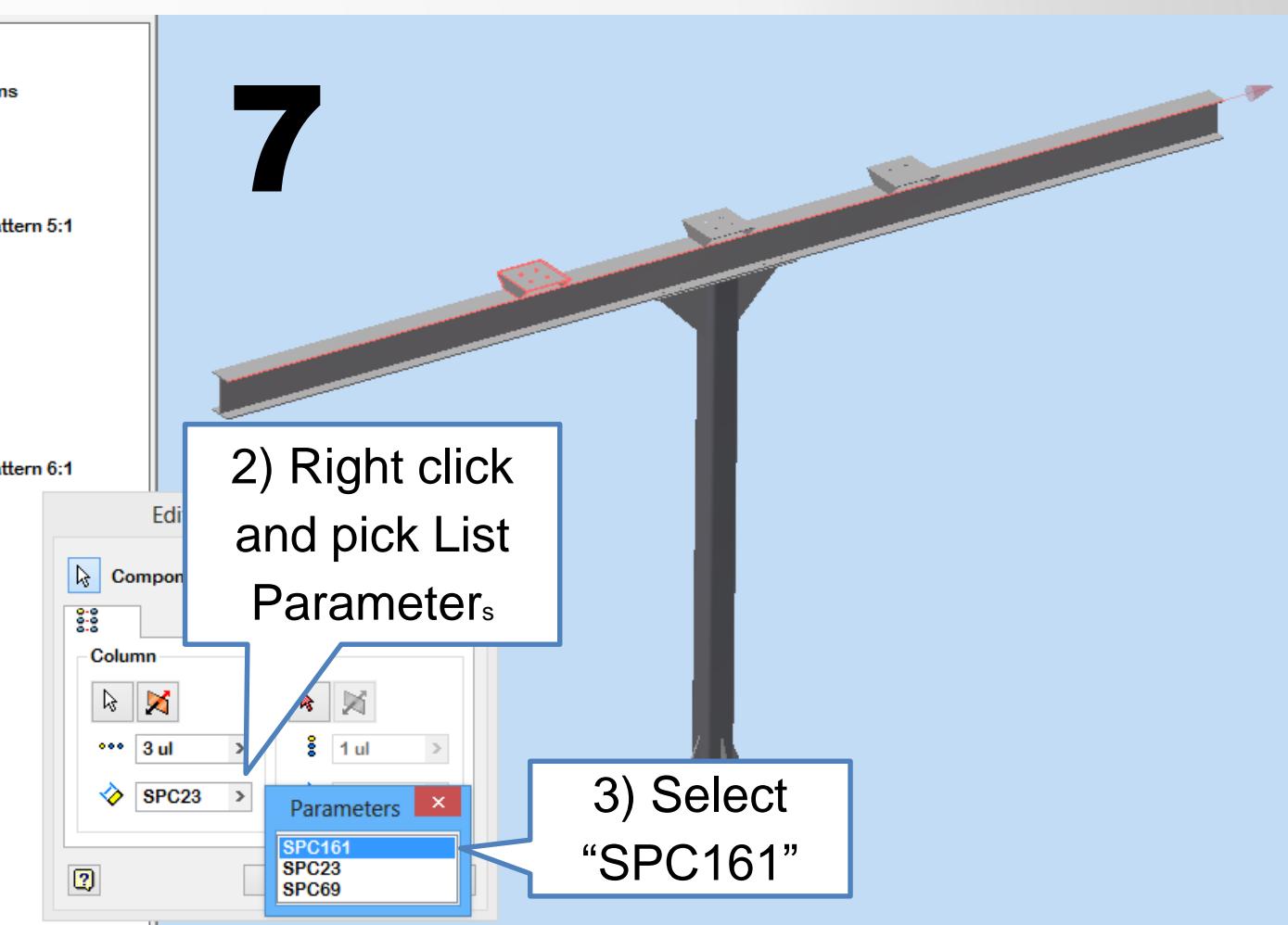
Standard Structural Models



6



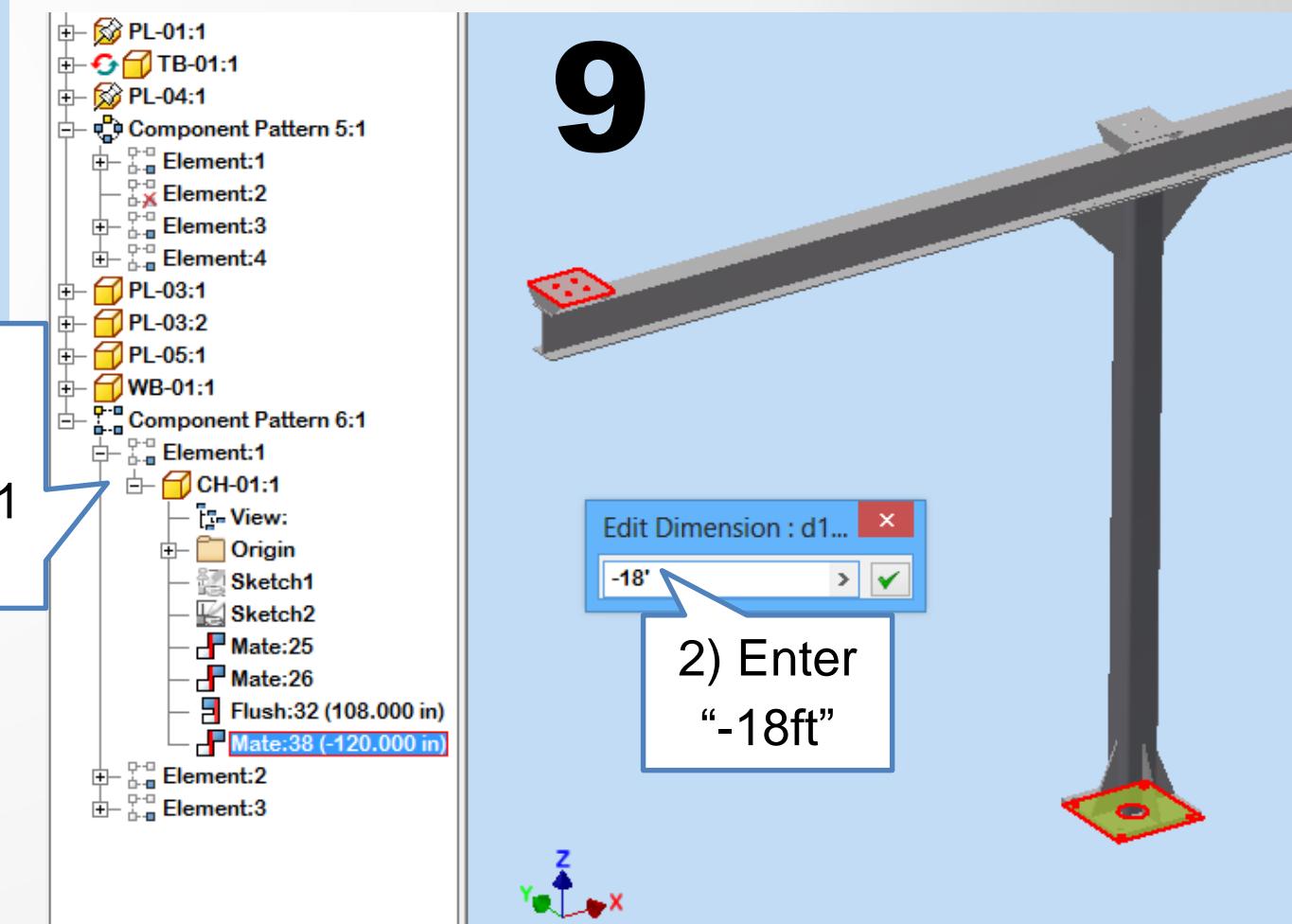
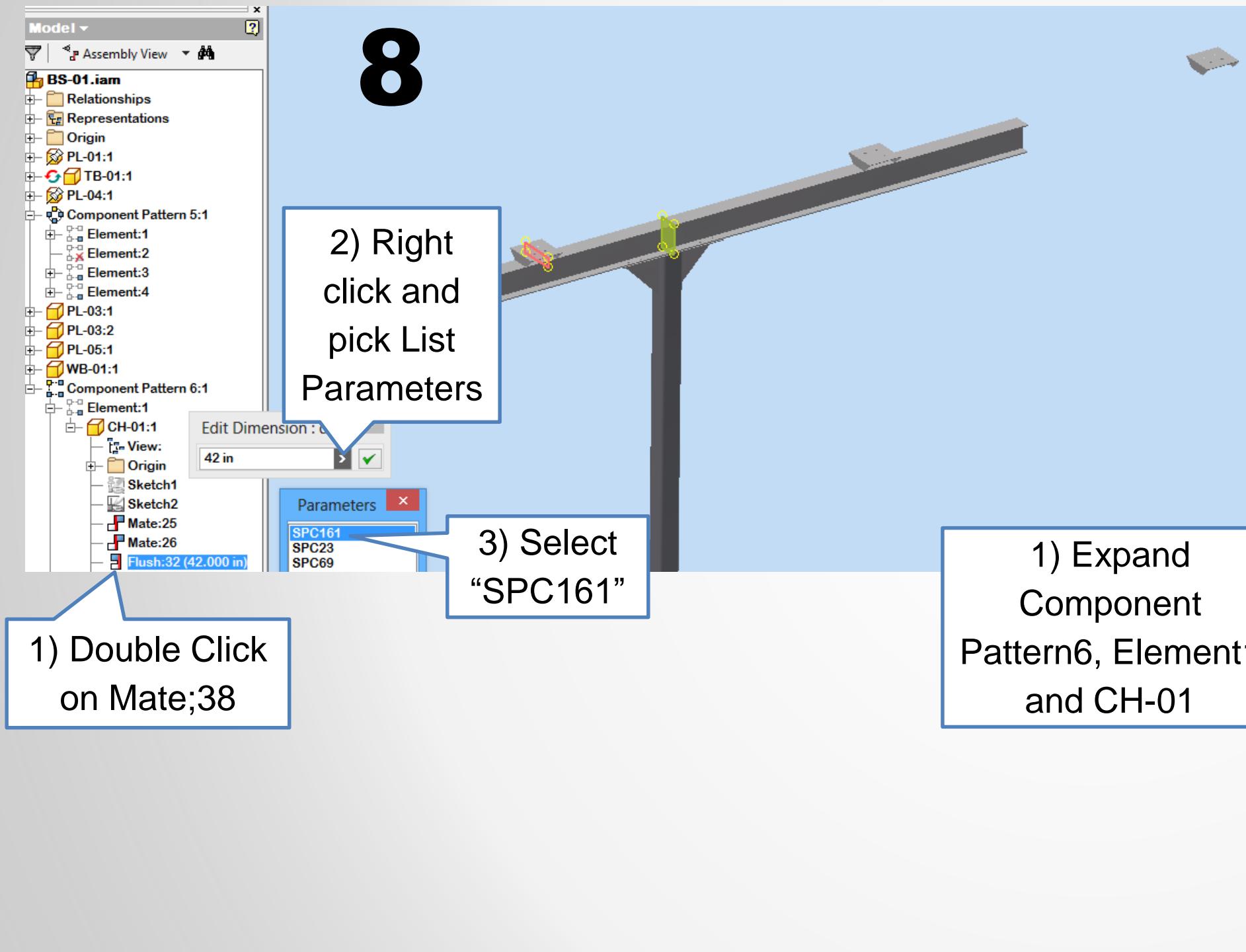
1) Double Click on Component Pattern6 to Edit



