Integrating project and the PDEC information model

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Abstract. PRORYV Project is one of the major advanced global projects in the nuclear power sector that provides for creation of the new generation nuclear power technologies based on closed nuclear fuel cycle using fast neutron reactors. On JSC “SGChE” site a Pilot Demonstration Power Complex, which consist of BREST-OD-300 (reactor with a lead coolant) and on-site plant based on closed nuclear fuel cycle is being built. On-site Plant will include the Unit for processing irradiated mixed uranium-plutonium (nitride) fuel and the Unit for fabrication the reprocessed irradiated nuclear fuel. The need to apply modern and progressive tools for process management within PRORYV Project facilities life cycle is required by following key features: due to the large number of participants in the project and the breadth of the range of tasks to be solved, there are different information, calculation and modeling tools and approaches to their application; the high degree results’ innovation introduces considerable uncertainty in the methods of their achievement and requires a large number of R & D, the results of which constantly cause changes in the facilities’ design. While developing PRORYV Project the Information Model is created. Information Model is a continuously updated structured set of electronic data and documents on each facility and technology, which is necessary and sufficient for each stage of R & D and facilities’ life cycle (location, design, construction, commissioning, operation and decommissioning). The Information Model has several modes that are architectural, construction, functional-technological, and design. The Information Model is linked to the Project Schedule and the requirements management system. The Information Model is the basis for the creation of other systems by linking them with each other. The Integrating Project is the visualized part of the Information Model, which represents a set of electronic data and documents on PRORYV Project and contains the actual design, engineering and technological documentation on the facilities, as well as advanced data monitoring capabilities (in particular: 3D model, 4D simulation model, construction 4D-model and mathematical model). Integrating Project is required for modeling all stages of the life cycle of facilities with the purpose of timely analysis of facilities’ characteristics and technological processes. The Integrating Project is created on the basis of the Information model and is part of it. At the stage of operation and subsequent decommissioning, the Integrating project is used and supplemented by the operating organization. Due to the application of Integrating Project tools, the following works have been executed: activity on optimization and justification of the number of personnel at the Pilot Demonstration Energy Complex is organized; discrepancies in the development of electronic management procedures in the course of verification of the manuals for the operation of Fabrication Unit equipment were revealed; at an early development, conflicts in project documentation were identified. Recommendations for adjusting the technological and design documentation on BREST-OD-300 reactor unit as well as Processing and Fabrication Units were developed and issued.
1. Introduction
The project direction “Proryv” (literally, “the breakthrough”) is one of the world’s most important project in the nuclear power industry that provides for creation of the new generation nuclear power technologies on the basis of closed nuclear fuel cycle using fast neutron reactors [1-2]. The creation of new generation nuclear power technologies on the basis of closed nuclear fuel cycle using fast neutron reactors is stipulated within the project framework. Over 30 companies are taking part in developing the solutions: industry related institutes, tertiary educational institutions, institutes of the Russian Academy of Sciences, the major enterprises of the State Corporation ROSATOM. There are nine Responsibility Centers (RC) created at the base enterprises for the project direction. These centers unite groups of highly qualified specialists, who have all the necessary competence in the scientific and technical fields. As of today, there is a pilot demonstration energy complex (PDEC) under the construction stage. It is designed with a 300 MW fast neutron reactor BREST-OD-300 (Seversk, Tomsk Region). There is also a concept project of an industrial energy complex (IEC) with 1200 MW fast neutron reactor and lead cooling (BR-1200) under development. The development of the project data for Unit 5 of the Beloyarsk NPP with a 1200 MW fast neutron reactor with sodium cooling (BN-1200) also shall be mentioned.

The need for using the cutting edge process management tools within the life cycle of the Proryv PD facilities is stipulated by the following factors:
• the information, computation and simulation tools and approaches to their use are not uniform due to a large number of participants and a broad range of tasks to be solved;
• high degree of novelty makes the ways to reach the established goals rather uncertain, requires a large scope of R&D work, and the results of the said R&D work provide continuous modifications of the facilities design.

In order to support the lifecycle process of the Proryv PD facilities, a unified information environment (UIE) has been developed as the sum total of databases, data transmission channels, software & hardware support and methodology, ensuring a joint operation of the project participants, unified information services for private projects, and an integration with IT systems of individual projects. UIE provides a fast and safe access for all participants of Proryv PD to the Information Model, the Specification Management System, the Integrating Projects, and to other services and resources of the project direction [3].

