

# **USING WEB-BASED IMMERSIVE GRAPHICAL INTERFACES TO ACCESS POWER SUBSTATION DESIGN AND STANDARDS INFORMATION**

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

## **Abstract**

The purpose of this paper is to demonstrate how an electric utility can use immersive imaging technologies to access physical engineering construction and standards data for a typical electrical substation. Existing systems employed by utilities typically require a user to manually search drawing indices resulting in a longer information retrieval process. The first case study utilizes a VRML landscape while the second involves the use of interactive panoramic imagery. The primary model will be a typical 138/12kV Nevada Power substation design and the application will demonstrate how a user can navigate through the virtual model and access relevant engineering data via embedded hyperlinks. The pros and cons of each information retrieval methodology will be discussed, as will the lessons-learned during their use and development.

## **Case I. A VRML Model**

VRML, pronounced ver-mal, is an acronym for the Virtual Reality Modeling Language. VRML is intended by its designers to be the standard language for exchanging virtual worlds, (three dimensional scenes), including interaction possibilities and multi-user abilities via the Internet [1]. 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. To view VRML "worlds" a web browser equipped with a VRML plug-in is required.

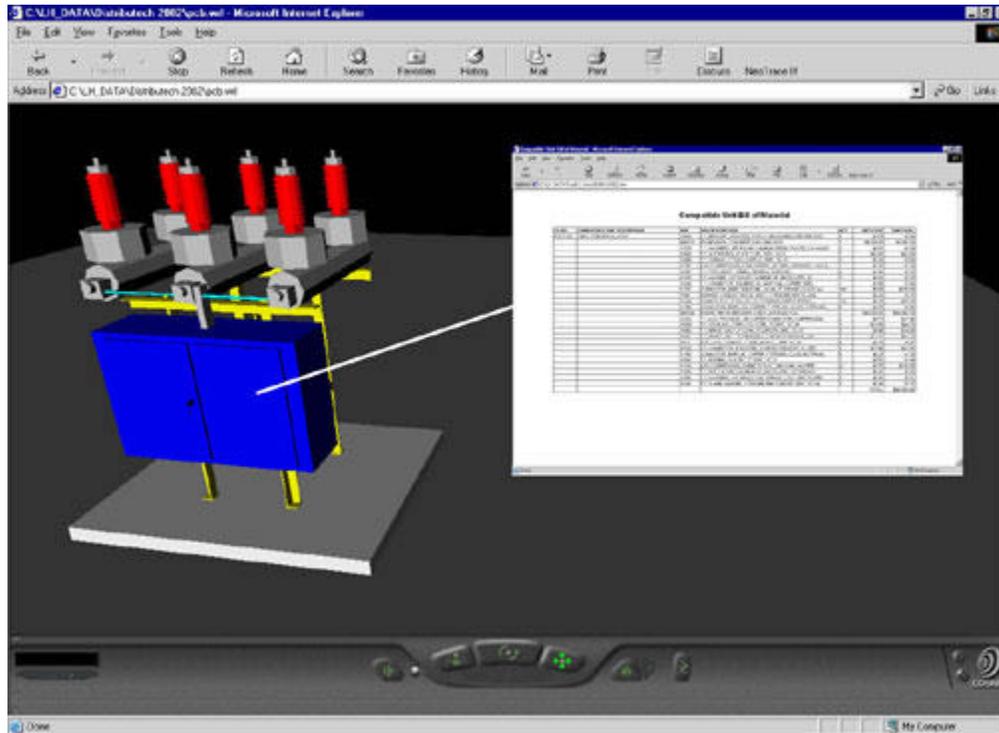
## **Viewing VRML "Worlds"**

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. VRML plug-ins 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 series of node declarations. Scene graphs are created using nodes which are the fundamental VRML programming unit and contain data and event fields that define both state and behavior [3]. Shape nodes are used to describe the base geometry of objects in 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, “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 VRML view of a substation's 69kV circuit breaker and its associated bill of material hyperlink.



