

# Distributed control of production system

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**Abstract.** *Distributed control systems a more and more penetrating to control structures. Decentralized control systems are merging to bigger units, which control one or more coordinators. This way creates distributed control systems. All parts of control are independent, but they are connected together by networks and they together make one unit. When corporation design production system, it should consider about network connection to other systems to create distributed structure. This paper introduces production system, which consist of various support systems. These support systems are independent and each other communicate through industrial network. Presented production system is controlled by these systems: Programmable logical controller, robot controller, camera system, visualization systems, information system, management information system, discrete model system.*

## Keywords

Production system, Programmable Logic Controller, Distributed control system, industrial network

## 1. Introduction

This paper describes design of control production system (PS) in multilevel distributed control system (DCS). This PS is part of DCS built at Department of Cybernetics and Artificial Intelligence (DCAI) of the Faculty of Electrical Engineering and Informatics (FEEI) at Technical University in Košice (TUKE). PS is controlled by Programmable logical controller (PLC), robot controller (RC), camera system, visualization systems, information system (IS), management information system (MIS) and discrete model system for modelling and analysis. Mentioned control systems are independent and interconnected by industrial networks. Communication interface is PLC between PS and control systems. Control algorithms are developed independently and control system coordination provides PLC. DCS is not realized only on information systems, but DCS is realized on lower level on control of PS, too. PS is divided to some parts (posts), which are controlled by various industrial networks.

## 2. Description of production system

PS is built on principle of serial production. Where every post presents parallel perform operations. Pallets are

moving on main conveyor, which serve for transport semi-product in production process. Individual posts add components on pallet. Finally, these components create full product. Posts 1, 3 and 4 are manufacturing posts and posts 0, 2, 5 serve manipulating with products on line or store. Every manufacturing post consists of material stack. These material stacks contain materials, which are necessary for produce product. PS is on figure 1.



Fig. 1. Production system.

The manufacturing process assemble product, sequentially. Product consists of base, bearing, shaft and cap. Product is moving by pallet on production process and manipulator puts full product on output store. This manipulator and output store is post 5 on PS. Production begins on post 1, where base eject in random time from stack to the side conveyor. Camera system is in post 2. Camera system evaluates base position and industrial robot Mitsubishi take base from side conveyor to pallet which is prepare on main conveyor. Main conveyor is post 0. RC controls industrial robot. Camera system in personal computer (PC) calculates coordinates, camera system send this coordinates to PLC by network Ethernet and PLC send coordinates to RC by network ProfiBus. Pallet with base move to post 3 on main conveyor after robot put base on pallet. Input stack of post 3 contain bearings which can have different height. Bearing suitability is tested. If bearing has good height, then rotary manipulator put bearing into base. Then pallet with semi-product move to post 4 on main conveyor. Post 4 move and test shafts and caps by rotary table. Shaft testing have two steps,

the first step is height checking and the second step is colour checking. Cap testing includes material checking. Cap can be steel or aluminous. Wrong shafts and caps are scrapped from production. Good components are took into semi-product on pallet by manipulator, at first shaft is put into bearing and then cap is put on shaft. Product is complete now. Complete product is moved on main conveyor to post 5. This post is output store, where manipulator move product from pallet to store. Empty pallet remains on conveyor and it is moved to begin of production [1].

Production is initialized in three ways:

1. *operator panel* which is a local visualization,
2. *visualization computer* which is remote visualization
3. *information system* which is evaluating orders and preparing production plan

Posts of production process are connected to control PLC by industry networks. Post 1 is connected to PLC directly by inputs and outputs cards. Camera is above post 1, it is connected to image recognition computer by interface FireWire and this computer is connected to PLC by Ethernet. Industrial robot Mitsubishi is on post 2, it is connected to RC directly, RC is connected to PLC by ProfiBus. PLC is communication node in this case between camera system and RC. Sensors and actuators on post 3 are connected to remote unit of inputs and outputs and this unit is connected to PLC by industrial Ethernet. Sensors and actuators on posts 4 and 5 are connected to remote unit of inputs and outputs too, but remote unit is connected to PLC by network DeviceNet. Three-axis manipulator on post 5 is connected to network DeviceNet directly and it is controlled by PLC. Schematic connections of individual posts to PLC control are imaged on figure 2.

