Virtual Commissioning

Maplesoft
Mathematics • Modeling • Simulation
A Cybernet Group Company

Executive Overview

Technology is driving dramatic transformation in the manufacturing sector. The rise of the internet of things (IoT), automation, advancing digitization, and electrification are propelling the industry forward and helping manufacturers deliver a vast range of state-of-the-art products. Technological changes benefit manufacturers by achieving significant time and cost savings through mass optimization of production lines.

However, today's production systems require extensive development and validation to meet the needs of the highly competitive manufacturing industry. This is a high-risk activity. Manufacturers must adhere to very tight schedules and budgetary constraints when deploying these upgrades and new systems. After all, a manufacturing facility cannot generate revenue while lying dormant, waiting for a new or upgraded production system to hit the factory floor.

Virtual commissioning is a solution. It allows production planners to start developing and validating systems using simulation before any physical commissioning occurs. It also empowers manufacturers to make better decisions, reducing both costs and the risk of long production delays. This report endeavors to provide guidance on adopting virtual commissioning. It addresses several deployment issues.

- The first section identifies change drivers for organizations developing and commissioning production systems, including continued reduction in manufacturing costs and the impact of transformative product changes.
- The second section defines virtual commissioning. It examines the people, processes, and technologies associated with it; the resulting practice and process changes manufacturers must make; the changes to the organization's roles, skills, and knowledge base; and identifies key technological enablers.
- The third, and final, section identifies paths to value for virtual commissioning, including reduced development times, lowered costs thanks to thorough vetting of production system upgrades, and the ability to enable widespread innovation.

Each production system has its own unique lifecycle and must integrate new equipment and processes to keep pace with industry demands. Virtual commissioning offers manufacturers a highly efficient and effective process. It mitigates risks of change, and expedites innovation to the factory floor.

Planning and Commissioning Production Systems

Every production system goes through two major development phases: planning and validation. During planning, manufacturers select equipment, place cells, lay out lines, and organize the entire facility to fulfill manufacturing requirements. They also plan and develop the software logic of the human-machine interface (HMI) and programmable logic controller (PLC) hardware, which drive the cells, lines, and facilities, during the development stage.

During validation, manufacturers test that the production system does, in fact, fulfill manufacturing requirements, and resolves all issues associated with HMI and PLC logic. This latter part is very close to identifying and fixing software bugs. Thus, the activity is commonly referred to as “debugging” the production system.

The main goal is to facilitate smooth and swift deployment of any new or upgraded production system. This is not without challenges. Such systems are composed of highly complex HMIs and PLCs, and use an array of complicated and interconnected equipment. An insignificant change to one component causes a domino effect across a production facility. As such, it is not easy for manufacturers to plan, install, and commission any modern production system. adopting virtual commissioning. It addresses several deployment issues.

Manufacturing Costs will Continue to Drop

Financial forecasts predict that the cost of manufacturing will continue to drop. Specifically, material costs and manufacturing overhead will be lower across the board. Manufacturers aim to capitalize on this shift, demanding lower prices from suppliers. Such drops translate to a need for shrinking production costs.

In response to this trend, manufacturers must implement novel, low-cost approaches to protect margins. Manufacturers could merge several production operations into one to deliver faster and reduce holding costs. They could optimize their systems to eliminate more waste from their manufacturing process. They could employ more automation. In each of these cases, manufacturers must adopt new or upgraded production systems that are free from errors and provide minimal downtime. Again, these changes come at both capital and operational expense, where associated risks must be mitigated to maximize the manufacturer's profitability.

Products are Undergoing Transformational Change

With few exceptions, today's products are evolving, thanks to increasing consumer demands and advancing digitization. Cars are a clear example of this evolution. They are no longer regarded as simple vehicles, but as mobility solutions, powered by electrified and autonomous technologies. Additionally, they are integrated with digital devices, providing drivers and passengers with the connectivity they now demand. Simultaneously, autonomous vehicles continue to push the automotive market forward, unleashing new business models and modes of travel. This is just one example of product transformation. Such change is occurring in almost every industry.

