Virtual Commissioning: Achieving a Flawless Launch

CIMdata Commentary

Key takeaways:

- *Virtual commissioning enables a complete simulation of machine capabilities included software execution—validating functions and speeding verification processes.*
- *State of the art virtual commissioning capabilities include the ability to mix and match physical and virtual controls and sensors to support hardware-in-the-loop and incorporate physical machines into the simulated machine environment enabling an agile-like methodology within the machine engineering domain.*
- *Solutions such as Siemens Mechatronics Concept Designer and Automation Designer provide a virtual machine control that interacts with geometric and simulation math models so machine operations can be realistically and reliably previewed before a physical machine is built.*
- *Siemens AG is unique within the machinery industry in that they create commercial software to design, simulate, and produce machines; they design and produce machines in a number of industry segments; and they provide controllers and software that drive the physical instance of the machine, i.e., the product.*

Introduction

The machine commissioning process is common across many industries. Historically this has been done by building a physical version of a machine and all of its controls, then testing the system manually to assure that everything works as specified. This can be time consuming and very expensive. When flaws are found, it is almost always late in the development process, typically with deadlines and penalty clauses looming. Virtual commissioning uses product models, simulations, and physical components to verify how a machine will operate, and how it will be controlled before the physical machine is built. Later, the same virtual-physical model can be used for operator training and to validate expansion of the machine capabilities through software and hardware upgrades. This enables shorter development time, lower costs, and higher quality, ultimately leading to a flawless product launch.[1]

Virtual commission uses a variety of software tools linked with preexisting physical items (hardware in the loop, or HiL) to simulate and validate product fit, function, safety compliance, control, and performance. The scope covered with modern virtual commissioning tools combined with actual hardware and human operators can simulate most, if not all, validation testing derived from product requirements. Furthermore, virtual commissioning enables testing to be done in less time and the use of potentially destructive or hard to execute tests, providing additional product insight. Data captured from physical products via IoT can be used to drive the virtual models helping to ensure that real-world scenarios are used for verification and validation.

Early implementations of virtual commissioning focused on physical fit and function. However, in recent years, the technology has expanded to support validation and verification (V&V) combining HiL, software in the loop (SiL), and human in the loop (HITL). HiL is a strategy whereby hardware devices (such as PLCs and safety switches) are connected to the software,

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electronics, and mechanical design model (i.e., the digital twin) to simulate and test operational characteristics of the complete machine. Using HITL, humans can be deployed to interact with those hardware and simulated software controls to validate that the machine will behave as expected.

The primary benefit of supporting V&V is that the functional behavior model of the machine can be simulated using software PLC and human-machine interface (HMI) inputs. The functional behavior model is an intelligent 3D model that demonstrates kinematic behavior response to inputs that can be initiated by the PLC code or by user interaction with a mouse or other input devices. In the model, users can open and close doors, engage with the HMI and other user interfaces (e.g., buttons and selectors). In response, motors cause rotation of shafts and change the position of the attached components, and so on. When these events can be sequenced and responses to signal-generating components (limit switches, etc.) can be registered, then the simulation can forecast what will happen when a motor is turned on for 45 milliseconds at a given voltage or until a limit switch is met. That sequence of operations can be fed into a PLC code authoring tool so the control system will know how to react when the machine is operational. The code can be finalized, and fed back into virtual PLC and HMI emulations for validation. By starting up the machine with the emulation, the digital model behavior is linked and responds accordingly. Collisions and code changes can be resolved almost immediately, and nearly every single use case for machine operation can be executed in a fraction of the time when compared with a physical machine, and without the risk of wrecking machine parts.

Beyond V&V, virtual commissioning also enables early training as well as remote training, a useful capability in our current work from home situation caused by COVID-19. Operators and technicians can test software and control concepts in a virtual or mixed virtual and real environment using a physical control to drive a virtual machine or a virtual control to drive a physical machine. This flexibility allows ideas to be tested early, improving products, and training to be done before the machine is production-ready, so when it is, the startup will be quicker and more productive.

