

Development of the Web-based Integrated Operations and Maintenance Management System Using Three-Dimensional Virtual Reality

Hyung-Jin Kim¹⁾, Tae-Hee Chang²⁾, Jae-Oh Song³⁾

1) Computer Integrated Engineering Lab., Plant Engineering Center, Institute for Advanced Engineering, Yongin, Korea

2) Wolsong Nuclear Power Plant Division, Korea Electric Power Corporation, Kyongju, Korea

3) Plant Engineering Division, Daewoo Construction Ltd. Co., Seoul, Korea

ABSTRACT

A web-based integrated operations and maintenance (O&M) management system using three-dimensional virtual reality (VR) has been developed for Wolsong Nuclear Power Plant in Korea. The use of this system has been found to be strong incentives to improve work processes and provide faster and more flexible access to the information needed to effectively manage and maintain the plant assets. This includes the initial engineering, design, and construction data as well as support to the long-term operations and maintenance. The VR files are converted from the 3 dimensional CAD models which include all of the fine pipes with less than 2.5 inches of diameter and even cable tray as well, and which were used in design and construction of Wolsong plants. A database including images, vector drawings, text files, and real time plant data has been built on the Windows NT platform. In addition to VR and DB, this system monitors key plant data such as radioactivity in the nuclear reactor building and vibration of turbine generator on power and yields the cost-effective O&M and high availability of resources.

INTRODUCTION

The competitiveness of preserve power service and making selection of a new site for nuclear power plant in Korea is a continual driving force for the improvement in plant performance and lower operating, maintenance, and administration costs. With the increase in the availability factor, the utilities supplement these difficulties. As competition heats up in the electric utility industry, cost considerations are becoming paramount. In particular, operations and maintenance costs have been rising rapidly as a proportion of the total electric utility expenditure. The relative importance of O&M expenses has been rising for more than a decade. At nuclear plants in Korea, for example, the O&M portion of power production outlays grew by more than 200% between 1990 and 1998 - to a level more than twice the increased rate of fuel cost component [1]. Figure 1 illustrates the average production costs in Wolsong.

There is no doubt that the advent of increasingly powerful information technology (IT) is changing the way we live and work. In every industrial and market sector, the use of new IT tools permits the evolution of work processes and practices that continuously strive for higher levels of efficiency, cost-effectiveness, reliability and safety. The Korean nuclear industry is no different. As the Korean nuclear industry matures, it has been recognized that greater emphasis must be placed on the plant operations and maintenance processes, as well as the IT systems and infrastructure supporting their implementation. Under the circumstances like this, Institute for Advanced Engineering (IAE), Daewoo Construction Ltd. Co. (DWC), and Korea Electric Power Corporation (KEPCO) have responded to these forces through the development of both a vision of integrated IT systems and a web-based 3D O&M management system as its prototype addressing all phases of nuclear plant operations and maintenance. This paper describes the web-based integrated O&M management system needed to manage both the operating plant data and maintenance to ensure the cost-effective, long-term viability of Wolsong nuclear power plant.

