

## **3D LASER SCANNING AND AUTODESK INVENTOR WORKFLOW IN SUBSTATION DESIGN**

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### **SUMMARY**

3D Computer Aided Design (CAD) technology is recognized worldwide. It is widely used in design industry and has proven to increase production efficiency and quality. In Hydro One Transmission Substation Design, implementing 3D technologies, such as laser scan capture and Autodesk® Inventor modelling supported by Autodesk® Vault Professional, has conveyed our design processes to new advanced levels and capabilities. This paper guides the reader through the various implementations of the 3D CAD tools by Hydro One Engineering.

### **KEYWORDS**

Scanning  
3D Modelling  
As Built  
3D printing  
Safety

The company that is today, Hydro One Networks, has been building transmission and distribution substations for over a century. As Hydro One looks to meet the needs of its customer base in terms of growth and reliability, we also face the challenge of safely and efficiently replacing and upgrading existing equipment and adding new facilities into stations. Stations whose drawings are 60 to 70 year old hand drafted records. In the context of maintaining electrical striking clearances, it is critically important to know exactly where the current installations exist so we can safely maximize the use of substation real estate.

As many designers have experienced, the actual placement of our designs on paper, when constructed, may deviate to some tolerable degree and not seen as warranting the submission of an As Built markup package. Our designers know in our challenging outdoor environments in North America and globally, we face the possible settlement or minor shifting of some of the structures over the many years in service.

We have found equipment that is obsoleted and removed may have left behind structures and footings that no longer appear on the drawing but are still physically present at the site. Local Maintenance and Support crews may bring in storage structures or maintenance items (oil storage) to site that would not necessarily be reflected in our drawings.

As a mitigation to the rework risk these scenarios pose, Hydro One is widely using 3D ground based laser scanning as a key tool in revolutionizing our workflows similar to the world of manufacturing. The composite data gathered allows us to capture structure and equipment locations down to 4-6 mm resolution.

3D laser scanning provides valuable high-precision geomatics data that can be stored, reanalyzed and loaded into CAD software system. We can convert these data sets into a 3D point cloud model of the station facilities. [1]

As a project begins, the drafting and design team compares overlays, created from the point cloud data, to the main station layout drawings, something we call Basic Layouts. As we compare PLAN views and ELEVATIONS to the existing CADD drawing, we can note disparities in locations or elements and implement corrections. These steps ensure that subsequent designs will be aligned with the true representation of the existing station. In doing so, we reduce or eliminate a source of construction change requirements and project delays.

We are now piloting the use of scanning and comparison as a closing step in the project workflow. Scanning at the end of a chosen construction milestone allows us to capture the true implementation of the designs. As in the initial stage, we compare the scanned area to the issued designs and create As Found or As Built drawings.

Hydro One uses 3D scanning in conjunction with our Autodesk® Vault Professional (“Vault”) library to create drawings for stations where those documents have gone missing, are unreadable or are possibly destroyed.

In Ontario, amalgamation of distribution entities takes place on a regular basis. In some of the cases, Hydro One absorbs or purchases smaller municipal utilities. As we align records of the utility with our own libraries, we have continued to find that many drawings or documents for the legacy facilities are lost without much hope of recovery. When we find such a situation, we have turned to scanning to help us create key drawings.

Ostrander DS was an early pilot of those legacy stations. The only site plan was from 1946 and showed a just a few footings without any indication of electrical elements installed there. Our sustainment group needed to have design changes made to the site feeder connection to allow for a Mobile Utility System connection to be installed, in *case the* transformer failed.

The resulting Point Cloud model allowed Engineering to develop highly accurate plan and profile views of existing station. By converting the point cloud to modelled objects and rendered info to which we add new assemblies, we can accurately create 2D, ready for construction drawings.

