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VIRTUAL COMMISSIONING OF A ROBOTIC CELL PRIOR TO ITS IMPLEMENTATION INTO A REAL FLEXIBLE PRODUCTION SYSTEM.

GENERATION OF THE ROBOT OFFLINE PROGRAMMING (OLP) AND VALIDATION OF THE PLC CODE.

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Abstract

With the rise of the Industry 4.0 and the digitization increase in the field of design of the automated devices and systems, raises the requirements to digitize all stages of the design processes, including Virtual Commissioning. This technology allows to verify the functionality of the device and/or systems, generate OLP programs for robots and test the functionality of the PLC code on the virtual model. The article presents research into the possibility of implementing a robotic cell into a real flexible production system in the Laboratory in order to eliminate defective products after an automatic control through the Quality-handling station. This technology was verified on the basis of a methodology through a virtual system model and a virtual control system in the Software-in-Loop using the Siemens Tecnomatix Process Simulate software.

Key words

Virtual Commissioning, Production System, Robotics, OLP, PLC, Process Simulate

INTRODUCTION/LITERATURE REVIEW

Automated assembly systems are characterized by high complexity, high variety and little standardization of their components. As a consequence, the development process is almost unique for every single automated assembly system. The implementation of a new automated devices and/or robotic stations into a real automated production and assembly systems in the continuous production process takes a time during real commissioning and validation of the

PLC program. It is also problematic to shut down production if the industrial robot is being programmed online using a teach-in method.

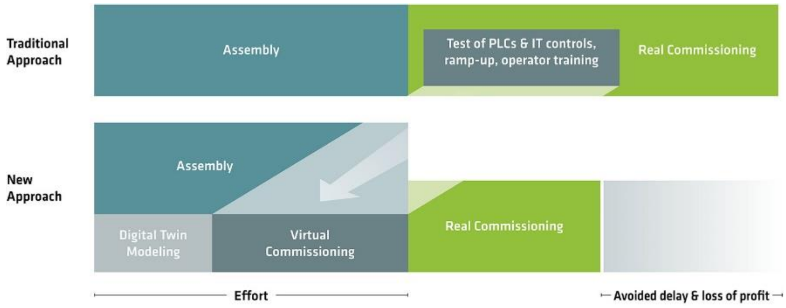

Fig. 1 *Comparison between the traditional and new approaches to the development of automated devices (2)*

A standard commissioning solution requires shutdown time, which in fact means an increase in costs (1). Implementation requires thorough virtual validation procedures that complement the early stages of the design and before commissioning and start-up. Real commissioning and debugging of the PLC code is realised at the end of the device development, Fig.1 (2).

Typically, virtual system components and simulations are executed without the integration of physical automation devices and components e.g. virtual machine behaviour is not validated with physical Programmable Logic Controllers (PLCs) (3). Off-line robot programming has long been used in industry, and most of today's virtual production tools support download robots and upload them to a virtual model (4).

Virtual Commissioning (VC) belong to the core elements of the technological (r)evolution Industry 4.0 - leading to the digitization of the whole production process. The digitization of the production process covers the entire spectrum of design as part of the digital PLM strategy (5). The main motivation to use VC as defined in the previous Fig.1, is to reduce testing and integration time during development (6). This is achieved by being able to test and integrate the control system before the physical production system is completely installed. The using a simulation model of the production system, undesirable behaviour can be detected well ahead of physical installation. In addition, VC enables tests that would be prohibitively expensive or even impossible to run on a physical system (e.g. unlimited virtual parts) (7). Virtual Commissioning is one example of the benefits of integrating virtual models with the physical system. Being able to simulate existing production systems using existing virtual manufacturing models is crucial for example when introducing new automated devices and robotics stations into an existing production system.

