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CASE STUDY OF THE 3D MODEL IN ANGRA 3 PROJECT

Altair A. Faloppa[1], Marcos V. Elias[2] and Lutzian Widuch[3]
[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN – SP)
Av. Professor Lineu Prestes, 2242
05508-000, São Paulo, SP, Brazil
afaloppa@ipen.br;

[2] Eletrobrás Termonuclear S.A. - ELETRONUCLEAR
Departamento GTP – T
Rua da Candelária, 65 Centro – 5º andar
20091-906. Rio de Janeiro, RJ, Brazil
mvelias@eletronuclear.gov.br;

[3] AREVA GmbH
Engineering Methods and CAD Tools
Henri-Dunant-Straße 50
91058 Erlangen, Germany
Lutzian.Widuch@areva.com

ABSTRACT

The 3D modeling has been increasingly used in NPP – Nuclear Power Plant from its design to its life cycle management. This paper presents experiences and developments regarding the methods applied for 3D Model in the Angra 3 NPP design using proprietary software PDS® - Plant Design System, and complementary in-house software developed by ETN. A description of the adopted methodology in all disciplines such as piping, piping support, equipment, civil, steel structure, HVAC and electrical will be detailed. The PDS® system is a comprehensive, intelligent computer-aided design/engineering application for plant design, construction, and operations. The use of PDS® and the developed tools has resulted in optimization in the design process as well as the project execution. After the design phase during the erection, commissioning and start-up of the plant, the 3D Model will be strongly helpful to obtain basic data about plant components such as piping, supports, valves, equipment and pumps. They can be easily found, opened, visualized and their properties analyzed in seconds. A corresponding data-base can also provide several different information queries. Furthermore the detailed 3D Model in the as-built condition can be used during operation and in-service inspections, reducing maintenance costs and improving safety of workers. It can also be used as an additional tool in training new operators.

1. INTRODUCTION

The main objective of this paper is to present the experiences and developments regarding the methods applied in 3D - Three-Dimensional Model of the Angra 3 NPP - Nuclear Power Plant design.

The NPP Angra 2 and future Angra 3 are PWR - Pressurized Water Reactors. Angra 2 is a 1245-MW that began commercial operation in 2001 and the Angra 3 is a 1400-MW that is planned to start commercial operation in 2017. Both units were designed with German technology supplied by *Areva*, former *Siemens/KWU* [1].

The first applications of CAD – Computer Aided Design were for 2D - Two-Dimensional drafting and the systems were also capable of performing only 2D modelling. In mid-eighties following the progress in 3D modelling technology and the growth in the Information Technology and Hardware, 3D modelling systems [2] became very popular.

The Brazilian nuclear energy company ETN - Eletronuclear decided to use the state of art technology to project new plants in order to improve the design and information control. In final nineties the first draft of the present 3D project was done. Piping library, valves and supports cell library were elaborated by *Areva*, together with Brazilian engineers from ETN, based on software version available at that time. Since the first draft the 3D Model project was based on *Intergraph PDS*® – Plant Design System, that is a comprehensive, intelligent computer-aided design/engineering (CAD/CAE) application for plant design, construction, and operations [3], which runs on *Microsoft*® *Windows*®, under *MicroStation*® *Bentley*® CAD and *SQL Server*® *Windows*® database. In that moment it was their corporate standard software for 3D project.

The PDS® *Intergraph*® platform has helped EPCs – Engineering Procurement Construction and owner/operators deliver the best design possible and do it more efficiently to reduce the total installed cost of the project. Due to its capability and commitment to the industry, many leading engineering firms and owner/operators have selected PDS® as their corporate standard [3]. Nowadays, the software supplier *Intergraph*® offers also a new generation of 3D modelling programs as an alternative to the PDS® platform. For this model, due to the complexity of the installation and aiming at specific optimized solutions for a given discipline, the basic 3D software PDS® has been complemented by several other applications mentioned throughout this paper, which have been customized and integrated into the PDS® environment.

It is worth noting that a great part of the Angra2 NPP project was developed without 3D CAD application, because in the final eighties and early nineties this technology was not broadly diffused or available. Notwithstanding during the erection of the Angra 2 NPP, in mid 90s some complementary application based on 2D CAD *AutoCad*® *Autodesk*® were developed by ETN body engineering in Piping discipline like ISOs (*SimpleISO*) and Piping Supports (*BqCAD*). In early two-thousand the development of the application for Civil discipline (*Civil3D)* was initiated. Other auxiliary tools aiming database appliance were developed using *VBA* language under *MS Access*®.

So, the digitalization of as-built condition was conducted transposing documents drawings from paper to digital using customized software *AutoCad*® and complementary application. In the same way with the intention to design Angra 3 NPP based on as built result of Angra 2 NPP the first prototype of the 3D Model was being prepared. At this time, auxiliary tools software were developed in-house, all catalogue content was revised as well as the adopted methodology.