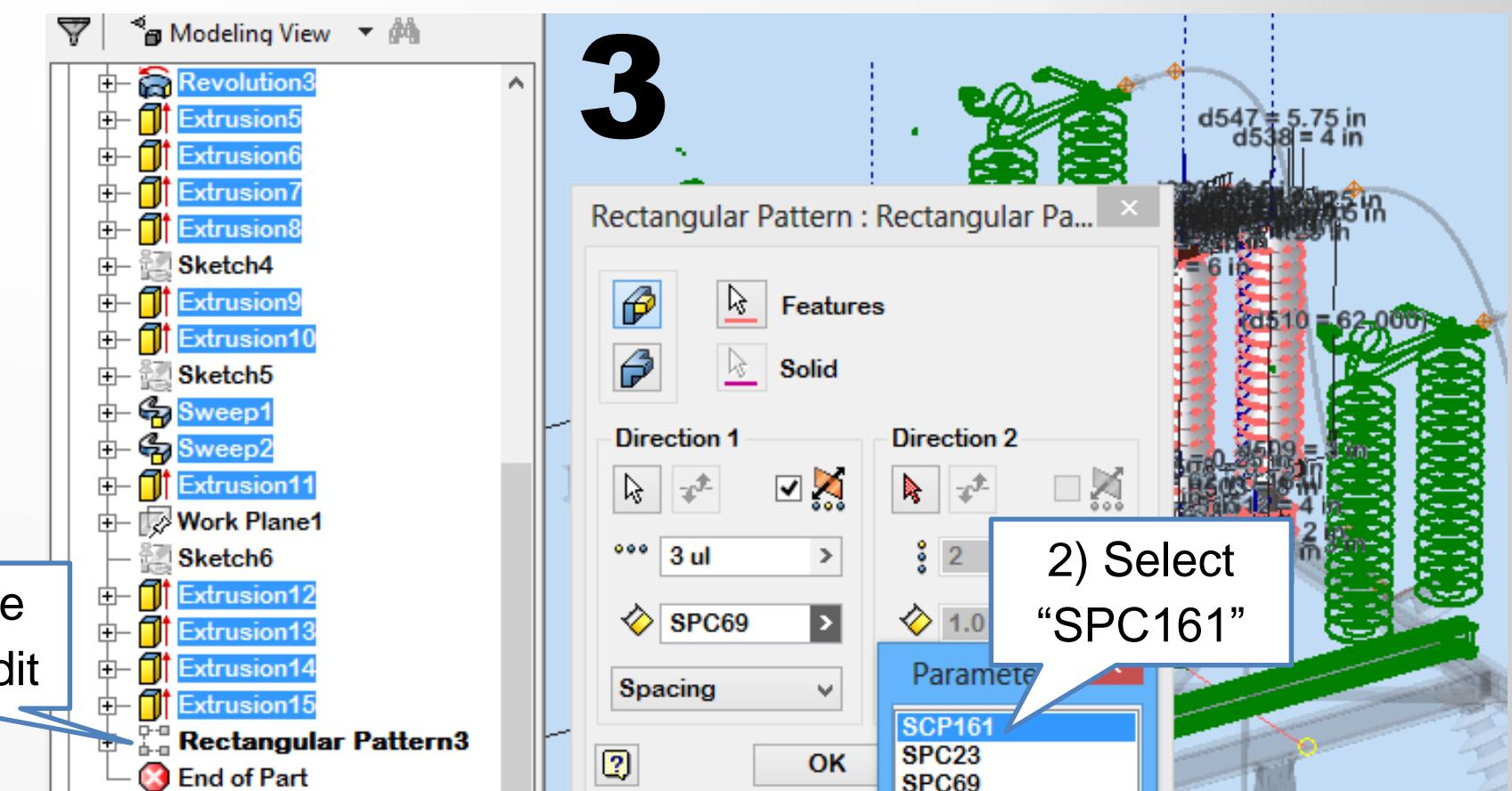
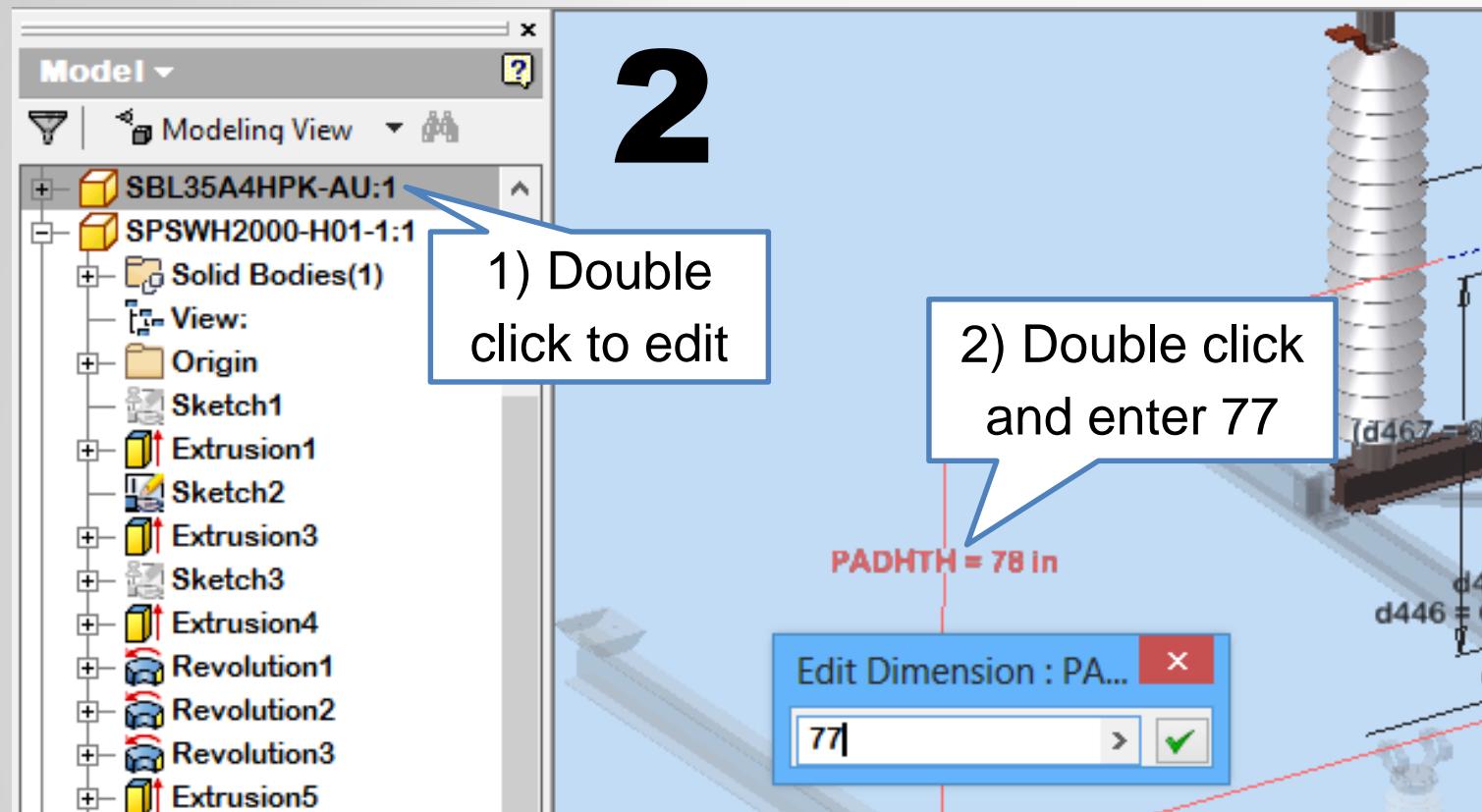
2) Right click and pick List Parameters

3) Select "SPC161"

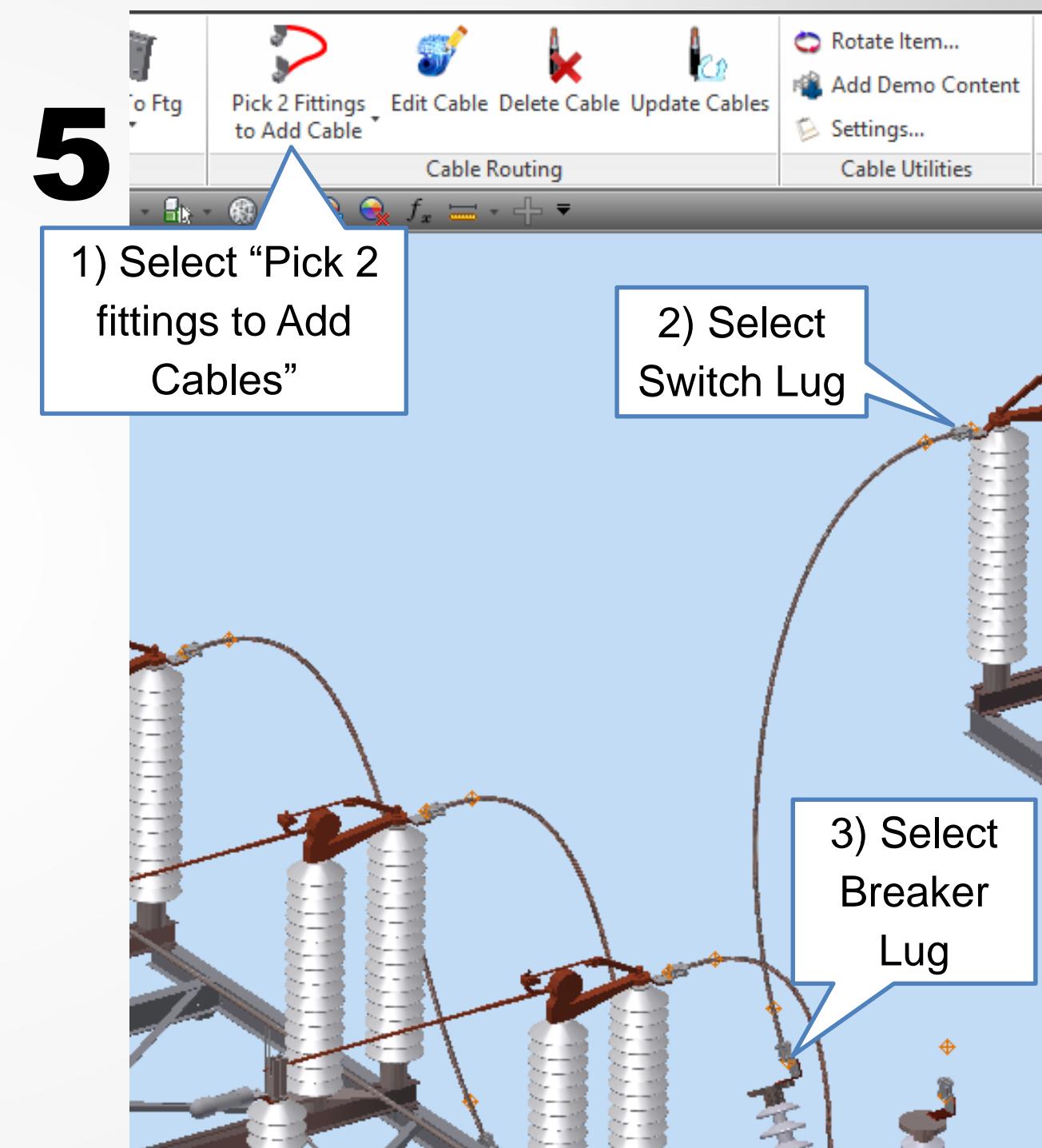
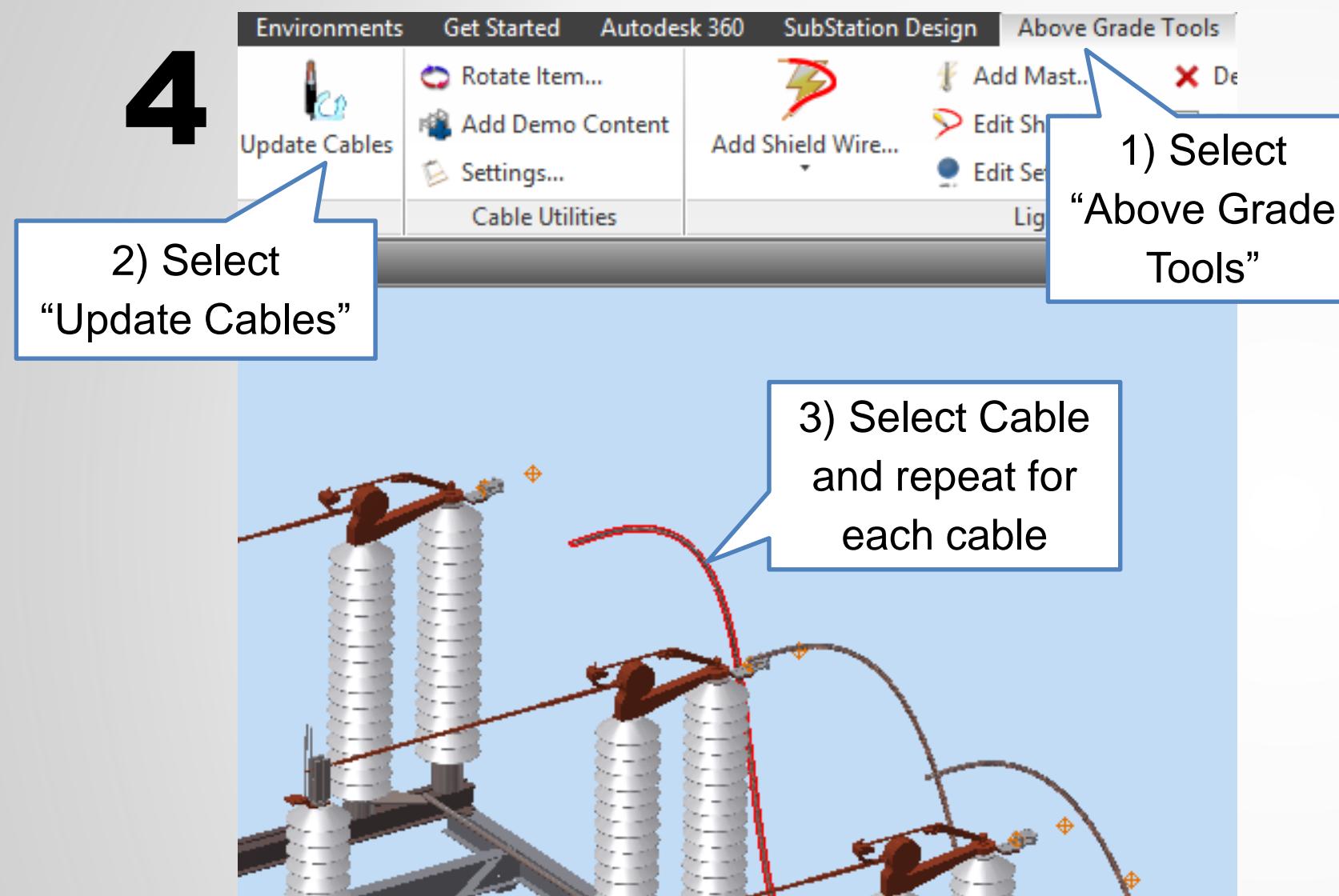
Standard Structural Models



