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Early Launch of Validation via an Evolving Engineering Simulator (ELVEES)

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ABSTRACT

ELVEES is Framatome's innovative and flexible simulation solution that helps operators gain early insight into their systems' future operating concepts, and supports the transition from analog to digital instrumentation, control, and human system interfaces.

Framatome ELVEES avoids costly and time-consuming revisions during project design, engineering, manufacturing and commissioning, resulting in reduced project risk.

The ELVEES strategy proposes an integration platform with combinable simulation blocks that will:

- grow with the maturity of the deliverables
- be available for the design team from the design phase
- support early and iterative validations
- ensure digital continuity

ELVEES introduces a new mindset to integrate dynamic testing during all design activities as well as immersion of design engineering in plant operation.

1 INTRODUCTION

As the worldwide reference supplier of safety Instrumentation and Control (I&C) systems, components and integrated solutions for nuclear power plants operation, Framatome must ensure the high quality of its deliverables. The deliverables qualified for safety-significant applications are complemented with likely qualified, dedicated human-machine interfaces (HMI) implemented as conventional, hardwired panels and installed along the main control room walls. The plants' main HMIs – multiple desktop screens installed on each operator's desk – are computerized and capable to intuitively visualize plant process data and effectively support operators' performance of plant operation tasks. The sets of displays shown on the desktop screens are renowned Framatome deliverables that perfectly match the procedural instructions in the plant operating manuals and optimally fit operators' needs. In the last phase of the design process for these V-shaped displays, the established Framatome practice of integrated system validation uses the plant's Full-Scale Simulator (FSS) prior to plant commissioning. The FSS is a mandatory tool for the training, subsequent licensing, and periodic re-training of plant operators. Notwithstanding the significance of the FSS role, it unfortunately becomes operational very late in the project, typically too late for both validation activities and

the challenging resolution of validation findings to be executed in a manner that doesn't overrun costs nor threaten the project schedule.

That's why in 2018 the Framatome I&C business unit joined its subsidiary CORYS to explore whether a lower-fidelity FSS, accessible to the HMI design team during the project's design phases, would enable and support the early and iterative validation of engineered HMI displays and other I&C systems. This lower-fidelity simulator will evolve in parallel with the progress of the project and the increasing maturity of the deliverables' design.

This Framatome strategy is not centered on the plant fluid and steam systems (as usual) but based instead on the deliverables of the I&C business unit. The adoption and implementation of Systems Engineering principles as well as Digital Continuity have been embedded in the overall engineering process.

ELVEES application in the new-build project Angra 3 (Brazil) and the further development of its evolving functionalities and capabilities follows a 5-step strategy described and illustrated below.