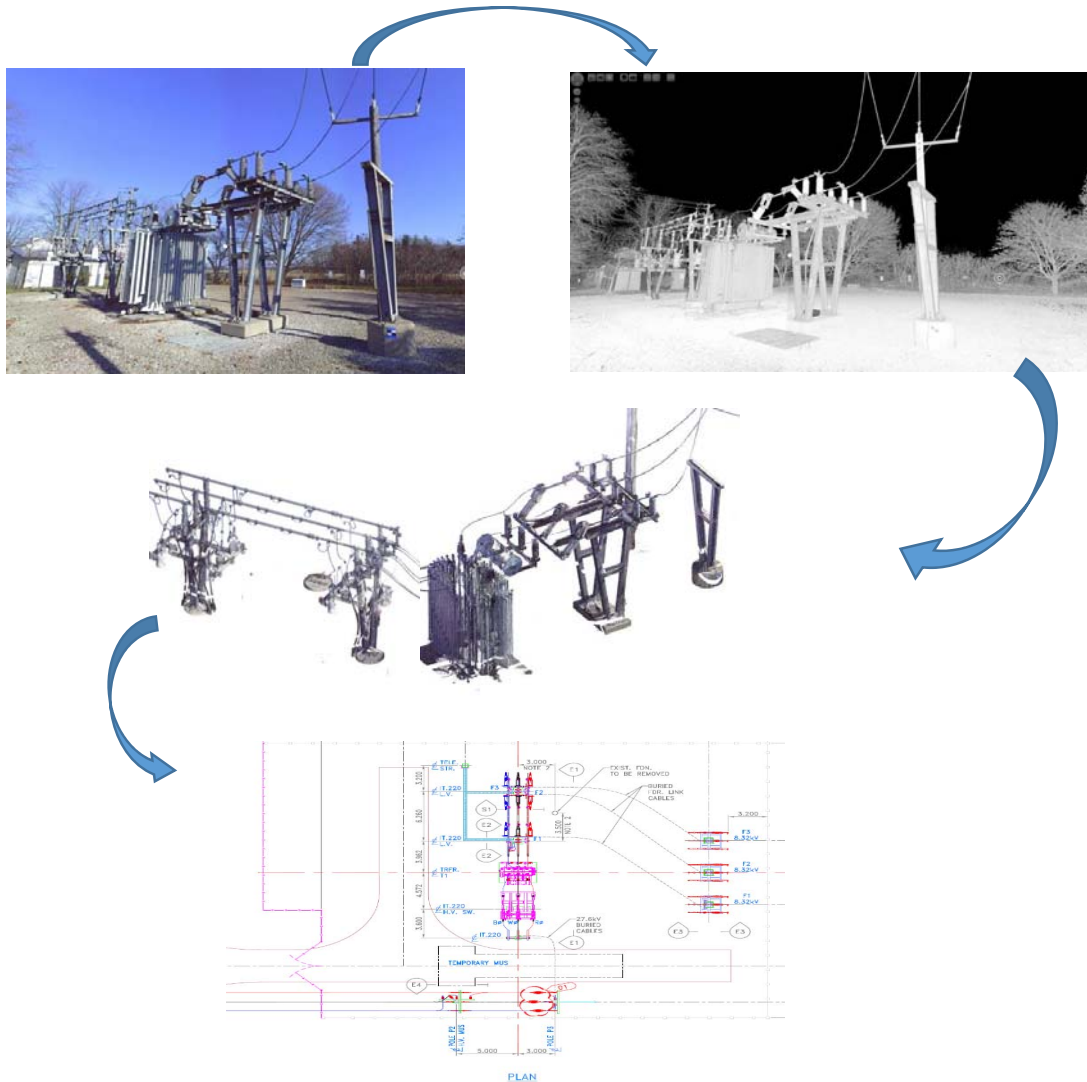


Figure 1 Dufferin TS Scan to Design Workflow

As many station designers can attest, existing stations can present very challenging problems as utilities look to replace end-of-life components. This is especially true for our urban indoor transformer facilities. Space is quite limited and the replacement equipment and busses may not orient exactly with existing connections. Without options, the scope of capital replacement becomes much greater and project costs rise.

In such a case, Hydro One has leveraged 3D scanning, Inventor 3D design and 3D printing to resolve just such a problem at a Toronto station called Dufferin TS. The replacement switch orientation was based on space limitations and electrical clearance issues. The required location meant the bus connections to existing bus work were taking on unusual angles and connection adaptors were needed.

Our designers used a 3D scan to model the installation in Autodesk Inventor. Once we understood requirements from adaptor plates, we develop 3D printed plastic prototype custom connectors. We applied the prototypes at site and, on the first connector, actually found issues with bolt alignment. Those issues were quickly resolved in a 2<sup>nd</sup> 3D printed prototype.

After site testing confirmed fit, we acquired working parts from a metal fabricator for the permanent conductive connector plates.