**Figure 1.** VRML View of 69kV Circuit Breaker and Bill of Material

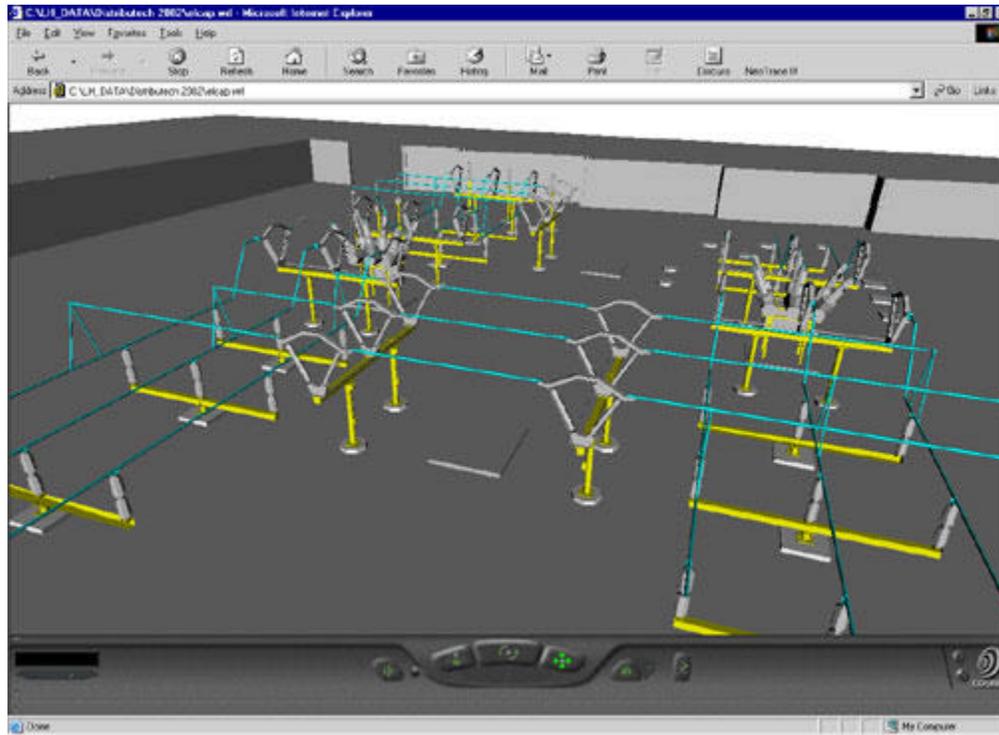
### **Preparation of the VRML Substation**

VRML interface technology will be applied to a Nevada Power 138/12kV-100MVA 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. The VRML substation world'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 created and imported into 3D Studio MAX format where materials and texture maps were applied. Finally the 3D Studio MAX, (.3ds), file was converted to a VRML world format, (.wrl). Figure 2. shows an overall view of the substation VRML scene.

### **Browsing the VRML Substation**

While navigating the VRML model of the as-built substation the user is able to hyper-link to all construction physical CAD drawings of the substation, connection diagrams, construction bills of

material and manufacturer's equipment drawings and Compatible Units data by clicking on hyper linked objects. Drawings pertaining to the overall substation layout are accessed using a separate menu that is included on each page, (e.g. plot plans for initial, ultimate, electrical, conduit, foundation, grounding layout and steel structure layout). Figure 2. shows a typical VRML scene within the substation.



