The Latest Application of Hitachi's State-of-the-art Construction Technology and Further Evolution Towards New Build NPP Projects

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Abstract

Shika Nuclear Power Station Unit No.2 began commercial operation in March 2006 as one of the latest new-build projects in the world. Hitachi-GE Nuclear Energy Ltd. (Hitachi) was the main contractor and supplied the entire plant including engineering, manufacturing of all major reactor and turbine-generator components, and executed the installation and commissioning. Hitachi completed the project on schedule and on budget owing in large part to its highly reliable advanced construction technology.

This article describes Hitachi's unsurpassed advanced construction technology being applied to the current new-build projects in Japan. Furthermore, this article addresses a possible form of applications to new build Nuclear Power Plants in North America.

1. Introduction

Since the first nuclear plant was constructed in Japan in the 1960's, fifty-five nuclear power plants have been built, and one more plant is currently under construction by Hitachi. Hitachi has constructed twenty-two nuclear power plants (NPPs) in Japan to date, and has played an active role in the field of nuclear power plant construction. Hitachi's advanced technologies, such as a unique 3D-CAD based integrated plant engineering environment and streamlined design-to-manufacturing systems have been successfully implemented in past NPP projects.

Over the last few decades, the plant construction environment has changed in Japan dramatically. For example, the pool of construction workers has gotten smaller and smaller, while the average age of workers has increased. Moreover, customer demands for costs reduction and shorter construction periods continued to become stronger. Therefore, achieving greater rationalization in construction is one of the most important issues in power plant business.

To meet these demands, Hitachi has developed construction strategies based on the abundant feedback gained from NPP construction experience and has made great strides in the rationalization and application of this feedback into its strategies. The strategies are very simple in principle, however, their effectiveness has been absolutely proven through the successes of the past projects. In addition, Hitachi believes their strategies are equally applicable to any and all power plant projects, including CANDU.

Utilizing all of Hitachi's accumulated technology, one of the worlds latest new-build projects, Shika Unit No.2 (Shika-2) of Hokuriku Electric Power Company with 1,358MW electrical rated output, was constructed "On-Budget and On-Schedule".

The Shika-2 was the first ABWR plant in which all the major equipment, including the reactor, turbine and generator, were supplied and constructed were provided by one main contractor, Hitachi. As well, Hitachi took responsibility for the entire plant engineering support from the basic design through to commissioning. The construction started with the foundation excavation of the main building in September 1999, and 58 months following rock inspection, the plant was declared in commercial operation.

This paper describes the latest technology that Hitachi applied to the design and construction of this plant and which are being further enhanced at the current project in Japan.

2. Applied Construction Technologies

In the construction of Shika Unit No.2, the following strategies were employed.

(1) Broader application of large module/block construction methods

(2) Open-top and Parallel Construction method

(3) Application of floor packaging construction methods

(4) Full application of information technology to quality plant engineering and construction achievements

As a result, there was an approximately 25% reduction in the peak work load at site achieved due to these improvements to construction procedures in work areas where many construction tasks take place operated were implemented.

From the next paragraphs outlines the methodology and technology used to accomplish this reduction.

2.1 Broader application of large module/block construction method

Large module/block construction method is one of Hitachi's construction strategies. This method utilizes heavy-lift crane to lift and install large scale modules/blocks which can be constructed at either site or a module shop.

Figure 1 RCCV Upper Drywell Module

Hitachi has employed this method since the early 1980's to the construction of nuclear power plants, with a total number of about 900 modules experienced so far. During the design, a Computer Aided Engineering (CAE) system is fully deployed with special features dedicated to a specifically for module engineering (such as automatic center of gravity calculation and assembly planning). Hitachi routinely applies this specialized CAE systems to the overall module engineering, and constructed a dedicated module factory in 2000 which is fully integrated with the CAE system. By making the best use of these assets, about 200 modules were designed and built for Shika-2. The figure 1 shows an example of a large scale module (RCCV upper drywell module) which consisted of pipe whip restraint structure, radiation shielding, piping, valves and other components in the drywell, totalling 650 metric tons.