Initially aiming at testing the methodology, software and feasibility, one redundancy of the Reactor Building Compartment, including UJA (Reactor Building), UJB (Reactor Building Annulus) and UJE (Main Steam and Feed Water) was chosen to be done, which represents a quarter of the nuclear plant area. After the success of this initial phase, the owner ETN decided to implement the 3D Model in all Angra 3 nuclear area design, including reactor building UJA/UJB and the buildings UJE (Main Steam and Feed Water), UKA (Reactor Auxiliary Building), UKH (Venting Stack), UKY (Bridge to Auxiliary Reactor Building), UJG (Semi Gantry Structure), UQZ (Compensation Pit) and UJF (Equipment Gate Structure).

2. 3D MODEL METHODOLOGY

2.1. Deployment of the Methodology

A major undertaking such as a NPP project requires the implementation of an integrated management system directed to provide a single framework for the arrangements and processes to address all the goals of the organization [4]. In this way, to perform an interdisciplinary 3D Model aiming NPP design with quality, a complex organization of all range of data and documents was required to be developed for this project. According to their characteristics and previous project management definition in Plant layout the design was classified in disciplines for each building [5]:

- CIVIL: Including all Concrete Civil Structure;
- ELECTRICAL: including Electrical, , I&C, Trays and Supports;
- EQUIPMENT: including Vessels, Pumps, Tanks, Valves and others;
- HVAC: Including all Ventilation and Air Conditioning System;
- PIPING: Pipes and Instrumentation Line;
- SUPPORT: Pipe Supports;
- STEEL STRUCTURE: Including Steel Platforms and Monorail.

Each discipline was divided by delimited volumes in the building and then corresponding partial models were created in administration environment to be modeled [5]. Figure 1 shows an overview of the main software applied in 3D Model of Angra 3NPP and their application field.

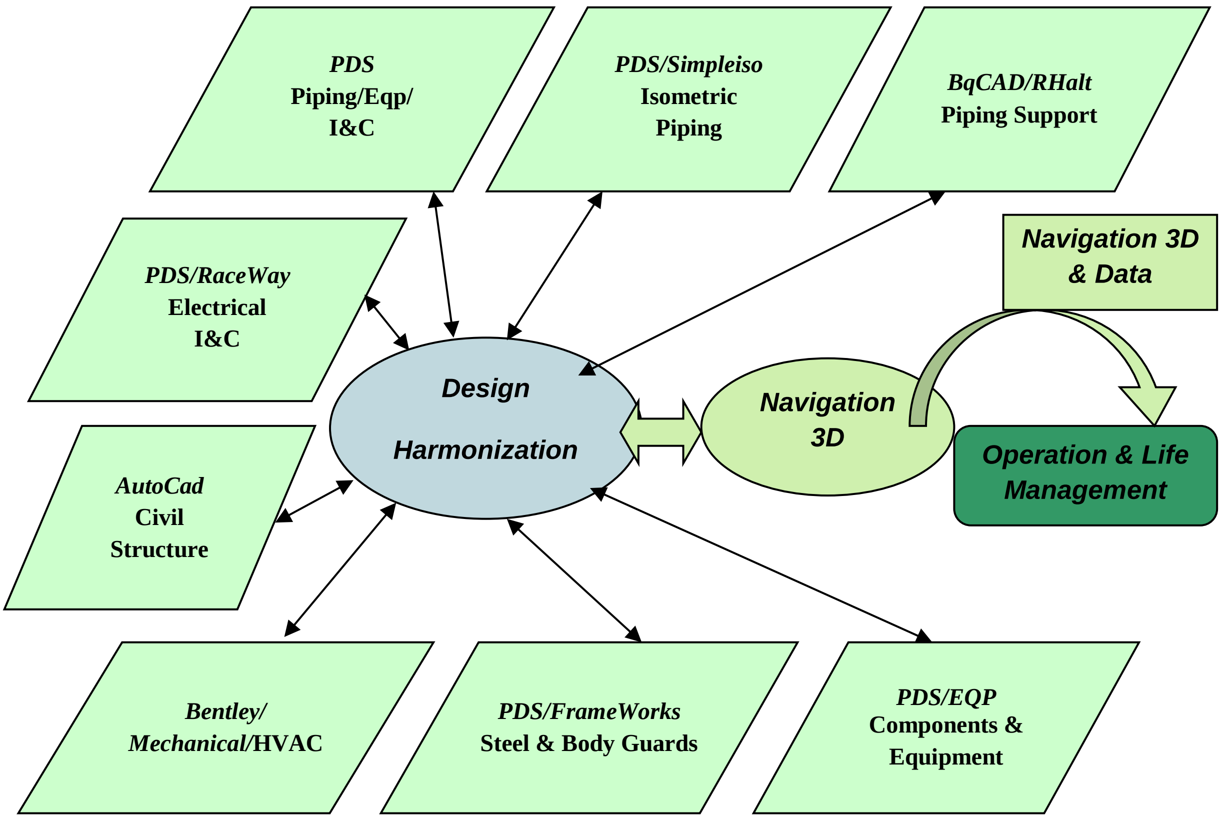

Figure 1 – Software and disciplines used on 3D Model

2.2. Information flow

As stated before, the modeling requires a complex organization of all data that comes from the various disciplines that make up the NPP. The Figure 2 [6] shows a scheme of this information flow used in whole project of Angra 3 NPP 3D design model.