**Figure 2.** 138/12kV Substation VRML Scene

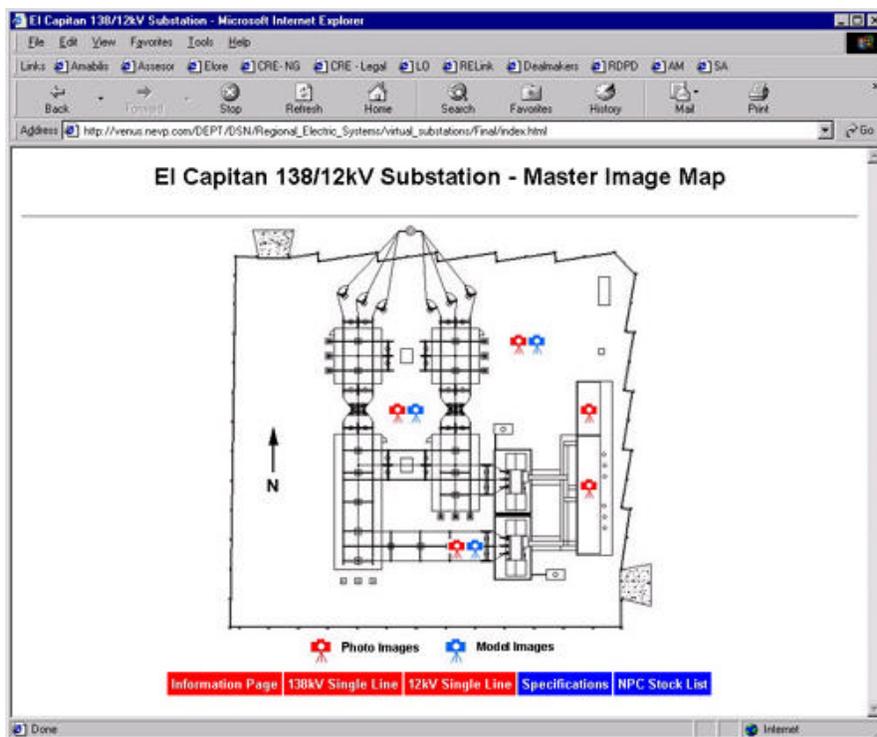
## **Case II. Panoramic Imaging**

In this case study an experimental web application will demonstrate how JAVA-based 360-degree immersive imaging can be used to access substation engineering design and construction data. This information is accessed from two types of panoramic immersive images; photographic images that provide access to as-built construction drawings and documents and 3D rendered CAD model images that access applicable Standards, Specifications and Compatible Unit design data. Recent advances in JAVA applet architectures relating to immersive panoramic imaging technologies allow a web viewer to explore detailed virtual environments. These applications move panoramic images from a flat, 2D format into a more immersive experience allowing the user to pan, zoom and navigate a virtual environment complete with interactive hyperlink components.

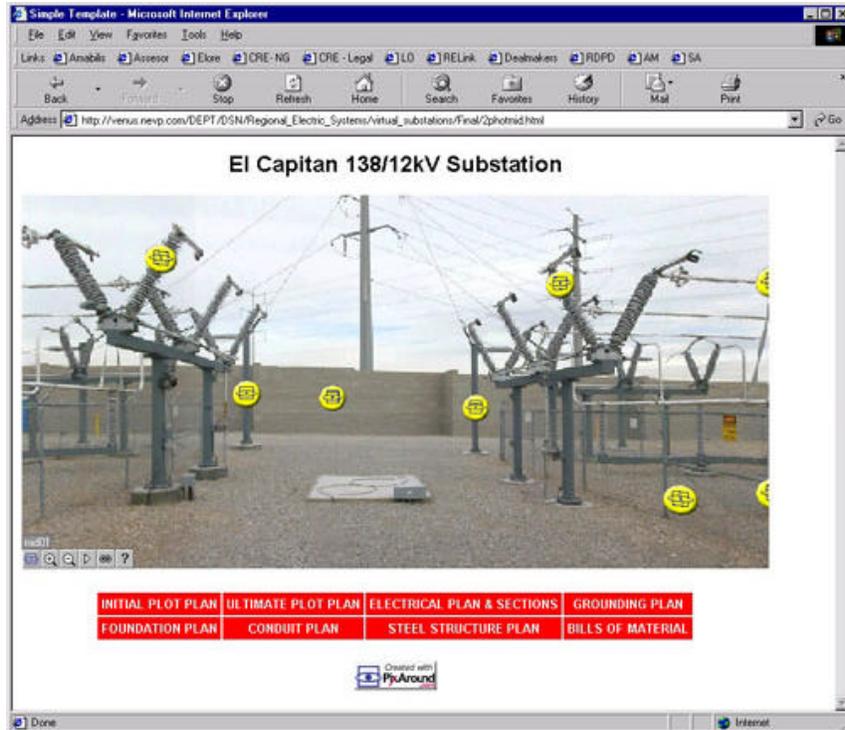
### **The User Interface**

The application's starting point is an interactive image map of the 138kV power substation's plot