Another example is the main steam tunnel modules (55 metric-tons each) which were fabricated with special features that minimize weld edge preparation and simplifies installation and connection work by employing 3-dimensional data measurement feedback from the site. Thus, Hitachi applied modular/block construction method at large scale, and been continuing sophisticating their technology for future plants.

2.2 Open-top and Parallel Construction method

"Open-top and Parallel-Construction method" is often applied to NPP construction in Japan now, and it was applied to Shika-2 without hesitation. In the most basic aspects, in this method construction work of both civil and mechanical disciplines are conducted in parallel with mutual agreements of scope of work, and major components to be installed in the area are carried in prior to the ceiling work of that area being installed. After the curing of concrete in the ceilings and walls, the installation work within the target area starts. At the same time, major components are brought into the upper floor level. Thus during the construction of the building civil structure, mechanical/electrical installation work can proceed which therefore, enables a levelling off of manpower peak at the construction site. As one may expect, since various activities are implemented at the same time, this method requires very detailed coordination between civil contractors and mechanical/electrical installation companies including delivery control of components.

2.3 Application of floor packaging construction method

Traditionally, hydro-static pressure testing in completed power plant systems needs to be implemented after the completion of system construction, which inevitably led to work loads peaking at or near the end of construction. Hitachi has developed a new concept for this issue, named "Floor Packaging method", which allows partial hydro-static pressure testing prior to completion of whole system construction. Figure-2 shows the concept of the method. After completing construction in each floor, the partial pressure testing is undertaken in the range of closed area. Therefore, the work area can be sequentially closed from the bottom floor, which helps a great deal of levering off the maximum workload.

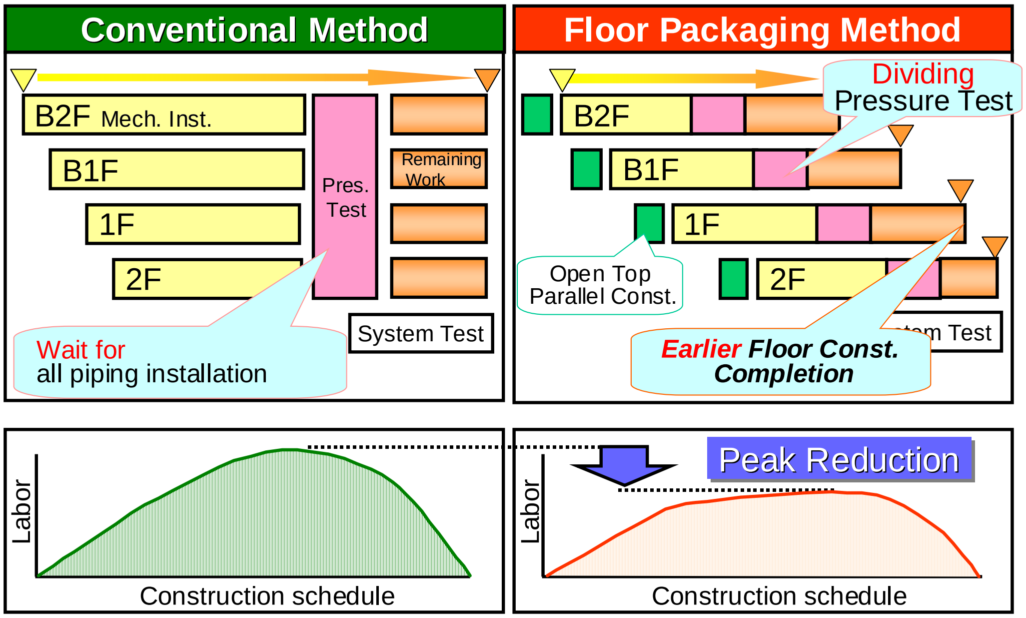

Figure 2 The concept of Floor Packaging Construction method

As shown within this figure, with the conventional construction method hydro-static pressure testing starts only once until system construction in all floors is completed, even if installation is completed in the lower floors. Implementing partial hydro-static pressure testing in each floor before completion of whole system construction makes it possible to distribute the work before hydro testing, and levelling off of the workload peaks.