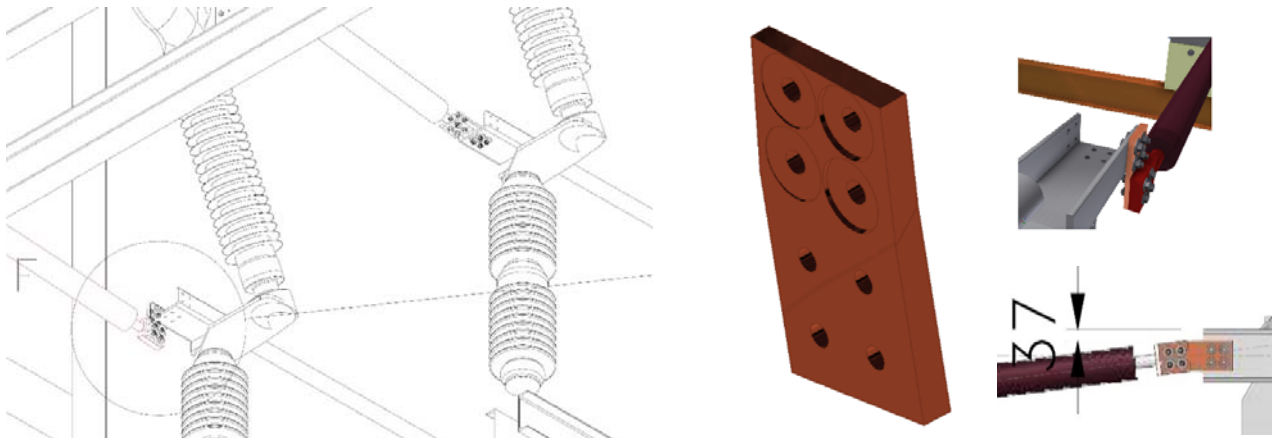


Figure 2 Dufferin TS Duresca Bus Irregular Connection

Hydro One’s first priority is the safety of the public and our employees. For Engineering, our “Safety By Design” initiative engages a wide range of Lines of Business for Continuous Improvement in worker safety and reliability. As safe work practices continue to evolve, Engineering uses its 3D tools to support their safe implementations.

We are utilizing 3D models to create 3D simulations of maintenance practices and the limits of approach to station elements. This has especially helped our organization assess its legacy structures as it plans its future sustainment investments.

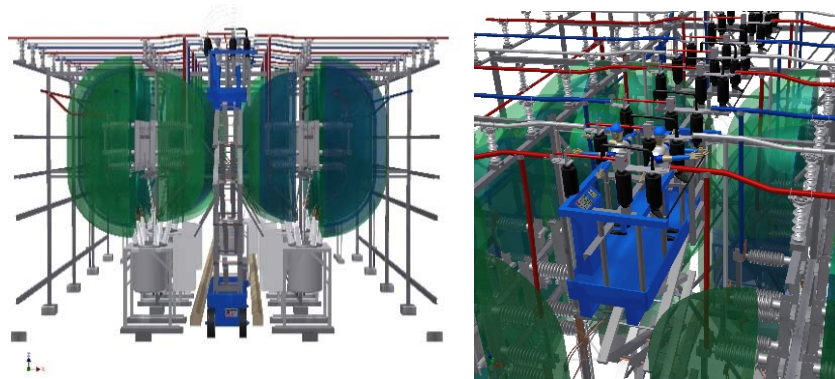


Figure 3 Simulated Feeder Tie Switch Maintenance and 27.6kV Limits of Approach

For new capital builds, Engineering is also simulating additions of temporary or permanent platforms and supports for emergency egress of personnel on top of transformers during maintenance where access by manlift or crane is limited due to sound barriers, firewalls or electrical buswork.

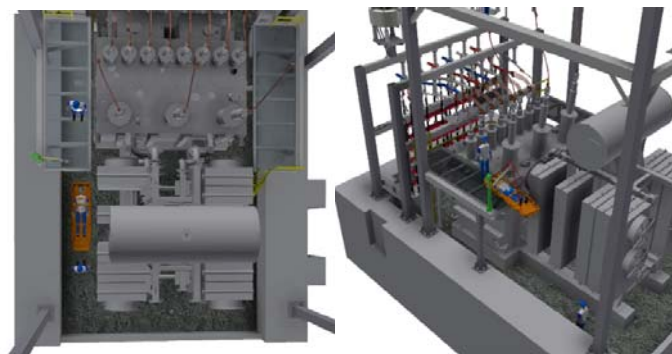


Figure 4  
Simulated Safety  
Rescue of Injured  
Worker from  
Transformer Area

The service area of Hydro One is large enough to cover two time zones with over 300 transmission level substations spread throughout the province. With a centrally based engineering team, accessing a field site for measurements or checks can be infeasible.

A valuable element of our scanning package is the Photogrammetry. While the laser is creating a data set of structures and objects around a scan location, the equipment is also capturing a 360 degree panoramic photo of the same surroundings.

The result allows us to provide a web-based environment to virtually explore the areas scanned. The product aligns the photo images with the point cloud data to allow for measurement of visual elements in the picture in 3 axes. ( $\Delta x$ ,  $\Delta y$ ,  $\Delta z$ )

This valuable tool has allowed us to minimize staff travel to site, providing improvements in terms of safety and costs.



