Olkiluoto 3 Experience

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This paper discusses the experience from the Olkiluoto 3 nuclear power plant project from regulator's point of view. There are certain factors that have affected greatly the project progress. First, Olkiluoto 3 nuclear power plant is the first European Pressurised Reactor (EPR) being constructed. Secondly, construction of the unit started after a fairly long break in nuclear power plant construction in Europe, which had resulted in loss of experienced and qualified engineering and manufacturing resources. These factors have to be kept in mind when evaluating the experience from Olkiluoto 3.

Experience discussed in this paper have to do with the licensing and regulatory oversight process, completion of the design prior to construction, experience and knowhow of the participating organisations, quality management in a nuclear construction project, advanced manufacturing and construction technologies, turnkey contract with regard to licensee's responsibility, safety culture aspects in a nuclear construction project, and the role and importance of regulator's oversight.

1. Regulatory framework in the country of construction

Each nation is solely responsible for the safety of its nuclear installations. Therefore, there are also national practices how nuclear power plants are licensed and how the safety and quality of these plants are verified during construction and operation.

Differences in licensing, regulations and regulatory practices may have an impact on the design of the plant. There may be differences in how the detailed design has to be documented and how and when it needs to be submitted for approval to the regulator. To avoid surprises due to differences, it is beneficial for the owner and plant vendor to familiarize themselves early enough on the national practices and regulations to ensure that regulatory expectations and processes can be taken into account in the project implementation. In addition, the owner and the plant vendor have to understand what are the national safety goals and safety requirements that the plant has to fulfill, and what they mean to the detailed design of the plant. These have to be clarified and explicitly defined by the owner in terms of design criteria in the bidding documentation to avoid difficulties in the future steps of the project. It is recommendable to discuss those design criteria also with the regulator in connection with the bidding process before signing the contract.

In the Finnish regulatory system, the licensee has to submit the design and working documentation[4] of safety significant systems, structures and components to the regulator for approval. Regulator's approval of the documentation for most safety significant structures and pressure equipment is required prior to start of construction or manufacturing. Also the pressure equipment manufacturers, and inspection and testing organisations have to be approved by the regulator prior to start of manufacturing, inspections and tests, respectively. If the information provided on the design or on the manufacturer is not acceptable to the regulator and needs to be improved, there may be consequences to the project progress. In addition, when reviewing the working documentation the regulator may define witness or hold point type of inspections. These inspections are conducted before and during construction or manufacturing to verify that the

[4] For example concreting plans, technical description of pressure vessel manufacturing, welding procedures, inspection plans, etc.

component is being manufactured as described in the documentation. These are generic examples on regulatory approval and inspection processes that are applied in Finland and which have to be taken into account in the Finnish projects.

2. Completion of the design prior construction

One of the most important factors that have affected the progress of Olkiluoto 3 project is the status of detailed design of the plant and its' systems, structures and components at the time when civil construction was to be started in the beginning. In general, it has turned out to be time and resource consuming to incorporate new conceptual features into the detailed design of the plant. In Olkiluoto 3, these new safety and design features had to do, among other things, with provisions against large passenger airliner crash and systems and structures needed to cope with severe accidents.

The amount of work needed to complete the detailed design is enormous and the design work may involve both in-house (vendor) and subcontracted engineering staff. Furthermore, design of a first of a kind plant may be much more iterative process than redesigning a plant that has already been built.[5] In this context, the management of the design process becomes very important. It is beneficial to all stakeholders to ensure the availability of qualified and experienced engineering resources and mature design management processes before start of the detailed design. This is needed to ensure a once through review and approval of the design and working documentation, i.e. to avoid rotation of documents between the involved parties.

Depending on the regulatory review and approval process, iteration of the design and design documentation may result in several rounds of regulatory review. This may overload the vendor, licensee and regulatory organisations. From safety and regulatory perspective it is important that the licensee and vendor are able to show when safety significant issues are going to be fixed and when regulatory approvals are expected. These points could be presented in a licensing schedule indicating all safety relevant points where regulator's review and approval is needed.