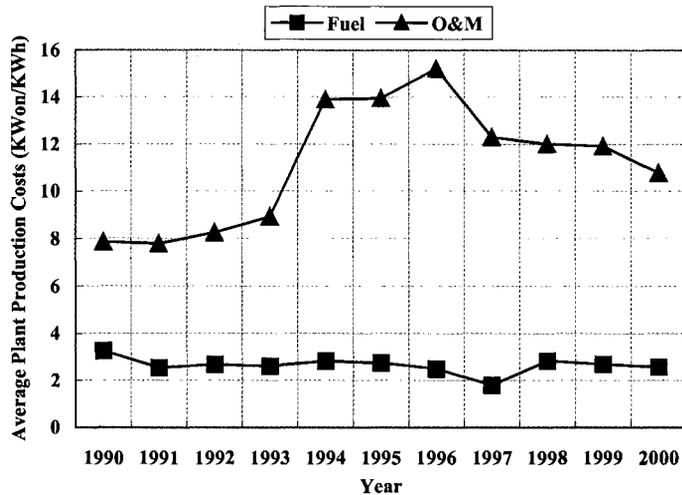


Fig. 1 O&M Cost vs. Fuel Cost in Wolsong Nuclear Power Plant

IDEAS ON HOW TO USE 3D CAD TO REDUCE O&M COSTS

IAE, DWC, and Atomic Energy of Canada, Ltd. (AECL) had developed 3D CAD models to use in design and construction phase of Wolsong nuclear power plant unit 3 and 4. These models were updated to reflect the 'as-built' status of the plant. The use of these models during the operating life of the plant was studied to be yield significant improvements in following areas [2-5]:

- Work Plan Preparation/Approval
- Operator Refresher
- Radiation Protection/Field Mapping
- Large Scale Outage/Replacements
- Abnormal Event Assessment
- Spare Parts Cross Reference
- Single Source Training Material
- Wiring/Connection Diagram Access
- Work Report Interface

In the point of work plan preparation, technical support staff members who prepare, review, check and approve the maintenance work plans can do the actual configuration to facilitate the preparation of complete and correct work plans. In this area these models are used for an independent perspective and evaluation of critical work plans, contingency plans, and backout plans. This can be particularly useful if a very experienced person leaves the site and is replaced by a relatively junior, less experienced person.

Field operators can review the configuration of infrequently used, high-importance component prior to applying an isolation permit to optimize the isolation procedure and eliminate incorrect or incomplete isolations. Also the participating maintenance worker can review the work plan and walk through the 3D CAD model to ensure full understanding of the task at hand and confirm the functionality and completeness of the impending maintenance task.

Radiation work plans with the 3D CAD models can be evaluated by the station health physicist to ensure that radiation

fields, distances, potential sources, corridors and access paths are consistent with the known station data. Also these models can be linked to the station radiation detectors to provide an integrated station field map. This can be of use in maintenance planning, emergency preparedness, licensing discussions, radiation training, etc.

Large scale maintenance or test jobs require extensive coordinating among many disciplines, some of which require special equipment with specific delivery or access time requirements. All of these kinds of jobs are simulated before starting the main jobs. The followings are some of the job examples that the 3D CAD can be applied:

- Prior to dispatching staff, review the anticipated area equipment to optimize staff time, minimize potential radiation exposure, and decrease the time at risk for the staff.
- Link the 3D CAD model to the station stores inventory to make a user-friendly means of directly accessing related components and devices replacements along with any categorization, qualification or quarantine information.
- Provide exact, correct training material display information with a minimum of training developer overhead. The same source is used for physical display information for different disciplines.
- Link the 3D CAD model to the station electrical wiring system database so as to provide direct and user-friendly access from the physical device, the terminal strip, or wire connection diagram.
- Link the 3D CAD model to the related work report entries to flag past practices what worked and what did not work. In this way, the workers do not lose the experience of one staff member when that person leaves the site for job opportunity, promotion, retirement, etc.

DESIGNING AND BUILDING THE SOLUTIONS

Application Model

One of the first decisions that must be made when designing a solution for this system is which type of solution is appropriate. It is common today for architects to classify logically all designs containing more than two tiers under the common descriptor of n-tier. In three-tier client/server architecture we have chosen, three layers are based on the services model, which is a way of designing an application as a set of specific functionality that is used to fulfill client requests. By modeling the application this way, a higher level of reuse can be achieved through better code and component reuse [6-7]. The three categories of services in this typical three-tier application are shown in the Figure 2.