2. Information Model
An Information Model (IM) - a structured sum total of electronic data and documents on the PD facilities and technologies is being developed and updated within the framework of developing the PD projects. It is necessary and sufficient at each stage of the project lifecycle (site selection, development, construction, start-up & adjustment, operation, and decommissioning) to:
• check the competitive ability of the solutions taken;
• minimize the costs;
• license the designs of the PD facilities;
• define the intellectual derivable and collect documents set for their registration;
• scientific and technical justification of the solutions taken.

The main goals and objectives of the IM are as follows:
• provision of a complete informational description of the facilities, processes occurring therein, and technologies being developed in the PD framework;
• ensuring that the information on the R&D results is complete and structured to the maximum possible extent;
• integrating the results of individual projects and providing the operational consistency;
• supporting the joint use of documents and data by the PD participants.

The IM has a facility-based structure (RM, FRM, RP) and includes several subdivisions: architecture & construction, functional & process, and design.
Figure 1. The IM structure

The unique characteristics of the PDEC IM:

- connection to the project roadmap;
- connection to the databases created by the PD experts (e.g. CM databases);
- connection to the Specifications Management System;
- transparency on each document revision;
- possibility to indicate the document approval status by interested parties;
- possibility to assign a KKS code automatically, when the document is introduced into the IM;
- the Integrating Project “Proryv” PD is developed on the IM basis.

The information model is essentially a database on the project and its facility, since it contains all documented data on the project and has extensive search tools. The IM acts as a basis of developing all other systems connecting them with each other.
3. Integrating Project
The Integrating Project (IP) is a part of the IM, which can be visualized. This is a sub total of electronic data and documents of the Proryv PD, containing the up- to-date design, engineering, and process documents on the facility and having extended capabilities of the data control (including: a 3D model, an imitation 4D model, a construction 4D model, and a math model of facilities) to simulate all lifecycle stages to ensure that the facility parameters and processes (figure 3) are analyzed/optimized in good time (including in advance, at the creation stage). The IP is developed on the basis of the information model of “Proryv” PD and is a part thereof. The IP of a facility is to be used and updated by the operator at the operation and decommissioning stages.

IP composition and tools:
- TOR, individual TORs
- specifications, criteria of competitive ability (!)
- basic design, detailed design documents (design companies)
- construction documents and detailed construction documents (engineering companies)
- PSAR
- Economic model (!)
- Mathematical model
- Imitation model
- Consolidated 3D model of the facility

Virtual simulation of the facility in advance allows:
- meeting the main process and economic criteria at the design stage based on the optimization process, detect non-compliances;
- reduce the construction costs;
- develop suggestions for optimizing the operation (including maintenance) and decommissioning.

Figure 2. Document approval in the IM

Figure 3. Concept of the Integrating Project.

The IP provides an access to the visual representation of facilities in 3D mode and with links and references to the documents on the model elements stored in the IM. It provides the design 3D models of the site and related detailed engineering 3D models (figure 4). A visual representation of the IP is a
unified structured data array based on the object representation of its structure to provide control/monitoring (via ??) and on taken scientific, process, and administrative decisions on all lifecycle stages of the facility and its individual elements (via the UIE as a whole) due to:

- final results of the PD facility development unified in the IP structure with available generalized technical specifications;
- virtual simulation of the facility in advance of its construction and checking its performance and safety with advance data control tools (3D modeling of the facility, schematics of the process and engineering parts of the design).

Figure 4. Visual presentation of the design and detailed design 3D model in the IP on the PDEC example.

3D models in the visual presentation system contain metadata enabling the users to select facilities, develop specifications and assign color codes (figure 5). Various participants of the PD can use this tool, since the access to it is provided in the UIE framework via a web browser.

Figure 5. Visualized equipment specifications with color marks.
4. Imitation 4D models

Imitation models of processes and the production systems outside of the reactor of the closed nuclear fuel cycle (CNFC) (the module of fabrication and the fuel refabrication startup complex, the fuel processing and RAO management complex module) give a possibility to research the interconnected performance, efficiency, controllability and monitoring ability of the production both on the level of individual processes, assemblies, units, and process conversions, and on the level of the entire production in a virtual environment under startup, transient, stationary conditions, as 4D models, which take into account kinematic and process rules, interactions, specifics and limitations. The process visualization with a computational cyclic graph for the module of fabrication and the fuel refabrication startup complex of the PDEC is given in figure 5.

The imitation models include:

- 4D models of the main process equipment of the production lines, hoisting machinery and line transport equipment located indoors;
- a calculation cyclic graphs for the equipment operation and the operational staff work load with detailed information to the production units and process operations;
- a calculation model of material flows, including the composition of fissile materials flows.