Virtual Commissioning permits precocious evaluation, optimization and validation of the entire production system, particularly integration of product, production system's mechanical and electrical components as well as control software (8). The goal of "virtual commissioning" is to introduce complex automation systems based on digital models and methods, especially with the targeted use of 3D simulation and visualization (9, 10, 11). Its goal is the comprehensive planning, implementation, control and constant improvement of all the core production processes and resources in conjunction with real production. The aim of this research field is to develop universal design and simulation tools for automation technology to simulate and assemble a complete production line with all integrated components such as robots, PLCs, feed and transport equipment and sensors (12, 13, 14, 15). On this basis, it is possible to optimize layout, develop robot and control programs, and check for accessibility and collisions. Simulation of all motion sequences, manipulation processes and interactions with the periphery ensures the transferability of the results to the actual production system.

CASE STUDY/PROBLEM

Tested scenarios for the implementation of the new robotic cell into the real production system by use of virtual commissioning will be realized on a real model of the flexible production system with robotic tending. Flexible production system of iCIM 3000 showed in Fig. 2 is a system which is combined with machines and equipment such as automated warehouse, assembly station, test station, CNC lathe and CNC milling. The workpieces are stored on carriers and move on conveyor system through a system to all stations. Flexible production system iCIM 3000 includes CNC milling machines on which is produced the base plate with holes in Ø= 30 mm diameter. The hole is designed for mounting of next component. One part of iCIM 3000 system is the Quality-handling station, showed in Fig. 2. The automated inspection station is responsible for testing of the base plate in system and the middle hole is checked. The diameter of the central hole of the base plate is measured. The measured data are transmitted to SCADA (MES) system where is evaluated the measuring (OK part – diameter is complied, BAD part - diameter is not complied). The results can be performed in two types: tested products are within the tolerance and out of the tolerance (17).

***Fig. 2** Flexible Production System in process at the Research Centre with detail focused on the Quality-handling station with possibility to select defective products*

If the tested product is out of tolerance, it should not be returned to production and should be separated from the material and production flow. It will also take up free space in the warehouse and mix with good products. It is therefore good to include a sorting station in the system, which will select after evaluation of the bad products and not sort at the end of the process in the production system, Fig. 3 (17).

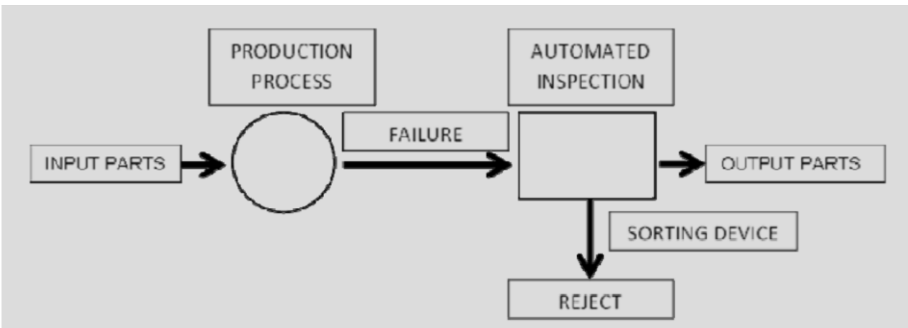

***Fig. 3** Scheme of inspection system with rejected product out of tolerance (17)*

The main role of active inspection system is the automatic elimination of various influences and factors that negatively affect the accuracy of parts and capacity of the production system.

Methodology/Simulation

Basic building block of digital and virtual implementation is to create a digital twin for a real production system. In order to achieve the desired goals in terms of saving time in the design of the assembly systems and the efficiency of the effort and resources made, the digital model of the robotic sorting cell has to be designed in detail from all functional details, there is no difference between the digital model and the realistic device / system. On the Fig. 4 is showed the Digital Twin (CATIA V5-6R2013) compared with real flexible production system.