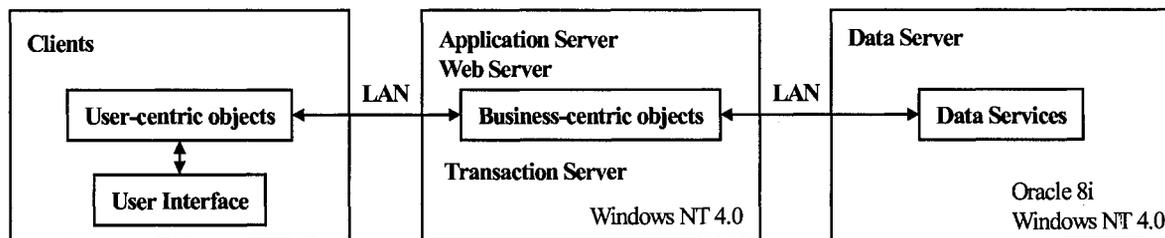


Fig. 2 Three-Tier Client/Server Architecture

User-Tier

The user layer in Figure 2 is the user interface of O&M management system that we have developed. It provides the visual representation of data collection and display. In this layer, the interface is divorced from any implementation of the business logic. The user-centric objects shown on the user's workstation manage the attributes and methods necessary to

provide a faster performing user interface. The goal of this architecture is to cut back on the number of round trips made across the LAN every time the user interface needs to validate some information. It does this while still keeping the user interface ignorant of business rules. This keeps the user interface thin and easily transportable to different technologies.

A web browser is a basic platform for the client. The users of this application are people who work at the Wolsong nuclear power plants and are familiar with using the tag number. Therefore, the interface for a service can basically be a 3D graphics or a text input (tagging number) to give a user-friendly feature. To give a 3D interface in a web browser, virtual reality files that use '.wrl' extension have been developed from the 3D CAD models which were already used during the engineering design and construction phase of Wolsong nuclear power plant unit 3 and 4. First, these models have been separated into component parts using MicroStation® according to the basic system index (BSI) that is the standard numbering system used in CANDU type plants. Next, each of these files with extension of 'dgn' were converted into the virtual reality files with extension of 'wrl'. A hierarchical file control system can merge these child files into a single parent file. Users can walk-through this system and zoom a specific component in and out. Figure 3 illustrates the graphical user interfaces that are the main page of the system and application pages.

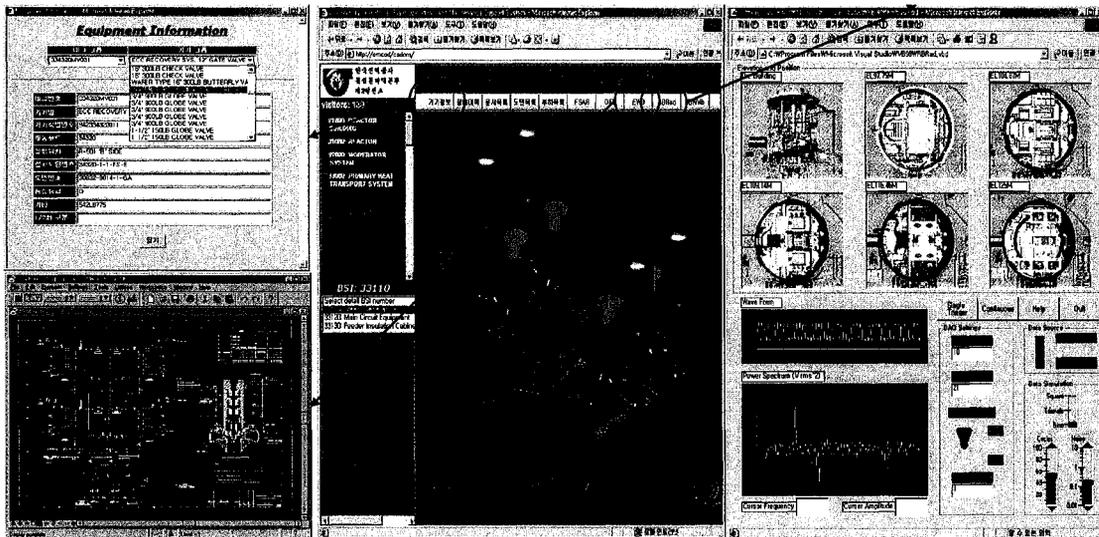


Fig. 3 Example of User Interface

Business-Tier

The business layer is where all of the business logic and rules in Wolsong plants are contained and can be shared. They have been encapsulated in the number of components and are responsible for servicing the requests from the user layer. They act as the liaison between the data layer and the user layer. When the user layer executes a specific task, the business layer is responsible for accessing the data layer and retrieving or saving the data with the appropriate business rules being applied or enforced. Because business rules can change, encapsulating them in components that reside in this layer allows for changes to occur without affecting the user layer or data layer. This allows for resources and object pooling, security, and all the other things that middleware such as Transaction Server and Internet Information Server (IIS) can provide. The workflow and data connection logic have been also included in this layer. A workflow process model is essentially a map of how work gets done in the context of the new solution – that is, who does what, who needs permissions to do what, and so on. It is an extension of

