Using factory automation simulation system in study process

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Abstract
This paper describes advanced distributed model-based factory automation system for teaching and research in Laboratory of Factory Automation of Department of Electrical Drives and Power Electronics. The system hardware, software and applications include simulation functionality, that can be used in study process. Distributed control examples for advanced studying are described.

Keywords
Factory automation, study, simulation, Festo Didactic, robot, PLC, distributed control

Introduction
Before modernization of Laboratory of Industrial Automation there was different Programmable Logic Controllers (PLC) for studying industry automation, but there was no good complex teaching equipment to practice their usage in real industry situation. Students saw real industrial applications, when they had excursions into the factories or into other laboratories, but it is not the same, as experimenting on real machines.

In November 2005 our department got equipment including modern factory simulation system named Festo Multi FMS (Flexible Manufacturing System) for the laboratory of industry automation. The system is built by Festo DIDACTIC GmbH & Co. KG. The functions of the system are processing, checking and assembling different size and color of pneumatic cylinders.

The system consists of multiple workcells and separate control unit (PLC or robot control unit) for each workcell. These PLC-s are networked over Ethernet connection. By default the Ethernet connection is used for connecting visualization application to the PLC-s, but the network can be used to communicate between PLC-s and study distributed control systems.

1 Hardware setup
Festo Multi FMS system consists of two manufacturing systems Festo Micro FMS and Festo FMS 50. These systems itself consist of the following stations shown on Fig. 1 and described below.

1. Conveyor system
2. Distribution station
3. Testing station
4. 6 axis robot with slide for CNC feeding
5. CNC milling machine Mill 105
6. Place for CNC programming workstation
7. Assembly with 5 axis robot station
8. Handling station
9. Sorting station
10. Buffering conveyors
11. Handling station 2
12. Processing station
13. Place for SCADA workstation [1]

Fig. 1. Festo Multi FMS studying system
The Micro FMS system consists of a CNC-machine EMCO CONCEPT MILL105, a Mitsubishi robot RV-1A, a linear axis, the commissioning station and programming workstation (objects 4, 5, 6, 10 on Fig. 1). The central element in FMS 50 system is transport station. All of the other stations are connected to this station. There are some empty places of missing stations on the Figure 1. They are planned to be added later. The FMS 50 stations (see Fig. 1) can be separated from conveyor and they can be combined by themselves or programmed to work separately (see Fig. 2). The stations itself has a flexible built up, like an LEGO constructor system. The layout of the station parts can be easily and freely reconfigured. This means that student can explore exercises with different hardware configuration. For studying purposes different types of sensors, pneumatic and electrical drives are used in the system. [2][3]

2 Software

For robot programming COSIMIR Robotics software (Fig. 3.) is used. Its educational purpose model library consists of over 30 robots and workcells (including assembling station). Robots can be programmed in robot programming language MELFA Basic IV (for Mitsubishi robots only) or in IRL (Industrial Robot Language).

COSIMIR Robotics software is designed only for learning purposes and therefore for simulation of the application in the computer. To download tested and simulated robot application program into real robot COSIMIR Professional software is used. In COSIMIR Professional software the robots of different manufacturers (ABB, Fanuc, KUKA etc.) can be programmed. New workcell with different robots and PLC-s can be designed. Also new components can be constructed. If a student is very interested about finding a solution of the exercise, the demo version of COSIMIR Robotics software can be downloaded and installed into his personal computer from Festo DIDACTIC web page [4].

For simulation of the PLC controlled work cells the COSIMIR PLC software is used (Fig. 4.). The programs for Siemens S7 PLC can be tested in software environment (Software PLC). To test programs for other manufacturers PLC-s, a hardware PLC is needed. The connection between PLC and PC is managed with Festo EASY PORT device and corresponding application.

In addition to the course materials, composed by lecturers, Festo provides a good and detail help documentation system named MPS Mechatronics Assistant. It is used by students when they prepare themselves for making exercises.
3 Study process

At the moment the laboratory system is used in three courses named Industry Automation, Advanced course of industry automation and Advanced course of Robotics. Because above-named workplaces are equipped with two different types of control devices, two basic versions of the exercises are prepared. First exercise is programming one station having a Siemens PLC. The exercise is divided into following steps:

- Documenting the manufacturing process
- Development of the algorithms and programming
- Simulating, testing and debugging the program in virtual PLC
- Testing the program in station PLC
- Documenting the hardware solution and electrical circuits
- Creating a final report

Second exercise includes the programming of the station with robot and robot controller. It has following basic steps:

- Introduction of the robot hardware and Teach-box functions
- Choosing and configuring robot hardware and programming software
- Defining positions and writing a program for robot
- Simulating, testing, debugging and optimizing the program with virtual robot 3D model
- Creating a report

Described two basic variants of exercises have many sub variants depending on PLC station which is used or which accessories are used with robot station.

An additional exercise is to create the visualization application for PLC station. The solution should be connected with the real PLC, so the current situation of the station is also visible and controllable from PC.

For advanced study (master and doctoral courses) more complex workcell for special case can be designed and constructed or distributed control can be studied.

The examples for studying distributed control would include comparing master-slave and multimaster (Fig. 6. and Fig. 7.) setups and energy management of complex manufacturing system.

![Fig. 6 Master-Slave configuration](image)

![Fig. 7 Multimaster configuration](image)

Today the automation systems are physically and logically complex and require more than one control unit. This kind of studying can be done also with this training system. It consists of several Siemens S7-300 series PLC-s which are connected to the Ethernet network. Therefore different software level configurations can be used and tested to find the results of using different setups. By default setup the communication between the PLC-s is done by using I/O connections of PLC-s. The Ethernet connection is used only for collecting data in the system with SCADA application. When studying distributed control, the data between units is changed through the Ethernet network. The communication through PLC-s I/O connections should be used only for some real-time variables. For example the Assembly station can be informed when there is no workpiece coming anymore and the servos of the robot can be turned off for saving energy. If workpieces are coming again on the conveyor, the servo motors of the robot will be turned on a while before the workpiece reaches the Assembly station. So the robot will be ready to work again at this moment.

The energy consumption in the world grows every day. Therefore it is important to design processes, that use less energy and power. With such networked system the usage and timings of the usage of energy can be managed. It can be measured, how much power it is needed for different process steps of the product manufacturing. Every process step will put into priority order. Then one PLC will be used for managing the processes so that power usage is kept as stable as possible. The processes on the different units, which need more power, will be not carried out at the same time. The production processes having higher priority will be finished first and continuing with the lower ones. Even this particular system doesn't have very remarkable power consumption, it can be studied, what type of processes need more power and if that kind of management is suitable for this kind of system or if it makes the production process too
slow, because the manufacturing process must be economical at overall.

Even if the power consumption and current peaks are not very actual problem in normal supply case, it will be more critical, when using backup power. For example in the powering network there can appear brakes. If we power our system through UPS (Uninterruptible Power Supply) system, the power consumption and currents are critical. Therefore the system can work optimized for production speed until there appears to be power line failure.

**Conclusion**

It takes some time to learn all the features of the Festo Multi FMS. Department of Electrical Drives and Power Electronics already use system in study and research process. We have many ideas about extending and upgrading equipment. For example adding a distant monitoring and controlling feature over the internet or GSM mobile network. The system is quite complex and can be used in master and doctoral study also. Above described distributed control and energy management and saving tasks are today very actual. Practical experience in factory automation and robotics gives to students much better understanding of industrial control systems.

**References**