These cross-industry sea changes are forcing manufacturers to retool facilities and plants. Their existing production systems simply are not capable of making these new offerings. To ride the wave of success in the midst of such fast-moving change, manufacturers must implement new or upgraded production systems rapidly. Manufacturers must not allow facilities and plants to sit idle while a new production system undergoes its debugging process. Instead, they must accelerate a new production system's development and validation. Slow turnover results in manufacturers losing market share. capitalize on this shift, demanding lower prices from suppliers. Such drops translate to a need for shrinking production costs.

Driver Takeaways

- Decreasing material and manufacturing overheads drive the development of increasingly efficient production systems that help manufacturers protect margins.
- Manufacturers must introduce new or upgraded production systems quickly, or risk losing market share thanks to excessive downtime.

People, Process, and Technology

Virtual commissioning is the practice of using simulation and modeling to test and verify new production systems or proposed changes to existing ones. In virtual commissioning, manufacturers debug the logic and programming of HMI and PLC hardware in a virtual environment before commissioning any physical equipment. This mitigates the risks of revenue loss and prolonged downtime.

Manufacturers must focus on two key changes for virtual commissioning initiatives.

1. The first involves introducing widespread use of 1D system simulations, which assess the operation of the system and provide manufacturers with a safe and virtual place to test and optimize proposed changes. Such analyses transpire during the planning stages. Simulations also enable manufacturers to make better decisions before commissioning any physical equipment. Virtual commissioning begins with the creation of 1D models of the production system. Next, production planners test the models with those of other production systems to ensure the accurate simulation of the manufacturing line, cell, or entire plant. Combining different models guarantees the system's interoperability and impact on surrounding systems.

2. The second change involves the progressive replacement or integration of 1D system simulations with the manufacturer's physical HMIs and PLCs to validate their logic and programming. Here, planners replicate the behavior of one or more pieces of hardware within the software environment and connect it to real, physical hardware. The goal is to create a virtual environment that mimics the real hardware used in the manufacturing plant, permitting production planners to validate individual parts of the production system long before engineers complete a physical commission.

Changes to Practices and Processes

The adoption of virtual commissioning also requires other changes to a manufacturer's operating procedures. The manufacturer must bring in its production planning team during the early stages of the commissioning process. This entails a cultural shift. Such an up-front investment in the planners' time pays off in the long term, by providing the manufacturer with the means to identify and rectify any issues early. Advocates of virtual commissioning must clearly communicate this benefit to the manufacturer's executive team in order to win buy-in.

Early and continuous use of 1D system simulation throughout the development of a manufacturer's production systems requires more changes. Manufacturers must transform existing workflows and embrace a number of new processes. In order of implementation, these processes include:

- Model-in-the-Loop (MiL): First, production planners create a digital model of the PLC or HMI software logic. They then connect it to a simulation model of the production cell or line. They run a coupled analysis to determine whether the proposed production system behaves as expected. This process is a completely digital activity. It allows production planners to make informed decisions and optimize the system without the time and expense of physically commissioning any equipment. If the simulation produces an error, they change the logic model and rerun the simulation. The production planner then continues to tweak the model until it generates the right outcome. This digital approach to debugging production systems is a fast and easy virtual verification method that does not require compiling the software.
- Software-in-the-Loop (SiL): Next, production planners verify that the logic in the model is the same once the software is compiled. The code is automatically generated and run on an emulator to mimic hardware in the target HMI or PLC. Planners then test the software within the modeling environment, permitting production planners to develop and verify the software across different, detailed control strategies within a virtual simulation environment. Any errors that do occur were made during the transition from the MiL to SiL stages.
- Hardware-in-the-Loop (HiL): This step enables production planners to verify that the compiled software running on the PLC or HMI controllers still acts as expected, in real-time, when responding to realistic, but virtual, stimuli and scenarios. Production planners also use HiL to determine whether the model of the physical system is valid. This stage pushes the manufacturer closer to physical commissioning and to testing its controller before moving into a live environment. Planners also test for extreme, potentially catastrophic events that are unlikely to occur. These tests allow planners to make mitigation plans for such events, just in case.