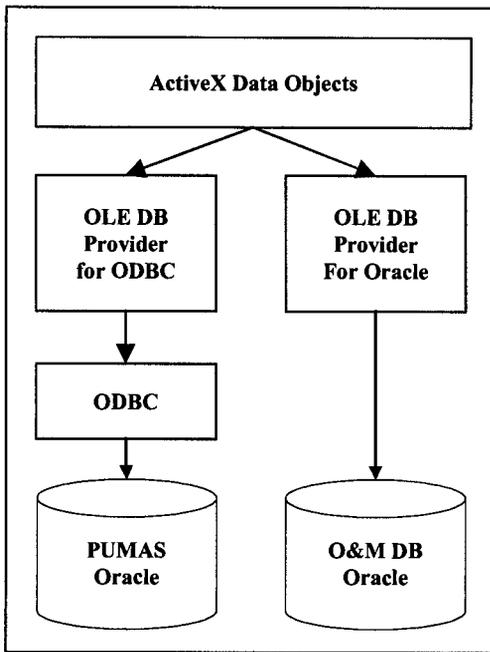


Fig. 4 ADO Communication with DB

the use cases we did in the analyzing requirement phase. It focuses around three types of entities: people, components, and the interactions between them [8].

Under Internet Information Server, an application is any collection of files in a directory whose properties can be set and that can run in a separate process space. Active Server Pages (ASP) that use '.asp' files are just one type of application that can run under IIS. The '.asp' extension tells the Web server that the page contains server script that it should process before returning the page to the browser. The main difference between ASP and HTML pages is the location where the script is run. DHTML, or client script, is run on the client, in the browser, after the page is sent from the server. ASP, or server script, is run on the server before the page is sent to the browser. Both ActiveX Data Object (ADO) and Object Linking and Embedding Database (OLE DB) have been used in data connection component to access data in either O&M DB or PUMAS. OLE DB is a system-level programming interface to diverse data sources. It specifies a set of Component Object Model (COM) interfaces that contain database management system services [9-10]. ADO provides a layer between the ASP and the underlying O&M DB or PUMAS and communicates with the database using OLE DB. It is made

up of three top-level objects: the Connection, Command, and Recordset objects. Each of these objects is created and destroyed independently of one another. Figure 4 shows how ADO communicates with the database in the business layer of this system. When we created an ADO Recordset object, the recordset was created on the server. This was referred to as a server-side cursor. According to our experiments, it has been measured to be expensive operation because it consumes server system resources. So, we have used SQL commands, instead of creating a recordset and using methods of the Recordset object.

Transaction Server has been used to get a new programming and run-time environment model that is an extension of the standard COM. The basic structure of the Transaction Server run-time environment involves several parts working together to handle transaction-based components. This architecture comprises one or more users, application components, and a set of system services. We have evaluated that approximately three hundred people in Wolsong site simultaneously access this system. And the application components have modeled two important activities of monitoring radiation field in reactor building and turbine vibration. These components that share the plant resources can also be packaged to enable efficient use of server resources. The following diagram, Figure 5, shows the structure of the Transaction Server run-time environment and the system services that support transactions [11].