If the design is not complete enough prior to construction, it risks the timely start and continuous progress of construction. This may result in construction and manufacturing delays, difficulties in contracting and managing subcontractors, challenges in the design configuration management, redesign and rework on site due to a need to change already completed civil works.

3. Management of design in a construction project

As written in the previous paragraph, subcontractors may do significant parts of the detailed design of the plant's systems, structures and components.[6] In addition, the nuclear industry is widely globalised and also the vendors may be multinational. This means that the detailed design of the plant can be done by several organisations and in different locations.

Both the use of subcontractors and the global nature of vendor organisations highlight the importance of proper design management processes. This includes written a description of design configuration and change management processes, together with a transparent and traceable requirement management. In principle, it should be possible for an outsider to be able to follow how plant level design requirements are transferred and communicated to the system level and from there to the design of structures and

[5] Eventhough the plant has been built somewhere else, there is anyhow some redesign that needs to be done due to site specific aspects, due to different in subcontractors, and due to different owner and regulatory requirements in a country of construction.

[6] This may depend on the vendor and project type

components. Design management process should ensure adequate communication between civil, process, electrical and I&C engineers. One should also ensure that safety and risk experts are directly involved in the vendor's design review process. They should verify that for example the principles of redundancy, separation, and diversity are consistently applied in all disciplines including both frontline and support systems.

One important factor for avoiding misunderstandings and for managing the interfaces between the design levels and the different organisations that work on the plant, system and component level designs is provision of explicit design and implementation requirements.[7] Explicit requirements will also ensure that the design of structures and components meet the requirements set by the system and the plant level. It is not possible for the licensee and regulator to approve the documentation if it is not explicit. This causes additional updates of the documentation and extra work for all organisations.

4. Experience and knowhow of the licensee and the vendor, management of subcontractors

Licensee's and vendor's key persons (e.g. project directors, people responsible for safety and design of the plant, Quality Assurance and Quality Control) shall have experience in nuclear power construction or operation. This is the key to the success. Right experience ensures that nuclear specific issues are known and timely identified and right amount of attention, resources and time is allocated to the important areas.

Regulator should verify that the licensee has adequate human resources for the project from the beginning. Resources should include e.g. staff needed to oversee the activities of the vendor and staff needed to review and approve of the plant's design. Licensee's need of resources varies during the project and hence it should conduct staff planning covering the entire project. In the plans it should be able to show the number of staff and their qualifications needed in different phases of the project as well as where licensee can find the resources. Staff planning is important especially in a small country if more than one nuclear power project is starting or ongoing. The use of consultants in lieu of licensee's own staff should be planned and justified. When balancing the use of consultants and own staff it should be taken into account that the design and construction phases are most useful for the licensee to build up the know-how and experience which is needed to operate the plant safely.

Depending on plant vendor's in-house capabilities the amount of subcontracted work varies. If the vendor does not have manufacturing or construction capabilities in its own organisation, the amount of contracted work is significant. This type of situation highlights the importance of subcontractor management. The subcontractor selection criteria and approval process should be clearly defined and agreed between the vendor and the licensee. Licensee may want to consider setting restrictions to the length of the subcontractor chain (e.g. vendor's subcontractor may not order work from another subcontractor unless agreed prior contracting). It should be understood by the licensee and the vendor that subcontractors with limited or no nuclear experience require special attention with regards to training and guidance prior to start of activities and oversight during manufacturing and construction.[8] In addition, contracts between the vendor and its subcontractors shall be clear especially in nuclear specific issues (e.g. quality assurance and quality control requirements differing from conventional industry). The understanding and implementation of these requirements shall be audited prior to start of activities and verified when the activities are ongoing.
Olkiluoto 3 project faced a challenging situation in the beginning of the project being the first nuclear construction project in Europe since several years. Idle period in Europe had led to a situation where many

[7] Design and working documentation shall not contain implicit expressions such as "mainly", "in principle", "in general", "and/or" "whenever possible" etc.