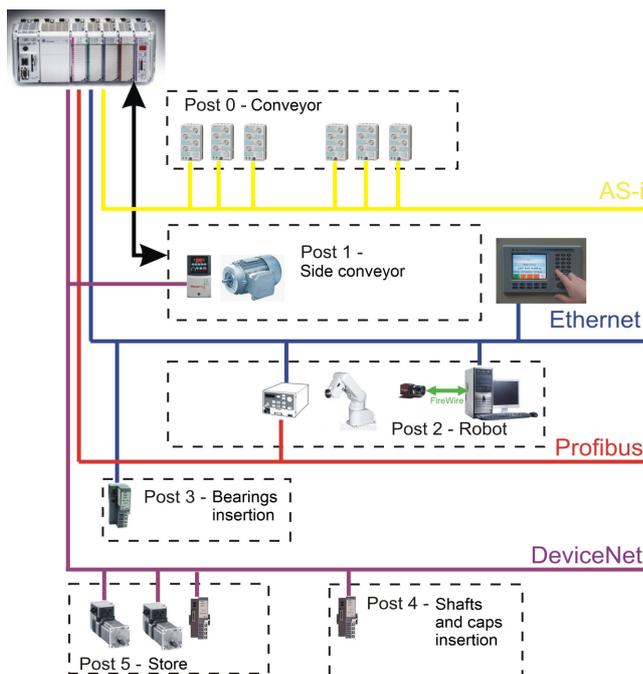


Fig. 2. Posts connections to PLC.

Production systems do not use any types of industrial networks in real conditions, because configurations and diagnostics are difficult with any networks. But this PS is intended for pedagogic and research purposes and this solution is useful for mentioned purposes. Integration of several industrial networks in one system allows wider use of distributed structures in control. Diagnostic task of these networks is also one of the research areas.

PS is controlled by camera system, RC and PLC, this was mention above. These systems represent direct control of PS. Other systems are added to mentioned systems for local and remote visualizations, IS for production control, systems for modelling of PS, data collection and processing to databases, and MIS. These parts of control and manage can be divided to several levels within DCS. This level describe next chapter.

### 3. Distributed Control System

Distributed control system (DCS) is a control system, usually PS, process or any dynamic system in which the system elements are not located centrally but they are distributed, divided into smaller parts, subsystems that are controlled by one or more control devices/controllers. Current distributed control system utilize mainly hierarchic (pyramidal) architectures containing physical and logical distribution elements, integration as a whole, open and scalable. Intelligent features have been applied on a large scale recently whereby direct hierarchic relations are turned into network relations. Emergent trends have also started to appear to a great degree, i.e. merging of originally independent systems, which can result in their new features generation as a whole. Individual world-wide automation leaders develop their own models that are adapted to their scope and production. Whole control of production process can be divided to several levels within DCS. Pyramid model of PS can be seen on figure 3, that model is divided to 5 levels within DCS.

Technological level consists of sensors, actuators, manipulators, motors, industrial robot, rotary positioning table, camera and construction of PS.

Direct control of production system level consists of image recognition computer, RC and PLC especially. Image recognition has two steps. The first step detects base rotation and position in y direction. This coordination is sent to PLC. Than PLC send this coordination to RC. Robot move and rotate grippers to correct position in y direction. Than image recognition go to next step. The second step monitor base. If base is under grippers, then robot takes base and put it to pallet [4, 7]. RC is controlled industrial robot and PLC is controlled whole production process and coordinated image recognition and industrial robot with RC.