2.4 Full application of information technology to quality plant engineering and construction achievements

(1) Application of Advanced Technology and 3-dimensional CAD over the complete plant design and work plan

Hitachi has applied Computer-Aided-Design using the latest computer technology to the plant arrangement and layout design for Shika-2. By fully applying an improved system compared with the previous power plant designs, more sophisticated plant and piping layouts were enabled. For example, the advanced CAD system allowed engineers to more easily allocate adequate operational space, equipment disassembly space, and temporary storage space for equipment. (Ref. Fig. 3) Furthermore, the CAD system made it possible to simulate machines disassembly and inspection during the design phase. This feature resulted in centralization of plant data information management, improving the advance work plans for inspection, and allowing engineers to identify interferences between components during construction. (Ref. Fig. 4)

The application of this advanced CAD system made the plant layout design more efficient and accurate. In addition, its simulation function helped leverage practical engineering for accessibility, constructability and maintainability. Simulations also made it easier to confirm the transport paths of disassembled equipment and to examine the transport procedures. From a variety of different perspective, quality design and highly efficient work were achieved.

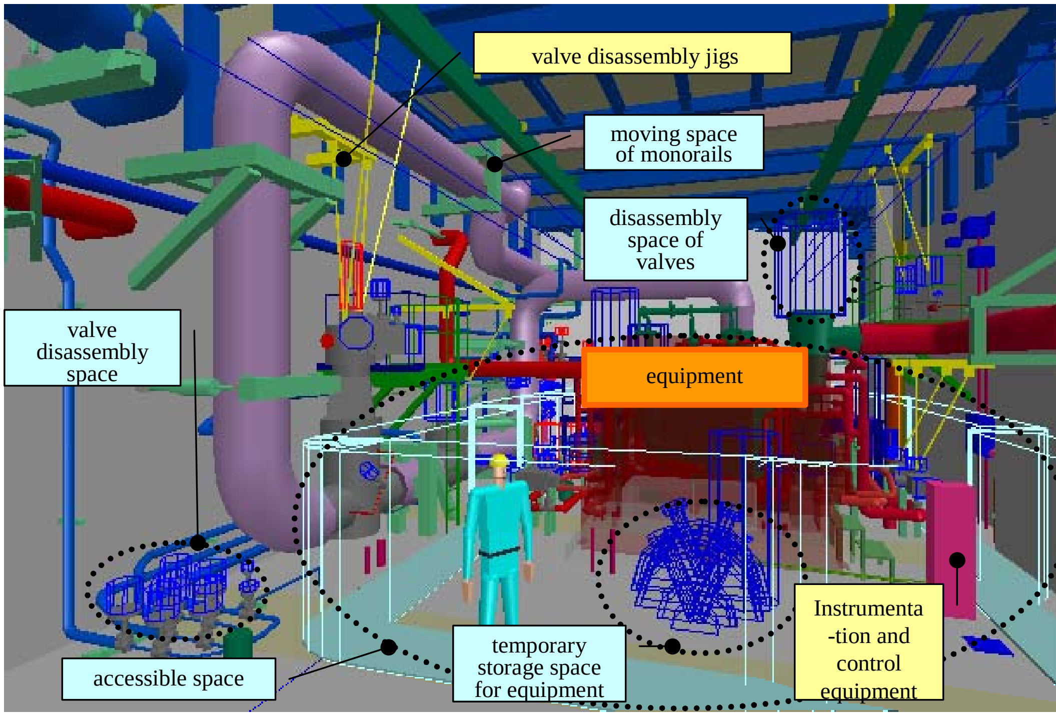

Figure 3 Examination of area layout

This figure shows the examination of the area layout, with inspection space and equipment disassembly space, using 3D-CAD. This kind of simulation made it possible to plan rational layout during the design phase.