Standard Electrical Models

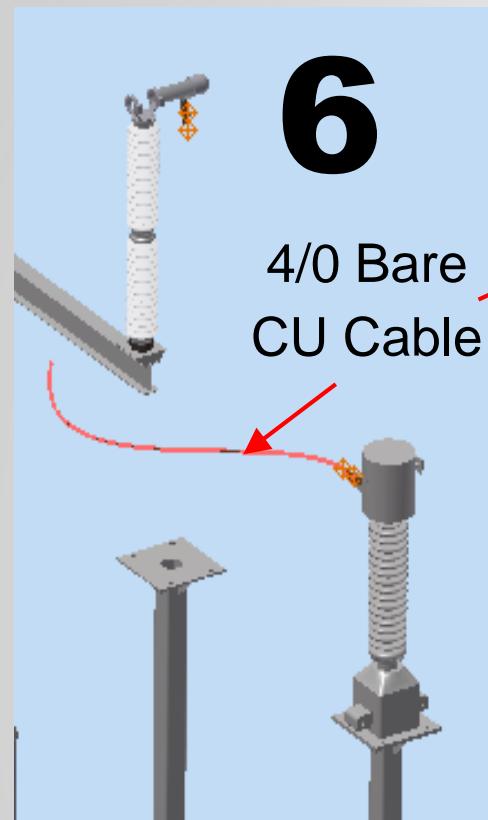


Standard Electrical Models



Standard Electrical Models

6



4/0 Bare CU Cable

B-001

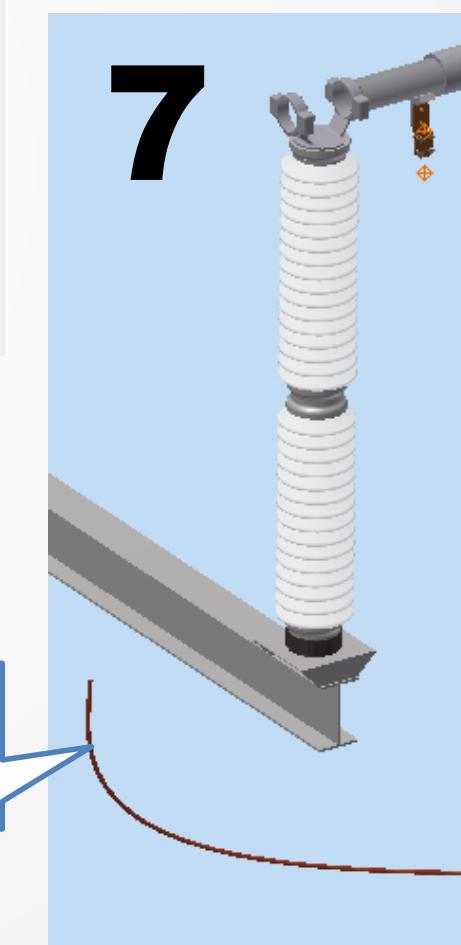
Model Data Structured Parts Only

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		IBE POWERLOK
B-130	Each	Each	2		SBC BUS SUPPORT
E-01	Each	Each	2		161kV 5BC
E-02	Each	Each	2		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

Bus Support Spacer height calculated from parameters

1) Pick PT Lead to edit

7



2) Choose to resize cable

Edit Bare Cable

Cable Size: CABLE CU BSD 4/0 19S

Sag Percent: 61

Add Mid:

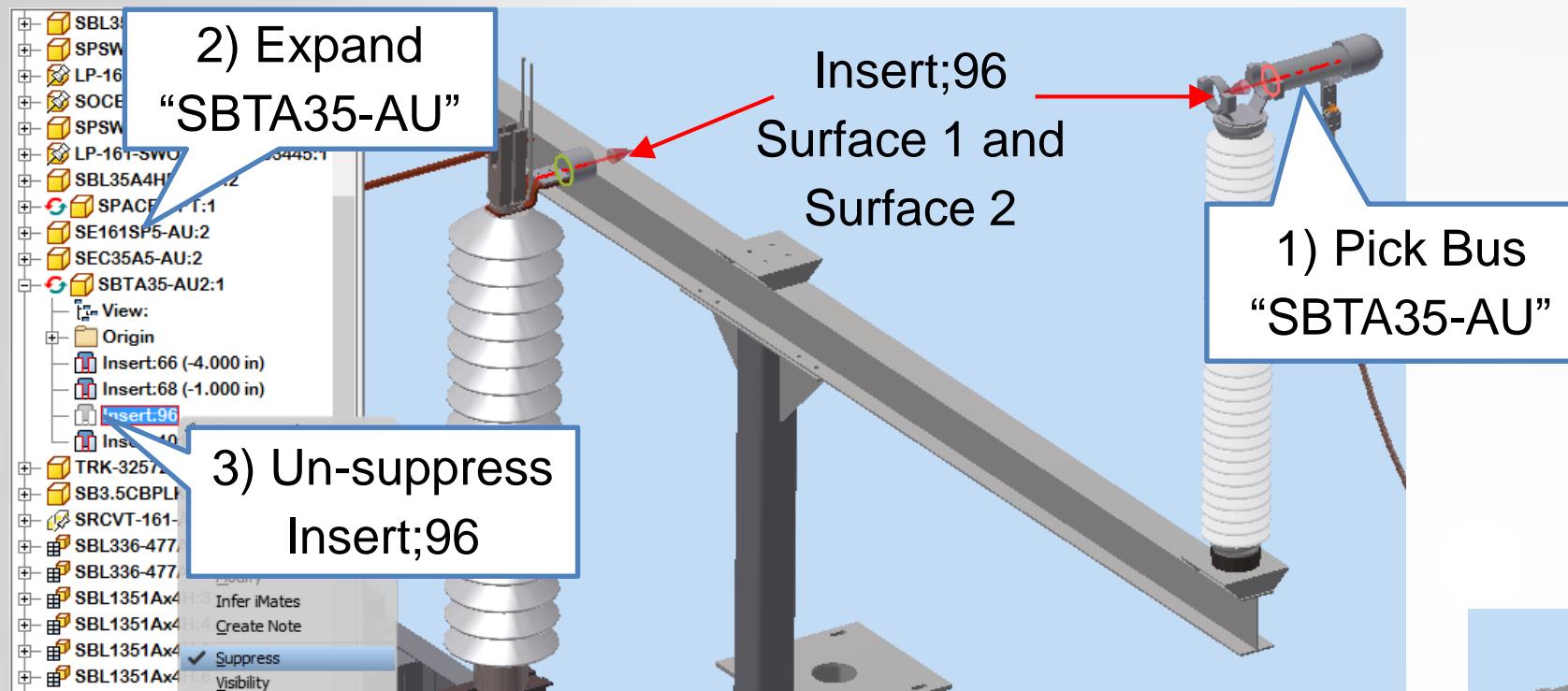
Flip Cable

Flip Cable

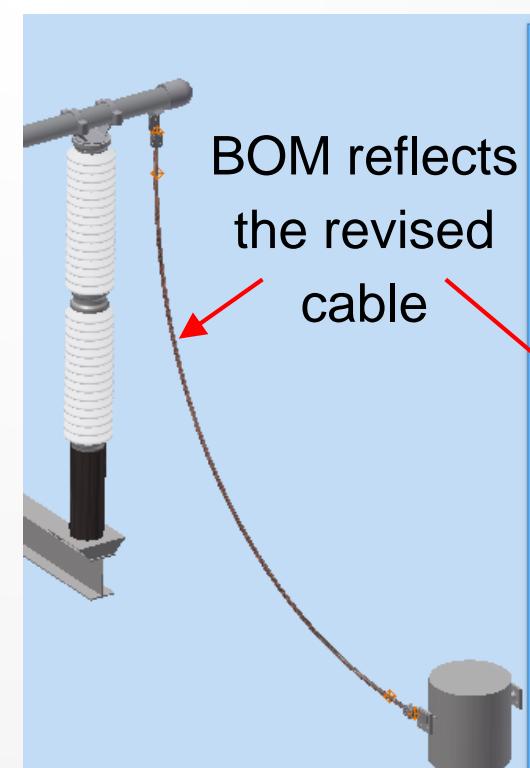
* Enter 0 to re

- CABLE ACSR BARE 1/0 6
- CABLE AAC BARE 1351.5
- CABLE ACSR BARE 2 6/1
- CABLE ACSR BARE 4/0 6/1
- CABLE ACSR BARE 477 18/1
- CABLE ACSR BARE 795 36/1
- CABLE CU BHD 1/0 7S
- CABLE CU BSD 1000 MCM 61S
- CABLE CU BSD 1500 MCM 91S
- CABLE CU BHD #2 7S
- CABLE CU BHD 300 MCM 19S
- CABLE CU BHD 4/0 7S
- CABLE CU BSD 4/0 19S
- CABLE CU BHD 500 MCM 19S
- CABLE CU BMD 500 MCM 37S
- CABLE CU BSD 750MCM 61S
- CABLE CU BHD 4/0 7S (GROUNDING)
- CABLE CU BSD 4/0 19S (GROUNDING)
- CABLE CU BMD 500MCM 37S (GROUNDING)
- CABLE AL 25KV EPR 4/0 W/CN 3CP
- CABLE CU 25KV 2000 1/C
- CABLE CU 25KV RIAB KE 4/0 1/C
- CABLE CU 25KV EPR 4/0 W/CN 3CP KE
- CABLE CU 600V RINC 500 1C

