The introduction of CP Factory production line, ideal technological platform for study and research in the field of automation

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Abstract: *This year we have open a new laboratory of automation and robotics in the Department of Technical Studies at the College of Polytechnics in Jihlava. Our laboratory is equipped with a FESTO CP Factory production line in the biggest configuration in the middle Europe. This system which includes physical components and many virtual tools can be used in education, research and cooperation with industrial companies.*
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1. Introduction

The CP Factory system is an educational industrial production line comprised of individual stations. Every station consists of a conveyor and an application module (drilling module, heating, press etc.). Both the parts are independent and can be easily switched. The control system is based on PLC Siemens ET200. Its program contains not only a control loop for the application and the conveyor but also a web server and primarily an interface of the MES4 program, which creates the user interface of the entire line. Further, every station is equipped with a Siemens HMI panel for manual control and potential configuration in the offline mode. Online communication is based on a unique protocol, defined by FESTO, which uses the standard TCP/IP protocol at the transport layer, but it is ready for OPC UA implementation..

Fig. 1 *This figure shows the actual installation of the CP Factory production line in the Laboratory of Automation and Robotics at the College of Polytechnics in Jihlava.*

2. Mes

MES role in Industry 3.0 a 4.0

The main principle of the Industry 3.0 system is a hierarchical control structure. In this approach, MES is the central control system which directly manages all subsystems and components at lower levels. It is the master giving orders to the target PLC and other systems.

In the Industry 4.0 definition, MES is only a datasource, ideally distributed over all subsystems of the target production process including the processed material and workpieces.

But the user function of this system must be the same. MES has to provide us especially with:

- Process control system (information about resources, storages, material etc.)
- On- line process control by lower control levels
- Order management
- Process and order history
- Production tracking and history monitoring
- Quality parameters reporting

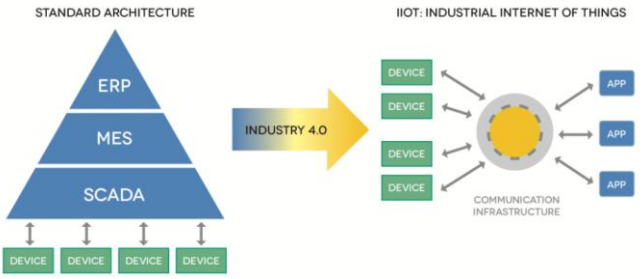


Fig. 2 *The basic Industry 4.0 idea is a change of hierarchical control structure to open communication interface between independent and intelligent objects.*

FESTO implementation

FESTO MES4 is a graphic tool containing a database connector and a communication interface to all parts of the production line.

The database contains complete information of production stations (resources), materials, products and actual or planned operations. Each type of a production part is represented by a record in the database. The record unambiguously identifies all information about the history of the part and its connections to the target production process.

The MES4 database is used as a data source when the production station is to decide whether and by means of which operation the target part will be produced. On the product, there is only one component ID that is stored in an RFID chip of every product carrier and connected to the database record. From this point of view, it is a data-controlled production process. FESTO implementation is therefore really close to the ideal Industry 4.0 MES idea, but it is not completely faithful. The datasource is centralized to one physically MS Access database here. It is not distributed over lower subsystems.

Communication protocol

The communication between the MES system and target resources is executed by a special communication protocol, defined by FESTO and based on the standard TCP/IP layer. Each operation or query is represented by a unique command with defined ID and structure. These commands can be transported via the TCP layer in the binary form or as a pure text. The string form is ideal for education and for demonstration of the function of target command. The binary form is intended for real deployment.

In the OSI model, this protocol could be placed in presentation or application layer. Session layer is not used in this case. This protocol can be switched to the OPC UA standard, ideally without any change at lower layers. FESTO currently does not have a satisfactory implementation of OPC UA, so there is space for our further research and development.

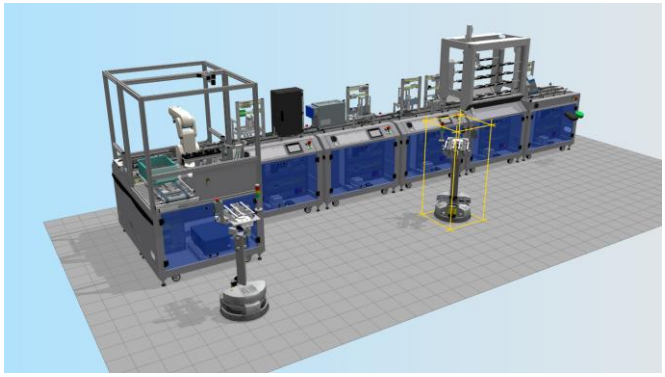
3.Virtual part of the system

CIROS

CIROS is a 3D development studio that provides not only the 3D model drawing but also programming and simulation of its behavior. The created model can be connected to a virtual or physical PLC. Hundreds of models of industry robots from many global producers are integrated in the studio (Kuka, ABB, Mitsubishi etc.). In CIROS it is possible to develop a robot's software in native programming languages and run the program not only in simulation, but also upload it to the real robot.

