The optimal approach for the processes of verification and validation of NPP software and hardware complexes

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Abstract. Nowadays the task of increasing the quality of software and hardware complex development has not lost its urgency. The problem mentioned has still been solving by the search of an optimal structure, stage content and life cycle processes. The current system of international standards has been developed on the basis of advanced software complexes for aviation, space and defense industries being designed during the second half of the 20th century. However, it lacks a holistic approach for verification and validation. The paper presents the analysis of Russian and international regulatory framework and current verification and validation methods in the context of the life cycle of NPP software and hardware complexes. Basing on the data obtained, a new approach for verification and validation methods has been introduced.

1. Introduction
According to IEC 61513, the life cycle of a software and hardware complex (SHC) is an essential activity that is carried out from the initial stage of the development of the concept and requirements, to the final stage when the system can no longer be maintained [1].

The international ISO / IEC 15288 standard defines the framework for the agreement, organizational, design and technical processes. The ISO / IEC 15288 standard emphasizes the necessity of its customization to the tasks of a particular industry, specifically to the tasks of NPP software and hardware complexes [2].

2. Software and hardware NPP complexes lifecycle features
According to the ISO / IEC 15288 standard, technical processes should include the following:
- definition of stakeholders requirements;
- requirements analysis;
- architecture design;
- implementation of system components;
- integration;
- verification;
- implementation of the system;
• validation;
• operation;
• support (maintenance);
• decommissioning.

Figure 1 presents a generic V-model of a typical NPP software and hardware complex with the consideration of the possibility of modernization. The given flowchart does not show the technical processes №1 and 11 from the standard mentioned, however some of the processes are merged into one block. In fact, all processes shown in Figure 1 are carried out and described in the relevant contracts, terms of reference, project, engineering and operational documentation [3].

Verification of the compliance of the NPP software and hardware complex with the requirements for functional and performance characteristics is one of the important development stages of the NPP software and hardware complex life cycle.

Such verification includes the processes of verification and validation of the NPP software and hardware complex.

Different international and domestic life cycles of NPP software and hardware complexes having been analyzed, the V-model of the life cycle is the best applicable one at present.

![Figure 1. The life cycle of a modern nondomestic NPP software and hardware complex.](image)

![Figure 2. V-model diagram.](image)
A systematic approach for the processes of verification and validation of the V-model of the NPP software and hardware complex envisions that the following conditions should be met:

- the verification of the N – N+k stages is carried out consistently
- the number of N stages coincide with the number of M stages
- optimal strategy is used to validate the M – M+l stages (The notes being discovered during verification and validation should be identified and implemented)

The next chapter will examine the methods of systems verification and validation that are implemented in domestic (Russian) and nondomestic reference documentation, in order to assess their applicability to the life cycle of the NPP software and hardware complex.

3. Optimal method choice for verification and validation of NPP software and hardware complexes.

The following applicability criteria for verification of the NPP software and hardware complex were defined:

- Time to prepare for the usage of the method;
- Time to apply the method;
- Qualification level of the specialists;
- Possibility of using early achievements for the method;
- Efficiency of the application of the method.

Positive and negative aspects of all methods having been analyzed and the assessment of the methods according to the criteria listed in the table below having been performed, the most relevant methods were selected, in order to achieve a systematic approach for the verification and validation of NPP software and hardware complexes [4].
Table 1. Methods used for the verification of NPP software and hardware complexes.

| Common method      | Method                           | Verification |
|--------------------|----------------------------------|--------------|
|                    |                                  | Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 |
| General expertise  | Technical expertise              | +       | +       | +       | +       | +       |
|                    | Walkthroughs                     | +       | +       | +       | +       | +       |
|                    | Traceability analysis            | +       | +       | +       | +       | +       |
|                    | Audit                            | +       | +       | +       | +       | +       |
|                    | Requirements adequacy analysis   | +       | +       | +       | +       | +       |
| Specialized        | Usability expertise              | +       | +       | +       | +       | +       |
| inspection         |                                  |          |          |          |          |          |
| Static analysis    | Rules checking                   | -       | -       | -       | -       | -       |
|                    | Model checking                   | -       | -       | -       | -       | -       |
| Functional and     | Functional and timing simulation | -       | -       | -       | -       | -       |
| formal methods     | within the framework of automated design environment | -       | -       | -       | -       | -       |
|                    | Monitoring                       | -       | -       | -       | -       | -       |
|                    | Unit testing                     | -       | -       | -       | -       | -       |
|                    | Integration testing              | -       | -       | -       | -       | -       |
| Dynamic methods    | System testing                   | -       | -       | -       | -       | -       |
|                    | Black-box testing                | -       | -       | -       | -       | -       |
|                    | Load testing                     | -       | -       | -       | -       | -       |
|                    | Stress testing                   | -       | -       | -       | -       | -       |

Optimal method choice for verification and validation of NPP software and hardware complexes presented in Table 2.
## Table 2. Methods used for the validation of NPP software and hardware complexes.

| Common method         | Method                        | Validation Stage 6 | Validation Stage 7 | Validation Stage 8 | Validation Stage 9 | Validation Stage 10 | Validation Stage 11 |
|-----------------------|-------------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| General expertise     | Technical expertise          | +                  | +                  | +                  | +                  | +                  | +                  |
|                       | Walkthroughs                  | -                  | -                  | -                  | -                  | -                  | -                  |
|                       | Traceability analysis         | -                  | -                  | -                  | -                  | -                  | -                  |
|                       | Audit                         | +                  | +                  | +                  | +                  | +                  | +                  |
|                       | Requirements adequacy analysis| -                  | -                  | -                  | -                  | -                  | -                  |
| Specialized inspection| Usability expertise          | +                  | +                  | +                  | +                  | +                  | +                  |
| Static analysis       | Rules checking                | +                  | +                  | +                  | +                  | +                  | +                  |
| Formal methods        | Model checking                | +                  | +                  | +                  | +                  | +                  | +                  |
| Dynamic methods       | Functional and timing simulation within the framework of automated design environment | + | + | + | + | + | + |
|                       | Monitoring                    | -                  | -                  | -                  | -                  | -                  | +                  |
|                       | Unit testing                  | +                  | +                  | -                  | -                  | -                  | -                  |
|                       | Integration testing           | -                  | -                  | -                  | -                  | -                  | +                  |
|                       | System testing                | -                  | -                  | +                  | +                  | -                  | -                  |
|                       | Black-box testing             | +                  | +                  | +                  | +                  | +                  | +                  |
|                       | Load testing                  | +                  | +                  | +                  | +                  | +                  | +                  |
|                       | Stress testing                | +                  | +                  | +                  | +                  | +                  | +                  |

## 4. Conclusions

Optimal distribution of work related to verification and validation for the stages of the NPP software and hardware complex life cycle and improved quality of the implementation of these stages can be reached by the application of the approach discussed and the algorithms developed. Consequently, it raises the efficiency of the execution of the NPP software and hardware complex.

The proposed methods of a systematic approach for verification and validation can be applied both to the NPP software and hardware complexes and systems of a wide range of applications, allowing to mark a high practical usefulness of the work presented.

## References

[1] IEC 61513-2011 2012 Nuclear power plants: Instrumentation and control important to safety. General requirements for systems

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[6] IEEE STANDARD 1012-2012 2012 IEEE Standard for System and Software Verification and Validation

[7] IEEE STANDARD 829-2008 IEEE Standard for Software and System Test Documentation

[8] ANSI/IEEE 1008 Standard for Software Unit Testing (Note: Approved 2003-04-18)