Standard Electrical Models



8

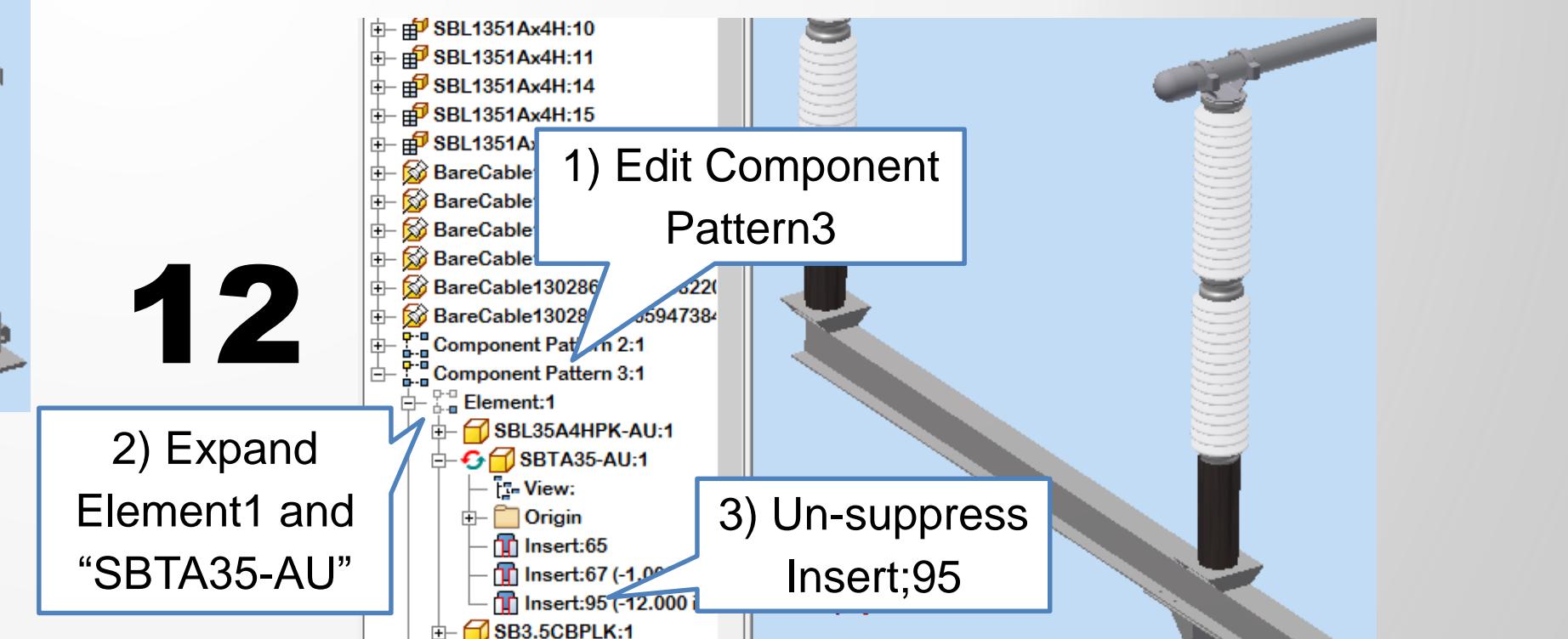
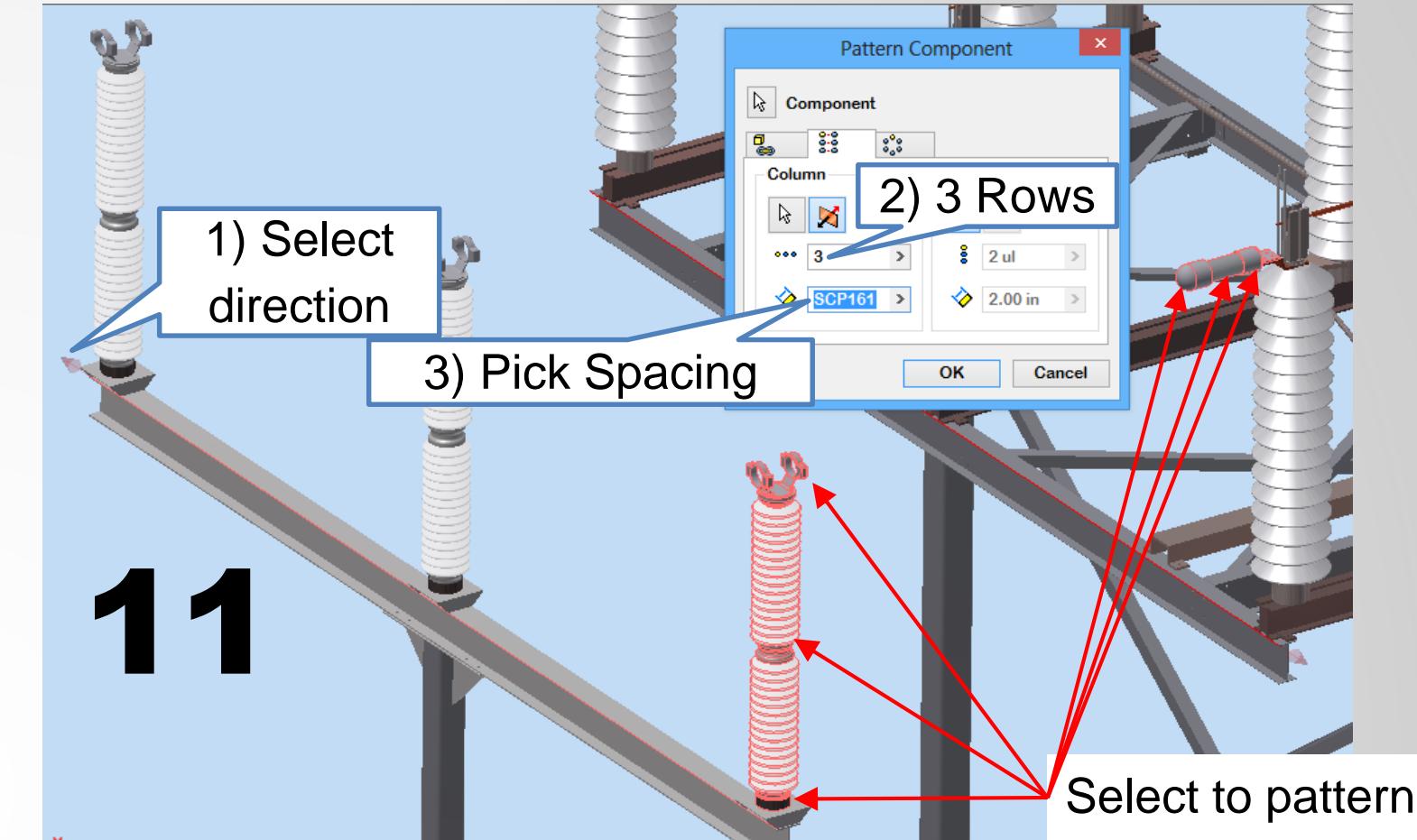
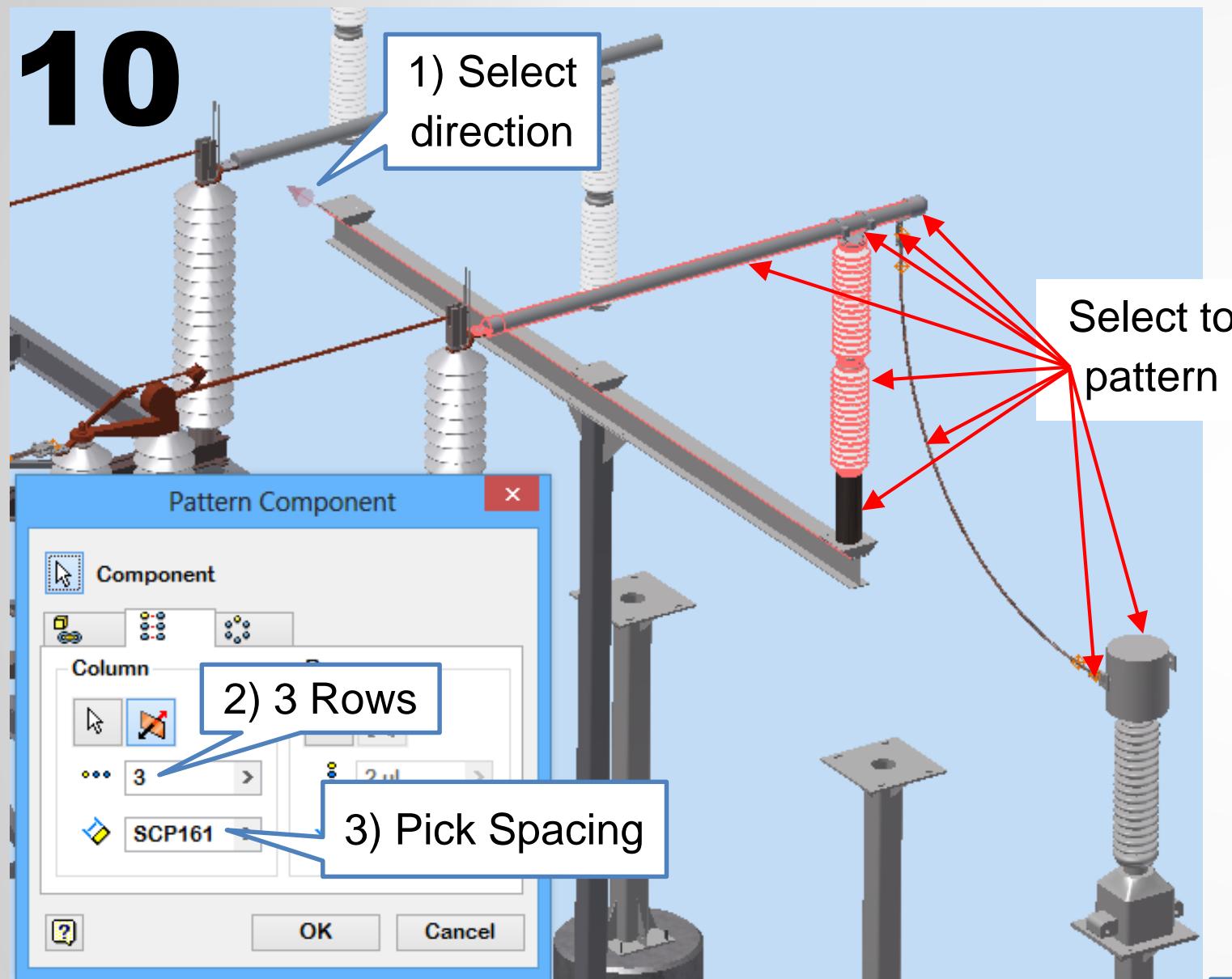


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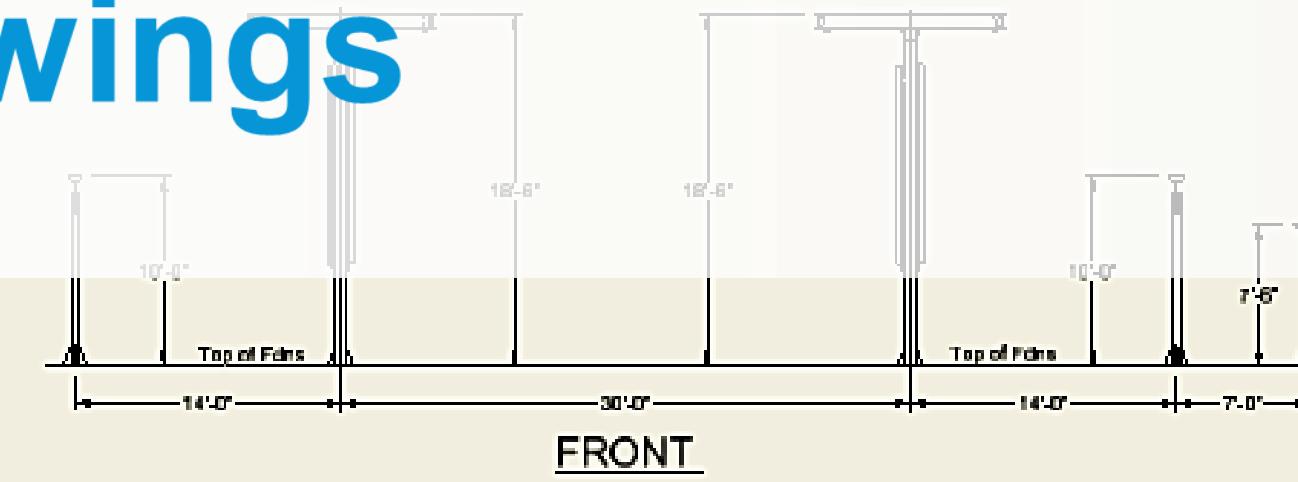
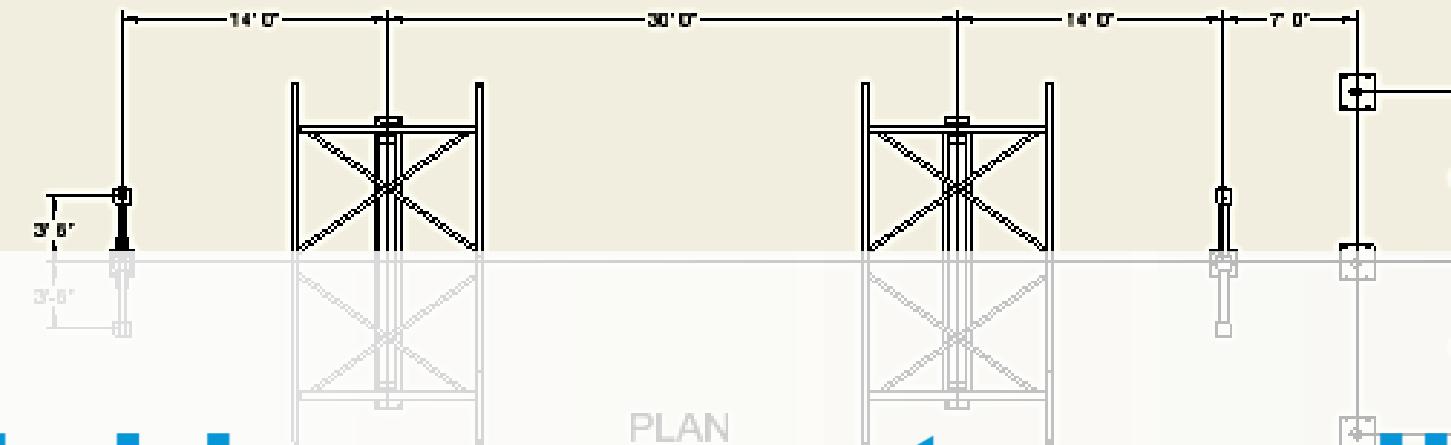
Title	Base Unit	Base QTY	QTY	Part Number	Description
B-09	ft	*Varies*	42 ft	SBCA1351	CABLE AAC BARE 1351.5 KCM 61
B-02	ft	*Varies*	11 ft	SBTA35	TUBING AL 3 1/2
B-03	Each	Each	2	SBL35A4HPK	TERMINAL LUG 3 1/2 AL 4H POWERLOK
B-032	Each	Each	12	SBL1351A4H	TERM LUG 1351.5 AAC 4H
B-04	Each	Each	1	SBT35ALX2HW	CONN T 3 1/2 AL x 2 H WELDED
B-05	Each	Each	2	SB3.5CBPLK	BELL CORONA 3 1/2 AL TUBE POWERLOK
B-119	ft	14.1054...	14 ft	SBCA477	CABLE ACSR BARE 477 18/1
B-120	Each	Each	2	SBL336-477A2	TERM LUG 336-477 ACSR 2H
E-01	Each	Each	2	SEC35A5	CLAMP BUS SUP 3 1/2 AL 5BC BUS SUPPORT
E-02	Each	Each	2	SE161SP5	INSULATOR BUS SUPPORT 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 5EC 18 in
O-01	Each	Each	1	SOCBH(H01B)	CB 161KV 2000A 1000V Custom "DT1-170FK-F1"
P-01	Each	Each	1		
R-01	Each	Each	1		