The development process uses design and engineering 3D models of buildings and equipment, which were created in the responsibility centers and at manufacturing plants.

5. Integral computational model for the PDEC

The integral computational model (CM) for the PDEC (Pilot Demonstration Energy Complex) is designed to simulate the operation of the PDEC (a power unit with the BREST-OD-300 reactor and on-site nuclear fuel cycle facilities) dynamically in a nominal mode and certain transient and emergency modes.

The simulation of the models joint operations provided in advance of construction and start-up and adjustment operation and accounting for the maximum scope of interfaces will make it possible to analyze the operation of future facilities as united in a single production cycle and to detect any involved issues with the process parameters.

The feature of the integral model is that it has not been developed from scratch, but is assembled mostly of specific computational models and codes already available in the Proryv Project Direction; thus, the maximum involvement of the authors of source models is ensured. It also provides the elimination of detected controversies and an applied use of connected calculations.

A unique practice of computations within the integral model is implemented according to scenarios agreed between the main work participants.

Functions of the integral computational model:

- control of completeness and consistency of the design data;
- computational check of design solutions (similar to the work at the VVER-TOI NPP projects);
• development and automated check of the instructions; optimization of the personnel work load;
• the use to develop PDEC simulators in the training and information center (excludes the doubled costs of developing simulation models);
• educating and demonstration function for the students of industry related tertiary educational institutions.

6. **The software complex of modeling the personnel actions and their work load**

The project direction has developed and now applies a software tool to simulate the personnel actions for the PDEC management, which allows for developing electronic control procedures based on the operational instructions or expert assessments, which in turn act as the basis to plot the personnel workload diagrams.

Electronic control procedures are developed jointly with the APCS engineers and experts of the operating company. They will be further used for operating instructions and for the personnel training.

7. **Construction 4D model**

A construction 4D model is used for verification and optimization of the administrative and process solutions related to the facility construction (construction management plans, work performance plans, activity progress charts). The model is developed by binding elements of the 3D model with the activities of the process chart. Providing attributive data to the activities in the process charts makes it possible to generate reports on required resources, the progress of CAPEX assimilation and physical scope. The use of this tool at the construction stage provides for visualizing the planned and actual state of the facility, to analyze the work performance progress, to take decisions on necessary compensating measures, and to analyze the decisions for inconsistencies:

• time and space issues:
• inconsistencies for performing the management and process operations;
• inconsistencies of time and space provisions for material resources;
• objects unaccounted in the schedule and in the cost estimations.
• resource issues:
• distribution of human and material resources along the construction periods.

Visualization of the PDEC construction 4D model is given in figure 6.

![Figure 7. Construction 4D model of the PDEC.](image)

8. **Current results of the IP application**

The following results were achieved thanks to the IP tools applied at the PDEC facilities in 2017:
• the IP completeness and tools allowed optimizing the design documents of the module of fabrication and the fuel refabrication startup complex and power unit with BREST-OD-300 reactor - the joint savings made for 11.6 billion rubles;
• the IP visual model (the module of fabrication and the fuel refabrication startup complex and power unit with BREST-OD-300 reactor) corresponding to current R&D and design results made it possible to detect and eliminate controversies in the documents for the further installation of the equipment;
• the imitation model of the module of fabrication and the fuel refabrication startup complex allowed to demonstrate a possible increase in the fuel production capacity from 15 to 25 ton per year;
• repair and replacement activities for the main reactor coolant pump set for the current dimensions of the reactor service hall of BREST-OD-300 were checked, which in its turn provided for the process visualization, detection of several inconsistencies and formulation of the list of issues for the used equipment and work organization;
• works on the optimization and justification of the number of PDEC personnel were organized;
• some errors and non-compliance issues in development of the electronic control procedures were timely detected in the course of verifying the operating manuals for the fabrication-refabrication module equipment;
• inconsistencies were detected at the early stage of development, and recommendations on corrections were made for the process documents and the diagram of the processing module.

9. Conclusion
Work in the Project Direction is organized in digital space, which provides for an advanced simulation of facilities in the virtual environment.

Applied IP tools allowed consolidating the management process and the development results of the Proryv project direction. They also ensured that the participants’ efficient cooperation against continuous optimization of projects with a timely accounting for results of R&D and start-up and adjustment activities, which are carried out simultaneously.

The use of IP tools has practical benefits, which is proved by the results of the PDEC projects in 2017-18. It also provides for optimization of processes at all life cycle stages of facilities within the project direction.

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