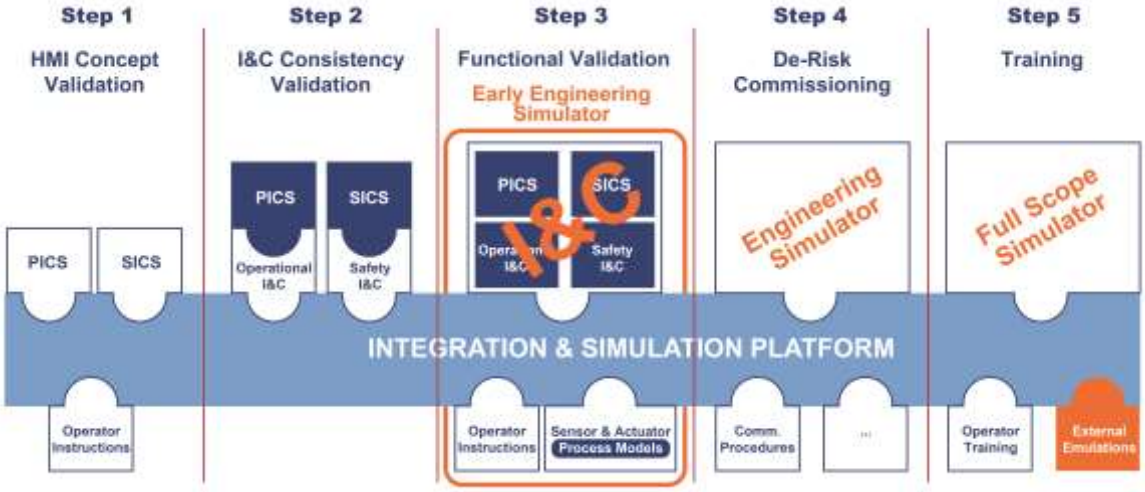

Figure 1: the stepwise ELVEES approach

Step 1 - The validation of operator displays is identified as the first step. Drafted using a standard graphic editor, the displays are imported into ELVEES and integrated into the simulation environment. A set of graphic functions is thereby linked to an inventory of display elements and used to drive them. HFE-guided validations can be conducted in a dynamic environment of sufficient fidelity. While full-fledged plant behavior cannot yet be represented, the characteristics of the representation provided by each of the simulated displays is duly reflected and can be viewed and evaluated. The import of displays that are no longer drafts and already implemented using the plant HMI platform is also possible.

Step 2 – The validation of the consistency of the plant I&C systems (operational and safety-related) is identified as the second step. All different I&C modules can be virtually integrated whereas at the real test bay full interconnection is not always possible. Early validation of these modules' interfaces is definitely promising! Combined with the displays of Step 1, understanding of the I&C functions is effectively enhanced and their complexity reduced. The view of an animated display representing the dynamic closed-loop level control in a tank and the corresponding actuation of the control valve and pump, for example, is easier to grasp than the underlying piping and instrumentation (P&I and logic circuitry diagrams. Nor

are additional testing routines required. The testing routines already developed for the open loop control test can be reused.

Step 3 – The functional validation is identified as the third step. This is the costliest step as it requires a plant model, including accurate models of the systems' hydraulic and electrical parts. Models can be based on the CORYS simulation workshop ALICES® or on any other (plant) models used in the project.

Step 4 – At this step, ELVEES is a worthy Engineering Simulator able to effectively support commissioning activities and eliminate their associated risks (de-risking). The preparation of commissioning procedures and instructions for tests of the complex I&C logics will be considered as well as Hardware-in-the-Loop testing.

Step 5 – The transition from an Engineering Simulator to a simulator used for the (operator) training (named OTS or FSS) would be quite small when both share the same models. Commonly known FSS-related challenges can be considerably simplified and would just consist (optimally) of the erection and cabling of a replica of the plant Main Control Room. Thus, de-risking the project helps also to de-risk the "FSS project" and allow to propose the training earlier.

Step 6 – No need to stop. ELVEES can also be used to develop and evaluate proposed ideas of innovative plant optimization.

2 RESULTS

The stepwise approach allows the release of some new practices aiming to de-risk each design step and, at the end, the commissioning. For this purpose, ELVEES has been deployed on the project Angra 3 since 2018 (on Framatome's scope) and on three other smaller projects. It reached the intended objective to insert an engineering simulator inside of the engineering process. This leads to an improvement of the deliverables, and also brings engineering disciplines together to jointly solve encountered challenges.

