USING A VRML INTERFACE TO ACCESS SUBSTATION ENGINEERING DESIGN AND STANDARDS INFORMATION

Larry D. Helwig P.Eng., Nevada Power Company

Introduction

Traditionally, power utility engineering design and construction documents are retrieved using one of three processes; hard copy, electronic copy on a LAN server and electronic copy on a web-based server. In this paper a VRML-based document retrieval application will be described and demonstrated using a typical power utility high voltage substation as the model.

VRML, pronounced ver-mal, is an acronym for the Virtual Reality Modeling Language. It is a specification for displaying 3-dimensional objects on the World Wide Web. VRML produces a hyperspace, (or world), which appears as a 3-dimensional space on a web browser. One can figuratively move within this space by pressing keys to turn left, right, up or down, move forwards or backwards, zoom and hyperlink to other web objects. The images on the screen change to give the impression that one is moving through a physical environment [1]. To view VRML "worlds" a web browser equipped with a VRML plug-in/browser is required.

The purpose of this paper is to demonstrate how an electric utility can use VRML-based interface technology to build an application that accesses the complete set of physical engineering construction and standards data for a typical electrical substation. VRML interface technology will be applied to a Nevada Power 100MVA-138/12kV substation. The base model for the VRML scene was created from the vector-based detailed 3D CAD model originally used to render utility engineering drawings used by substation construction personnel. A demonstration of the application will show how a user can navigate through the substation model and access relevant apparatus engineering data from embedded hyperlinks. Other utility-related applications of VRML will be explored and, in addition, a focus on lessons-learned during the development of this application will be discussed.

Viewing VRML

VRML appeared after traditional web browsers like Internet Explorer and Netscape Navigator. Because VRML is very complex content compared to text and images these browsers must rely on plug-ins or helper applications. VRML plug-ins or browsers display VRML content seamlessly within the context of the browser itself. Cosmo Software's Cosmo Player was used for this application. Cosmo Player is equipped with several navigational controls allowing users to zoom, roam, pan, rotate, hyperlink to objects and save selected viewpoints [2].

VRML Structure

The VRML language is essentially a hierarchical arrangement of node declarations. Primitive shape nodes are used to describe the base geometry of a scene. These include boxes, cylinders, cones, spheres, extrusions, faces and lines. Other node declarations such as directional lights, color, texture maps and material set the physical parameters of the VRML scene. The anchor node is analogous to HTML language's anchor <A> element and defines hyperlinks in VRML. Anchor nodes associated with groupings of primitive geometric shapes, (i.e. "children"), provide

hyperlinks to associated web documents. As a user moves through a VRML world the appearance of the mouse pointer will change when it is moved over the child of an anchor. Figure 1. shows a substation 69kV circuit breaker and its associated bill of material hyperlink.
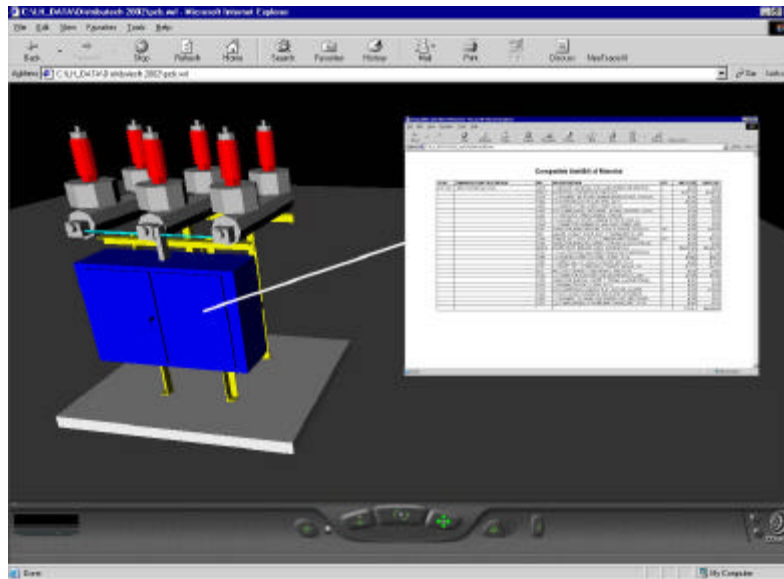