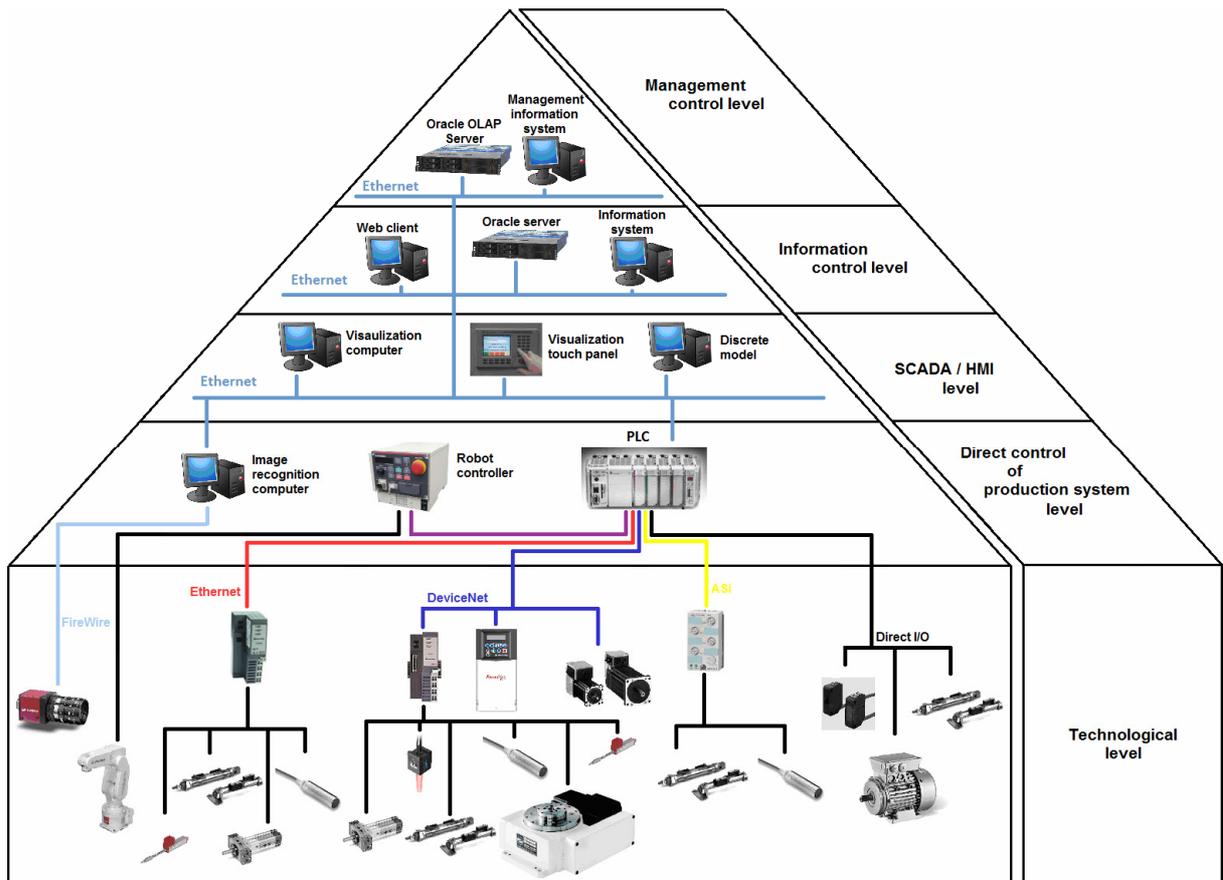


Fig. 3. Distributed control system of PS.

SCADA/HMI level includes discrete model system, local and remote visualization. PS is modeled through colored and timed Petri nets (PN), these nets reads information from PS and than PN model operation of PS. Model results are analyzed and through analysis is optimized model or control. Through model can be analyzed material flow in PS or production time [2, 3]. Model of PS can be seen on figure 4 and this model is modeled by colored PN.

Local visualization in touch panel serves as operating panel for local control in automatic, service and manual mode. Touch panel is situated on post 3, because operating panel is usually placed close to the production for control. Local visualization is intended for production operators. Visualization screens do not contain any animations, but they contain buttons to direct control for testing, failure and emergency cases. On figure 5 can be seen local visualization of post 1.

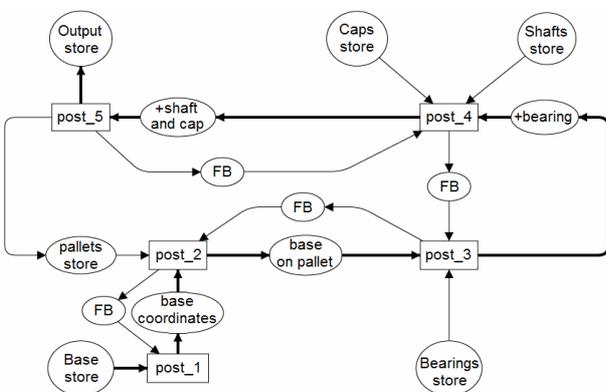


Fig. 4. Colored PN model for PS.