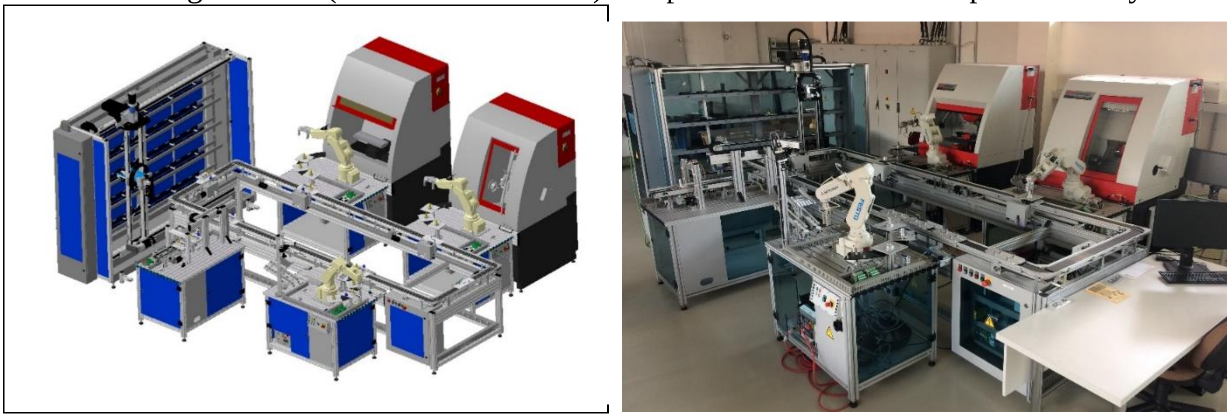

Fig. 4 *Digital model of the Flexible Production System for the Digital Twin realization*

If the CAD engineering done in detail and according to patterns to form a manufacturing and technical documentation and generate production programs through the postprocessor in production systems and machines and the full PLM platform is used, the created models will be realistic. It only depends on the assembly and completion of a technical work with certain deviations and inaccuracies. Virtual commissioning provides a standardized approach and is based on established and proven methodologies (18, 19, 20, 21, 22), tested in the past (23, 24).

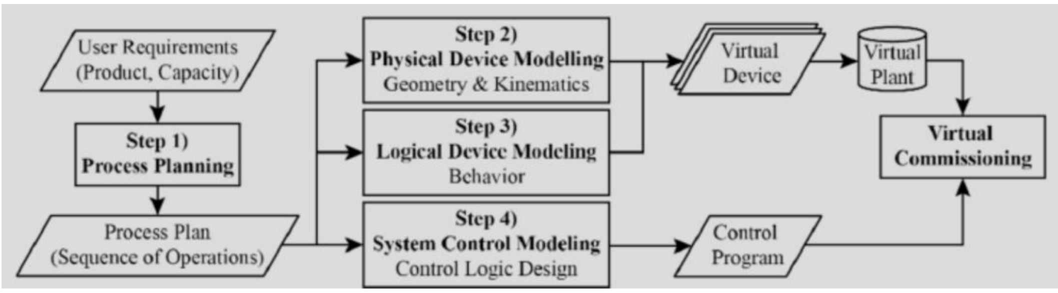

Fig. 5 *Design procedure for Virtual Commissioning*

On virtual commissioning it is necessary to have software support for the development of control programs with virtual testing and validation programs and testing their functionality. The digital twinning software platform for virtual commissioning (Siemens Tecnomatix Process Simulate14.0.1) allows you to link both units, virtual models and control programs to software or hardware interfaces to enable real-time testing of real-time virtual control model behavior and although it is possible to optimize process sequences. With the real-life virtualisation concept, it is possible to simulate in real time all current and future operating processes in the respective production environment through the control system and its program.

The Quality-handling station and implementation of the robotic cell was prepared in several virtual commissioning design stages, as shown in Fig. 6.