Figure 1. VRML Scene of a 69kV Circuit Breaker and Bill of Material

Preparation of the VRML Substation

The VRML substation scene's creation was a three step process; AutoCAD 3D model, to 3D Studio MAX, to VRML. An AutoCAD 3D physical model of the substation, (one used to prepare physical construction drawings), was first imported to 3D Studio MAX format, (.3DS), using the AutoCAD application. The 3D Studio MAX file was then converted to a VRML 2.0 world format, (.WRL), using the *Crossroads* conversion application developed by Keith Rule. Figure 2. shows an overall view of the substation's VRML model.
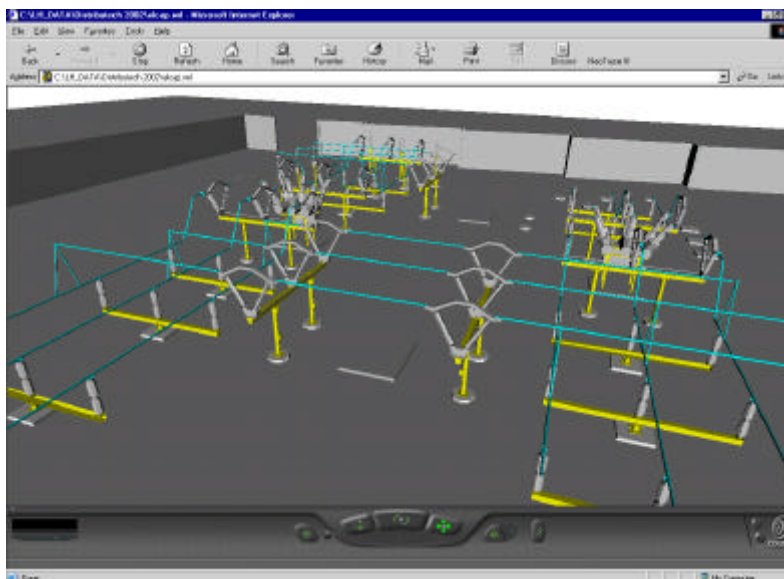

Figure 2. 138/12kV Substation VRML Scene

User Interface Options

Two user interfaces were considered for the VRML substation application. The first used the full VRML substation scene with several built-in Viewpoints, (Figure 2). Another option used a web-based image map of the substation plot plan as the starting point with hyperlinks to select VRML scenes of major apparatus, (Figure 3). The latter choice was ultimately chosen for its ease of use and lower PC resource draw, (the complete substation VRML scene is quite large). This interface also includes links to general information documents and overall plot-plan drawings that are not VRML scene dependent. These documents pertain to the overall substation layout are accessed using a separate menu, (e.g. plot plans for initial, ultimate, electrical, conduit, foundation, grounding layout and steel structure layout). Figures 4. and 5. show typical substation apparatus VRML scenes accessed from the main image map.
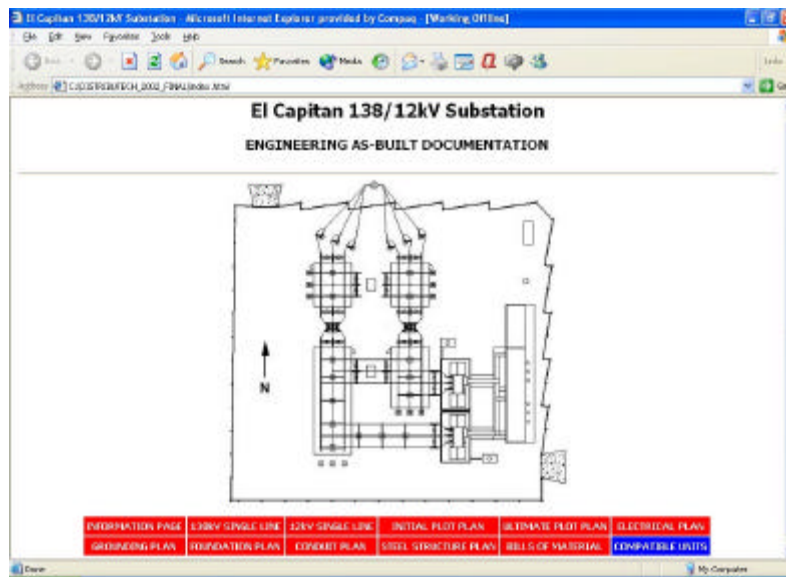