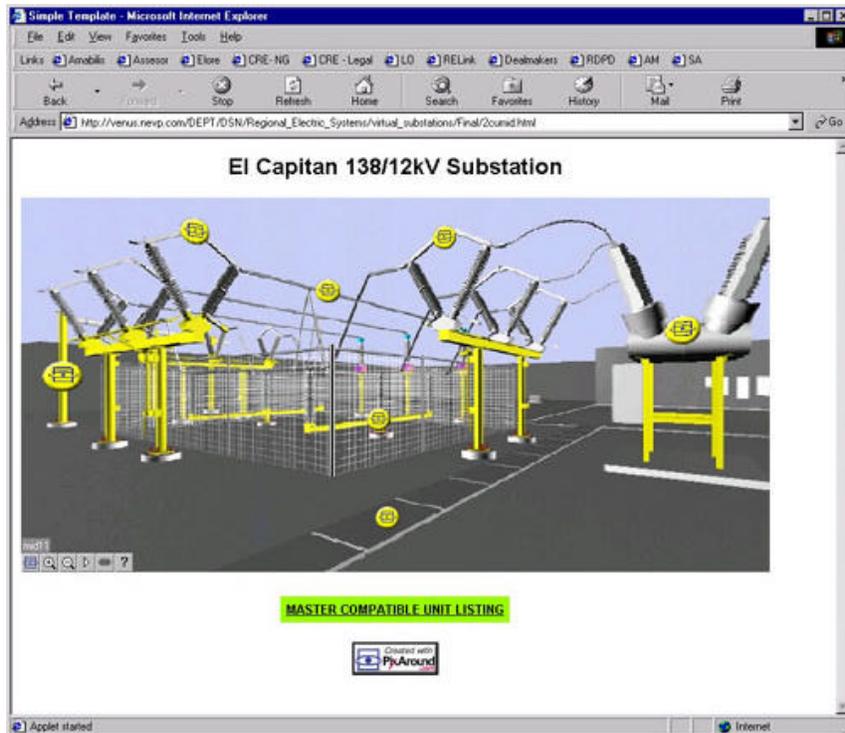
plan shown in Figure 3. From here the user can activate one of several immersive “camera” locations and enter 360-degree virtual views of the substation. These “cameras” allow a user to pan around from several key vantage points and navigate the power substation’s physical layout. By accessing embedded hyperlinks the user can access as-built construction drawings, material specifications and Compatible Unit data. The immersive images are of two types: those that view the as-built substation layout via the panoramic photographic images of the as-built substation and those that view the designed substation via a 3D CAD model. In the latter case the images are created from rendered views of the 3D CAD design model of the substation. Using the photographic immersive images of the as-built substation the user is able to hyper-link to all construction physical CAD drawings of the substation, connection diagrams, construction bills of material and manufacturer’s equipment drawings by clicking on hyper linked objects. Figure 4. shows a browser view of a substation photographic immersive image with hyperlinks. Drawings pertaining to the overall substation layout are accessed using a separate menu that is included on each page, (e.g. plot plans for initial, ultimate, electrical, conduit, foundation, grounding layout and steel structure layout). The other type of immersive image navigates the 3D design model and is used to access Compatible Unit Standards information. The user can click on objects in the virtual substation, (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. Figure 5. shows a browser view of a substation 3D model immersive image. 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 3.** Interactive Substation Plot Plan



**Figure 4.** Photographic Immersive Image in Browser



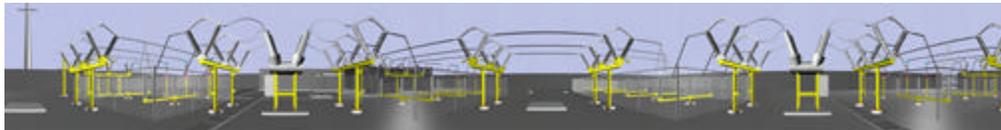
**Figure 5.** 3D Model Immersive Image in Browser

## **Panoramic Image Preparation**

The photographic images were created by taking a series of digital photos at several key locations in the substation, each covering a 360-degree pan. The digital images were then electronically “stitched” together. The application used to stitch the images was PixMaker 1.0 developed by Pixaround, a Singapore based company. Figure 6. shows a typical stitched photographic source raster image. This application produces a raster image that coupled with a JAVA applet can be viewed in a web browser. This browser-based image has additional zoom, pan and hyperlink capabilities. Creating the 3D model images required a more complex preparation process. An AutoCAD 3D physical model of the substation, (the one originally used to prepare physical construction drawings), was imported into 3D Studio MAX where materials and textures maps were applied. Next virtual cameras were created with focal lengths identical to those of the cameras used for the photographic images. Rendered stills were generated using the virtual cameras covering 360-degree pans. Pixmaker was again used to stitch a raster source image which is shown in Figure 6.



