Making Autodesk® Inventor® Work for Substation Design

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UT3565: Do you want to cut your design time in half? Have you had trouble finding one design tool to meet the variety of engineering requirements for electrical substations? This class demonstrates how Nashville Electric Service adapted Inventor to handle all aspects involved in designing the physical layout of high-voltage electric substations. You will learn the steps to create intelligent 3D digital prototypes, produce construction drawings, develop bills of materials (BOM), and connect with AutoCAD® Electrical. We will cover how to test for structural integrity and check for electrical clearances. You will learn how using Inventor straight out of the box automates the process of upgrading out dated structures and equipment while increasing accuracy and saving time.

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

• Convert AutoCAD blocks to Inventor parts
• Create an intelligent digital prototype of a substation
• Produce construction drawings and export the parts list
• Update the model, the drawing and the parts list simultaneously
• Check for electrical clearances and structural integrity

About the Speaker
Terri Humel is the Principal Associate Engineer in the Substation Design section at Nashville Electric Service. She developed and wrote the procedure and training manual for AutoCAD® 3D modeling to use for designing the physical layout of electrical substations. She facilitated the implementation of Autodesk® Inventor® Professional as a substation design tool. She received an Associate’s Degree in Mechanical Engineering from Nashville State Technical Institute. She’s worked in the in the electric utility business for 28yrs. She participated in the Utility Symposium at AU 2009 as a panelist. In 2010 she presented at AU and in the Autodesk booth at DistribuTech 2010.

Joe Weaver has worked in the Control Design section at Nashville Electric Service since May of 1985, designing electrical substation protection, as well as control and communications systems. Over the years, the tools used for drafting and design have evolved from vellum and pencils, through many versions of AutoCAD®, leading to the adoption of AutoCAD Electrical a couple of years ago. During this time, he has also served as CAD manager for this section as well as many others in the Engineering Department. Currently, Joe is developing/adapting AutoCAD Electrical for use at Nashville Electric Service, as well as evaluating the new Substation Design System being co-developed by Autodesk and Duke Energy.

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Introduction

Autodesk Inventor is 3D modeling tool intended for the manufacturing industry. Here at NES, we have adapted it to meet our requirements for designing substations. There are a variety of engineering disciplines involved in designing the physical layout of electric substations. We design foundations, conduit runs, grounding, structures, mount electrical equipment according to NEC standards and produce construction drawings with a bill of material.

We are facing the same challenges as other utilities. One of our biggest issues is an aging work force. In the next 5 years we could lose half of our workers in the Substation Design Section and the other half only has 5 to 10 years’ experience. Another issue is the aging infrastructure. That’s compounded by growing customer demand. Something that’s become an issue recently is aesthetics. Our customers want reliable service but they don’t want to see any structures or equipment.

We were introduced to Autodesk Inventor in 2008. The intelligence provided by Inventor meets our design requirements and addresses the challenges we are facing. After weighing the pros and cons we implemented in January of 2009.

Facts about NES

- Formed in 1939
- Publicly Owned Utility
- Purchase power - TVA
- Cover 700 sq. miles
- Over 359,000 customers
- 5725 miles of pole line
- 12th largest Electric Utility in the nation
- 2010 – One of 6 utilities awarded APPA’s Reliable Public Power Providers (RP3) Diamond Status the industry’s highest designation for reliability and safety.

Facts about Substation Design

- 3 Designers & 3 Engineers
- 68 Primary Substations - 30 Customer Stations - 120 Distribution
- Perform 15-20 Station upgrades per year
- Build 1 new Station every 2-3 years
- AutoCAD® Version 1.2-1985
- AutoCAD® R14-Designed 3D Station-1995
- Autodesk® Inventor®-2009

Facts about Control Design

- 3 Designers, 4 Engineers & 4 Contract Support Designers
- 68 Primary Substations – FO Comm. Network (Ethernet, SCADA & Protection)
- Build 1 new Station every 2-3 years
- We work 25-50 Station upgrades per year
- AutoCAD® Version 1.2 - 1985
- AutoCAD® Map3D - 2007
- Autodesk® Electrical® since 2010
Convert AutoCAD Blocks into Inventor Parts

**AutoCAD 3D Blocks**
1. Open an existing 3D block in AutoCAD.
2. Check to make sure it is all one solid. (So it will be one part in Inventor)
3. Export using the ACSI.SAT format.
4. Select the 3D block.
5. Open the SAT file in Inventor.

The body of the part can be edited using the “Edit Solid” command or Fusion and new features can be created using the model environment commands.

**AutoCAD 2D Blocks**
1. Open an existing 2D block in AutoCAD.
2. Right click to copy to the clipboard.
3. Open new part in Inventor.
4. Paste to sketch, constrain and dimension.
5. In Model Environment, Extrude to create body and bolts.
6. Filet to create a realistic representation.
Build the Substation

1. Place from Vault and Constrain the Foundations, Columns and Trusses

Vault is data management software that comes with Inventor. It keeps up with what parts go with each assembly and has great searching capabilities.

