Modular assembly manufacturing system operation

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The idea of this paper is to describe the components of a manufacturing system, it characteristics and present it operation. The laboratory set up has five units with a conveyor between each one. This equipment offers flexible training according to the industrial reality, simulating a real assembly process and including different technologies from Industry 4.0. The assembly system consists of an automated cells with five separate stages and a conveyor: assembly, handling, quality inspection, transfer and warehouse. It is the fruitful option to research and training in automation area. The main advantage is that it has fully modularity in keeping with industrial reality. The technologies included in its different assembly modules, as well as the assembly process with several variants, allow the user to develop the professional skills required by advanced automation. In this work the conventional control approach is presented with programmable logic controllers and supervisor control level. The idea of fuzzy logic applied for a pneumatic element diagnosis algorithm is introduced. The applicability of the case study is confirmed with laboratory equipment.

Manufacturing system, intelligent manufacturing system

1 Introduction

The manufacturing is considered as a new paradigm that make work smarter and more connected, bringing speed and flexibility through the introduction of digital innovation [7, 8]. Today, digital innovation is linked to the innovable of companies. Digitalization is a inseparable principle which is based on the concept of circular economy. It enables an economy model promoting the use of solutions like platforms, smart devices, artificial intelligence that help to optimize resources.

The main part of Smart Manufacturing is Flexible Assembly Systems (FAS) [10, 12]. This is a fully integrated production system consisting of computer numerically controlled assembly stations, connected by an automated material handling system, all under the control of a central computer. It is capable of simultaneously compound a variety of product items in small to medium-sized portions and at high rate comparable to that of conventional transfer lines, [10].

The aim of this article is to present basic hardware components of an assembly system and discuss it characteristics and describe some real applications [7], [8].

The automated manufacturing environment has been the ultimate goal of industrial companies that for a few decades already [2]. Years ago, the idea was to put forward with the rise of the Computer Integrated Manufacturing (CIM) in the early 1980s [4]. Nowadays communication technologies, big data analytics, Industry 4.0 technologies, complex solutions integrate electronic components and modules, enable automation possibilities of new business models [8, 12]. However, one may say a small number of companies still aims for a completely deserted and fully automated manufacturing. Only the automated factory with an optimal supported flexible workforce can lead the industry to an efficient mass-customization of goods. To achieve these goals, FAS is pivotal as shown in the next section. An effective human machine collaboration enables companies to establish a production line or factory site suited for complex and/or highly integrated products that will continue to be profitable in future. Even though today's machines run automated processes, these are typically based on linear control systems. Automated factories conduct major steps from material preparation via production to testing in an automated manner. The demand, driven self-operation of production, allows parallel instead of linear production workflows within one factory and along the entire supply chain, e.g. products are being tested virtually while materials are being prepared for its production.

2 System description

This is a flexible assembly system FAS – 200, installed at laboratory of *Intelligent Automation Manufacturing Systems* in the new Centre of Competence *"Smart Mechatronic, Eco- and Energy Saving Systems and Technologies"*. It is described a training equipment in mechatronics connected with Industry 4.0 technologies [4, 9].

Figure 1: The photo of the overall view of the equipment.

The FAS 200 [7] is comprised of different stations, each performing a part of assembly process. The flexible assembly system has been specially conceived for persons to acquire professional capabilities in connection with the Occupational Groupings of Electricity/ Electronics and Maintenance, such as: Installation, Electromechanical Maintenance and Line Transport; Industrial Equipment Maintenance; Automatic Control and Regulation Systems. It enables the development of various skills associated with pneumatic, electropneumatic, electrical, robotic and handling automatisms, programming and PLC technologies, industrial communications, supervision, quality control and fault diagnosis and repair. It also allows the study of a wide range of sensor types: - magnetic detectors; inductive detectors; optical fiber sensors; photoelectric detectors; capacitive detectors; pressure and vacuum switches; linear encoders. The system includes a flexible automation cell which carries out an assembly process involving a number of predetermined parts with different possibilities. The parts are transported consequently to the connected modules with corresponding stoppers and precision lifters-positioners. Parts are mounted on pallets. The process modules function either independently of the transport system, in single or couple modes, or integrated into it, in cell mode. Each station has its own electrical panel, where the wiring system are fully visible, while new elements may be fitted to the panel if it is necessary. The users may design and build their own projects and subsequently integrate them in the station. Can be develop a further series of skills envisaged in the training cycles for those persons who form the target group for the cell. The front of each station incorporates the start, stop, step-by step/continuous cycle and reset pushbuttons. In addition, the control pushbuttons incorporate a main switch on/off and emergency pushbuttons for emergency stops. The system is modular and may be extended, which allowed a future incorporation of other process modules according to the user needs. In addition to transport processes between cells a linear conveyor is added, shown on figure 2 and is composed by long line, connecting the five modules to facilitate the envisaged assembly process. The available units are presented below as follow:

FAS 203: Module for feeding and transferring of bearings
FAS 204: Measuring module
FAS 209: Cap classification station
FAS 210: Cap rejecting and transferring
FAS 215: Inspection and rejection station
FAS 216: Storage station

Figure 2: The transfer line.