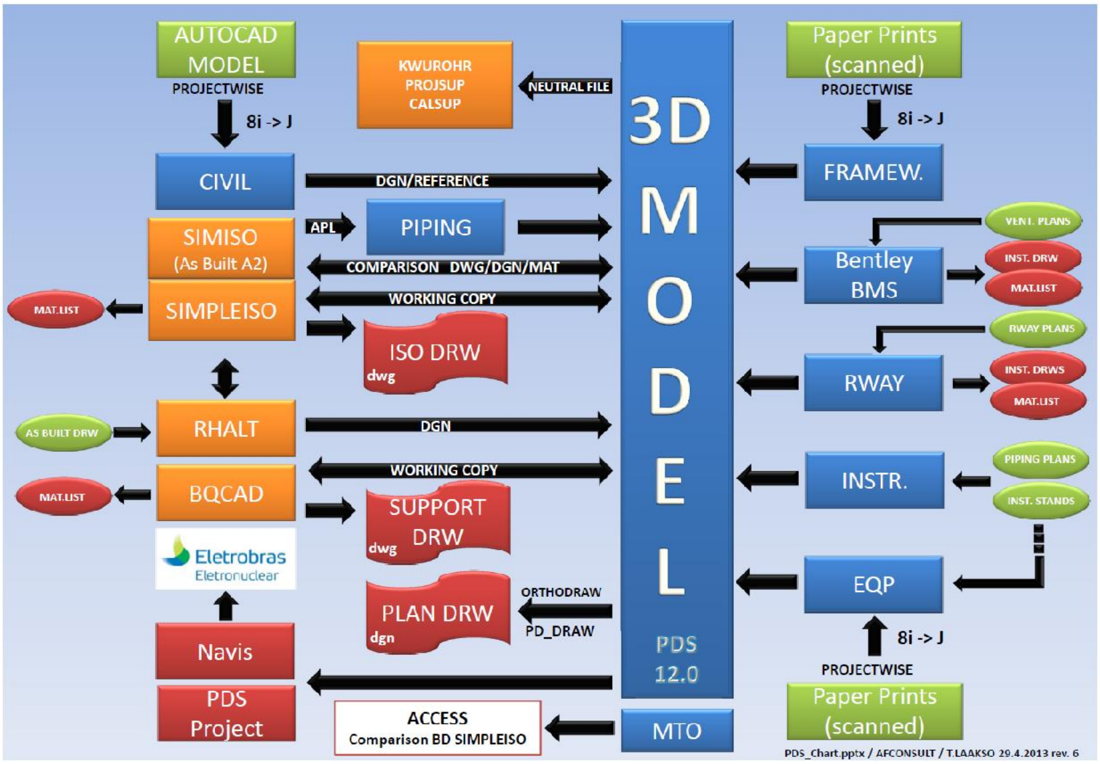

Figure 2 – Information flow organization

It is also worth mentioning that all software shares the same database server and are tightly interconnected, as shown schematically in Figure 2. The majority of data captured were obtained through as built 2D drawings and adding some project modifications.

Almost all applications used for modeling and also for the 2D drawings, either market license, or in-house development, generate several tables with specific information. It was therefore possible with own development to create general data-bases which integrate the information coming from the various sources. Queries from these data-bases are possible for several information purposes and even for the quality control of the model.

2.3. Applied Software Description and Results

As mentioned before, ETN chose *Intergraph*® PDS® as software of Angra 3 3D Model that runs under *MicroStation*® using data from Angra 2 as-built. The items below describe and mention the specific application and details applied in each disciplines.

- PIPING: Piping and instrumentation line;

The *Piping* application from PDS® platform was used to draw the piping and instrumentations lines. In order to improve the work, the most 3D isometrics were imported from Angra 2 as-built drawings previously done in 2D dimension by SimpleISO (in-house developed software based on AutoCad®) using the *APL – Alphanumeric Piping Language* application within PDS® in an automated process. In the 2D drawings generated with this application, there are coordinates and data information that could be transposed to 3D Model. Complex piping lines, additional piping lines and modifications are manually modeled. Figure 3 shows an example of this automated process and related data.