2. Build Electrical Sub-Assemblies. There are three basic types.

Station Specific – typically major equipment such as breakers, switches, transformers and the connectors and conductors associated with the equipment are “Demoted” in to a sub-assembly. In the example to the right, the breaker, two switches, leads and terminal lugs are one sub-assembly.
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Standard Sub-assemblies – interchangeable between several stations such as the main bus or transfer bus shown on the left

Top Level Assemblies – the completed model used to create the construction drawings as shown on the right

3. Generate Cable from AutoCAD Electrical Drawings

The first step is to export the wire and pin information to an XML file from an existing ACADE schematic drawing.
Next the XML file is imported into the Cable & Harness environment in Inventor. The pin names in the exported file must match the Inventor model pin names before the wire is generated.

After the errors are fixed the cable is generated then routed through the segments.

4. **Add Conduit and Grounding**

The station is completed by installing the conduit from the equipment to the hand holes, the duct runs between the hand holes and to the control building. The ground grid is shown in blue. The columns and equipment are connected to the grid.

Note: The hand holes, duct runs and ground grids are installed first when a station is constructed in the field.
1. Start the drawing by choosing “Base View” on the Place Views Panel.
2. The sections are cut from the base view using “Section” on the Place Views Panel.
3. Place Dimensions from the Annotate Panel.
4. Place Mark Nos. using the “Balloon” tool on the Annotate Panel. The Balloons can be edited by adding Leaders, Attaching and Editing text.
5. Place the Parts List by choosing the “Parts List” tool on the Annotate Panel. The Parts List Dialog Box opens. Choose the Model and BOM settings to display the desired parts. Choose the location and place the Parts List. Edit or Export the Parts List as necessary.
Perform Upgrade

Install (1) Low Side Breaker and (1) Switch, Transfer (1) Switch, Remove (1) Switch and Rearrange Metering Equipment

1. Remove the existing electrical sub-assemblies.

2. Replace Structure

Two Trusses and one Beam need to be removed to install the new electrical sub-assemblies.

Use "Replace" from the Assemble Panel to change out the existing structural sub-assembly with the new structural sub-assembly from the Vault.
3. Place New Electrical Sub-Assemblies

The revised model is completed by constraining the electrical sub-assemblies in the new locations to the structure.

4. Update the Drawing

To the right the preview of the drawing in the Vault shows that the Breaker is not installed yet.

When the drawing opens the breaker is visible and the Parts List is updated. The Model, Drawing and Parts List are updated simultaneously.
Export the Assembly BOM and the Parts List

1. Export the Assembly BOM

Attached to every assembly is a database that contains all the part properties. Inventor refers to this as the Bill of Materials or the BOM. The properties and custom properties can be displayed in any arrangement. The display of the data is manipulated by the BOM structure of the sub-assemblies.

The BOM can be exported to many file types as shown on the right. The Unicode CSV format is used for this example.

The CSV file is imported into Access as a linked Table. By linking, any change made to the model is made to the table when the CSV file is re-exported. This is a quick way to get information to other departments.
2. Export the Assembly BOM and the Parts List

The Parts List displays the information about the parts that is contained in the Assembly BOM.

The Parts List is exported to a CSV file. The same file type choices are available as when the Assembly BOM is exported.

The CSV file is imported into the Excel Bill of Material template.

3. Update the Excel Bill of Materials after the upgrade is complete.

Re-export the updated Parts List is to the same CSV file. Import the CSV file in to the Excel File and the Bill of Material is immediately updated.
Check for Electrical Clearances

Auto-limits are used to warn for clearance violations. In this example the minimum distance is set to be from 0in to 42in between the two switch blades.

Check for Structural Integrity

Use the Stress Analysis tool to simulate the stress on the structural members and create reports. Shown here is the Safety Factor. The color coding shows how each member reacts to the stress.
Time Study

We had a unique opportunity to compare the time required to create a model in AutoCAD vs. Inventor. In 2005 we upgraded the main and transfer 69kV bus at our Watkins Park substation. The drawings for the Electrical Layout were on paper. It took 6 weeks to create the AutoCAD 3D model. In 2009 we upgraded the 69kV breakers in the same 69kV structure. It took 3 weeks to create the Inventor model. We’ve cut our design time in half.
Conclusion

**Inventor works for Substation Design**

- AutoCAD data is used by exporting and/or cut and paste to Inventor
- Build the digital prototype in the same process as it is built in the field
- Cable is generated from an AutoCAD Electrical schematic
- Quality and accurate construction drawings are produced
- Drawings and parts list are updated automatically when the model is updated
- Assembly BOM and parts list exported to multiple file types

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