Figure 5 Screen Capture from Scan Web-based Exploring Tool

At the outset of the adoption of 3D tools in our substation design process, Hydro One selected Autodesk Inventor 3D design and Autodesk Professional Vault Data Management. There are many products on the market that can be used for 3D design, these programs met our requirements and, with the support of our Information Services Division, we upgrade at critical junctures to ensure we can have the key program abilities at our disposal.

With Autodesk Vault Professional, Hydro One 3D Data is secured and well organized in respect to different engineering disciplines, controlled by revision management capabilities, searchable and able to reuse design data for new project.

Early in our employment of 3D tools, we focussed on development of a comprehensive library of assemblies and components. We leveraged the significant knowledge base we had with our many station design standards complemented by our database of material masters.

Within Vault, the Libraries folder is used as the central location for standard station and lines parts, assemblies, and subassemblies. It allows users to share all standard models from a central location.

To facilitate the Libraries use, we leverage the Vault folder and subfolder system;

#### 1) SAM – Station Assembly Model

The Station Assembly Model (SAM) folder contains predefined 3D assemblies, subassemblies, and part files. In this folder are template components that contain derived versions of the predefined 3D components. These derived components have a reduced level of detail in order to use less memory [3]. They are used on a reference basis and support the hierarchal design of an assembly.

The “design template” electrical assemblies typically consist of the major equipment component(s), mounted on the appropriate support structure with representative footing(s) and



all associated electrical connections, hardware and grounding. These template assemblies can be copied and manipulated based on individual project requirements. (Examples in Figures 6, 7, 8 & 9)

Utilizing these modular assemblies as much as possible on new projects saves designer and drafting time, and will help maintain design consistency and accuracy.

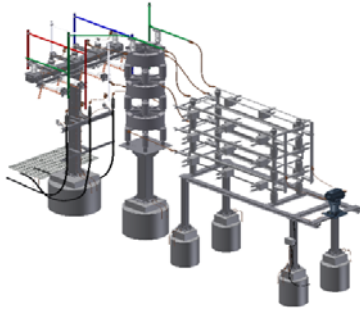


Figure 6 "Design template" assembly for 44kV Static Capacitor Bank

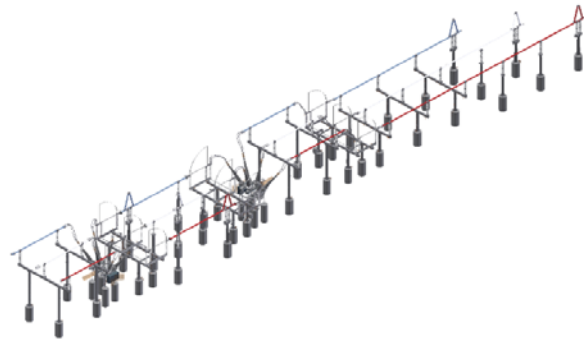


Figure 7 "Design template" assembly for 230kV Diameter (half) with solid structures

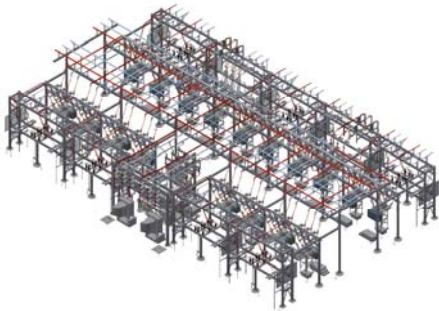


Fig. 8 "Design template" assembly for IT 210 DESN

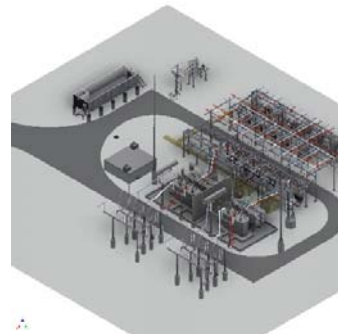


Fig. 9 "Design template" assembly IT 210 DESN for Runnymede TS

## 2) SAPC – SAP Components

The SAP Components (SAPC) Folder in Vault contains 3D standard part files. Standard parts are created from Customer Outline Drawings received from various suppliers with which Hydro One has purchase agreements. Standard parts can range from connectors to major equipment such as transformers and breakers. Standard part files are stored and categorized under sub-folders that are derived from SAP's "Group" classification. This library has approximately 2000 models of commonly used electrical components in a nominal system voltage range of 27.6 to 500kV. The electrical components include most variations of material master cable and bus connectors, cable trench parts, insulators, surge arresters, CVT's and so on. Components will continue to be added on demand. All our standard rigid bus and cable sizes are also readily available.