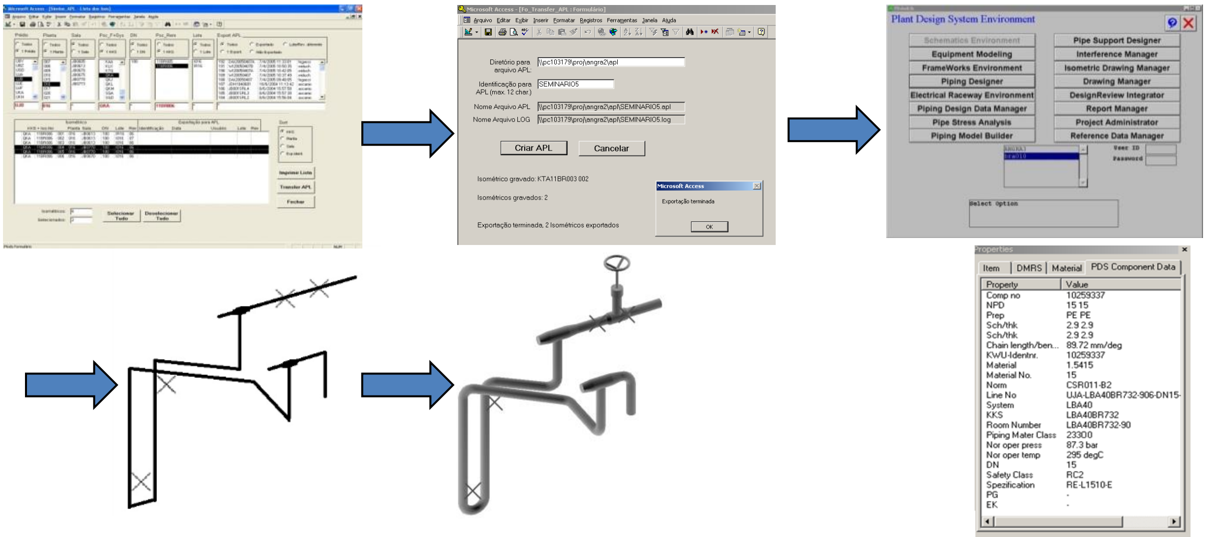

Figure 3 – Piping line and data information example

- SUPPORT: Piping supports;

The *AutoCad®* / BqCad and *MicroStation®/RHALT* [7] application used to model the components of this discipline were fully developed in-house. In the as-built digitalization process of Angra 2 all drawings, complement or modification of design were made using the *AutoCad®* / BqCad application. Applying a list of parts and cells corresponding to the support catalogue of the project, previously created, BqCad generated 2D drawings of fixing points and data to be used in the 3D Model. The *MicroStation®/RHALT* application imports data from 2D drawings of Angra 2 NPP and builds the 3D Model for the majority of simple piping supports in an easy widely automated way. Figure 4 shows an example of this automated process.

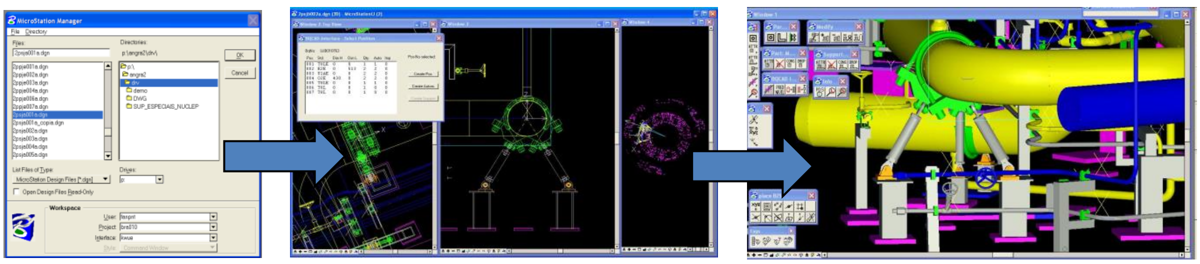

Figure 4 - Piping support process

Figure 5 shows, in navigation mode, a simple support and information such as support ID, coordinates, material list position, standard type, description, and material specification.

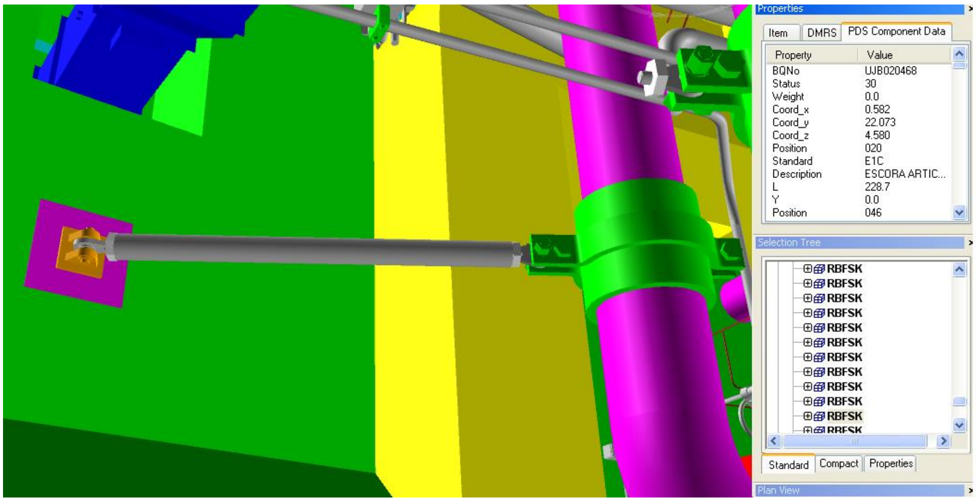

Figure 5 - Simple piping support and data information example

To build complex piping supports the application can be used in manual way adding complex parts and information by traditional tools of the MicroStation®. Figure 6 shows an example of complex sway-strut support.