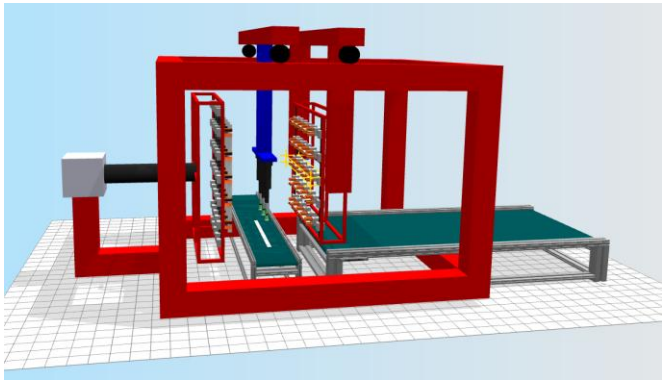
The line and robotino model

The picture shows a model of our actual CP Factory line. On the MES level, this model is a digital twin of the real system. It is not a full-blown virtual twin, however, if we focus on deep detail. This model is not able to simulate, for example, physical properties of the components or the environment, such as inertia, thermal expansion or gravity. It is therefore clear that the term "digital twin" cannot be considered absolute. It is necessary to relate it to the context and level of detail of the model.



Box making machine model

The picture shows a basic proposal of a robotic machine for paper box completion. This is an example of a machine that is currently being designed in the Department of Technical Studies at the College of Polytechnics in Jihlava. It is convenient to create it in CIROS and show its function to a customer.



4.Robotino

Autonomous robots called Robotino are an independent part of the CP Factory system. They are mobile robots equipped with multiple sensors and cameras that are able to move independently and that provide material transport. They can be included in the CP Factory system, but they can also work quite independently. Robotino is Linux-based and every mode of behavior is started as a regular UNIX application. For the mode independent of the CP Factory system, a number of development tools are provided. FESTO provides the RobotinoVIEW development tool, which offers graphical programming such as LabVIEW (a tool from National Instruments). However, there are many others programming interfaces provided, e.g. libraries for C, MATLAB or LabVIEW. Not all of these development platforms are provided for the latest version Robotino 3, though. For example, libraries for MATLAB are provided only for the 2011b version or later. To develop in the current MATLAB version, HTTP communication protocol and REST-API have to be used. A library for direct MATLAB control of Robotino is the aim of our current research in the Department of Technical Studies at the College of Polytechnics in Jihlava.

Robotino in CP Factory system

Two different communication protocols used for the interaction between Robotino and the CP Factory system must be distinguished. Firstly, there is the MES protocol, and secondly, the protocol for Robotino. Both protocols are independent and have their own unique commands and attributes. FleetManager is a special software tool serving as a bridge between these two protocols.

A typical command of the MES protocol is *GetOperationForResource*. This is a general query which gets an ID of the planned operation for the target resource. An example of Robotino protocol command can be *LoadBox*, a specific order for loading a box with material, applicable only for Robotino.

However, both of these protocols are based on standard TPC/IP. Due to the absolute openness of the whole system, it is possible to communicate via Robotino protocol manually and therefore simulate not only the MES system, but also the FleetManager bridge, but only in case that Robotino is switched to the CP Factory compatible mode. We can order Robotino to go to a target position in the CP Factory map system, but we cannot control single sensors, motor drivers or the camera. This is possible only in the mode independent on CP Factory via RobotinoVIEW or other programming tools.

RobotinoSim

RobotinoSim is a virtual tool for the simulation of Robotino's behavior and its interaction with its environment. The tool implements basic kinematics principles and the behavior of all designed objects is consequently really close to reality.

5. Conclusion

Virtualization and simulation is an integral part of industry production in this time and their importance will be increasing in the future. It is because of requests of maximal efficiency of production and production processes. The basic goal is an integration of many different subsystems and solutions over all production process. In this case, CP Factory system, based on maximal openness is a good solution offered easy integration of other components from third part producers. Our next research in the Department of Technical Studies will be focused on integration of an industry communication standard OPC UA.