Bus Support Spacer height is recalculated

Standard Electrical Models



Quickly generate quality construction drawings



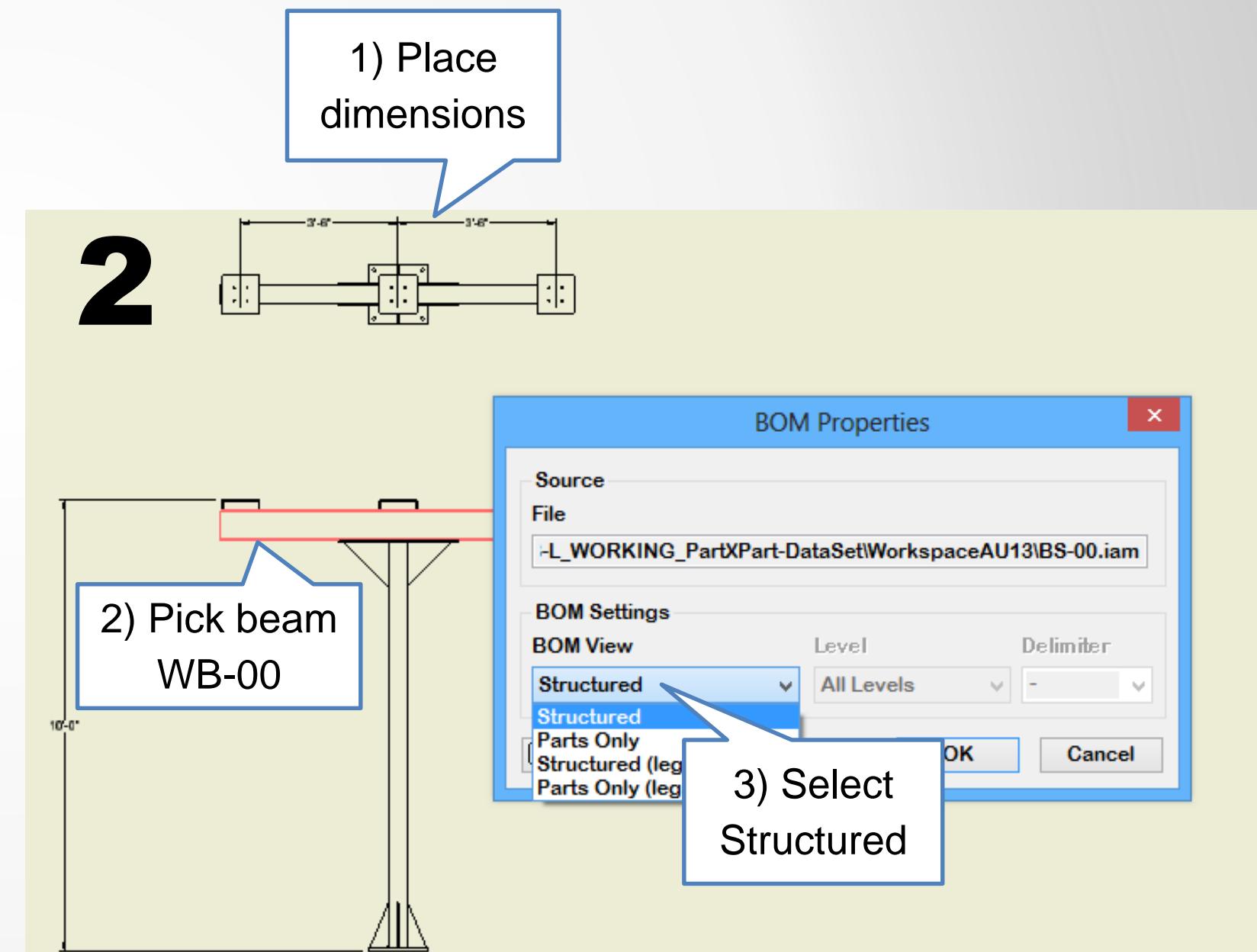
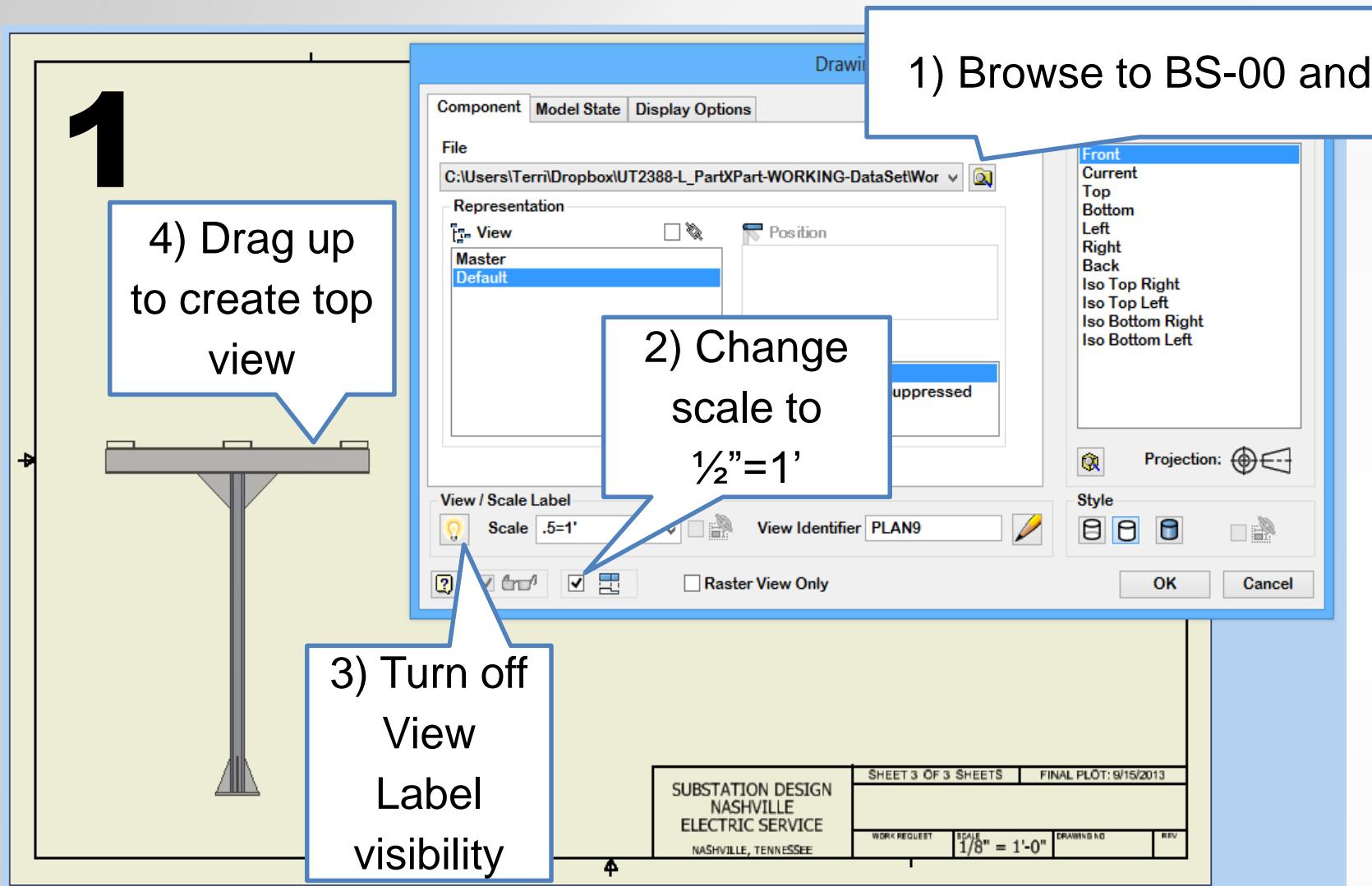
SUBSTATION DESIGN
NASHVILLE
ELECTRIC SERVICE
NASHVILLE, TENNESSEE

SHEET 2 OF 3 SHEETS		FINAL PLOT: 9/15/2013
161kV BREAKER BAY STRUCTURAL ASSEMBLY		
WORK REQUEST AU2013	SCALE NONE	DRAWING NO STR-H-BAY