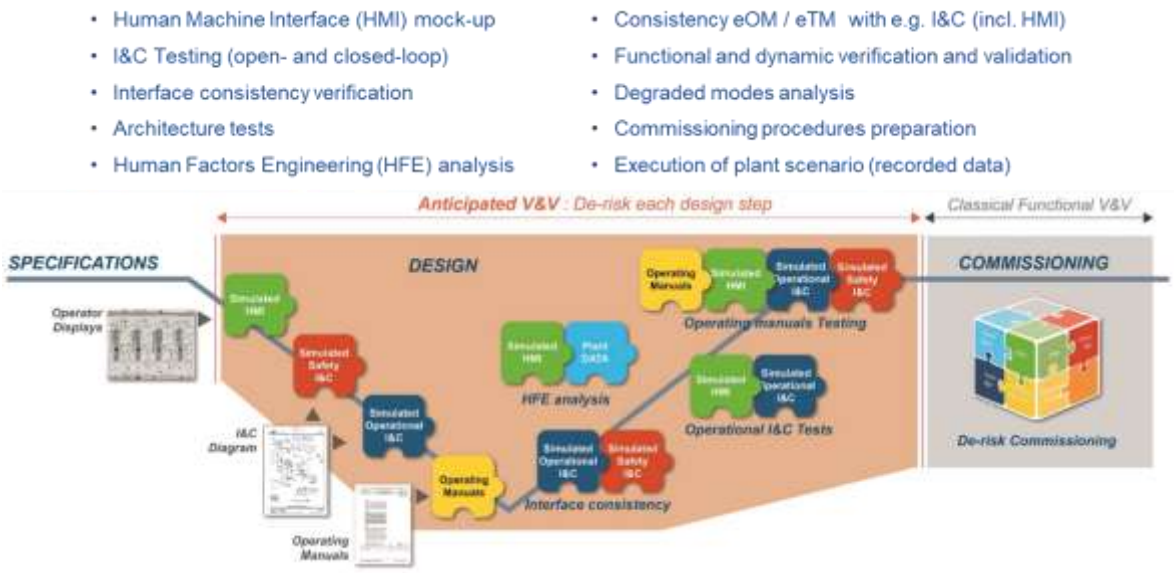

Figure 2: ELVEES Examples of Services

Step 1: HMI Concept Validation

Step 1 was adopted in 2019 by the Framatome engineering department. The new practice provides better formalization and standardization of the process of displays design and evaluation. Last but not least, looking at the operator display makes engineers of various plant engineering disciplines come together to jointly explore encountered problems and resolve them using a holistic approach, taking into account each discipline's tradeoffs and constraints (collaborative solution).

As illustrated in Figure 3 some customer requirements (impacted by the legacy of the past) might be disturbing for the operator when visualized on the real HMI.

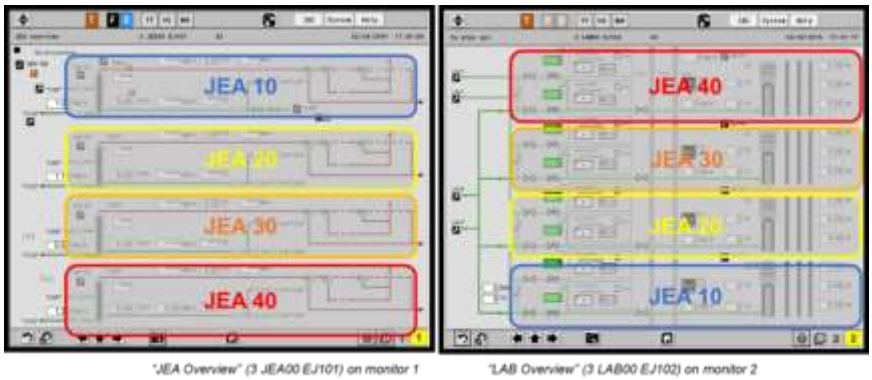

Figure 3: Step 1 example: two operator displays planned to be used together

Step 2: Validation of the Consistency of the plant I&C systems

All different I&C systems (operational and safety-related) using potentially different I&C technologies can be virtually integrated, whereas at the real test-bay full interconnection is not always possible (as different systems from different suppliers are required at the same place and at the same time within a suitable configuration). Through the combination of the displays (developed in Step 1) and different means used to integrate the I&C in the simulator, the understanding and testing of the I&C functions are effectively enhanced. Testing material used during the (single) system open-loop test campaign can be re-used in this new context.

The platform also assists in drafting electronic plant operating manuals.

As a practical example we can mentioned the execution of Architecture tests to verify the correct signal propagation…tests that are difficult to organize prior to the site commissioning.

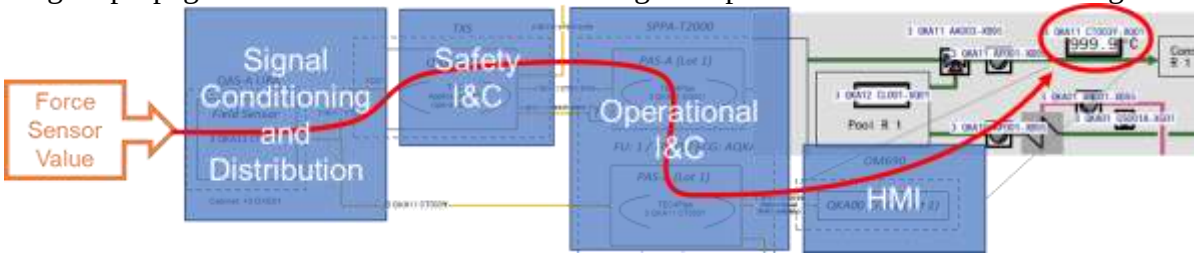

Figure 4: Step 2: Architecture Finding example

Step 3: Functional Validation

The strategy helped ISOGEN[1] on the Isotope Production System (IPS) project to dynamically validate the Software Specification i.e., I&C specifications prior to the I&C implementation (subcontracted). Even if the scope was small (less than 30 devices to be synchronized to handle a compressed air circuit), in the time of "work from home" due to Covid restrictions the identification of specification mistakes has been greatly simplified via the use of a simulator. Live demos (or video) illustrate and support the exchanges with the customer. A problem on the entire system performance was identified.