Changes to Roles, Skills, and Knowledge

When using virtual commissioning, a manufacturer depends on 1D system simulation to understand the interaction between HMI or PLC logic and the equipment in the production system. This requires a specific and specialized skill set in the production planning teams, who must:

- Build, validate and optimize system-level and component-level models;
- Use a range of modeling techniques to increase simulation accuracy;
- Design and conduct suitable tests to validate model predictions; and
- Develop simulation plans to address specific technical issues.

Production planning teams must also work at the intersection of physical and virtual environments. They must connect physical HMI and PLC controllers to the software simulation and tests before moving into a live environment. It is possible that production planning teams already have these skill sets or are closely connected to the organization's skilled installation teams. Either way, a manufacturer's production planning team must adopt these skills internally to utilize each virtual commissioning phase and run necessary simulations.

It is unlikely that a manufacturer new to virtual commissioning already employs a workforce that possesses all of the required skills and experience. So, any organization adopting a virtual commissioning initiative must acquire workers who possess the necessary skills to fulfill its virtual responsibilities.

Depending on the project requirements, manufacturers may build a proficient workforce in one of several ways. They may train existing production planners, hire new talent, or work with specialist contractors. Permanent hires are a long-term solution, but by using contractors, manufacturers can retain the flexibility to source the right skills at the right time.

Key Technological Enablers and the Maplesoft Solution

Today's 1D models and simulations permit production planners to test changes seamlessly within the safety of the virtual world. The iterative nature of the MiL, SiL, and HiL processes allows production planners to analyze system behavior early in the project cycle, make necessary changes without physically commissioning any equipment, and explore a broad range of design options. They can also mock up the system and conduct a range of studies, within specified parameters, to understand what variables are crucial to enhancing system performance. This also allows them to explore the impact small changes will have on the facility.

As a result, manufacturers can balance many of the complex trade-offs necessary to optimize their production facilities and processes. This can help them drive profitability and sustainability as a business. Using 1D models and simulations, they can fully explore an issue in the digital domain, identify the root cause of a problem, and make the best decision to solve the issue. The manufacturer can make smarter decisions thanks to the insight that 1D models and simulation provide. This technology can be used in many areas of the supply chain. Manufacturers can also extend simulations to model the entire system inside a single environment, enabling them to test the impact of any proposed change and detect any issues that arise from unexpected interactions between different lines, cells or systems.

To achieve this level of connectivity, virtual commissioning models must work together. Yet, different people design these models using different software systems. Software applications change over time as well, exacerbating any potential interoperability issues. This is where component libraries help production planners reuse models across different simulations. Every component in a library requires thorough testing to verify behavior and guarantee the accuracy of the simulation. Once verified, these component libraries supply production planners with a powerful toolset to run accurate and full virtual commissioning simulations.

Manufacturers do not have to create component libraries from scratch. With the MapleSim solution, production planners embrace virtual commissioning with minimal disruption. MapleSim is an advanced system-level modeling tool that empowers manufacturers to create component libraries and leverage the power of MapleSim's existing Block Library.

Key Technological Enablers and the Maplesoft Solution

Using its intuitive drag-and-drop interface, production planners construct the modeling environment and import existing models created in other Functional Mock-up Interface (FMI)-compatible software.

The FMI standard facilitates exchange of disparate models in a standardized format. Manufacturers trade proprietary models and use existing models from the MapleSim toolset. When a production planner connects two models to generate a comprehensive view of a production environment, this process is called co-simulation. It is only achievable because of the interoperability standards the FMI offers.

These technologies and tools also enable seamless creation of a digital twin, which is simply a virtual representation of a physical system. A production planner builds the mechanism using MapleSim's customizable components or a CAD import. MapleSim actuates and analyzes the digital twin before exporting the virtual model and pushing it through the virtual commissioning workflow.

This is a repetitive process. The digital twin is updated and improved until the desired outcome is achieved. Since model-based digital twins do not require physical performance data to predict behavior, they are also used for a range of engineering tasks. These include virtual commissioning, the development and testing of conceptual designs, complete online diagnostics to proactively detect failures, and the introduction of smarter devices to the factory floor.

Paths to Value

Virtual commissioning provides manufacturers with many paths to value, including a range of proven and tangible time, cost, and resource benefits. Through the provision of this simulation framework, manufacturers can reduce the timescales associated with commissioning a new production line or facility, reduce the costs of maintaining and managing their existing facilities, and expedite innovation across the wider business.