3 Operation

To operate the whole flexible system are used industrial programmable devices (PLCs), figure 3. All stations with labels: FAS 203, FAS 204, FAS 209, FAS 210, FAS 216 are wired with individual controller.

Figure 3: The control device.

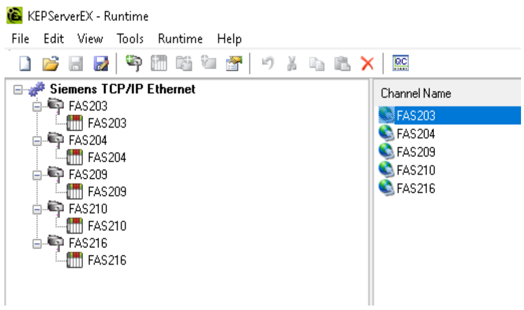

Figure4: The KEPServer project.

The local network with Profinet specification is configured. The user programs are made. The software tool for server configuration was used to create a project, given on the figure 4. Each programable device is presented as a client and is defined with individual settings, figure 5. The KEPServer is used for devices communication and Supervisory Control and Data Acquisition (SCADA) system ensuring, [9]. Generally, the control device type is selected, the local IP address and the proper name, related to the application are given.

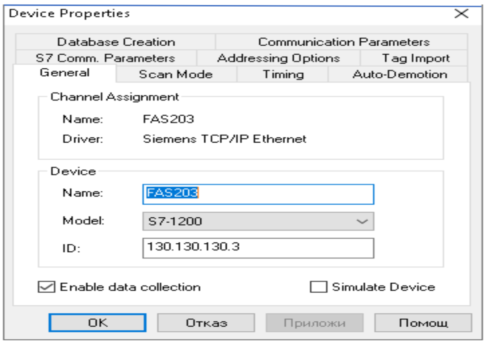

Figure 5: The device type and parameters definiction for the first cell.

The SCADA project is made with Omron software CX-Supervisor and the starting screen is shown on the figure 6. Each module has separate relevant page, which can be reached by the menu button.

Figure 6: The main SCADA screen.

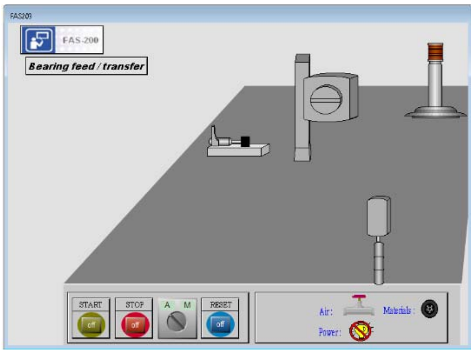

Figure 7: The page for the first module.

A simple screen of the FAS 203 is given on the figure 7 and operating can be monitored. It is for feeding stage of the manufacturing system. The supervision and control for the first module works correctly. In the same way the other pages in the frame of the SCADA project are made for all manufacturing cells.

4 Fault detection

The fault detection is important and is a first step of the maintain of the pneumatic actuators. The classification aimed at fault localization and (or) fault description, both of which can be helpful for targeted and faster maintenance. In this section a cylinder A from the measuring station is considered.

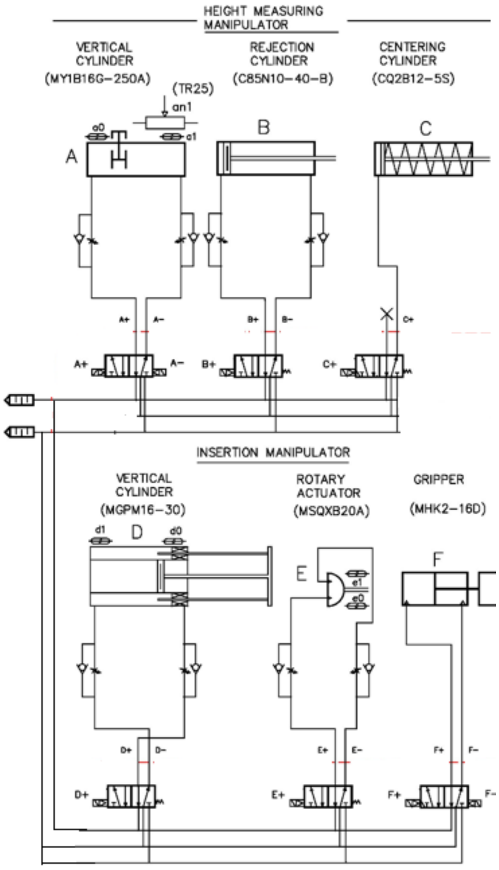

Figure 8: The pneumatic scheme of the measuring station.