1.	Model Library for Digital Twins (Quality-handling station, Robotic cell)
2.	Creation of machine kinematics
3.	Create the necessary logical links and EVENT BASE simulations
4.	PLC a OLP Program
5.	Integration between PLC control and virtual model
6.	Virtual commissioning through technology

Fig. 6 *The basic architecture of the concept of virtual commissioning*

The sorting cell is designed as a platform with industrial robot ABB IRB 120 with Pick and Place device as the manipulating gripper. The selected defect products will be send to the end of the conveyor and moved by robot to the box designed for the storage of the plates. After commissioning and testing of the movement of the industrial robot and conveyed parts (skid, plate) without collisions of the all environment of the both stations in the TIME-BASED SIMULATION was generated the Offline programming (OLP) with defined Targets and Paths with Commands, defined Speed, WorkTool, WorkObjects and Zones. The OLP program was generated to ABB RAPID program by RCS Module postprocessor, Fig. 5.

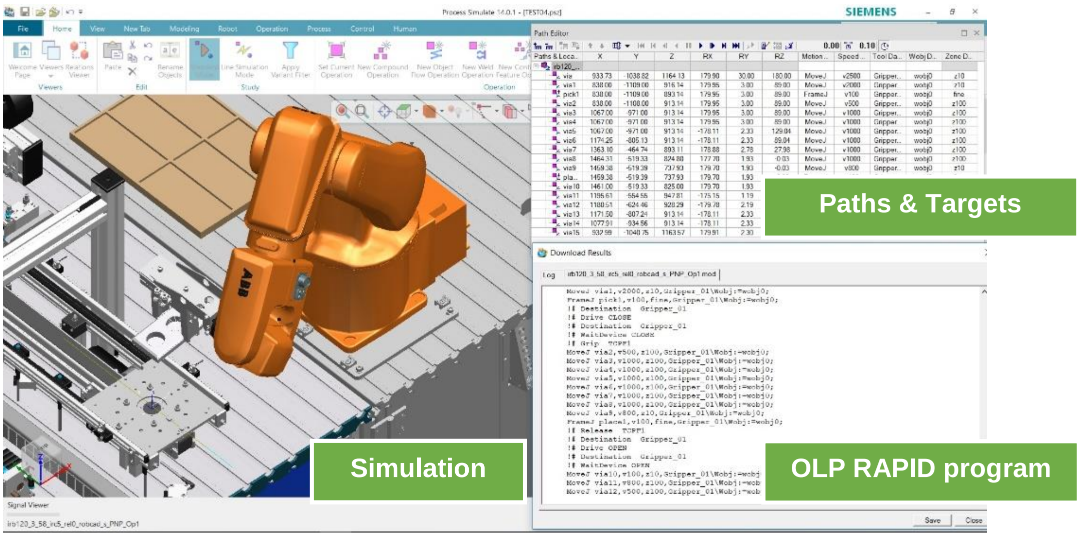

Fig. 5 *Robot ABB IRB 120 in the Pick position with created Paths and RAPID OLP*

After the creation of the required signals (inputs, outputs, position of the conveyed skid) and behavior models of the kinematic devices (robot, gripper, conveyor, stoppers) the simulation was replaced into the Line Simulation Mode as an EVENT-BASED SIMULATION. The simulation model was connected to the Siemens TIA Portal V14 through the SIMATIC S7-PLCSIM V5.4 software, as shown in Fig. 6.