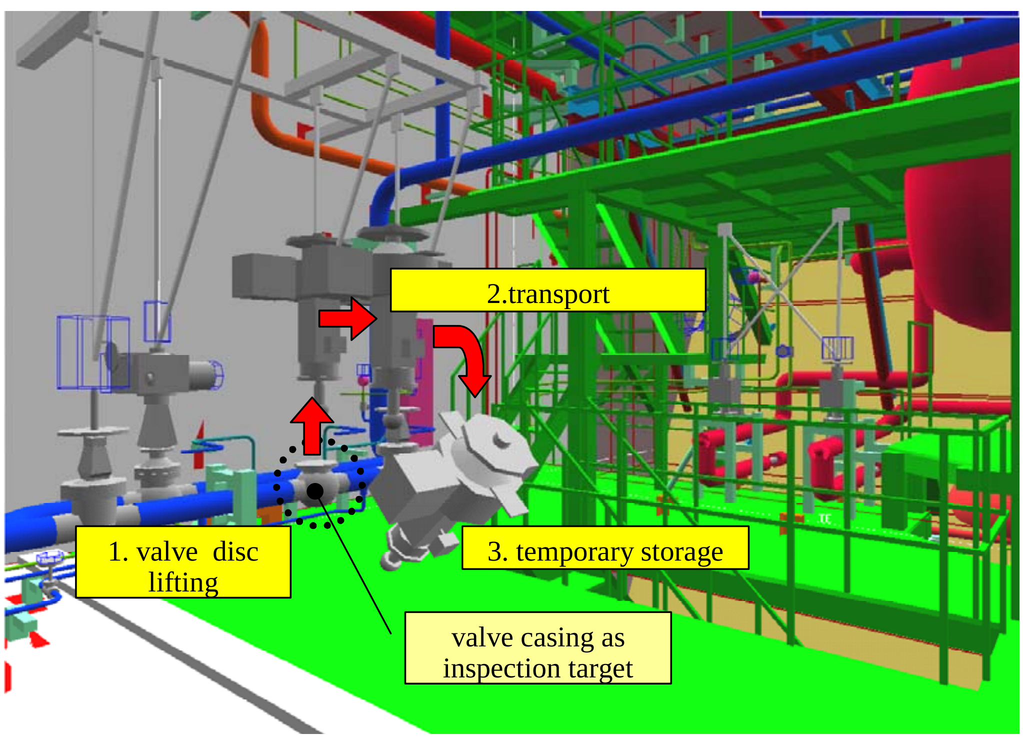

Figure 4 Examination of equipment disassembly simulation

Using 3D-CAD makes it possible to visualize the work-procedure and to detect the interferences between components under installation.

(2) Establishment of a local network

In order to fully utilize the quality plant engineering data received from the construction site, the information needs to be shared among main project participants appropriately and rapidly. For Shika-2, engineering offices, manufacturing facilities, and site offices were connected by computer network, and the site office was directly connected to each major satellite construction area for high-speed interactive communication. The network made it possible to communicate and download any design information at the satellite construction sites. (Ref. Fig. 5)

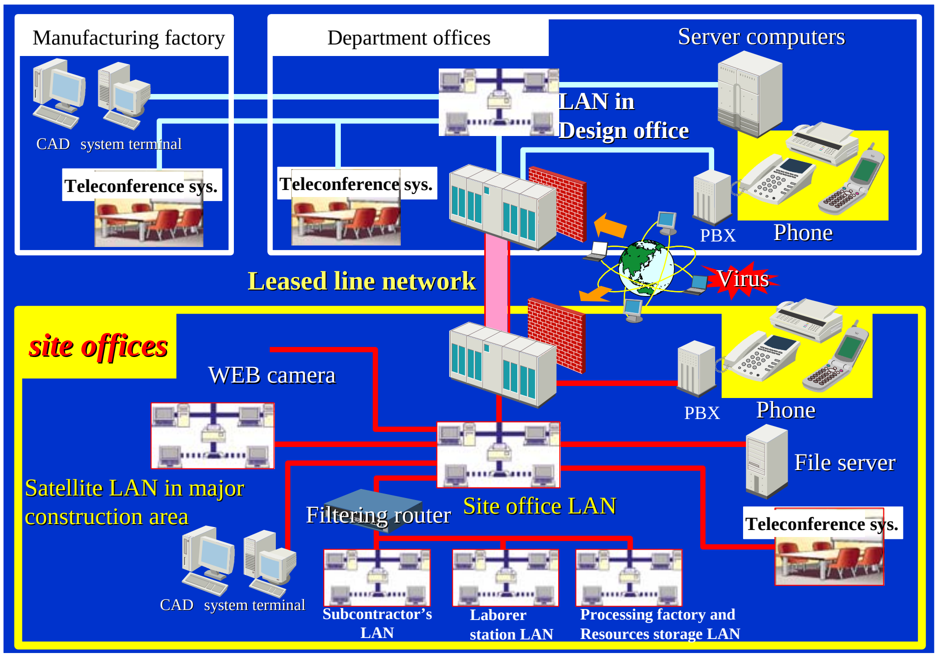

Figure 5 Structure of network facility

This figure shows the structure of the network between engineering offices, site offices, and site.