**Photographic Panoramic Source Image**



**3D Model Panoramic Source Image**

**Figure 6.** Source Panoramic Raster Images

## **Access to Substation Engineering Documents**

Both the VRML and interactive panoramic substation models allow access to several types of NPC substation engineering documents via embedded Hyperlinks. These include 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 7,8,9 and 10 show typical engineering data that is accessed.

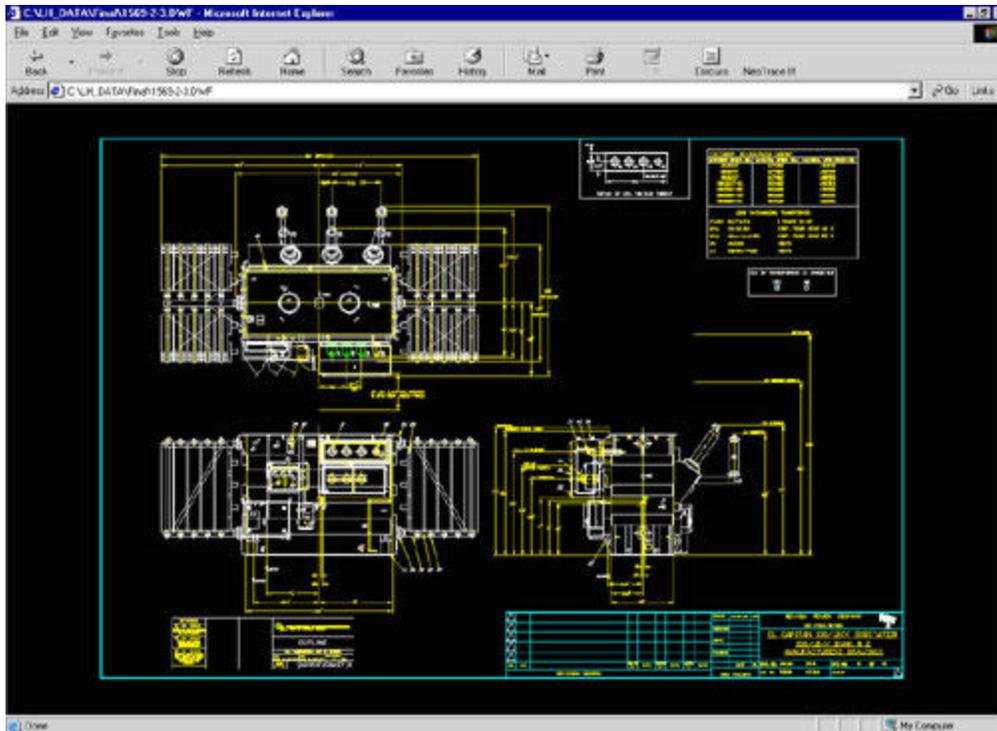


Figure 7. 138/12kV Transformer Physical Outline Drawing

The screenshot shows a web browser window with the address bar displaying 'C:\H\_DAT\Paper\1562-10-1.dwg'. The main content area contains a large table with multiple columns, likely representing a Bill of Materials (BOM) for a substation construction. The table lists various electrical components, their quantities, and specifications. The table is rendered in yellow lines on a black background.