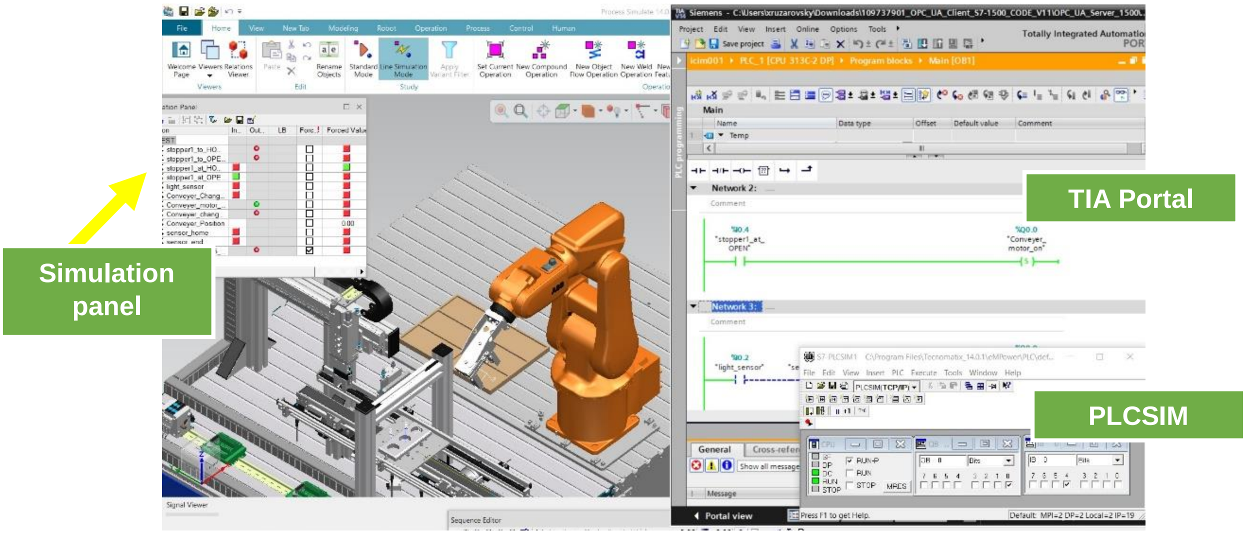

Fig. 6 *Event-based simulation and validation of the PLC code*

The developed Software-in-Loop Virtual Commissioning model (virtual PLC + virtual model) allows testing of various possible scenarios of the PLC code without real collisions. The PLC code is verified on the virtual model and can be download into the real PLC.

RESULTS

The results from the virtual commissioning of a robotic cell prior to its implementation into real flexible production system were validated. The import of the robotic cell was tested through simulation. The industrial robot with gripper allows the achievement of all required locations (Targets). Also verified was the PLC Code. Fig. 7 shows the sequence of the verified virtual model of the robotic cell with the Quality-handling station.