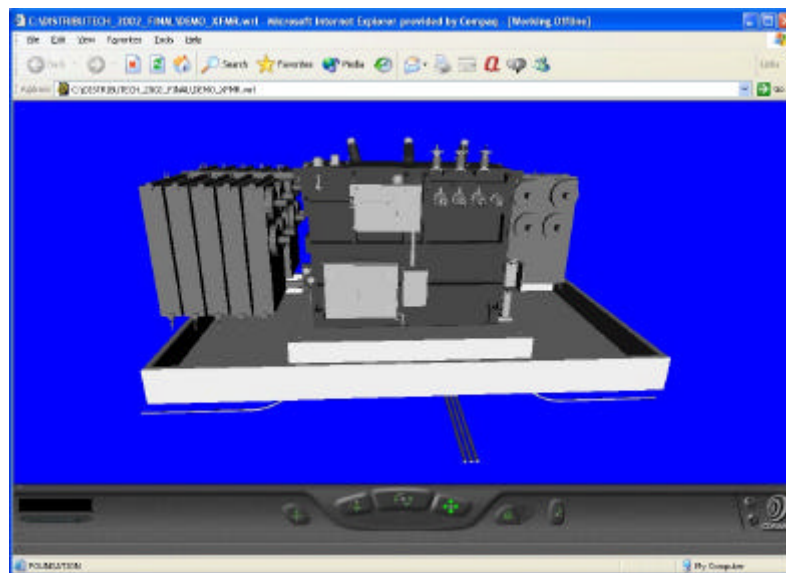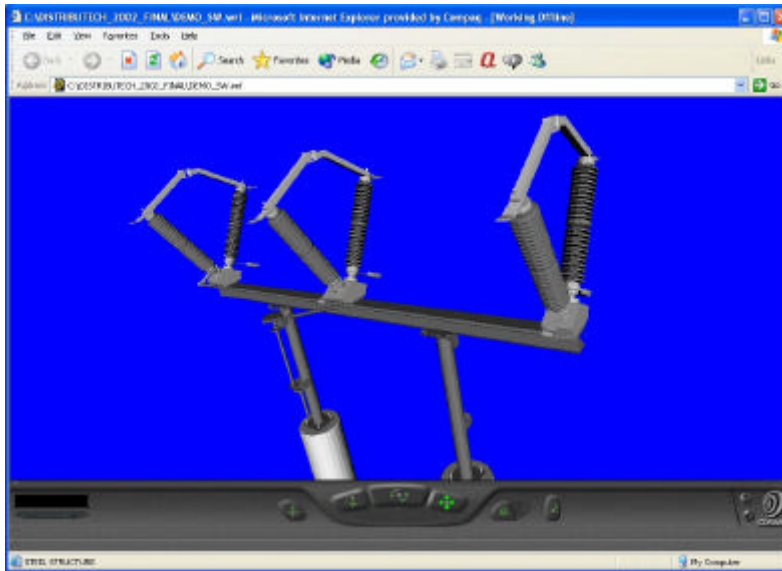**Figure 3. Substation Image Map Interface**

Figure 4. 100MVA 138/12kV Transformer VRML Scene

Figure 5. 138kV Disconnect Switch VRML Scene

Several key components of the VRML scene, (e.g. electrical apparatus, foundations, steel, conduit, etc.), are associated with anchor, (hyperlink), nodes. While navigating VRML scenes of substation apparatus the user can hyperlink to construction detail drawings, connection schematics, construction bills of material and manufacturer's equipment drawings.