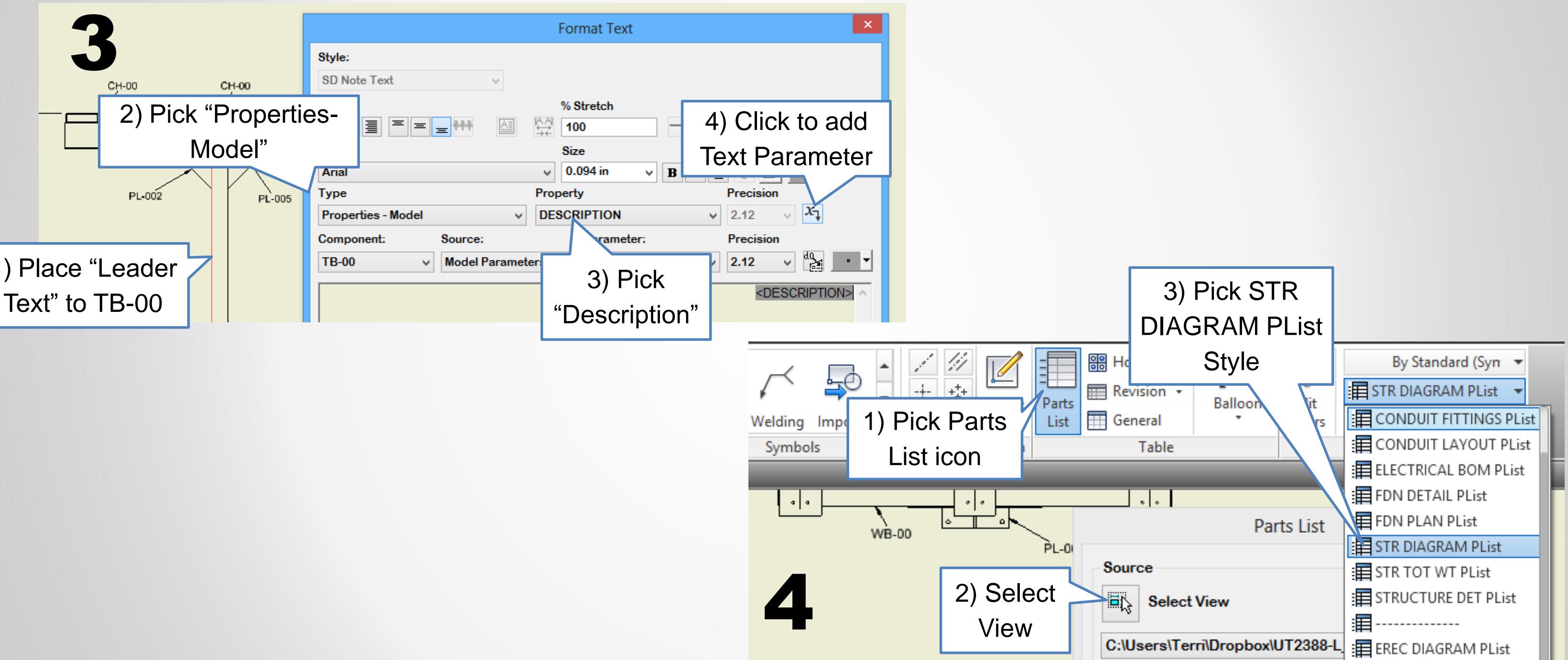
Generate Drawings

- 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

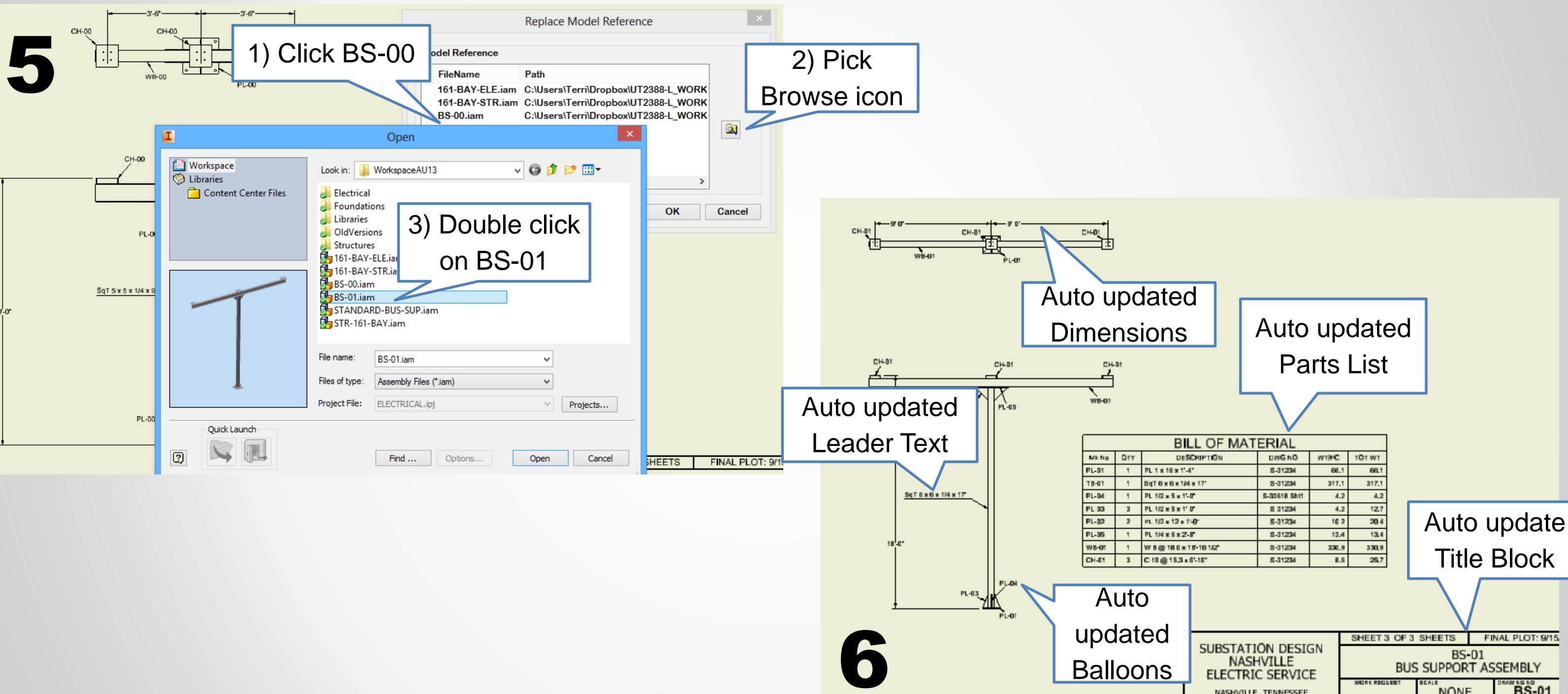
Standard Drawings



Standard Drawings

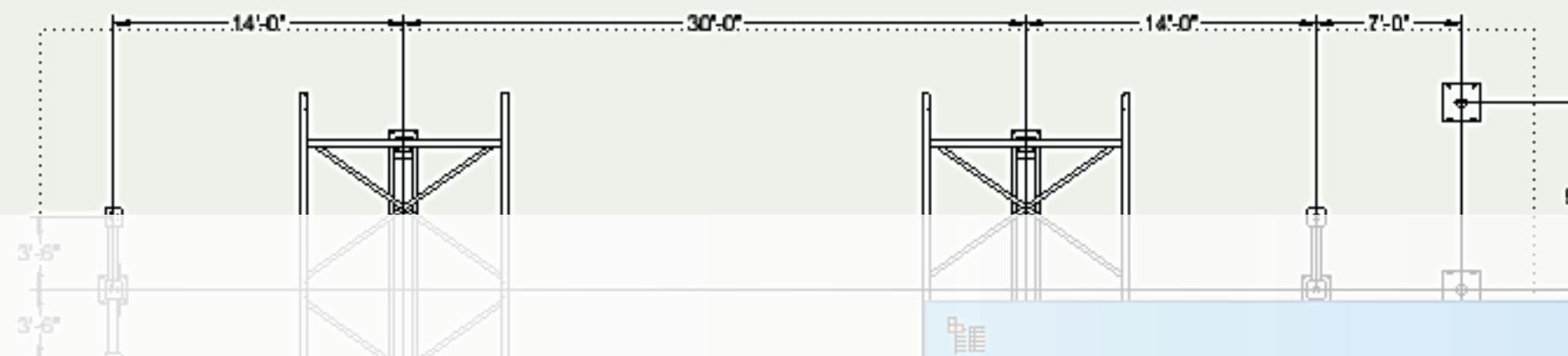


Standard Drawings



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



Create an accurate parts list using intelligent 3D models

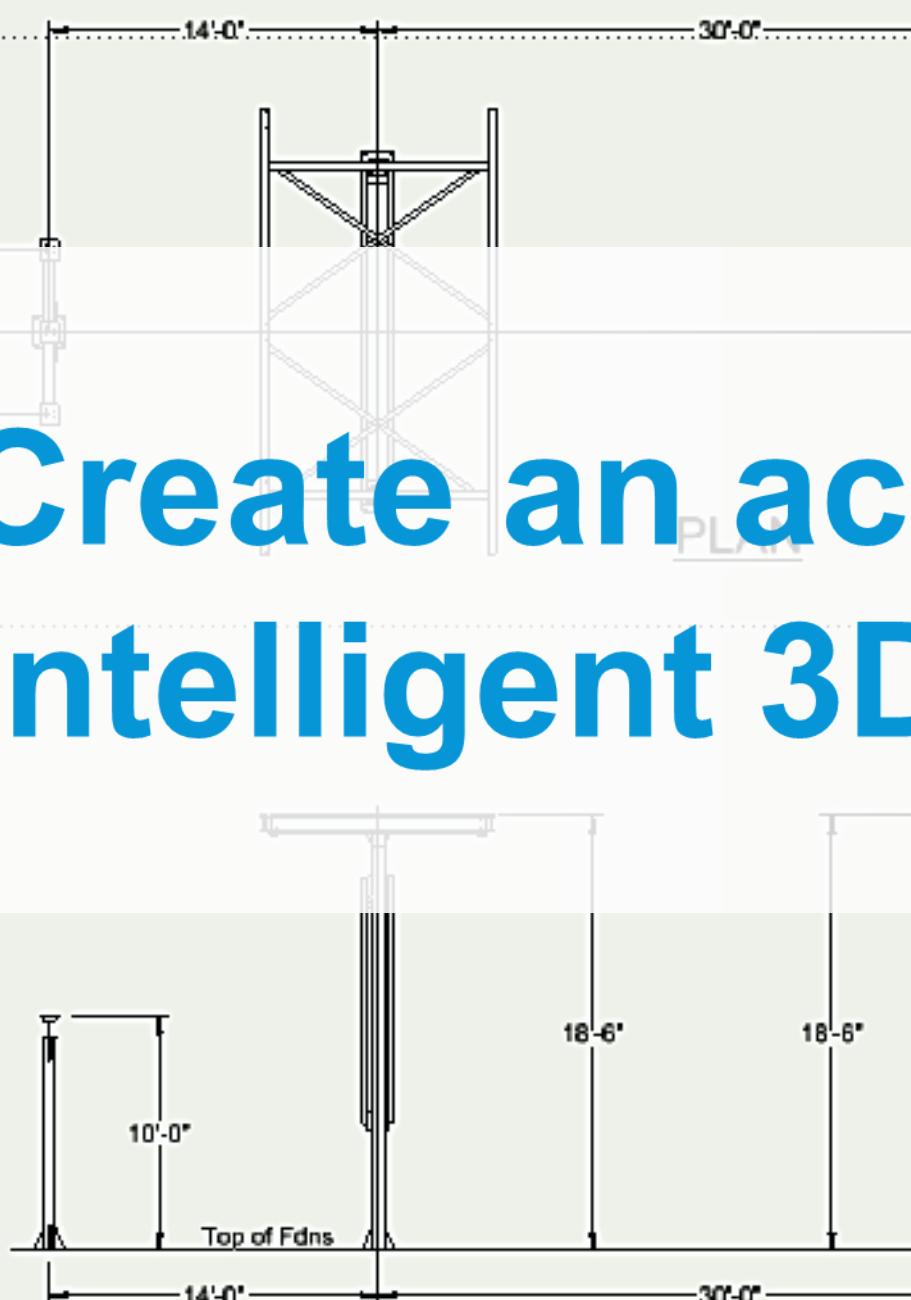
Bill of Materials [161-BAY-STR.iam]

PLAN

Model Data Structured Parts Only

Number	Title	QTY	Description	Mass	Total	Dwg#
PT-01	PT-01	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