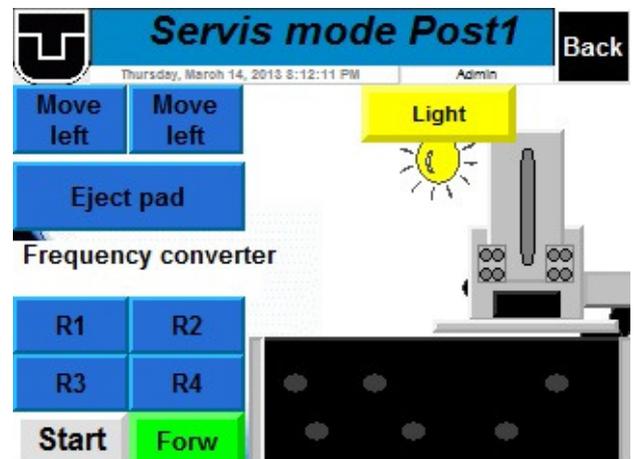


Fig. 5. Local visualization: service mode post 1

Remote visualization serves remote control of PS only in automatic mode. Remote visualization also serves data processing and archiving. Remote visualization contains many animations which are included “scripts” which support data processing. Data are visualized through real and historical trends and they are saved to databases or extern files. Difference between local and remote visualization is that remote visualization has not buttons for direct control, because this visualization is often away from PS. This visualization is situated on PC. One of remote visualization screen can be seen on figure 6. This screen is visualization of post 4.

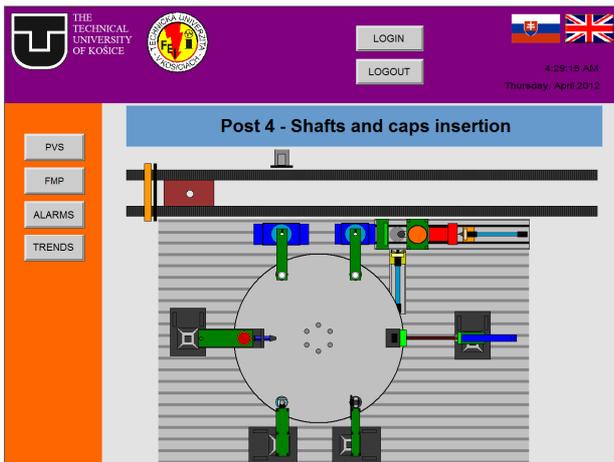


Fig. 6. Remote visualization of post 4.

Information control level is aimed to IS for PS. IS allows:

- Login and identification of working position
- Receiving and processing orders for productions
- Creating production plan
- Production control and monitor
- Store inventory control

IS is connected with database ORACLE, this database storage production data and data from IS. To IS can be connected through client application. IS screen can be seen on figure 7, this screen serves order processing [5].

Privileges	Roles	Users	Orders	Processing	Stocks	Configure	Logout
Id	Owner Name	Executor Name	Products no.	Controls			
3240	Peter Papcun	Peter Papcun	0	view	3	remove	
3243	Peter Papcun	Peter Papcun	0	view	3	remove	
4030	Matej Čopik	Peter Papcun	2	view	3	remove	
4031	Matej Čopik	Peter Papcun	2	view	process	remove	
4032	Matej Čopik	Peter Papcun	1	view	3	remove	

Fig. 7. Order processing in IS.

Management control level represents MIS. MIS is intended for strategic decision making support and MIS

creates system analysis. MIS is connected directly with database ORACLE. This database uses data processing through multi-dimensional cubes using OLAP (Online analytical processing) technology. The MIS outputs are 2D or 3D graphs and tables, mostly. On figure 8 can be seen 3D graph through this graph can be analyzed development of the orders numbers at the time [6].



Fig. 8. The MIS output – orders numbers at time.

## 4. Conclusion

Control PS with distributed method has great importance mainly for options of independent application creating and independent network control and connections. Independent application creating is important for developers. If application creating would not be independent, then developer would have to know programming PLC, creating visualizations, programming IS, etc. Nowadays programmer do not program whole PS, even programmer do not program whole IS application or whole PLC program. Nowadays programmer program only part of application and other programmer program other part. Later these parts merge into one whole application. This is possible thanks structure of DCS. One PS has implemented many independent applications which communicate together and they create one unit. DCS design and realization require principles observance with regard to intercommunication. Communication between applications can be direct (for example database and IS) or indirect by other application (for example communication between camera system and RC run via PLC). Production systems control with distributed method is very advantageous and often used in practice.

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