A VRML scene of the interior of the metal-clad switchgear was also created to access system protection and relay equipment information, (Figure 5). In this particular case photographic bitmaps of individual devices were incorporated into the VRML scene. Hyperlinks provided access to panel layout physical drawings that hyperlink to individual component panel mount drawings, relay settings sheets, instruction manuals and corporate material specifications.
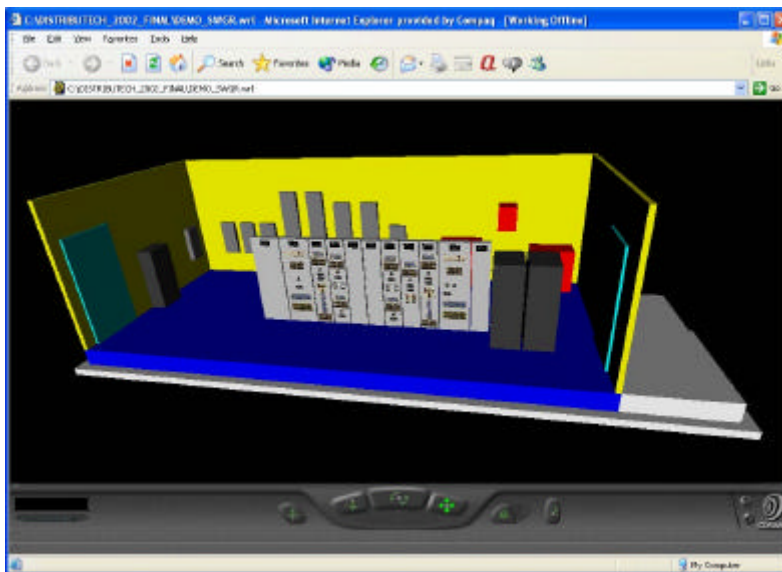
Figure 6. Switchgear Control Room VRML Scene

Compatible Unit Standards information can also be accessed via a alternative plot plan image map. The user can click on objects on the substation plot plan image map, (i.e. transformers, power circuit breakers, CCVT's, etc…), and hyperlink to their associated Compatible Unit 3D

model images and Compatible Unit bills of material. Each page of this type also includes a link to the Master Compatible Unit Index where all compatible units are listed complete with links to 3D model images and their associated bills of material.

Figure 7. VRML Switchgear Control Room Detail

Access to Substation Engineering Documents

Using embedded links in the VRML model several types of NPC substation engineering documents are accessed; as-built physical construction drawings and their associated bills of material, manufacturer's drawings, engineering Material Standards, Compatible Unit Standard model images and Compatible Unit bills of material data. Figures 8,9 and 10 show typical engineering data that can be accessed.
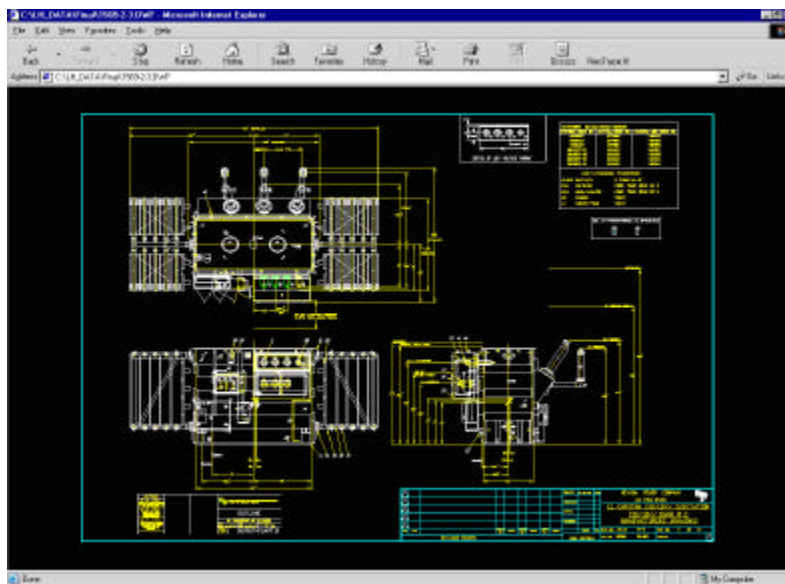

Figure 8. 138/12kV Transformer Physical Outline Drawing, (.DWF)

Figure 9. 138/12kV Transformer Compatible Unit Model, (.JPG)

Figure 10. 138/12kV Transformer Compatible Unit Bill of Material

Physical Construction Drawings

The physical construction drawings are 2D AutoCAD drawings of the as-built substation. These were initially created by referencing the 3D model of the substation. This methodology conserves both disk space and time as one can alter the 3D physical substation model and the changes are automatically reflected in the construction drawings, from which it is referenced, (AutoCAD XREF) [3]. One changes the 3D model to make physical alterations to substation. Annotations and dimensions are revised by editing the 2D construction drawings. By placing objects in specific layers an array of physical construction drawings can be generated from the 3D model. These drawing categories are listed in Table 1.