Our approach to Vault use allows for concurrent exchange information between electrical, structural, and civil engineering groups. Any changes can be shared in real time. Once the electrical equipment is chosen and located, the structural and civil components are generated through a 3D design tool that involves "master" or "intelligent" assemblies. These assemblies contain all components and their variations, with predefined options for selection. Therefore, the final substation design becomes the

summation of all assemblies. Each assembly consists of parametric parts/subassemblies from the library or specifically created.

Transitioning from 2D CAD to 3D assemblies with Inventor and Vault allows our teams to leverage a great range of supporting data and analysis tools within the programs.

Autodesk Inventor and Vault enables us to:

- Use the embedded Content Center library - containing over 1.1 million parts categorized by international standard
- Check component interferences during design stage and reduce problems previously caught only in construction on site during execution creating rework and delays.

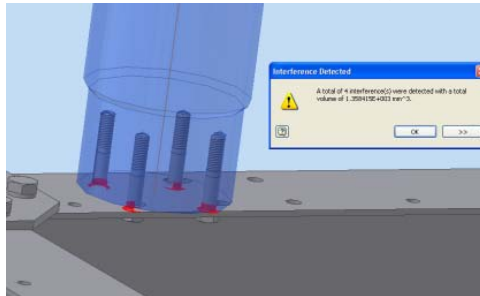


Figure 10 Component Interference Analysis

- Generate a detailed and accurate bill of materials (BOM) automatically which allows for detailed cost estimating, project material scheduling and effective auditing.
- Perform finite element analysis (FEA) to optimize the design
- Assign weights and masses to determine center of gravity for modelled structures.
- Reduce modification time. If one or more sizes of the steel are changed, model is modified and all related drawings are updated.

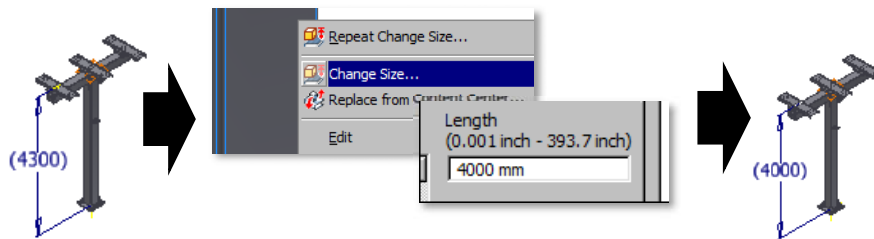


Figure 11 Assembly modification

- Generate and update drawings automatically. If views of the same assembly or a part exist in multiple drawings, any changes of the model will appear in all drawings immediately.

The prospects of application of 3D design technology are very wide, and it has excellent practicability in the field of electric power construction. [3]

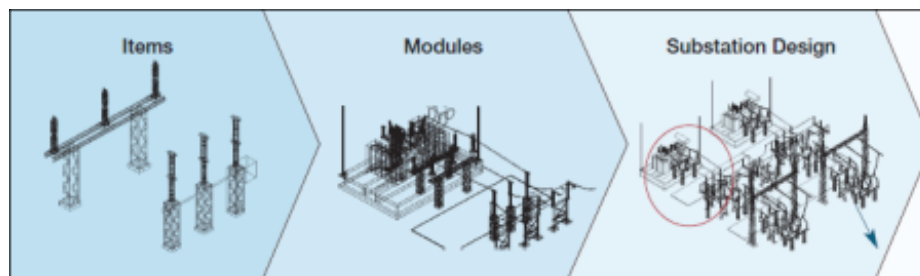


Figure 12

We have spent much of this paper covering how we have utilized 3D modelling and scanning for our design efforts. One of the valuable added benefits is greatly enhanced ability for visualization of the designs and project staging for other key stakeholders in our projects. With 3D images and animations built off of our design models, we create presentations:

- 1) For use by our Project Delivery teams to assist in securing executive and board approvals for high value investments.
- 2) To share the designs with our Construction and support partners as they develop their project plans and staging in the form of Building Information Modelling (BIM) tools
- 3) Include as a key part of Public Information sessions that are part of our Environmental Compliance requirements to obtain regulatory approvals.
- 4) To create enhanced training environments for Operations staff using Virtual Reality equipment.

Hydro One Engineering's use of 3D CAD and its supporting central libraries will continue to grow and we look to leverage more advanced compatible tools to improve the reliability, efficiency and accuracy of our production efforts. The software suites are only growing in capability and Hydro One is well positioned to capitalize on existing and future developments in this field.

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