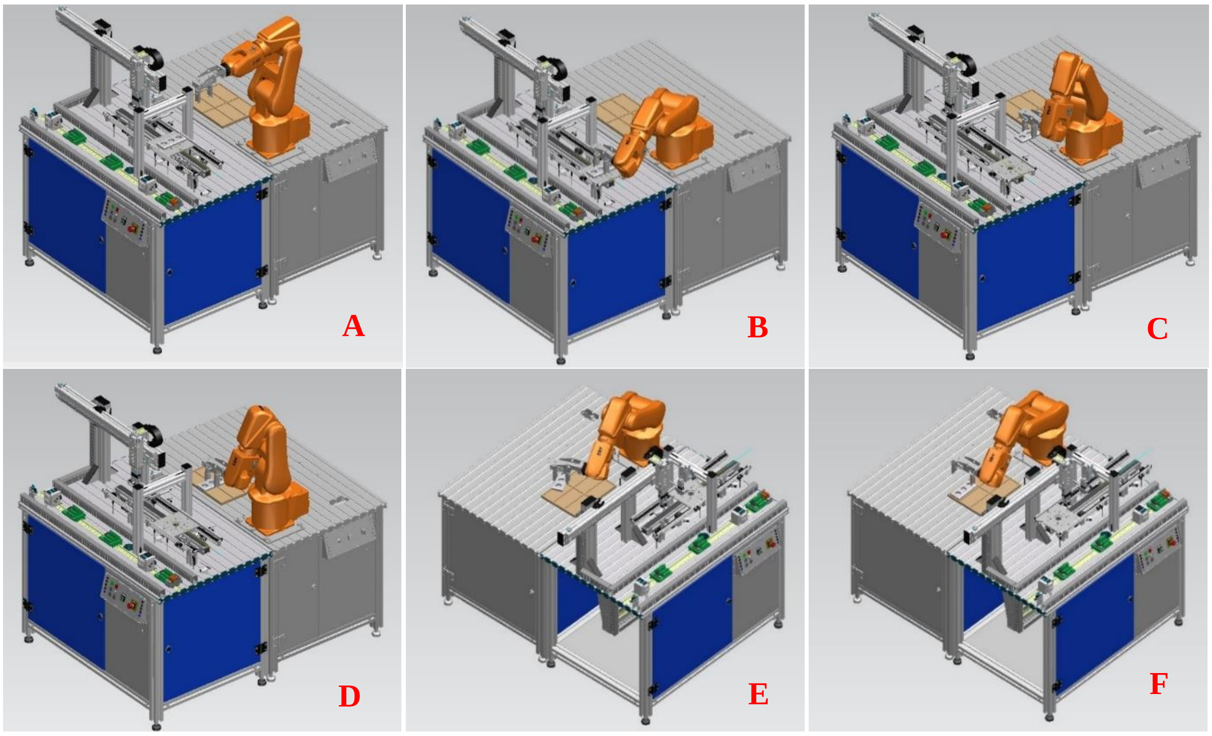

Fig. 7 *The sequence of the robotic cell with Quality-handling station virtual commissioning*

The basic sequence consists of partial steps and actions. The skid (pallet) with defective product (plate) is conveyed to the end of the conveyor (Fig. 7A). The pneumatics stopper allows the movement of the skid. The light barrier detects the plate on the pallet and the inductive sensor detect the pallet. The signals inform the controller of the robot and he comes picking the plate (Fig. 7B), moves to the free place of the box (Fig. 7C) with signal for release the pallet on the conveyor (Fig. 7D). The empty pallet drives to the origin of the conveyor and robot places the defective plate into the box (Fig. 7E, F).

DISCUSSION/OUTLOOK

With the onset of Industry 4.0 and the increase in digitization in industrial production and in the design of automated devices and systems, the requirements for digitization of all stages of process design are growing. This means that the virtual commissioning share will grow and have a perspective in generating the OLP programs and validating the PLC code. Based on the established methodologies of virtual commissioning, each step in the implementation of a robotic cell into the real production system was verified. The applied PLC code is functional with respect to the virtual model. The further research will be focused on testing the PLC code and its integration into the Quality-handling station, and validating the OLP RAPID program in the ABB IRB 120 industrial robot control system.

Based on the results of simulation and testing of various production scenarios in the manufacturing system, it was assessed that the integrated robotic cell would be very poorly utilized and a storage system is very busy. In the future, it would be advisable to implement a ready-made assembled product, as seen in Fig. 8. There is also a limited warehouse with respect to semi-finished products. An industrial robot would import new blanks through empty pallets and, of course, replace discarded defective plates.

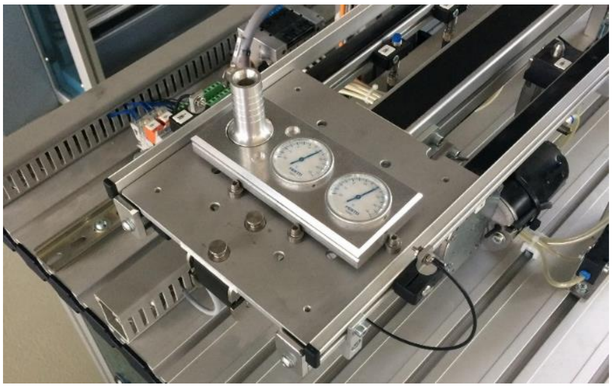

Fig. 8 *The possibility of pulling out the finished assembled products through designed robotic cell*

CONCLUSION

Virtual commissioning based on the verified research is perspective since it allows generating an OLP program for a robot without requiring the ownership of a robotic cell and the possibility of a damage to testing. It is also possible to test and validate the PLC code on the virtual model, which happens in the traditional design only when the automated device is built and thus hardware changes represent more money and time investments. Virtual commissioning requires a realistic digital twin and spends a lot of time with kinematics, behavior modeling, and signal generation overall.

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