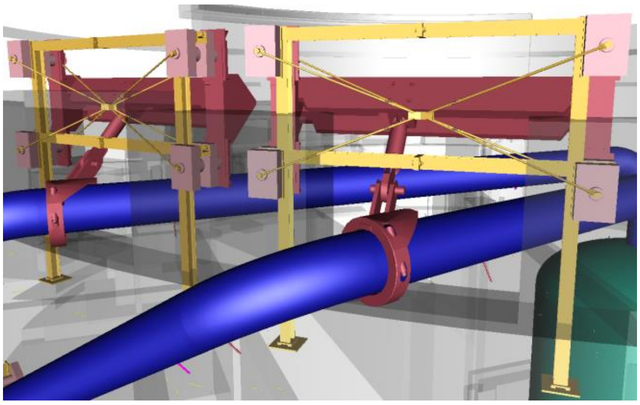

Figure 6 - Complex piping support

- EQUIPMENT: including all components like vessels, pumps, tanks, valves, monorail, rods, special parts and others.

The EQP application from PDS® platform was used to build all vessels, pumps, valves, tanks, valves stem extension, instruments, monorail and others. All equipment are modeled according to specification of Angra 3 NPP design and located in precision coordinates fitting with piping lines and civil structures. The equipment has specific information that was introduced in PDS® database such as equipment ID, type and localization.

Figure 7 shows examples of equipment such as pump and tanks.

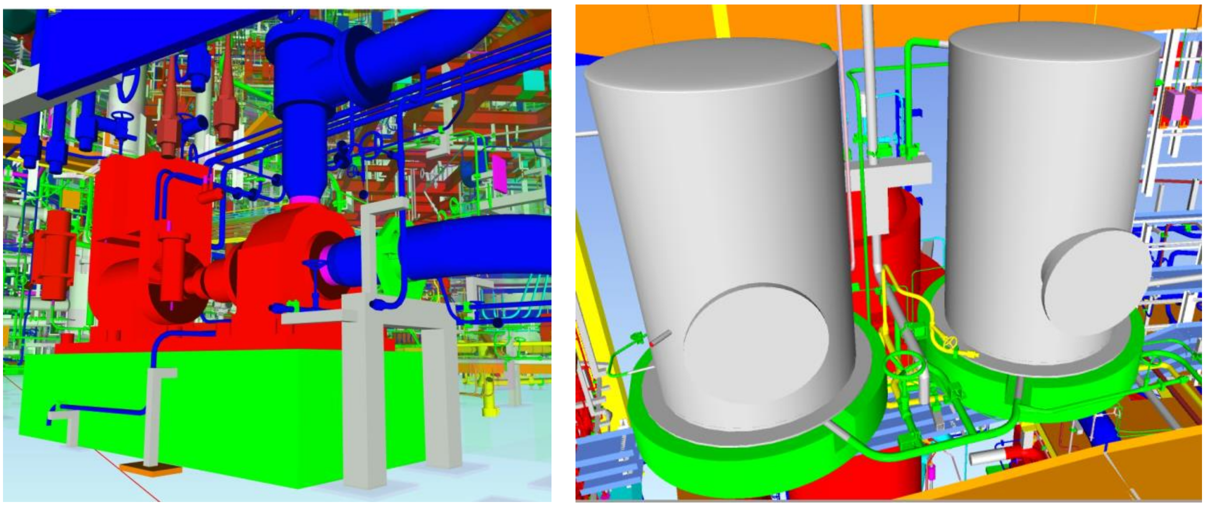

Figure 7 - Equipment

- CIVIL: Including all concrete civil structure;

As there could not be found a market solution to build complex 3D civil structures, including cylindrical and spherical walls with the possibility to apply embedded parts like anchor plates, ETN decided to develop software used to model this discipline. In this way the Civil3D [8] application running under AutoCad® environment was developed. This application permits to model all civil concrete structures of the buildings with their embedded parts in an easy way. An additional feature is the possibility to automatically import anchor plates from 2D drawings previously drawn and linked with SQL database that contain coordinates and properties. As there are about 40000 anchor plates in the plant, this feature reduces drastically the amount of modeling work and at the same time increases the quality by avoiding modeling errors. The built models are converted from AutoCad® to MicroStation® extension and attached in the PDS® 3D Model. Figure 8 shows an example of the civil structure modelling.