[8] This may also apply to experienced manufacturers if they have not had nuclear specific work for some time.

of the experienced manufacturers had left the sector due to lack of business. This meant that the vendor had to educate many new subcontractors to be able to work for Olkiluoto 3 project. Education has taken a lot of effort from the vendor and in some cases first components or structures produced by a new manufacturer have not met the criteria. It has turned out to be a very difficult task to verify the real know how, experience and preparedness of the subcontractors on the shop floor prior to start of activities and this has not always succeeded.

5. Role of quality management

Requirements for Quality Assurance (QA) and Control (QC) are very specific to safety critical applications like nuclear power plants. In general, the conventional industry is nowadays quite familiar with the international quality standards like ISO. It has to be noted that ISO and other conventional standards alone are not enough for safety significant activities in a nuclear power project. What is enough shall be clarified, defined and agreed between the regulator, the licensee and the vendor in the very first days of the project. Requirements for the quality assurance and quality control shall be commonly understood throughout the project (e.g. regulator, licensee, vendor and its subcontractors). This means for example that quality requirements to be applied in different safety classes are clearly defined and agreed before subcontracting and procurement starts so that they can be clearly written in contracts and specifications.

One specific example is the definition and process for a non conformance. The criteria for a non conforming performance or a product shall be clear. Raising and reporting a non conformance shall follow a uniform process throughout the project. Criteria to classify a non conformance to minor, significant or critical shall be well defined, Roles and responsibilities to report and resolve a non conformance shall be clear. The process has to be effective (e.g. closure of a non conformance should not be too time and resource consuming). In Olkiluoto 3 project, the utilisation of non conformance process tends to stop when the direct cause for the non conformance has been found and corrective actions to repair the problem has been completed. Root causes are not always studied thoroughly which sometimes results in repetitive non conformances.

Management at different levels has to be educated to understand the role and significance of QA and QC in a nuclear construction project. Understanding will lead to management's commitment to high quality. Commitment comes visible when management uses the information and the system as a management tool (e.g. grouping, categorisation and analyses of non conformances leading to activities to minimize non conformances in the future).

6. New and advanced manufacturing technology

As well as new design features, also new and advanced manufacturing and construction technologies may require additional time and effort to be qualified for the purpose. Areas where new technologies will be applied should be identified in the beginning of the project to be able to pay attention and allocate adequate time for the qualification process. Experience in Olkiluoto 3 project has shown that in some cases the qualification pieces have not met the specifications at the first attempt.

7. Licensee's responsibility in turn key contract

From regulator's point of view, licensee is always responsible for safety independently of the contract type. Licensee has to control and oversee everything that has to do with safety of the plant. With a turn key contract the licensee has contracted a vendor for example to design, build and commission the nuclear power plant. In practice it also means that the vendor is responsible for the design, construction and commissioning of the plant. Vendor again may shift the responsibility to its subcontractors depending on the area subcontractors are responsible for.

Turnkey contract type highlights the importance of clear and explicit requirements for the design, manufacturing, construction, installation and commissioning of the plant. Olkiluoto 3 project has shown that it is not always simple for the licensee to interfere the project when the work is in progress and requirements for the work are not explicitly defined. It can be simpler to wait and interfere afterwards and prove that the component or structure does not meet the criteria (even though it may have been obvious when the work was in progress).

Even turn key projects are manageable, but in addition to explicit requirements a necessary prerequisite is systematic, transparent and traceable requirement management process applied together with strong, competent and safety oriented QA/QC personnel who are able to verify compliance with the requirements.

8. Safety culture in a construction project

Construction of a nuclear power plant does not differ from an operating nuclear power plant from safety culture point of view. Safety and quality must have higher priority than costs and schedule. This message has to be very clear and transmitted from the licensee and vendor management to all participating organisations and to all levels of the organisations. Management's acts and decisions in the project have to be consistent with the message.