NO	DESCRIPTION OF MATERIAL	UNIT	QUANTITY	REMARKS
1	...	...	...	...
2	...	...	...	...
3	...	...	...	...
4	...	...	...	...
5	...	...	...	...
6	...	...	...	...
7	...	...	...	...
8	...	...	...	...
9	...	...	...	...
10	...	...	...	...
11	...	...	...	...
12	...	...	...	...
13	...	...	...	...
14	...	...	...	...
15	...	...	...	...
16	...	...	...	...
17	...	...	...	...
18	...	...	...	...
19	...	...	...	...
20	...	...	...	...
21	...	...	...	...
22	...	...	...	...
23	...	...	...	...
24	...	...	...	...
25	...	...	...	...
26	...	...	...	...
27	...	...	...	...
28	...	...	...	...
29	...	...	...	...
30	...	...	...	...
31	...	...	...	...
32	...	...	...	...
33	...	...	...	...
34	...	...	...	...
35	...	...	...	...
36	...	...	...	...
37	...	...	...	...
38	...	...	...	...
39	...	...	...	...
40	...	...	...	...
41	...	...	...	...
42	...	...	...	...
43	...	...	...	...
44	...	...	...	...
45	...	...	...	...
46	...	...	...	...
47	...	...	...	...
48	...	...	...	...
49	...	...	...	...
50	...	...	...	...
51	...	...	...	...
52	...	...	...	...
53	...	...	...	...
54	...	...	...	...
55	...	...	...	...
56	...	...	...	...
57	...	...	...	...
58	...	...	...	...
59	...	...	...	...
60	...	...	...	...
61	...	...	...	...
62	...	...	...	...
63	...	...	...	...
64	...	...	...	...
65	...	...	...	...
66	...	...	...	...
67	...	...	...	...
68	...	...	...	...
69	...	...	...	...
70	...	...	...	...
71	...	...	...	...
72	...	...	...	...
73	...	...	...	...
74	...	...	...	...
75	...	...	...	...
76	...	...	...	...
77	...	...	...	...
78	...	...	...	...
79	...	...	...	...
80	...	...	...	...
81	...	...	...	...
82	...	...	...	...
83	...	...	...	...
84	...	...	...	...
85	...	...	...	...
86	...	...	...	...
87	...	...	...	...
88	...	...	...	...
89	...	...	...	...
90	...	...	...	...
91	...	...	...	...
92	...	...	...	...
93	...	...	...	...
94	...	...	...	...
95	...	...	...	...
96	...	...	...	...
97	...	...	...	...
98	...	...	...	...
99	...	...	...	...
100	...	...	...	...

