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VIRTUAL VALIDATION OF AUTOMATION INTEGRATION FOR DUAL MANIPULATORS ON A 25 MN OPEN DIE FORGING PRESS

By Johann Dupré

pen die forging presses represent strategic industrial assets whose performance and availability directly affect production output, product quality, and business continuity. These machines typically operate for several decades, and any modernization must therefore be managed with both technical precision and production risk control in mind.

Recently, a major French forge initiated a program to replace two legacy rail-bound manipulators operating alongside its 25 MN open die press. The goal was clear: secure long-term production reliability and adapt the installation to future demand growth expected over the next 25 years. Because the press produces critical components for the energy, defense, and heavy equipment industries, its shutdown window for installation had to be strictly limited.

To achieve these objectives, the project team focused on virtual validation—using simulation tools and structured acceptance testing to ensure that the new automation system would perform flawlessly from the first production day.

In open die forging operations, manipulators are essential for positioning, rotating, and aligning large workpieces between press strokes. They must synchronize perfectly with the press to maintain process quality and operator safety.

The existing manipulators, installed at least two decades ago, had reached the limits of their reliability. Their control systems were based on obsolete electronics, spare parts had become difficult to source, and their communication interfaces were incompatible with modern PLC architectures. Beyond maintenance issues, their limited responsiveness and synchronization accuracy restricted throughput and flexibility.

Given the forge's expanding production forecast and commitment to operational excellence, replacing both manipulators was unavoidable. The new equipment would incorporate advanced hydraulic systems, proportional control valves, and modern automation networks. However, integrating these manipulators required a complete redevelopment of the PLC program that governs their interaction with the press — a task with significant implications for production continuity.

The modernization scope included the complete re-engineering of the press and manipulator control logic. This meant rewriting the PLC program to manage:

- Real-time synchronization between both manipulators and the press stroke.
- Smooth transitions between manual and automatic modes.
- Integration of safety functions and communication diagnostics.
- Adapted operator interfaces to the new manipulators status and alarms.
- Predictable, reproducible behavior from the first production day.

The press and its two manipulators are now governed by a new-generation Siemens PLC recently migrated to the TIA Portal environment. This controller communicates over a Profinet industrial network with several ET200SP remote I/O modules distributed across the press and manipulator systems.

This architecture provides high-speed deterministic communication, simplified diagnostics, and modularity for future expansions. The choice of TIA Portal also enables unified engineering -combining PLC logic, HMI development, and network configuration within a single environment—thereby streamlining program maintenance and version management.

The challenge was not only technical but also logistical. The forge's production schedule left a narrow shutdown window for commissioning. Any unforeseen issue discovered during on-site startup could delay production restart and have a significant economic impact.

To mitigate this, it has been decided to validate the complete automation logic before the equipment was even built, using a combination of virtual and physical testing platforms.

This two-phase validation approach—combining digital modeling and workshop trials -allowed the control program to be fully tested and verified before integration on the production line.

The first project phase focused on virtual validation using a dedicated simulation environment that could reproduce automation architectures, hydraulic circuits, and control logic.

A detailed kinematic model of the two new manipulators was created, including their motion axes, hydraulic control loops, and feedback signals. The PLC program was connected to this model via an interface that emulated real I/O exchanges. Real press movement curves were imported as input data so that the manipulators' control sequences could respond as they would in actual production.

While the model was not a dynamic simulation (no friction, efficiency, pressure loss, or fluid compression were considered), it precisely reproduced the control structure, the phases, and the operator interactions. The virtual setup also included the same HMI screens and command desk that operators would later use on the real machine.

One key aspect of this phase was the active participation of the forge's operators during simulation sessions. They used a dummy control station to drive the virtual manipulators and observed how the system responded to commands, sequence changes, and emergency stops.

This early involvement not only improved user acceptance but also allowed fine-tuning of control ergonomics—such as joystick control, visual feedback, and alarm hierarchy—before commissioning.

During the SPAT session, operators were invited to provide feedback on the Human-Machine Interface (HMI) design. Their comments focused on the organization of control pages, the visibility of key parameters, and the intuitiveness of alarm messages. All relevant remarks were collected and directly implemented by the automation engineers within the simulation environment. This proactive approach eliminated a fair number of potential adjustments that would otherwise have been discovered later during on-site commissioning, saving both time and production downtime.

The phase concluded with a Simulated Platform Acceptance Test, structured identically to a conventional Factory Acceptance Test but conducted entirely in the digital environment.