In order to ensure that safety and quality has the highest priority in every day activities throughout the project, everyone has to understand the safety significance of the work one is responsible for. Understanding is essential to promote personal responsibility for safety and quality. This is a challenge in a construction project where thousands of people are involved and many of them have no previous experience or knowledge on nuclear power plants.

The level of safety culture is tested whenever problem situations are encountered. One of the outcomes of good safety culture is that safety and quality problems are openly raised, discussed and reported. The ways and routes to raise them have to be made known to the workers. Atmosphere to report safety and quality issues has to be open, free of punishment and encouraged by the foremen. When a safety issue has been raised by a worker, foreman or someone else has to give feedback to the person and inform whether the issue was significant or not and how it was resolved. Otherwise the person may feel that the organisation is negligent to safety concerns or even wants to hide them. The importance of encouraging workers to raise safety and quality issues as well as the importance of giving feedback to workers has to be addressed in the training of foremen. At the Olkiluoto 3 site a number of different nationalities are working together. Therefore also differences in cultures and languages had to be addressed when reporting routes for workers were established.

It is management's task to create a good safety culture in the construction project. However, the role of foremen working with workers is very significant. Foremen have to be able to manage workers from different nationalities and cultures, encourage workers to report safety and quality issues, give feedback to workers, and especially to promote personal responsibility by making them understand the safety significance of their work. All this sets special requirements on foremen's selection, training and personnel management skills.

9. Regulatory issues in new construction

Olkiluoto 3 experience has shown the importance of stringent regulatory approach and inspections. These are needed to verify that the performance of the licensee, the vendor and the subcontractors meet the expectations and that the equipment and structures meet the specifications set by the design. There are some cases where Quality Control inspectors of manufacturer, vendor, and licensee may have not been

strong enough to enforce stopping of work and making necessary timely corrections. These may have something to do with a turnkey contract together with cost and schedule pressure caused by a stop of work. In such situation, an intervention by a regulatory inspector has been needed. Prerequisite is that regulatory body is competent, independent, has strong powers and enforcement tools.

Olkiluoto 3 project has raised a lot of media interest in Finland as well as internationally. The amount of interest has been remarkable and resource consuming. Therefore it is important that regulator is prepared to interact with media. One of the essential factors is that regulatory decisions are transparent and can be published either pro-actively or when asked by media, other organisations or members of the public.

10. Conclusions

Starting new build is very demanding because much of the earlier experience and resources have been lost from the nuclear industry. Therefore, adequate time has to be allocated to good preparation of the project before the actual construction start. This includes e.g. building competent organizations, complete design incorporating possible new design features, qualified new manufacturing and construction technologies, ensuring availability of qualified designers, constructors and manufacturers to implement the project, and resolving potential regulatory uncertainties.

Construction of a nuclear power plant is a complex project. It for example includes different technical disciplines within various stakeholders, a number of subcontractors, and workers from different countries. It is evident that challenges will be met in a nuclear power plant construction project. Therefore close monitoring and oversight both by the licensee and the regulatory body is necessary to ensure achievement of specified quality, i.e. meeting the technical standards and criteria that the vendor has specified and that have been approved as part of licensing and design documents.

The know-how and experience of all stakeholders has increased in Olkiluoto 3 project. Progress has been made during the project, and after the “teething problems” the civil construction has proceeded well. However, it seems to be characteristic that the beginnings of new phases in the project (concreting activities, welding activities, installation activities, commissioning activities etc.) require special attention and preparations from all stakeholders.

While there have been many non-conformances and re-manufacturing needs, the corrective actions have been taken in line with the Quality Assurance and Quality Control practices specified for the project. The final quality in Olkiluoto 3 structures and components has not been compromised although in some cases it has required special efforts to achieve and demonstrate the expected quality. These have included extensive and time consuming tests, inspections and extensive new analysis to prove that the required standards have been met. In some cases components or structures had to be re-manufactured or constructed. The observed difficulties at the construction stage have not raised concerns on the safety of the power plant when it will be ready to operate.