Figure 8. Substation Construction Electrical Bill of Material

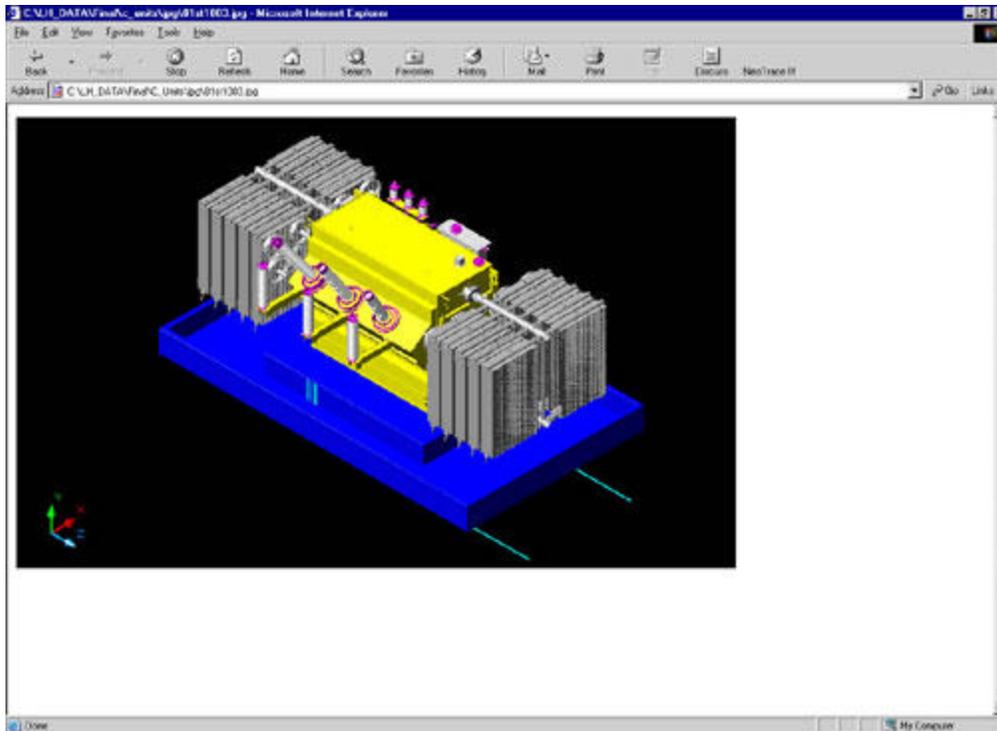


Figure 9. 138/12kV Transformer Compatible Unit Model

Compatible Unit Bill of Material - Microsoft Internet Explorer

Address: C:\H\_DATA\Fac\c... \1381103.htm

### Compatible Unit Bill of Material

CS NO.	COMPATIBLE UNIT DESCRIPTION	SKU	UNIT DESCRIPTION	QTY	UNIT COST	SUBTOTAL
13811001	138/12KV TRANS INSTALLATION (CONCRETE)	990011	TRANSFORMER, LOW PROFILE, 138/12KV, 50MVA, 6000000VA	1	\$726,000.00	\$726,000.00
		1447	P * MOLD, PARTIAL, 1/2" DIA 300MM TO 600 MM SPEC. SC-5	4	\$107.50	\$430.00
		1777	CONDUCTOR, BARS, 300 X 10MM, COPPER, 2 STRAND, CLASS B	1000	\$1.00	\$1,000.00
		1785	P * PART, TOOL, 3/16" DIA, SPEC. SC-5	10	\$4.00	\$40.00
		1449	P * MOLD, PARTIAL, 1/2" DIA 300MM TO 600 MM SPEC. SC-5	4	\$71.04	\$284.16
		7006	HANGER, CONDUIT, 3/4" DIA, 1" ROD, INCL. 1/2" DIA	4	\$0.24	\$0.96
		990002	FOUNDATION, CONCRETE FOR 138/12KV TRANSFORMER, CONT.	1	\$25,202.00	\$25,202.00
		1779	CONDUCTOR, BARS, 300 X 10MM, ALUM, 37 STRAND, CLASS AA	80	\$1.01	\$80.80
		1781	P * CONDUIT, 2" PVC, SCH 40, 10' SPEC. SC-13	1(2)	\$0.20	\$0.40
		990008	FOUNDATION, CONCRETE FOR 138/12KV TRANSFORMER, CONT.	1	\$15,000.00	\$15,000.00
		2142	W.D. COMPRESSION, CABLE TO PLAT, 3/4" DIA, 1/2" DIA	4	\$15.12	\$60.48
		1602	P * WASHER, 1/4" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.00	\$0.00
		2207	P * NUT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$1.00	\$4.00
		1708	CONDUCTOR, BARS, 300 X 10MM, COPPER, 2 STRAND, CLASS A	20	\$0.78	\$15.60
		1609	P * NUT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.00	\$0.00
		1707	P * NUT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$13.77	\$55.08
		1708	CONDUCTOR, BARS, 300 X 10MM, COPPER, 2 STRAND, CLASS A	20	\$1.20	\$24.00
		1247	P * CLAMP, HANGER, 2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.40	\$1.60
		2008	P * BRACKET, MOUNTING, FOR A JOINT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$4.75	\$19.00
		1702	CONDUCTOR, BARS, 300 X 10MM, COPPER, 2 STRAND, CLASS B	10	\$0.27	\$2.70
		1613	W.D. LOCK, CONDUIT, 2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.79	\$3.16
		1606	P * NUT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.00	\$0.00
		1741	P * CONDUIT, 2" PVC, SCH 40, 10' SPEC. SC-13	2(1)	\$1.00	\$2.00
		1605	P * WASHER, 1/4" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.00	\$0.00
		2061	P * BUSHING, PLASTIC, 2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$0.60	\$2.40
		1092	P * CONDUIT, 2" PVC, SCH 40, 10' SPEC. SC-13	2	\$4.20	\$8.40
		2002	P * NUT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$4.65	\$18.60
		1441	P * MOLD, SEE CONNECTION, 300MM TO 300MM GROUND ROD	2	\$174.00	\$348.00
		2060	P * NUT, 1/2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	4	\$25.50	\$102.00
		1003	P * W.D. LOCK, CONDUIT, 2" DIA, 1/2" DIA, 1/2" DIA, 1/2" DIA	2	\$0.75	\$1.50
		2000	P * CONDUIT, 2" PVC, SCH 40, 10' SPEC. SC-13	4	\$1.40	\$5.60
		1904	W.D. COMPRESSION, CABLE TO PLAT, 3/4" DIA, 1/2" DIA	12	\$1.75	\$21.00
		2000	P * CONDUIT, 2" PVC, SCH 40, 10' SPEC. SC-13	2	\$17.00	\$34.00
		2000	P * CONDUIT, 2" PVC, SCH 40, 10' SPEC. SC-13	2	\$25.20	\$50.40
			TOTAL:			\$795,846.72