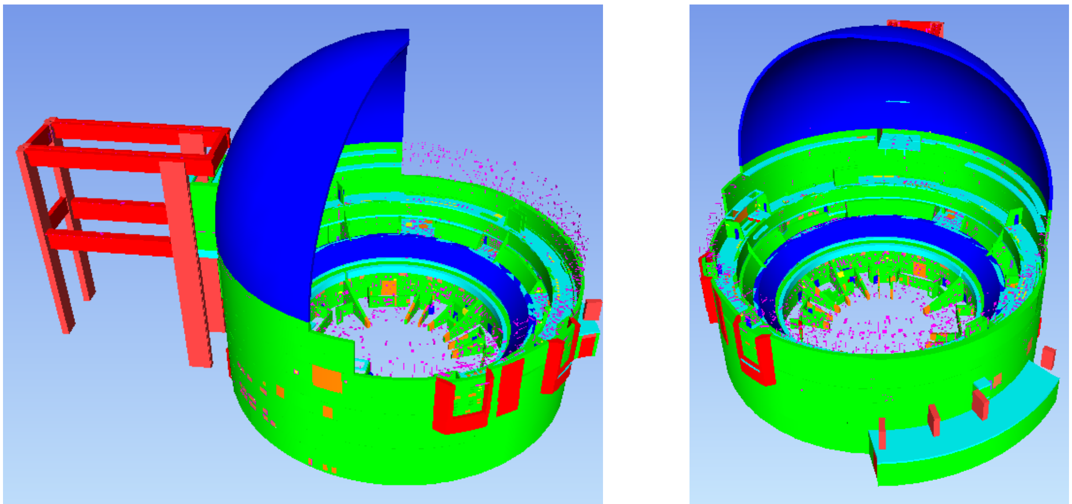

Figure 8 – Civil Structure and anchor plates

- STEEL STRUCTURE: Including steel platforms, monorail and body guards

The steel structure was fully modeled using the established Frameworks application from PDS® platform. This application creates the models fitting in coordinates previously defined by Angra 2 as-built drawings. The draftsmen built the model using all information contained in 2D paper drawings after Angra 3 NPP modifications. Figure 9 shows an example of the steel structure modelling.

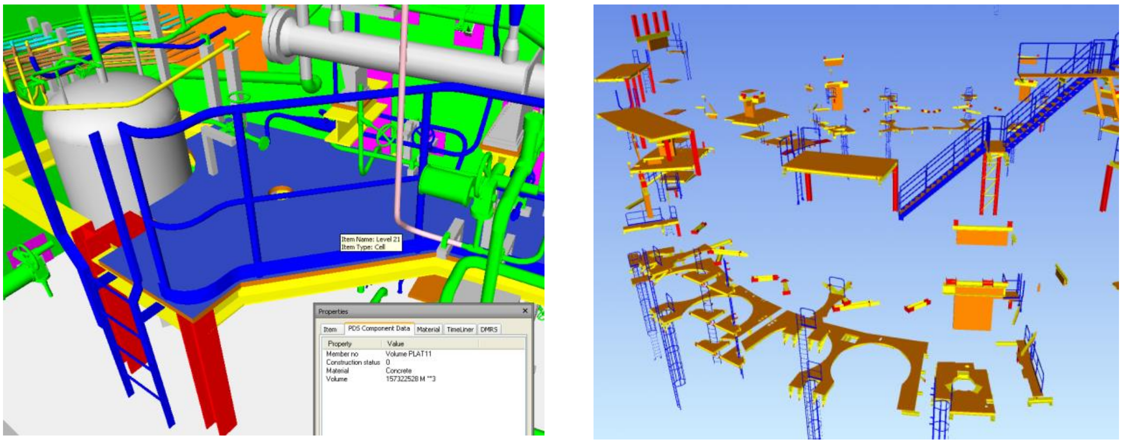

Figure 9 – Steel structure and body guards

- HVAC: Including all venting and air conditioning system;

The HVAC system including supports was modeled using the Mechanical® Bentley® software. Equipment of the HVAC system was modeled using the EQP application. Based on Angra 2 as built documentation and considering also specific Angra 3 NPP adaptations, all parts were modeled adding information such as supports ID, duct type and ID, location room and material type. Figure 10 shows an example of the ventilation and air conditioning modelling.

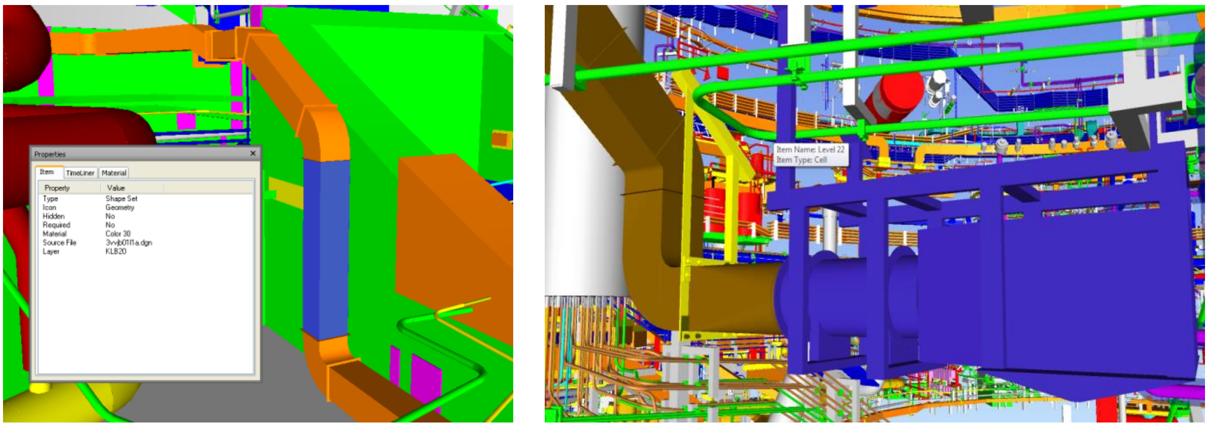

Figure 10 – HVAC –Ventilation and air conditioning

- ELECTRICAL: including electrical trays, I&C trays and supports;