Because of the ubiquitous nature of the Web, security issues can be much more complex than those of a typical file server environment. We have had to consider various aspects of Web technology and develop a security plan based on specific scenarios. Generally, the user's main concern is that the browser or the downloaded dynamic content does not endanger the user. Client compatibility is an important security concern, especially in a heterogeneous client environment such as the Web. For example, although plain text authentication is not as secure as the Windows NT Server Challenge-Response (NT/CR) mechanism [12-13]. For the server, the most important security concerns are to determine who can access this Web-based system, what files a user can access, and what type of access rights – read, write, or execute – the user has to. Secure communications and user identity are critically important for both client and server. Fortunately, we have

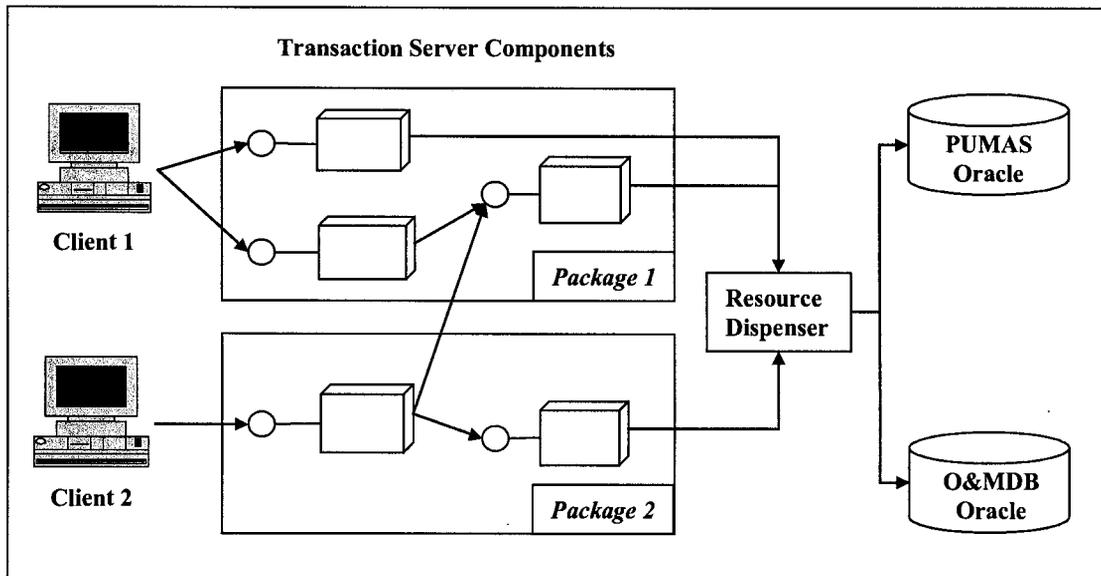


Fig. 5 Transaction Server Structure [14]

homogeneous users, and then we have implemented security using existing security features of both server and client – that is mixed security using Windows NT Server Security and Oracle validation. This kind of security proved useful in network environments that have a mix of clients, people who have different jobs but have the same aim. For those users that support trusted connections, Windows NT validates logins. For those users that only support non-trusted connections, Oracle validates logins.

Data-Tier

The data layer is responsible for maintaining, accessing, and updating data, based on requests from the business layer. These services may consist of one single data store, such as Oracle® or some other database, or they may be comprised of a variety of sources. For example, to fulfill a client request, the business layer may be requesting data from the data layer that actually resides in a database, a mainframe computer, and a collection of other non-heterogeneous database [15]. However, none of this is important to the user layer; all it's concerned with is using the business layer to request services. Separating the data layer from the rest of the application allows changes to be made to the data layer without affecting the user layer or the business layer. In this system, we have used two databases built in Oracle, the one is PUMAS and the other is OMDB. The former is one already existed in KEPCO, where it has all of the equipment information and maintenance history. The later is a new one, where it has operation flow diagram, electric wire diagram, load list, drawing list, document list, FSAR, and 3D VRML files, etc. Figure 6 illustrates the series of events that might occur when a user needs to know the total number of trouble report (TR) issued on a given date. In step 1, we see the application calling the `getNumberOfTR` method via COM or DCOM. The data-tier component creates the appropriate database query, and in step 2, this query is sent to the database engine using OLD DB and some proprietary networking protocol. The response process begins with step 3, where the database engine returns a recordset containing the requested data. In this case, the data is a single row with a single field because this is all that was requested by the component. The data component extracts the contents of this record and uses it in step 4 as the return value for the original method call. A fine line exists between the kinds of validation that are appropriate at this level and those that typically take place at the business-logic level.