Customer's feedback: "*The simulator ELVEES was a great tool for giving us quick feedback on the IPS logic; A+ score on problem solving. I am glad that we decided to have you use it.*"

Thanks to the test campaign the initial operator displays have been improved as they were being used by the designers.

Step 4: De-risk commissioning

Finally, and after having been through the entire process, ELVEES has been used on one of the Angra 3 Emergency Diesel Generator (EDG) to virtually demonstrate the correctness of the entire system including: HMI, implemented I&C, back-up panel, operating procedures as well as commissioning procedure.

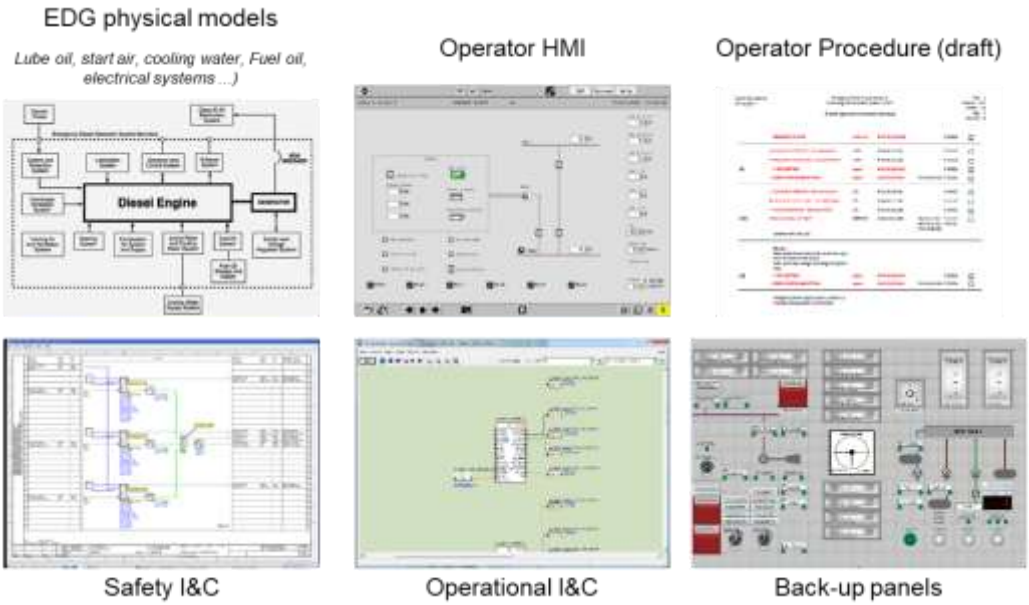

Figure 5: typical deliverables used and validated during Step 3

The Return on Investment (RoI) has been assessed and is as expected, positive (as 13 findings would have been discovered during installation / commissioning, 14 during functional tests, and five potentially during operation).

[1] ISOGEN: joint venture between Framatome and Kinectrics (https://isogen.ca/)

As Framatome I&C wants to enhance collaboration around model exchange with its suppliers and customers, a new project has been started consisting of integrating a KWU NPP plant model named NLOOP (developed by the Installed Based business unit of Framatome and used for plant transient analysis). The target is to couple it with the entire I&C of the Angra 3 project to perform dynamic tests at the plant level.

Step 5: Training
Step 5 and 6 are still under assessment.

3 CONCLUSIONS

The development of an I&C project can face several challenges: specifications more or less mature, partial immersion of the design team into plant operation, and a huge number of systems to be developed in parallel. First integrations and multi-system V&V are performed late in the project which leads to delays and extra costs for the project and the customer.

New tools serving new practices must be developed to master the challenge of integration of I&C systems which become more and more complex. Framatome is planning to further extend the use of ELVEES in its projects and on different technologies.

Early insight provided by ELVEES means that issues are discovered and corrected throughout the design process, avoiding costly and time-consuming redesign work later in the project, helping to secure the commissioning and support and optimize the I&C V&V efforts.

Engineers of various plant engineering disciplines come together and explore encountered problems and resolve them in a holistic approach with the ability to take into account each discipline’s trade-offs and constraints.

REFERENCES

[1] CORYS: https://www.corys.com/en/