(3) Development and Introduction of an integrated construction management system (ICMS)

During the construction period of a nuclear power plant, nearly countless equipment and components need to be well managed. Therefore, detailed planning takes place before the actual work commences, ensuring on-time delivery of products and documents and early acknowledgement of any discrepancy between plans are very important. To support and ensure this works properly and timely, Hitachi has been developing and perfecting an advanced site construction management system since 1996. This system enables not only the ability to share the engineering information and documents but also to store computerized construction records and other important data. As well as this, for Shika-2, additional key features, supporting the turnover and commissioning of systems were added. This system now covers the entire construction work at site. Thanks to this integrated system, highly efficient and quality construction work is achieved.

3. Development of Advanced Technologies

Hitachi is currently constructing new-build projects in Japan now. For this project, more advanced technologies beyond those applied at Shika-2 are developed and introduced. Application of RFID (Radio Frequency IDentification) is one of more advanced technologies. RFID is a technology which allows contactless recognition to obtain the information stored in the integrated circuit using an electronic reader and transmitter, and it has more advantageous features than barcode, which include better anti-counterfeit features and invisible recognition.

For NPP construction, it is imperative that precise and accurate traceability methodology are employed required, therefore significant manpower were traditionally spent at every project for this purpose. In the aim for more efficient and quality construction work, a more rational, less labour intensive strategy was required.. Therefore, by utilizing the RFID key features, Hitachi initiated the development and application of RFID systems to NPP construction. In this section, some of the application plans for RFID are described.

(1) Application to Product Control Subsystem

Conventionally, product was shipped from factory with an identification label on product and added to a shipping information list for use at site. On the arrival of the products at site, a work foreman would identify those products by checking the label attached on the products and comparing the information to that contained on the shipping list, and then manually record the results into the database as to which components had been delivered to site. This required a lot of time and effort to ensure product management.

In the newly developed system, product labels contained RFID are attached to the product at factory, and the product ID and RFID number are automatically linked to the database system. The work foreman can now easily identify products by reading the RFID information using a handheld reader, and the result can be transferred to the database. In order to apply RFID to NPP construction, significant research and studies were performed to ensure the RFID technology would operate as excepted under the extreme environmental conditions which could be present at a construction work site.

(2) Application to Construction Work management

Piping at its construction work site is typically managed by the relevant welding points, and the work record would be manually prepared and input to the database. For the improvement of this process, Hitachi also applies RFID technology to the welding process. With the newly developed systems, work instruction can be obtained by just pointing a PDA with a reader to the RFID on the piping to be welded, and the work records can be easily input via PDA adding worker ID and tool/instrument ID (which are also identified by their associate RFID). As well as improvement of the preparation of work record efficiency, this has led to a decrease in human errors in recording work completion and allows for rapid updates to work progress reports.

4. Application to new-build CANDU's in Canada

(1) Requirements from Canadian Nuclear Market

Amid the "Nuclear Renaissance", both Canada and Japan are two markets which have been maintained keen interest in building new reactors. Japan has been seeking the best lessons learned from other advanced countries, including Canada, with regard to management of nuclear construction issues. Canada and Japan have similar issues to be resolved in furthering nuclear development, such as safety, public acceptance, aging reactor fleets and need for new-construction to accommodate economic growth. Japan has observed the global nuclear performance and believes that the CANDU fleet in Canada is one of the best benchmarks for Japan to follow based on its high capacity factor and other outstanding operating records. In return, Japan is convinced that it can be used as an example for the Canadian nuclear industry by sharing and exchanging its expertise and experience, particularly, in the area of new-build project execution and construction, based on its over-30-year period of uninterrupted construction activities. Focusing on new-build projects execution, Canada has not had a new-build projects in place since the completion of the Darlington Nuclear Generating Station in early 1990's, while Japan has completed 4 ABWR projects with one other under construction. However, despite the recent experience of new-build projects implementation, other priority issues are basically the same toward successful deployment of new reactors. Some examples of major issues are listed below:

- Need to shorten overall project schedule, in particular, duration of site construction,
- Diminishing and in-demand pool of skilled trades,
- An aging labor force in the areas of engineering, manufacturing and construction,
- Reduced supply chain capacity.