- Verification of each manipulator's individual motion functions and safety chains.
- Coordination testing between both manipulators and the simulated press cycle.
- Execution of complete forging sequences reflecting real production workflows.
- Testing of emergency procedures, fault recovery, and interlock behavior.

The SPAT confirmed the functional integrity of the PLC program and ensured that all operational scenarios had been validated in advance.

With the virtual phase successfully completed, the project entered its second validation stage, conducted at the manipulator manufacturer's facility.

Before shipment, both manipulators will be temporarily installed on rails facing each other in the workshop. This configuration replicates their final layout on the forging press. The PLC system, equipped with the validated software from Phase 1, will control both manipulators simultaneously.

Since the actual press will not be present, its movements and signals will be simulated by the automation system using the same virtual model developed earlier. This hybrid configuration—real manipulators controlled by a PLC interacting with a simulated press—provides a powerful, realistic testing environment.

The workshop integration trials will allow the engineering team to:

- Validate all communication links between sensors, actuators, and the PLC network.
- Assess synchronization accuracy between manipulators under real hydraulic conditions.
- Adjust some movement profiles before shipment.
- Test fault detection and safety shutdown sequences under controlled conditions.
- Rehearse the commissioning procedures that will later be applied on-site.

This approach enables the automation and mechanical teams to collaborate closely, refining the system in a safe environment without time pressure. Once the trials are completed, the manipulators and PLC cabinets will be shipped to the forge, ready for final installation and connection.

By completing most of the testing work before arrival on site, the project minimizes the duration of the production shutdown and increases confidence in achieving the targeted restart date.

The success of this modernization project was also the result of a tightly coordinated collaboration between the forge operator, the manipulator manufacturer, and the automation integrator. From the early design stages, all stakeholders agreed on a shared objective: ensuring a reliable, predictable restart of production after modernization.

Regular design reviews were held to align mechanical constraints, hydraulic system performance, and automation sequences. The manipulator manufacturer provided detailed digital documentation and hydraulic schematics, which were directly imported into the simulation environment to ensure consistency between the virtual model and the real machines.

Monthly coordination meetings between automation engineers and the forge's project team allowed early identification of operational priorities. These exchanges proved invaluable during the simulation session, as operators could immediately confirm whether the control logic matched their real working practices.

The two-phase validation strategy provided significant benefits across all project dimensions:

1. Risk Mitigation - Early identification and correction of logic or coordination errors reduced uncertainty and prevented costly downtime during commissioning. Potential control conflicts were resolved long before equipment startup.

2. Predictable Shutdown Duration - Because the control software was thoroughly tested in advance, the production halt could be planned with confidence. The project team and customer shared a precise, validated commissioning timeline, aligning maintenance resources accordingly.

3. Improved Communication and Collaboration - The project brought together specialists in automation, hydraulics, and forging operations. Regular virtual reviews facilitated mutual understanding between software engineers, mechanical designers, and end users, leading to a more robust final solution.

4. Operator Familiarization - By participating in virtual testing sessions, operators developed an early understanding of the new control logic, resulting in smoother adoption during commissioning and fewer adjustment requests afterward.

5. Foundation for Digital Continuity - The simulation model created for this project is now a reusable asset. It can support training, future maintenance, and the development of enhanced diagnostic or predictive functions. The project thus lays the groundwork for a potential digital twin of the forging line.

6. Scalability and Replicability - This validation approach can be applied to other modernization projects, whether for forging presses, manipulators, or other motion-intensive systems where synchronization and reliability are critical.

Modernizing automation systems in heavy-forging environments demands meticulous planning, precise execution, and strong risk management. By adopting a structured, simulation-driven validation strategy, this project achieved all three.

The integration of two new manipulators on a 25 MN open-die press was not just a hardware replacement—it was a transformation in the way control systems are designed and validated. Through virtual modeling, operator-involved testing, and workshop trials, the project team demonstrated that digital engineering can effectively secure physical reliability.

This method provided tangible benefits: a predictable commissioning schedule, validated control logic, and high operator confidence before production restart. Most importantly, it allowed the forge to pursue its long-term growth strategy without compromising uptime on one of its most valuable assets.

As the forging industry continues its transition toward Industry 4.0, projects like this highlight a pragmatic path forward—one where simulation and physical testing converge to deliver safer, faster, and more reliable modernization outcomes.

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