Shortening Time to Full Production

Virtual commissioning cuts the time it takes for a new or upgraded system to move to full production, accelerating the on-site commissioning. It minimizes the time needed to debug a system physically, moving these time-consuming tasks into the virtual domain. Virtual commissioning also replaces the traditional **plan > install > test > debug > retest > debug** stages with just two steps: **plan > install > verify**. Manufacturers also multitask and run virtual tests on multiple projects. This gives manufacturers the ability to detect and eliminate any system flaws or software bugs, and resolve a range of technical, performance, and functional issues in advance.

Manufacturers demonstrate return on investment (ROI) of virtual commissioning pursuits in a variety of ways, depending on the organization's business goals. One method is calculating total revenue generated from diminished production downtime. Physically duplicating and debugging every new production system or upgrade requires significant time and money. Another technique is minimizing downtime throughout the factory. Advocates should communicate these tangible benefits of virtual commissioning across an organization.

Reducing Costs by Vetting Production System Upgrades

Virtual commissioning cuts costs by allowing planners to vet design changes. They can model and test a huge range of modifications to a system before making any physical alterations to it. This decreases the risks associated with such system changes and enables production planners to identify cost-saving opportunities.

Virtual commissioning thus represents a marked improvement compared to traditional commissioning. For example: a manufacturer devises a strategy that it believes will improve an existing system and reduce waste for a specific section of the production process. Without virtual commissioning, any calculations to verify this proposed approach are simplistic, inaccurate, and, therefore, fail to deliver the benefits of virtual commissioning.

By contrast, a full cost-savings analysis using virtual commissioning mitigates these concerns. Production planners can explore different changes to the production system in the digital world. It's not only simple to tweak the processes used in such simulations, it's also easy to confirm the resulting behavior at the cell, line, and system level. A cost-savings assessment is a comprehensive way to digitally test and bolster any proposed system upgrade, allowing production planners to gain business buy-in.

Making More Innovation Production Decisions

Virtual commissioning expedites innovation for production systems. It offers an efficient and feasible means to iterate over a comprehensive range of design possibilities, and find the best solution. Production planners test across more scenarios and options while planning the system in the virtual world. The virtual components of the system emulate the behavior of real-world counterparts without the expense of real-world commissioning. This drives innovation. Planners also automate this exploration process, enabling them to uncover design possibilities outside the bounds of the human imagination. As a result, production planners are armed with a greater range of insights into system behavior, allowing them to make better, well-informed decisions for system design.

Planners are better equipped to identify a revolutionary approach for the manufacturer, thanks to increased understanding of the system.

The production planning team also explores the impact of changes across the manufacturing line, cell and facility. As a design moves closer to physical commissioning, the team thoroughly tests the impact a change has on the wider production facility. Such in-depth exploration not only provides peace of mind to the planning team, it also enables planners to identify additional ways to cut costs and boost production. In short, mass optimization throughout system design and production processes lead to increased revenues for the manufacturer.

Summary and Recommendations

Summary

Falling manufacturing costs threaten supplier's margins, driving the development of increasingly efficient production systems. However, manufacturers must deploy changes with minimal downtime to avoid losing market share.

Manufacturers must embrace 1D system simulations, including the MiL, SiL, and HiL virtual commissioning processes, which require them to upskill and introduce new software solutions to reap the full rewards of virtual commissioning.

Advantages include: decreasing the time to full production for any proposed solutions, removing the need to physically debug systems, and lowering costs through analysis of all product system upgrades. Together, they accelerate innovation and help manufacturers make better production decisions.

Recommendations

Calculate the monetary impact of one round of validation

- On an upcoming project, identify the number of "rounds" of testing and debugging that physical commissioning would require.
- Calculate the time saved if that number was reduced to one round.
- Talk with a financial stakeholder. Determine the financial impact of realizing those savings.

Understand the scope of the change

- Talk to individuals across the entire production flow, and identify your pain points.
- Explore technologies and make sure you find the right fit for your organization, especially if seeking out a customized solution.
- Start small and try virtual commissioning in a pilot project first.