To overcome these facts and then to allow the successful launch of new-build projects, one of the most practical approaches is to utilize and mobilize advanced techniques such as Hitachi's advanced construction technology which have been tested and proven time and time again via new-build projects implementation in Japan. The advanced construction technology minimizes the impact of traditional bottlenecks at during site construction while facilitating standardization.

(2) Path Forward for Applications to New-Build CANDU in Canada

Localization is one of the key issues which leads new-build projects to success. Putting aside aspects of socio-economic, the following points have to be addressed for successful implementation/completion of new-build projects:

- Securing a sustainable group of skilled trades,
- A Robust local supply chain, particularly for ancillary components and bulk material (Piping, Cable, Valves, Raceway, etc.),
- Identifying capable local engineering/manufacturing vendors and/or partners,

- ◆ Ensuring transportability of large-scale major components and modules by having local manufacturing vendors and/or partners with suitable locations

Localization is one of Hitachi's challenges as its experience and expertise are based on its successful execution of new-build project in Japan. Hitachi has been working closely with AECL to be ready for deployment of new reactors in Canada for a decade. Hitachi and AECL have been in full agreement in utilizing/optimizing capability at both ends to yield synergy and complementary skill sets. Further, advantages from Hitachi's advanced construction technology can be maximized where Hitachi and local construction companies pull together. On this point, Hitachi is confident that it can achieve this goal by exercising its relationship with AECL and other local partners. Hitachi is also convinced that Canadian local companies will be able to utilize Hitachi's advanced construction technology which has already proved to be most beneficial for new-build projects.

5. Conclusion

This paper describes Hitachi's achievements for Shika Unit No. 2 of the Hokuriku Electric Power Co including various advanced construction technologies. In addition, more advanced construction technology being applied to the upcoming new-build projects in Japan is also described.

Although Hitachi's technology and experience have been cultivated through BWR projects, their practical engineering capability and methodology can be equally applied to CANDU projects. Against the background of great interest in nuclear energy in Canada, AECL and Hitachi, along with its subsidiary Hitachi Canada, Ltd, have started sharing each other's unique and extensive capabilities for new build CAND projects.

Hitachi is confident that it can contribute to execution of new-build CANDU projects in Canada by exercising relationship with AECL and other local partners. Hitachi is also convinced that Canadian local companies well appreciate Hitachi's advanced construction technology which is already proved to be most powerful tool for new-build projects construction/implementation.

Hitachi is committed to the endeavour for further development of advanced construction technology and to provide more economical, safe, and reliable nuclear power generation systems to the Canadian market as well as all over the world in the coming nuclear renaissance.

6. Acknowledgement

in developing and applying Hitachi's construction strategies and technologies, Hokuriku Electric Power Company helped and inspired our achievements. We sincerely appreciate the cordial help of Hokuriku Electric Power Company with good faith.

7. References

[1] S. Yamanari, et al, “The development of a comprehensive integrated nuclear power plant construction management system”, Hitachi Review, Vol.88, Iss.2, 2006.2, pp.173-178

[2] K. Morita, and K. Akagi, et al, “Advanced Construction Technology for Shika Nuclear Power Station Unit No.2 of the Hokuriku Electric Power Company”, Proceedings of the 15th Pacific Basing Nuclear Conference (PBNC) Sydney, Australia, 2006

[3] S. Asakura and N. Akane, et al, “New Build CANDU in Canada- Development and Application of Information management Systems for Latest Construction Technology”, Proceedings of the 28th Annual Conference of the Canadian Nuclear Society (CNS) 2007