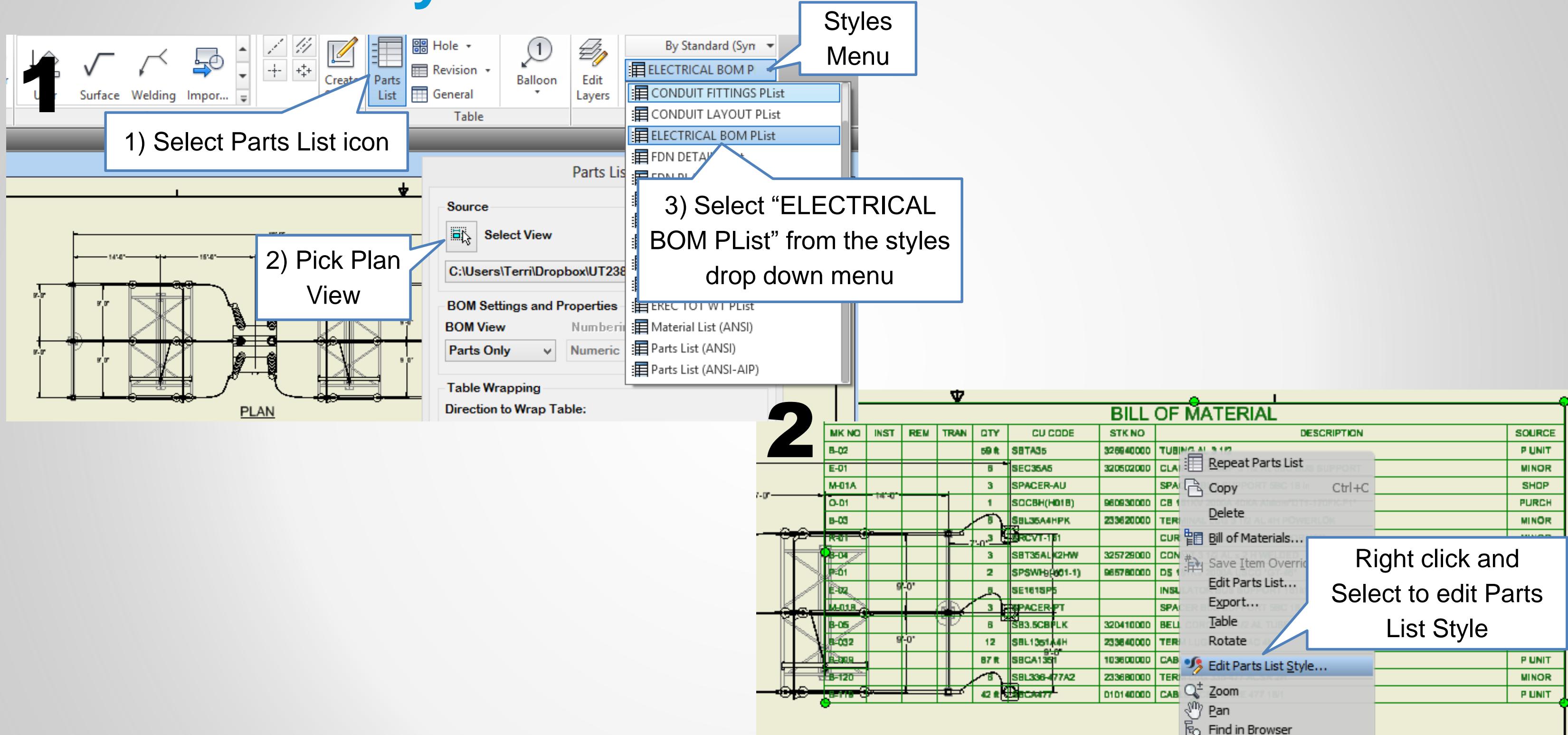


FRONT

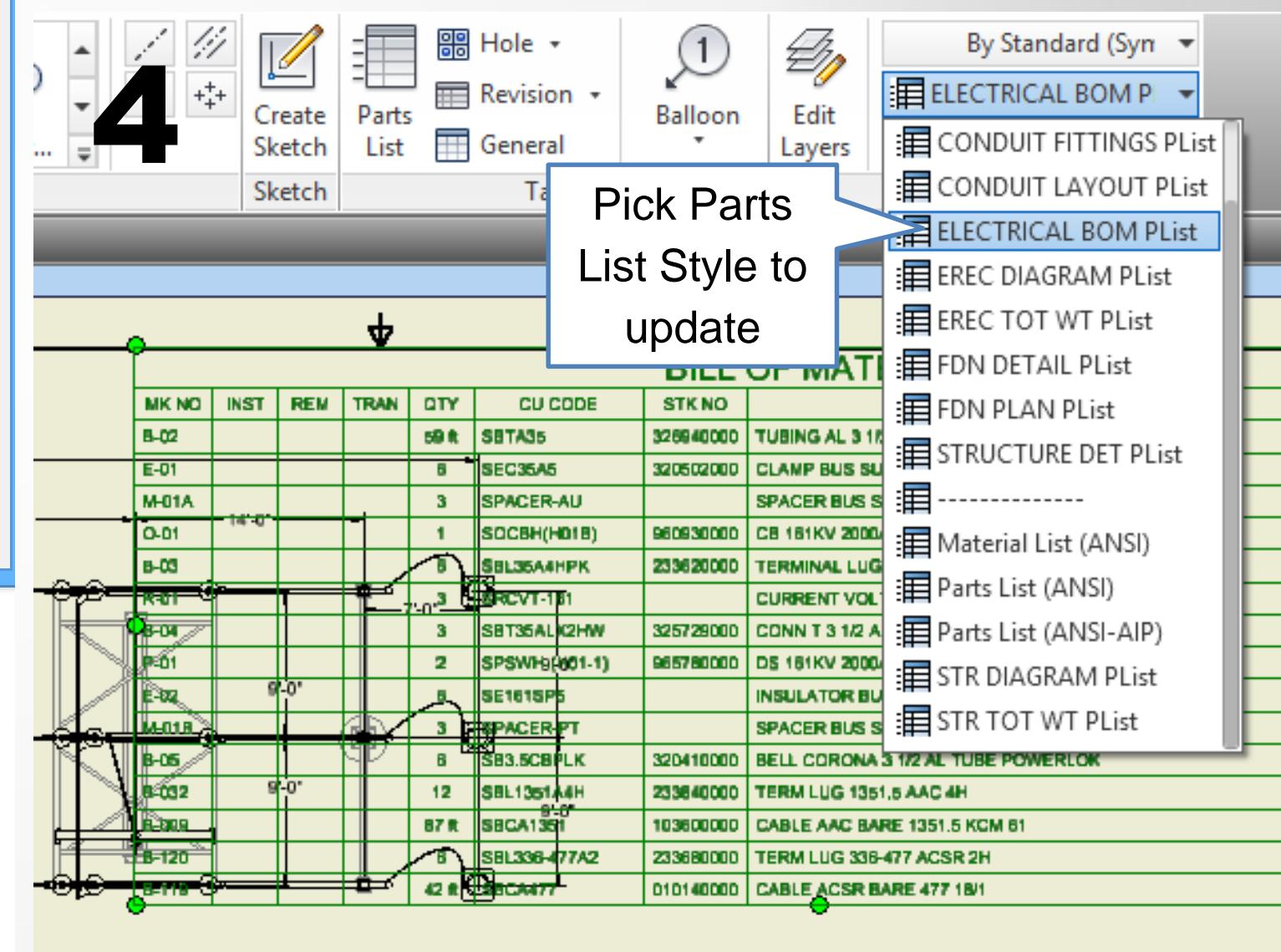
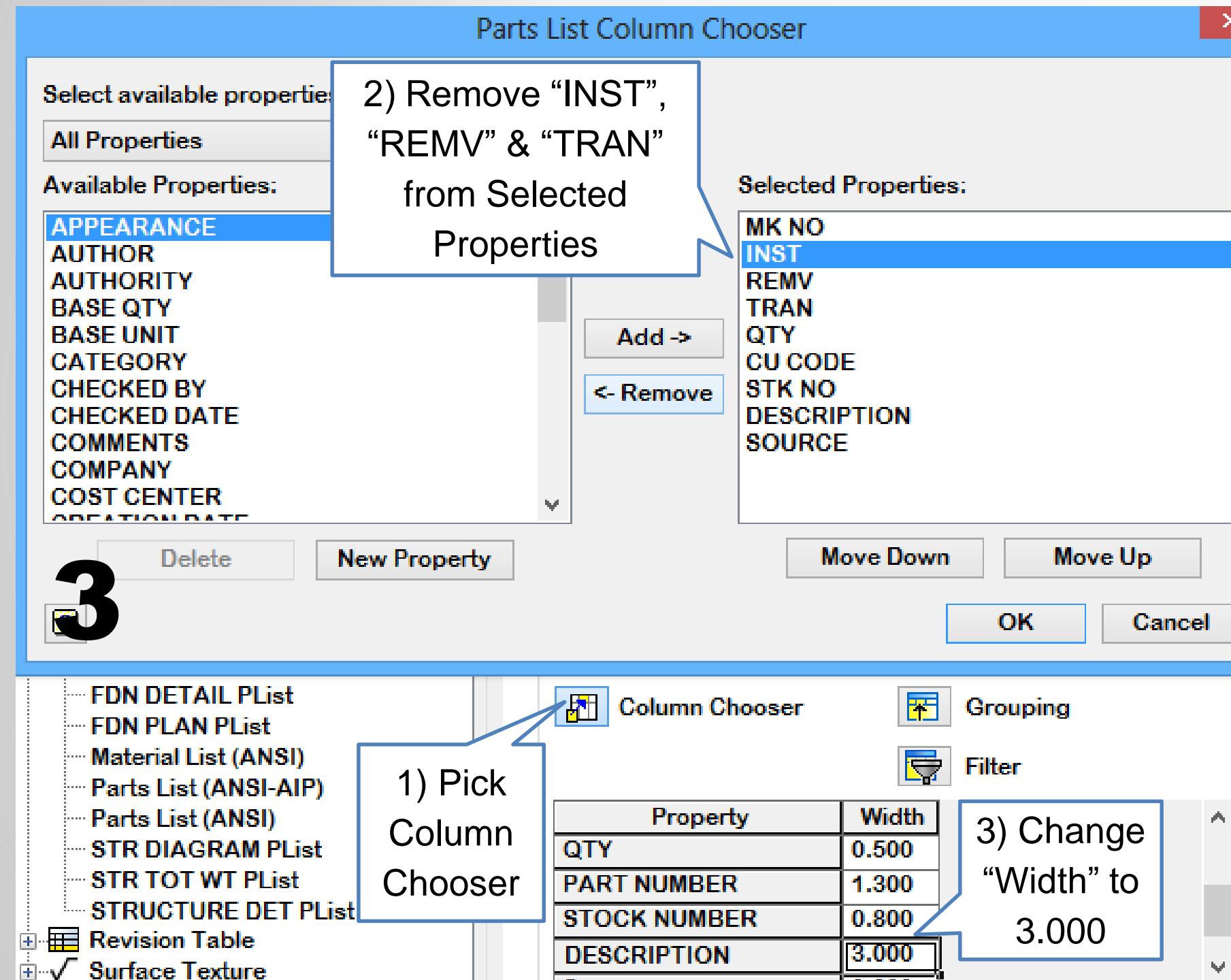
3D Model to BOM to Parts List

- 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.

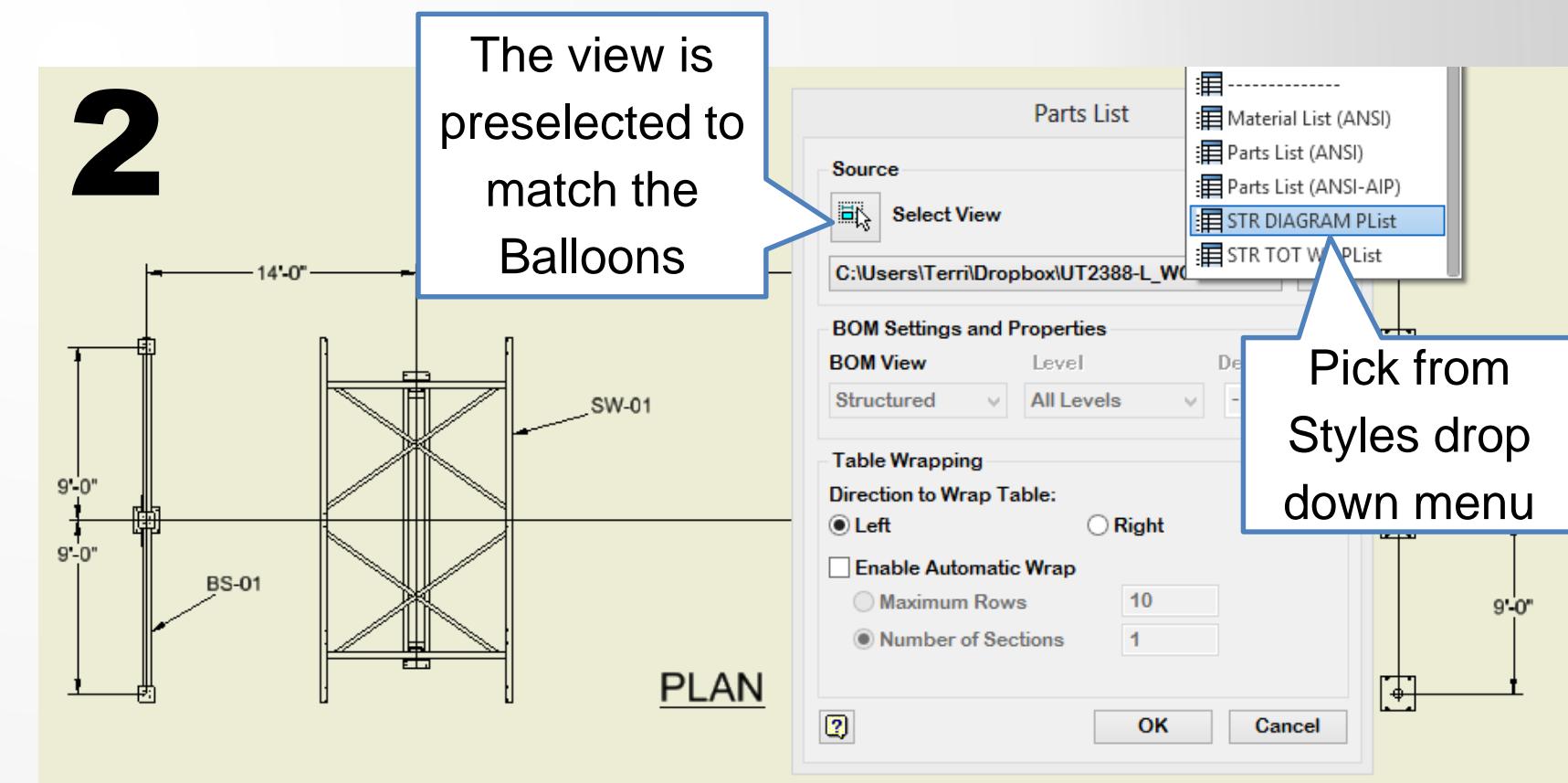
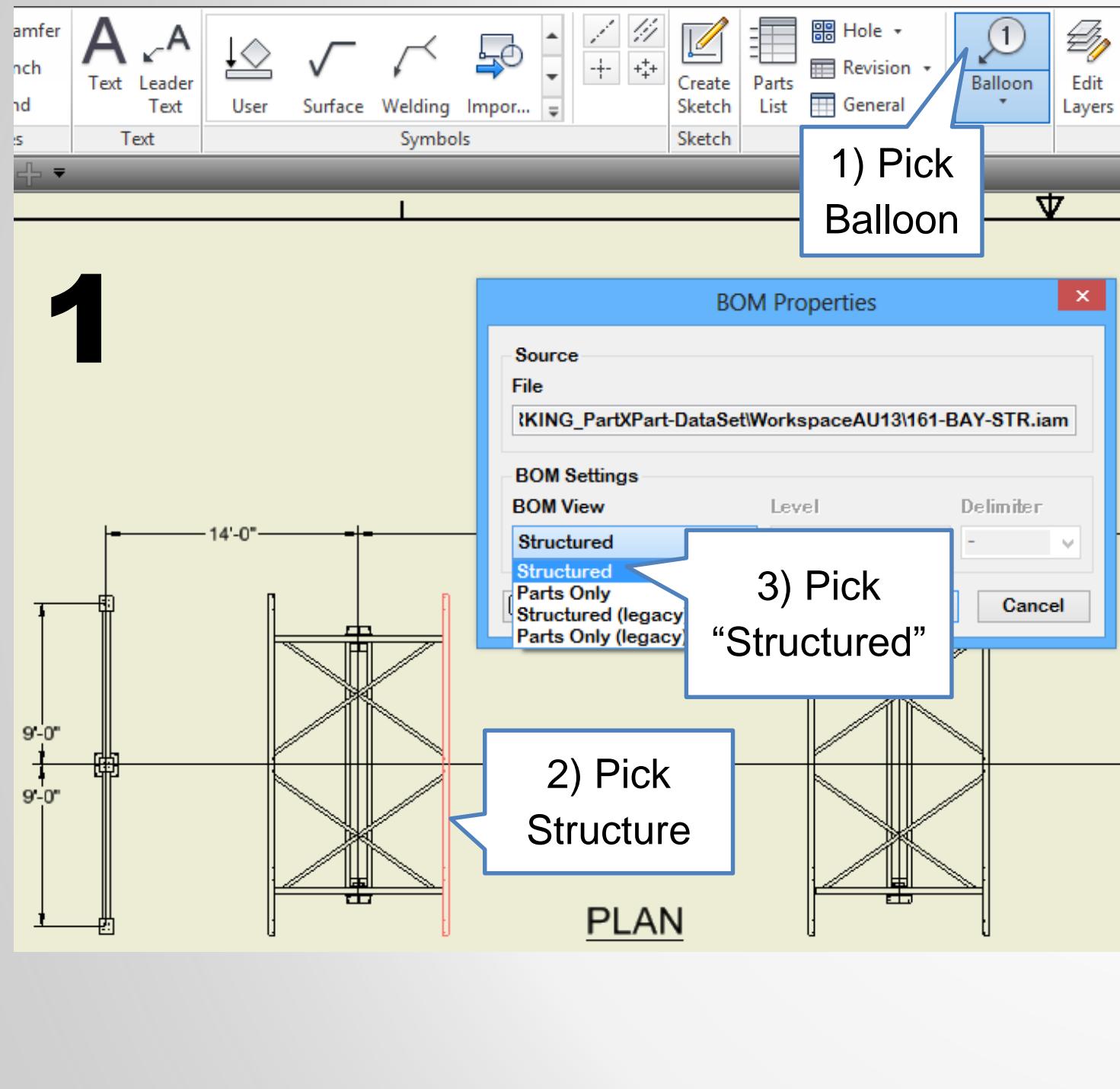
Parts List Styles