Drawing Series	Description
E11	Conduit Plan and Details, Underground Feeder Plan
E12	Initial Plot Plan, Grounding Plan and Details
E13	Electrical Plan and Sections
E14	Ultimate Plot Plan, (fully built-out substation)
E15	Switchgear Physicals
E20	Foundation Plan and Details
E21	Steel Structure Layout and Details

Table 1. Nevada Power Substation Physical Drawings

Compatible Units

Compatible Units are the standard construction units used by NPC Engineers to design the substation's physical layout. A typical unit consists of two components: a 3D AutoCAD model assembly and an itemized bill of materials. These bills of materials are stored in Microsoft Access tables and are displayed as simple HTML. For each Compatible Unit number, (primary index), they consist of a unit description, NPC stock numbers, descriptions and quantities and a total cost for the complete unit. An Access report is executed to output the individual HTML bills and another is used to prepare a master Compatible Unit Listing.

Hyperlinked Document Formats

CAD drawings are displayed to the user in .DWF format, (Drawing Web Format), using the AutoDesk WHIP! plug-in. The .DWF format allows one to display, pan, zoom and print drawings of AutoCAD origin inside a web browser. .DWF is a lightweight vector file format that preserves the security and precision of source DWG files, while ensuring the speedy display of drawings [4].

All other engineering documents and standards are displayed to the user in simple HTML, JPG or Adobe .PDF format using the Adobe Acrobat Reader plug-in.

Lessons Learned

The level of detail of the VRML model should match the application's purpose. With current 2002 state-of-the-art PC's, (PIII 1GHz, 256MB RAM), a large VRML scene, (>10MB), can take some time to load into a browser and navigation can be quite slow. One may want to determine if it is really necessary to show detail such as the every cable connector or insulator shed. Depicting these objects as simple VRML shape nodes can help reduce VRML scene sizes.

To ease navigation it may be necessary to create multiple viewpoints at strategic locations in the substation model. Most VRML browsers support the creation of Viewpoints that are accessed from the browser's main control panel.

In order for an application of this kind to be ultimately useful the VRML scenes and web information accessed should be kept as up-to-date as possible. The 3D vector models from which the VRML scenes are created should be updated with as-built physical construction data. Construction as-built drawings should also be kept up to date along with all engineering specifications and standard web documents.

Beyond Standards and As-Built Information

Currently this application provides hyperlink access to substation as-built physical construction data and design standards. The following are some other possible substation data links that the application could access provided a valid IP address exists: real-time relay settings and test sequences, relay event reports and alarms, substation automation, digital fault recorder information and substation security web cameras.

Another application enhancement would be to allow engineers and designers to exchange design mark-up information. In this scenario a user would enter the VRML scene, leave design mark-up information notes and issue the annotated scene to a designer. This enhancement would require more in-depth VRML programming.

Conclusion

This application creates an economical, information-rich visual data map of a HV power substation. Workstations onto which it installed require an Internet web browser, a VRML browser, AutoDesk's Whip! and Adobe's Acrobat Reader. Expensive applications such as AutoCAD and a relational database are not required on a client workstation. Cost savings in staffing can also be realized as non-technical users can access substation technical information in a simple visual manner.

The application is also portable. Engineers and field personnel can store several substations on a typical notebook PC. For a typical 138/12kV 100MVA substation the entire application including VRML scenes, browser, plug-ins and all substation engineering data takes up less than 30MB of HD storage space.

References

[1] LYCOS Webopedia, *http://webopedia.lycos.com/TERM/V/VRML.html*, 2002

[2] Walsh, A.E. and Bourges-Sevenier, M., Core Web 3D, Prentice Hall PTR, NJ, 2001

[3] Autodesk, AutoCAD 2000 User Manual, Autodesk, Sausalito, 1999

[4] Autodesk, Whip! Viewer Overview, *http://www.autodesk.com*, 2002