Simulation and Design Software

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1. Introduction

Chemical engineers are accustomed to software for designing processes and simulation. Simulation systems such as Matlab and Aspen Plus are commonly referenced in chemical engineering curricula as required courseware and study tools. Automation professionals are also becoming used to applying simulation to operator training, system testing, and commissioning of plant process control systems. Plant design simulation programs are substantially different from systems used for training and commissioning. Many of the most common plant design simulation programs are steady state, low-resolution simulations that are not usable for automation or plant life-cycle management.

2. Simulation

Simulation is usually integrated into the plant life cycle at the front-end engineering and design stage and used to test application software using a simulated I/O system and process models in an offline environment. The same simulation system can then be used to train operations staff on the automation and control systems and the application software that will be running on the hardware platform. In the most advanced cases, integration with manufacturing execution systems (MES) and electronic batch records (EBR) systems can be tested while the operations staff is trained. Once installed, the simulation system can be used to test and validate upgrades to the control system before they are installed. The simulator then becomes an effective tool for testing control system modifications in a controlled, offline environment. In addition, plant operations staff and new operators can become qualified on new enhancements and certified on the existing operating system. The simulation system can be used as a test bed to try new control strategies, build new product recipes, and design new interlock strategies prior to proposing those changes as projects to production management. The simulator can also be an effective risk management tool by providing the ability to conduct failure testing in an offline environment rather than on the operating process.

Simulation's ROI has been proven to be effectual and substantial across all process industries, from batch to continuous processes. The savings come from identifying and correcting automation system errors prior to startup and commissioning and by identifying so-called "sleeping" errors, or inadequacies in the system's application software. Additional savings come from accelerating operators' learning curves and the ability to train operators on upset or emergency conditions they normally do not encounter in day-to-day operations. This reduces operator errors in responding to abnormal situations.

3. Best practices for simulation systems in automation

Nonintrusive simulation interfaces allow the user to test the control system configuration without making any modifications to the configuration database. As far as the operator is concerned, the system is "live"; as far as the database is concerned, there are no changes. By nature, a nonintrusive simulation interface will provide a virtual I/O interface to the process controller application code that supports I/O and process simulation and modeling. It allows the application software to run in a normal mode without any modification so that the testing application software is identical to the production application software. In addition, the nonintrusive interface will not produce "dead code" that formerly was necessary to spoof the control system during testing.

This type of simulation interface supports complete and thorough testing of the application software and provides a benchmark of process controller performance, including CPU and memory loading, application software order execution, and timing.

4. Ground-up testing and training

Ground-up testing and training is an incremental approach, integrated with the automation project life cycle. This approach to application software testing and training has several benefits. Ground-up testing allows identification and correction of issues early in the project, when they can be corrected before being propagated throughout the system.

Additionally, ground-up testing allows the end-user and operations staff to gain acceptance and familiarity with the automation system throughout the entire project instead of at one final acceptance test.

Best practices dictate that training and testing are inextricably linked throughout the automation project. Here are some general guidelines for following this best practice:

● *Control modules* are the base-level database elements of the process automation system. These include motors, discrete valves, analog loops, and monitoring points. Testing of these elements can be effectively accomplished with simple tieback simulations and automated test scripts. Operator training on these elements can also bolster buy-in of the automation system and provide a review of usability features.

● *Equipment modules* are the next level of an automation system and generally refer to simple continuous unit operations such as charging paths, valve manifolds, and package equipment. Testing these elements can be effectively accomplished with tieback simulations and limited process dynamics. Operator training on these elements is also valuable.

● *Sequence, batch controls, and continuous advanced controls* are the next layer of the automation system. Effective testing of these controls generally requires a mass balance simulation with effective temperature and pressure dynamics models. Operator training at this level is necessary due to the complexity of the controls and the user interface.

● *MES applications and business system integration* is the final layer of most automation systems. Mass and heat balance models are usually required for effective testing of this layer. Training at this level may be extended beyond the operations staff to include quality assurance, information technology, and other affected departments.

● *Display elements* for each layer of the automation should be tested with the database elements listed here. In other words, control module faceplates are tested with the control modules, and batch help screens are tested with the batch controls.

5. Simulation system selection

The proven best practice is to use actual automation system controllers (or equivalent soft controllers) and application software with a simulation "companion" system. Simulation systems that use a "rehosted" automation system should be eliminated for system testing and avoided for operator training. Use of the actual automation system components with a simulation system allows effective testing and training on HMI use, display access familiarity, process and emergency procedures, response to process upsets, and control system dynamics. This approach builds automation system confidence in operations staff, resulting in more effective use of the automation system and greater benefits.

6. Simulation for automation in the validated industries

Automation system users and integrators for the validated industries need to be concerned about the GAMP4 Guidelines when they are applying simulation systems to their automation projects.

The GAMP4 Guidelines clearly state that simulation systems are allowable tools for automation system testing. The guidelines also make two requirements for the treatment of the automation system application software. First, they require that the application software be "frozen" prior to software integration and system acceptance testing. Second, they require the removal of "dead code" prior to testing. These two requirements dictate the use of nonintrusive simulation interfaces.

The GAMP4 Guidelines also state several requirements for the supplier of simulation systems for testing of automation projects. The supplier must have a documented quality and software development program in line with industry best practices. The product used should be designed specifically for process control system testing and operator training. Finally, the product should be a commercially available, off- the-shelf (COTS) tool, delivered in validated, tested object code.

Additionally, operator training management modules allow comprehensive development of structured operator training sessions with scripted scenarios and process events. Large or small automation projects can both use a simulation system with a scalable client/server architecture and a stable, repeatable simulation engine.

7. Conclusion

The use of simulation systems for testing and training process automation projects has been proven to reduce time to market and increase business results. The same systems can be utilized in automation life-cycle management to reduce operational costs and improve product quality.

References

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Osama Mohammed Elmardi Suleiman Khayal was born in Atbara, Sudan in 1966. He received his diploma degree in mechanical engineering from Mechanical Engineering College, Atbara, Sudan in 1990. He also received a bachelor degree in mechanical engineering from Sudan University of science and technology – Faculty of engineering in 1998, and a master degree in solid mechanics from Nile valley university (Atbara, Sudan) in 2003, and a PhD in structural engineering in 2017. He contributed in teaching some subjects in other universities such as Red Sea University (Port Sudan, Sudan), Kordofan University (Obayed, Sudan), Sudan University of Science and Technology (Khartoum, Sudan), Blue Nile University (Damazin, Sudan) and Kassala University (Kassala, Sudan). In addition, he supervised more than three hundred under graduate studies in diploma and B.Sc. levels and about thirty master theses. The author wrote about fifty engineering books written in Arabic language, and twenty books written in English language and more than hundred research papers in fluid mechanics, thermodynamics, internal combustion engines and analysis of composite structures. He is currently an associated professor in Department of Mechanical Engineering, Faculty of Engineering and Technology, Nile Valley University Atbara, Sudan. His research interest and favorite subjects include structural mechanics, applied mechanics, control engineering and instrumentation, computer aided design, design of mechanical elements, fluid mechanics and dynamics, heat and mass transfer and hydraulic machinery. The author also works as a technical manager and superintendent of Al – Kamali mechanical and production workshops group which specializes in small, medium and large automotive overhaul maintenance and which situated in Atbara town in the north part of Sudan, River Nile State