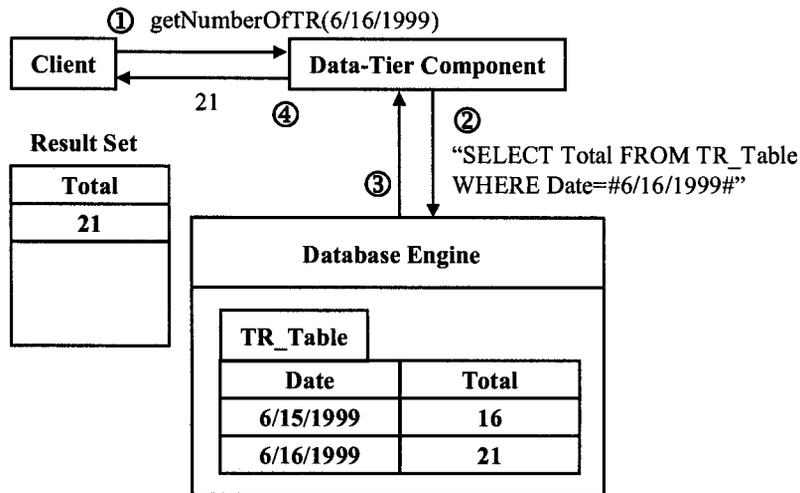


Fig. 6 Data-Tier Component in Action

The Benefits of the Three-Tier Service Layer Approach

Encapsulating and separating the functionality of the user interface, business logic, and data services into their own layers provide several benefits. The separation slows changes to be made to the individual layers without affecting the other layers. There are other benefits. Due to COM standards, application components are language-independent. Database connections and resources are utilized more efficiently, since the database is interacting with only the application components and not all of the clients. Security is enhanced and simplified since access is done on a component basis and not by all the client applications. The middle-tier components are accessing the resources and therefore can be controlled more easily. Accessing resources external to the application also becomes simplified, as this can be encapsulated within an application component. External resources become application components in the eyes of the client application. Such details are now transparent and can be modified with no impact on the other layers.

SUMMARY AND CONCLUSIONS

The web-based application of 3D CAD to an O&M has been developed for CANDU type Wolsong nuclear power plant from January 1999 to March 2000. Since the easiest way, we believe, to achieve success within a given period is to follow in the successful footsteps of the others, we have followed Microsoft Solution Framework in all phases of this project and also used Microsoft Products in the development phase except for the database.

The key functions of this system are as follows:

- Enabling the users to walk-through plant system via 3D virtual reality in their desktop
- Enabling the staffs or operators to prepare, review, check, approve, and simulate their jobs both prior to and after the work
- Monitoring radiation field in reactor building and turbine vibration
- Accessing all kinds of plant data from the 3D VR or independent requesting, etc.

The use of this system provides several benefits that help making the maintenance processes more efficient. First, transfer times between activities are minimized. Second, pre-defined rules and flows are rigorously followed and can be

tracked, measured and traced. Third, controllers have tools to monitor the accurate and up-to-date view of all ongoing activities. Fourth, all staff categories are guided in their work, and automatically receive the newest guidelines. Fifth, all support applications are integrated within a consistent framework and shown as a seamless set of functions to users. Sixth, evolution of processes and IT support is directly supported. And finally, it gives a cost-effective O&M and higher availability of resources. As shown in the Figure 1 on the page 2 we confirm the trend of decrease in O&M cost in 1999 - 2000 period, although more quantitative data collection is required.

On the line of extension of this project, we still have a good job to develop an online core monitoring system for Wolsong plants. This system is based on the Reactor Fueling Simulation Program (RFSP) developed at the AECL and real-time plant information from Digital Control Computer (DCC). By the time this project is completed, we can reduce the fuel costs by using optimized fuel loading method and see evidently the effect of this system.

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