Installation and Commissioning Issues

Machinery installations are often complex and costly. Machines are usually large and heavy, cost a lot to ship, often have to be assembled on location, require specialists (riggers) to position the equipment, and need many specialists (electricians, mechanics, and others) to assemble and test. Often this is the first time the whole machine has been assembled and surprises happen. Modules don't mate together, interfaces don't connect. The installation team is stressed and the design office scrambles to verify issues in the design and develop fixes and workarounds. It's usually a high-pressure event resulting in a lot of anxiety.

Beyond mechanically fitting together, electrical and electronic functions constitute another level of issues. Sensors and controllers have to manage real world physical problems with raw material inconsistences, signal issues from sensors, and timing issues. Because operators may have only had cursory training, basic setup and operation is more time consuming, delaying productive use of the machine.

Another critical issue is electronics obsolescence, especially when custom electronics are developed for a machine. Electronic components often have short lifecycles driven by the high-volume high-tech electronics industry. As components become obsolete, machine builders need to update designs to use the latest replacement components. Compatibility is sometimes an issue, but sometimes, a direct replacement is unavailable so a circuit needs to be redesigned.

Software is a difficult issue because it is not often managed in parallel with the hardware and electronics definitions and its integration typically happens late in the machine's development lifecycle. Also, machinery usually has lifecycles measured in years if not decades so software updates have to be managed and documented throughout. Choices in electronics and embedded software frameworks can last for decades, so finding people and technology to provide support can be difficult. As code is modified and extended over the years it has to be tested to assure it is bug free. Assuring that the installed software configuration is appropriate in the context of the machine's control systems is very difficult when software is not adequately managed and controlled in the context of the machine's design.

Within a virtual commissioning environment, the software is part of the configuration. So, multi-domain configuration management capabilities must include embedded software as part of the as-built configuration and keep track of field updates via the as-maintained configuration. During the course of a machine's life, multiple upgrades and capability additions are typical—from hardware and software upgrades, control system changes, and additional modules to expand the machine's capabilities to support the end customer's product mix changes. Having an accurate and comprehensive digital twin allows all of these changes to be validated, saving countless hours of machine downtime.

Siemens Solution

Siemens Advanced Machine Engineering (AME) is a subset of the Xcelerator portfolio focused on supporting machine building companies by providing all the appropriate portfolio technologies to support the three capabilities all machine builders need—multi-disciplinary design, configuration management, and virtual commissioning, in a single package.

A critical part of AME is Mechatronics Concept Designer, as it brings the model to life enabling commissioning to happen virtually. It provides a library of reusable data to build up a machine concept including joints, motion definitions, sensors, actuators, collision behavior, and other kinematic and dynamic properties for each component. The model built with this data is executable, that is it simulates the machine's behavior, including executing controller code in real time. The data formats and model element are compatible with the rest of the Xcelerator portfolio including NX for MCAD, Simcenter for multidomain and multiphysics simulation, Capital for ECAD, Polaron for software, and Teamcenter to tie the authoring tools and their data together with development processes into a comprehensive digital thread and actionable digital twin. Furthermore, virtual testing is supported, so machine functions can be validated in a fraction of the time it would take on a physical product, enabling more thorough V&V.

Teamcenter provides the data and process management backbone to manage the digital thread and digital twin through design, manufacturing, and production and ensure all configurations across the lifecycle are managed and fully traceable. To successfully commission a product, its data must be complete and valid and robust impact analysis is necessary to ensure inevitable product changes are implemented quickly and accurately. Teamcenter supports this activity as well. Siemens is able to bring in other elements of the Xcelerator portfolio including Mindsphere to support IoT requirements closing the loop on the end-to-end process.

Conclusion

The business benefits of virtual commissioning cannot be overstated. Using a model to make the right decisions and predict product and business performance before the production investment is made is the goal of most companies' digital transformation programs. Virtual commissioning should be a core element of any machine builder's digitalization strategy. Beyond commissioning the digital twin operation digital models can be linked via IoT to support condition based and predictive maintenance programs for the customer or more importantly in product as a service business models. This combination of digitalized product, production, and operation is the heart of virtual commissioning, and Siemens has all the parts assembled into their Advanced Machine Engineering solution.

For more information please see Siemens Digital Industries Software at:
siemens.com/plm/advancedmachinery

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