The Electrical system cable trays were modeled using the Electrical Raceway application from PDS®. Electrical supports were modeled using *MicroStation*®. Special databases of raceways and supports parts were developed according to Angra 3 NPP specification and implemented in the project libraries. Tag numbers for raceway supports were included in the model. Figure 11 shows an example of the raceway modelling.

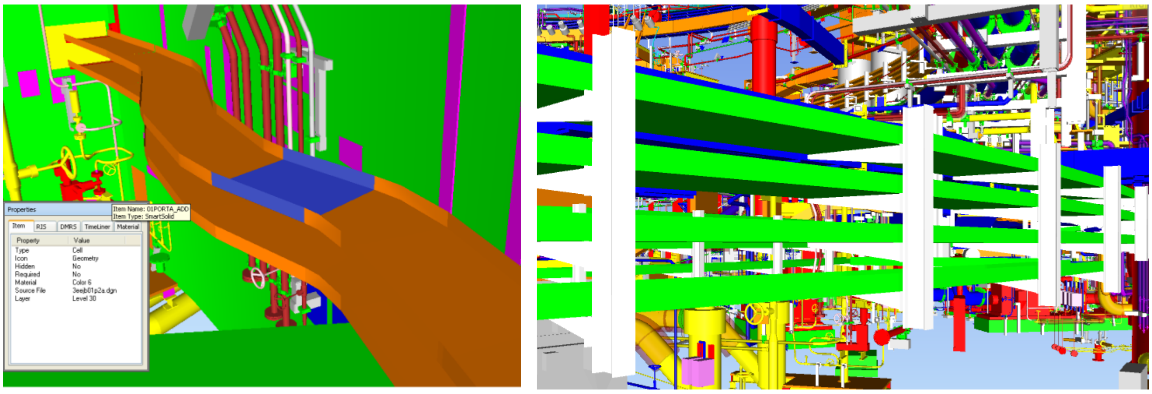

Figure 11 – Electrical cable tray and supports

- CLASH AND VISUALIZATION

Before 3D Model technology, the only way of finding interference was by looking at two dimensional drawings or 3D physical models (plastic model). The clash, interference checking and detection are a constant activity of the evolution of the 3D Model. All steps of activities from first draft model to final executive drawing of the 3D Model is consolidated by using clash tool of the *Autodesk*® Navisworks® software. In the same way the software is used to visualize models and properties of all items of the plant. Figure 12 shows an example of the identified clash and fly visualization.

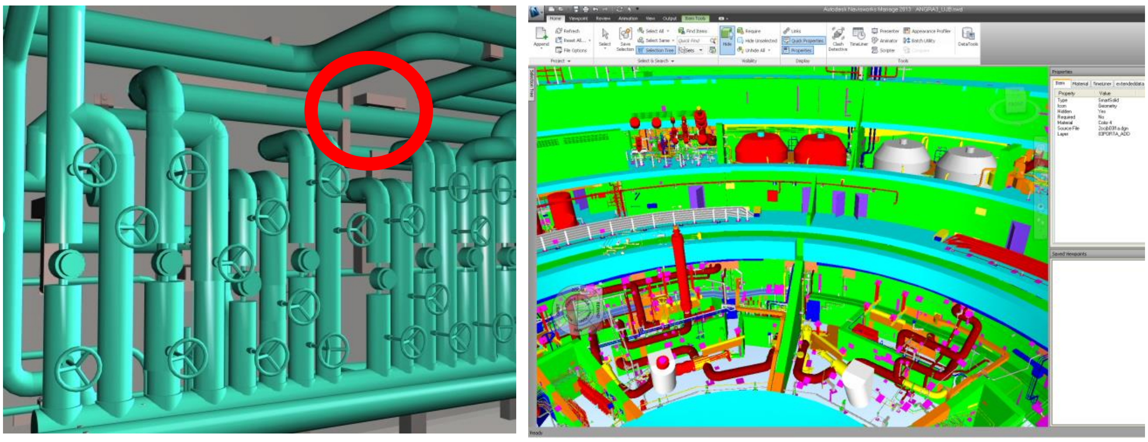

Figure 12 – Navisworks® Clash (red circle) and visualization

- DESIGN REVIEW AND QUALITY CONTROL

Concerning Design Review the program *Autodesk*®Navisworks® is used as a tool to identify items and parts. The program opens files from different origins together and identifies all properties creating a directory tree in an easy manner to manipulate. Because all data from the PDS® applications are shared with database SQL® system, the BDA Model 3D, in house developed application, can be used as data Quality Control from all information included in the 3D Model. The reference database comes from Angra 2 project including some Angra 3 inclusions and modifications.