The manufacturing module includes operations which are implemented by six pneumatic elements: elevator-measurer cylinder (A), rejector-measurer cylinder (B), centering cylinder (C), vertical cylinder of insertion (D), rotary manipulator (E) and pneumatic gripper (F) according to pneumatic diagram, given on the figure 8.

There are two types bearing with different width sizes. Can be assumed as a faulty bearing/element engender wrong function or stops the pneumatic station FAS 204. For the prediction of fault pneumatic cylinders status, can be considered with fuzzy representation. Each element could be described with a different fault detection algorithm and a fuzzy logic system is appropriate for this purpose, [5, 6,11].

In the next section a fuzzy logic approach is proposed to prevent of fault pneumatic cylinder status.

5 Fuzzy logic application

The fuzzy based system can find the unhealthy condition of pneumatic station from different data and assumption, different rule assign for getting appropriate result. The simple algorithm is proposed for the A cylinder. This is can be viewed as a basic configuration of the fuzzy logic application. As to the simplicity as a starting case is assumed that have two inputs and one output.

The first input with linguistic variable name “switch” where are taken the signals from downward auto-switch (a0) and upward auto-switch (a1).

The second input with linguistic variable name “solenoid”, where are taken signals from the solenoid valve.

The membership functions of input “solenoid” are in the same shape oriented to solenoid valve (A+) and solenoid valve (A-).

The output is titled “Cylinder_A”. It has a relation to the on or off state. As the result it generates and gives the condition of the pneumatic actuator. The Mamdani fuzzy inference mechanism is applied. Hence, the number of the fuzzy rules theoretically has to be calculated to be eight. For the inputs fuzzification are used two functions to represent the “switch” and “solenoid”. In our basic case with zmf and smf shapes membership functions are using for the two inputs. The three rules, responding to the defined inputs and output fuzzy sets are created as follow:

*R1: **If** (switch is downward - on) **and** (solenoid is upward) **then** (cylinder_A is normal)*

*R2: **If** (switch is downward - on) **and** (solenoid is downward) **then** (cylinder_A is fault_down)*

*R3: **If** (switch is upward - on) **and** (solenoid is upward) **then** (cylinder_A is fault_up)*

The list with rules for pneumatic sylinder status with statements in fuzzy environment is presented on the figure 9.

The simplicity of the case study is the main advantage with using fuzzy inference engine and in this way will be easy to forward to the real actuators as a standard fault detection procedure.

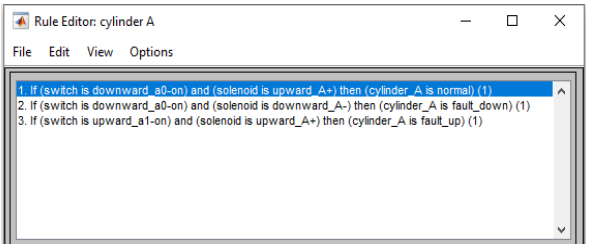

Figure 9: The rule base.

A program with idea for diagnostic has been developed in software environmet for the PLC. The test experiment was conducted. By activating light signaling when one error occurs, for the selected FAS 204 module, the respond was properly.

6 Conclusion

In recent years the manufacturers have invested most to the beginning and of the production process.

The basic hardware components of a flexible assembly system FAS 200 were presented

The article shows an example of system which is a part of Smart Manufacturing and can be viewed as fruitful any beginning of manufacturing process.

The proposed solution is inspired of the need of the companies where the pneumatic actuators are widely used.

The results obtained during operation of FAS 200 show a correct function of the system and software implementation.

The SCADA project is connected to all five PLCs using server and has the functionality in the laboratory system with applicability in the industrial area.

The idea using fuzzy logic statements was presented with simple rules. Fault diagnosis of an elevator cylinder were described in the frame of real applications.

The simplicity of the work is the main advantage and in this way will be easy to forward to the real actuators as a standard fault detection in TIA portal environment and industrial area.

The future work will be forwarded and focused to the programming of the by enlarged the fuzzy algorithm to all pneumatic actuators.

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