Parts List Styles



Balloons and the Parts List



BOM vs. Parts List

1

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	S-33432	1853.7	3707.3
BS-01	2	BUS SUPPORT ASSEMBLY		1581.2	

Right click and pick "Bill of Material"

Save Item Overrides to BOM

2

1) Make current

2) Double click

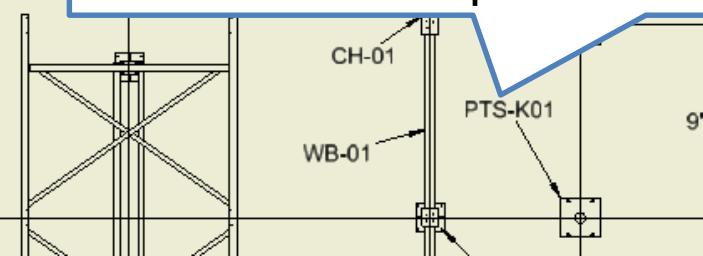
3) Select "Phantom"

Bill of Materials [161-BAY-STR.iam]					
Model Data					
BOM Structure					
<input checked="" type="checkbox"/>	Phantom	(3)PTS-K01	(3)PTS-K01	1	PT STRUCTURE (3)
<input checked="" type="checkbox"/>	Normal	BS-01	BS-01	2	BUS SUPPORT ASSEMBLY
<input checked="" type="checkbox"/>	Normal	FDN_PLAN	FDN_PLAN	1	FOUNDATION ASSEMBLY
<input checked="" type="checkbox"/>	Inseparable	SW-01	SW-01	2	SWITCH STRUCTURE ASSEMBLY
<input checked="" type="checkbox"/>	Purchased				1853.6600
<input checked="" type="checkbox"/>	Phantom				
<input checked="" type="checkbox"/>	Reference				

BOM vs. Parts List

3

Changing the BOM
Structure to Phantom hid
the BS-01 assembly and
listed the parts



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

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BILL OF MATERIAL					
MK NO	QTY	CU CODE	STK NO	DESCR	
B-00	1	326940000	326940000	TUBING AL 3 1/2	CE
E-00	5	320502000	320502000	CLAMP BUS SUP 3 1/2	IT
M-AU				SPACER BUS SUPPORT 5BC	OR
O-H01B)	1	960930000	960930000	CB 161KV 2000A 40KA Alstom"DT1-170FK-F1"	SHOP

Materials [161-BAY-ELE.iam]

1) Make Parts Only tab active

2) Delete from Description as shown

CB 161KV 2000A 40KA Alstom"DT1-170FK-F1"

Structured Parts Only

Title	Base Unit	Base QTY	QTY	Part Number	Description	Source
R-01	Each	Each	3	SRCVT-161	CURRENT VOLTAGE TRANSFORMER	MINOR
P-01	Each	Each	2	SPSWH-H01-1)	DS 161KV 2000A USCO "GT-45"	PURCH
O-01	Each	Each	1	SOCBH(H01B)	CB 161KV 2000A 40KA Alstom"DT1-170FK-F1"	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

BOM vs. Parts List

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BILL OF MATERIAL

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

Manufacturer is deleted from Description of Parts List

Delete from Parts List

Manufacturer is deleted from Description of the BOM

BILL OF MATERIAL

MK NO	QTY	CU CODE	STK NO	DESCRIPTION	SOURCE
B-02	59 ft	A35	326940000	TUBING AL 3 1/2	PURCH
E-01	6	SEC35A5	320502000	CLAMP BUS SUP 3 1/2 AL 5BC	MINOR
M-01A	3	SPACER-AU		SPACER BUS SUPPORT 5BC 18 in	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

6

CU Code/Part Number is deleted from the Parts List

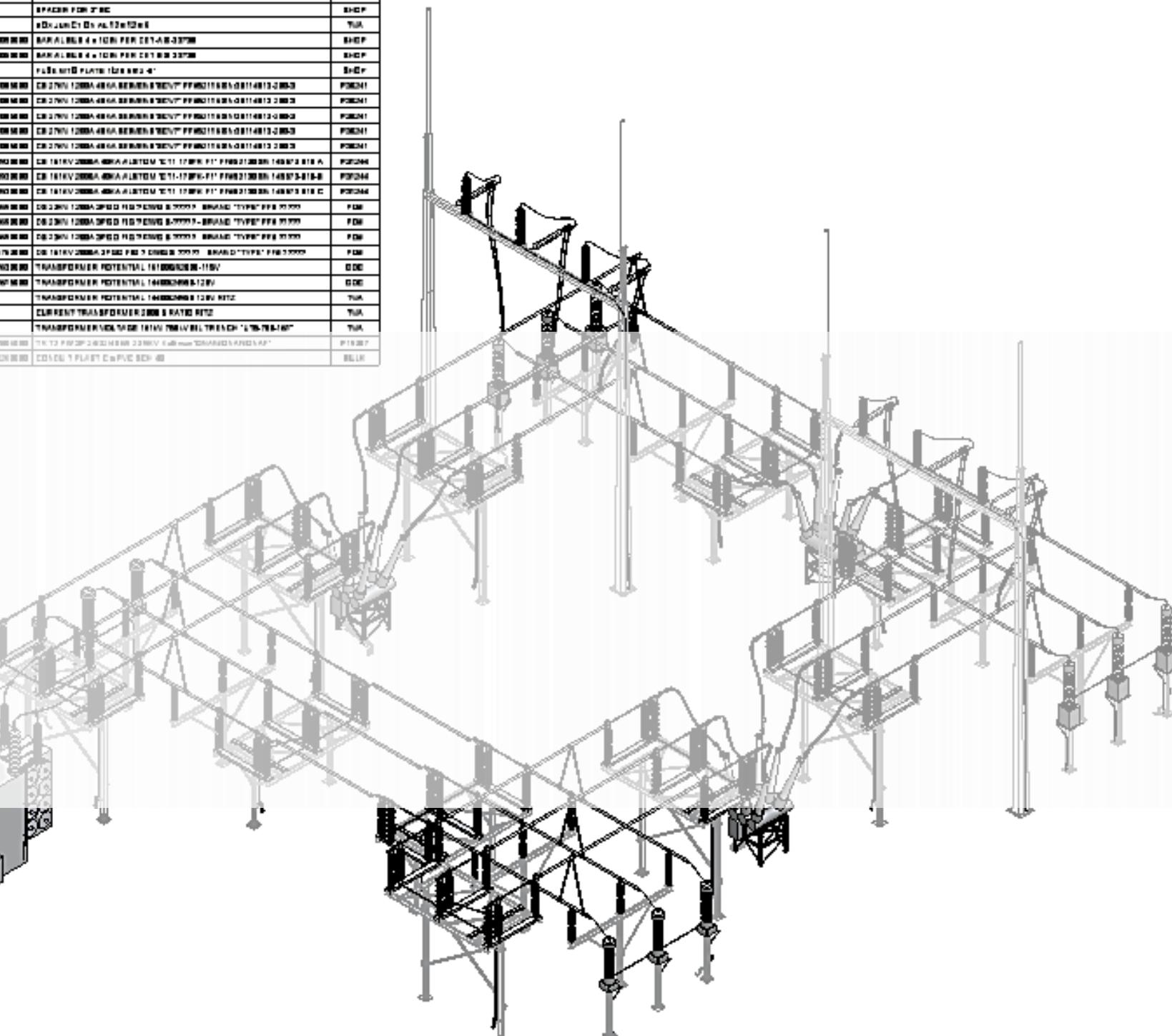
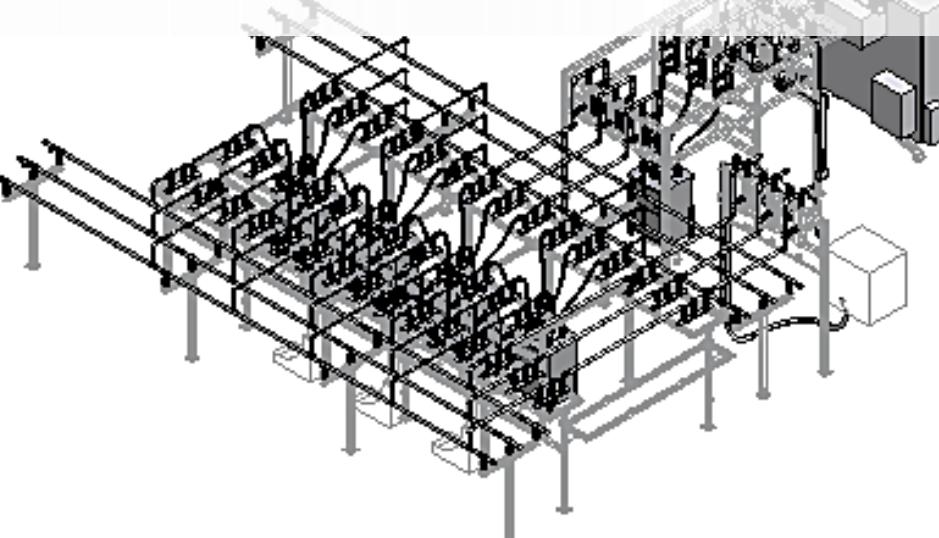
CU Code/Part Number is still populated in the BOM

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

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

Title	Base Unit	Quantity	Description	Source
R-01	Each	Each	CURRENT VOLTAGE TRANSFORMER	MINOR
P-01	Each	Each	DS 161KV 2000A USCO "GT-45"	PURCH
O-01	Each	Each	SOCBH(H01B)	PURCH
M-01B	Each	Each	SPACER-PT	SHOP
M-01A	Each	Each	SPACER-AU	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.



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