One of the main issues when constructing such a huge 3D Model is to control the completeness of the piping installation with regard of the process flow diagrams. To face this problem the specific in house software, BDA Model 3D, has been created, which controls the evolution of the model, split by piping plans (3D volumes), and based on the reference information of piping, piping supports and a line list (flow charts).

Concerning piping, there is no automatic extraction of isometrics drawings, or support construction from the model. However, by using an integrated data-base "Fecha_planta" there is an automated cross checking of the material lists coming from the 2D drawings and the part codes included before in the 3D model, therefore assuring the correspondence with one another and contributing to the overall quality control of the model. Figure 13 shows an example of the visualization of the model and data base application "Fecha_planta".

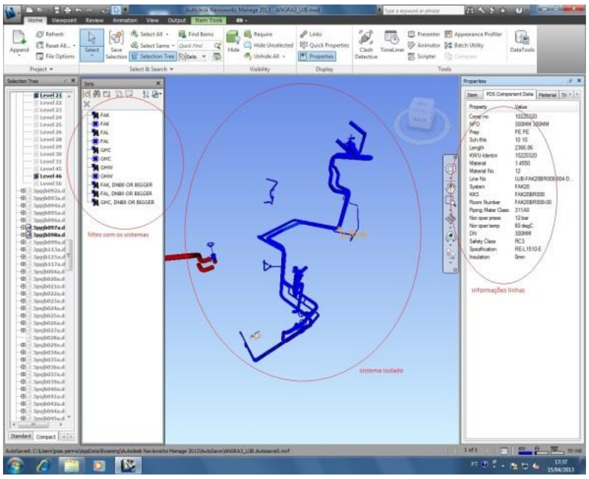

Figure 13 – Navisworks® and in-house quality control application

3. APPLICATION AND DISCUSSION

The 3D Model for design and as-built provide EPCs and owner a better detailed information of the design with virtual model of project design, this way 3D Model allows for identification of possible errors in design phase normally not possible to see in 2D plans. The final version of PDS 3D Model, all files and database will be used for erection planning aiming easier information access. For instance, in the piping line modeled, as defined in [5], any item can be identified by attributes, like part identification number, line ID and flow direction.

All 2D execution drawings will be extracted from the 3D Model. Execution plans in general such as piping, or ventilation will be extracted directly from the 3D Model. Isometrics and piping supports will be extracted through a 2D working copy with an additional compliance control by the "Fecha_Planta" application which verifies also material list, comparing the 3D Model with the 2D databases.

Table 1 shows an approximate quantity of the main items modeled in the Angra 3 NPP 3D Model.

Table 1 – Quantities of modeled items

Item	Quantity (unit)
Isometric	20700 (drawing)
Impulse Lines	1910 (part/line)
Piping Support	24400 (drawing)
Equipment	2120 (part/drawing)
Electrical Race Way	55 (plan)
HVAC Duct	67 (plan)
Steel Structure	580 (part)
Civil Structure	All buildings

The application of 3D Model was briefly discussed in previous items, such as to optimize the design process, finding clashes, the harmonization of disciplines and in erection process.

A good example of application is the use of 3D Model to extract data of main lines aiming producing isometric drawings for stress calculation being directly used by stress analysis program. This activity can be developed during the process of harmonization to promote a straight interaction between piping engineers, piping support designer engineers and draftsmen.

Another consolidated application that is described in [9] is the extensive use of the 3D Model linked with project tools such as market application Primavera® in the construction schedule.

After the design phase and during the erection, commissioning and start-up of the plant, the 3D Model is strongly helpful, a detailed 3D Model in the as-built condition can be used during operation and in-service inspections, reducing maintenance costs and improving safety of workers.

Developed with the latest technologies, 3D visualization integrated with virtual reality could be used as tool in operators training plans for visualizing plant dynamic characteristics and component behavior.

In early two thousand Bilalis [2] said "CAD systems have the ability to provide a digital prototype of the product at early stages of the design process, which can be used, for testing and evaluation. Many people from various departments can share it; they can express their opinion for the product at early stages, in order to complete the design in less time and with the least mistakes." Most researchers accept that having the digital prototype in early stages allows more effort to be spent on the definition stage (early stage) of the design process and not in redesigning an already completed design. For the last two decades EPCs and contractors have used 3D Models to improve their projects since design until Life Cycle Management establishing and implementing state-of-the-art of the methodology.

4. CONCLUSIONS

Recent advances in hardware and software of computerized visualization technologies have enabled an ever-increasing use of 3D Models. With respect to the Angra 3 project, the use of a 3D Model was also an important tool for consolidation and harmonization of the large amount of the reference information to be considered. All interfaces and functions were successfully implemented and used. With respect to the intervention and optimization on design tasks, several iterations have occurred in order to ensure the accuracy and quality of the design. At this moment, 2015, the 3D Model and project are being conducted by sub-contracted Engineering Companies under supervision of the owner ETN. The modelling of the electromechanical installation in the different buildings is more than halfway advanced.

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