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

### 3.1 Physical Construction Drawings

The physical construction drawings are 2D AutoCAD drawings of the as-built substation. These were 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) [4]. One changes the 3D model to make physical alterations to substation while annotations and dimensions are revised by editing the associated 2D construction drawings. By placing objects in specific layers an array of physical construction drawings can be generated from the 3D model. NPC substation drawing categories are listed in Table 1 below.

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 HTML. For each Compatible Unit, (primary index), they consist of a unit description, NPC stock numbers, descriptions and quantities and a total cost for the complete unit. A batch report is executed to prepare the individual HTML bills of material and another is used to prepare a master Compatible Unit Listing.

#### Hyper linked 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. All other engineering documents and standards are displayed to the user in Adobe .PDF format using the Adobe Acrobat Reader plug-in.

#### Discussion

At the moment VRML allows users to navigate worlds and retrieve information but offers few opportunities for the user to alter the design. The future of VRML will likely lead to allowing

users to influence the virtual environment to a greater extent and allow greater multi-user functionality. A power utility's ability to develop a system of this kind with appreciable detail is dependent on the existence of 3D vector models of its substation facilities, apparatus and equipment. A small but increasing number of utilities create 3D vector models as part of the engineering design process. If such information exists a VRML world application is much easier to create. Otherwise a 3D model of each substation will need to be created.

One advantage of interactive photographic panoramic imagery is that it provides an undisputable accurate record of the as-built substation. The development of such a system is not dependent on the existence or creation of a 3D model. The development timeline may be shorter as the interactive model is built by simply building a detailed photographic record of the substation. Its shortcoming is that a user may have to try several panoramic vantage points in order to find the information that they are seeking. Panoramic imagery also limits the user to a circular browsing at pre-determined locations. This can be frustrating especially if the user is seeking information in a confined space, (e.g. switchgear relay panels). A major advantage of VRML browsing is the user's ability to freely navigate the entire substation facility.

## **Conclusion**

These applications create economical, information-rich visual data maps of HV power substations. Technical and non-technical users of these applications will have the ability to retrieve engineering design data by simply selecting the applicable substation apparatus and equipment. In addition, these applications are quite economical. The user can view complex design drawings, bill of material data and engineering resources without having CAD or relational database applications installed on the client workstation. Workstations onto which the applications are installed require an Internet web browser and three installed plug-ins: a VRML browser, Whip! and Adobe Acrobat Reader. Cost savings in staffing can also be realized as non-technical users can access substation technical information in a simple visual manner.

## **References**

- [1] Broll W., Koop T., VRML: Today and Tomorrow, *Computers and Graphics*, vol. 20, no. 3, 1996, p.1
- [2] Walsh, A.E. and Bourges-Sevenier, M., *Core Web 3D*, Prentice Hall PTR, NJ, 2001
- [3] Walsh, A.E. and Bourges-Sevenier, M., *Core Web 3D*, Prentice Hall PTR, NJ, 2001, p.188
- [4] Autodesk, *AutoCAD 2000 User Manual*, Autodesk, Sausalito, 1999

## **Contact Information**

Larry D. Helwig, P.Eng  
Senior Design Engineer, Substations  
Nevada Power Company  
6226 West Sahara Ave. M.S. #10  
Las Vegas, Nevada 89151  
Tel. (702) 227-2318  
Fax (702) 367-5489  
Email: [helwig@ieee.org](mailto:helwig@ieee.org)

## **Biography**

Larry Helwig is a Senior Substation Design Engineer at the Nevada Power Company in Las Vegas. He is an IEEE Member and a licensed member of Professional Engineers Ontario, (PEO). His main areas of work are substation design, engineering design application development, substation Standards Intranet technologies and CAD systems. In terms of applications his major tools are AutoCAD, Visual Basic, Access, VRML and 3D Studio MAX. He received a Bachelor of Applied Science and Engineering from the University of Toronto, Canada in 1986. Other interests include panoramic photography, computer graphics and digital amateur radio.