Distributed Measurements and Control Systems for Rapid Prototyping of Artificial Intelligence Controller

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Abstract. *The paper deals with distributed measurements and control systems for rapid prototyping of artificial intelligence controller of fluid power driver. The proposed distributed system of measurements and control consists of two PC computers: Target and Host where the first computer directly controls the fluid power driver and is connected to controlled systems, while the second functions as the operator towards the direct control layer. PC computers run Windows with Matlab-Simulink software package. On the basis of the distributed system of measurements and control the fuzzy logic controller of electro-pneumatic servo-drive and adaptive controller of electro-hydraulic servo-drive were designed.*

Keywords: Distributed Measurements and Control Systems, Rapid Prototyping, Fluid Power Control Systems

1. Introduction

In the extended procedures of data acquisition and processing measurement when the advanced control algorithms in fluid power control drives (electro-hydraulic servo-drive and electro-pneumatic servo-drive) are applied both the processing capacity and PLC controllers communications are considerably limited. On the basis of PC computers running Windows XP environment with Matlab-Simulink software package advanced configurations of distributed measurement, control and adjustment systems were set up. To facilitate data acquisition and control fluid power drives a distributed environment running on two PC computers was created. The first computer is connected to controlled systems – fluid power driver while the second functions as a supervisory control layer and the operator towards the direct control layer. In the supervisory control layer complex controlled processing is carried out, the state of controlled system is analyzed and the parameters of control procedures are adjusted to obtain the optimal control conditions. The supervisory control layer, in addition to identification and optimization procedures, may contain a model of controlled system with control algorithm. In the direct control layer the processing, measurement and filtration procedures are conducted. The supervisory control system generates executable files and sends them to the direct control system. Data transmission between PC computers is carried out by TCP/IP protocol (LAN, Ethernet) or by means of serial ports of RS232 type. Industrial distributed measurement and control systems are based on Ethernet networks. The PC computers used in real time systems generate sampling frequency up to 100 kHz. Sampling frequency depends upon processing speed and controlled systems parameters. Distributed measurements and control systems support many input/output formats while additional modules: *xPC Target Explorer* lub *xPCrctool* are used for data processing and acquisition.

The proposed distributed measurements and control systems based upon two PC computers Host and Target are shown in the Fig. 1. The distributed system was used for rapid prototyping of fluid power servo-drives (electro hydraulic and pneumatic servo-drives) in real time. On PC computes Matlab-Simulink and *xPC Target* were installed. In Matlab-Simulink package it is possible to create processing procedures for both conventional and artificial intelligence controllers and to execute own control and visualization applications. PC has the card of analog input/output and *Real-Time xPC Target* system which is used for measurement data acquisition and fluid power drives control. Target PC can simulate the flow of control and measurement signals in real time by means of HIL *(Hardware-in-the-Loop)* method. Applications run by Simulink model use a real time kernel of the PC computer. Host PC and Target PC communicate with each other by TCP/I protocol. The communication of supervisory control layer in Host PC with direct control layer in Target PC may occur continuously, periodically or at operator's specified time intervals. The software suite used in Host PC and Target PC and connections between the two computers are shown in Fig. 2. Working with the rapid prototyping suite consists in building a model of the control algorithm in Simulink. Next the model is compiled and sent to the Target PC which serves as the controller of fluid power drives together with the input/output card and the *Real-Time xPC Target* system. Measurement sensors and transducers are attached to the Target PC through the measurement card. Thanks to *xPC Traget Spy* software the visualization of the processed data and the analysis of the process of controlling fluid power drives is possible.

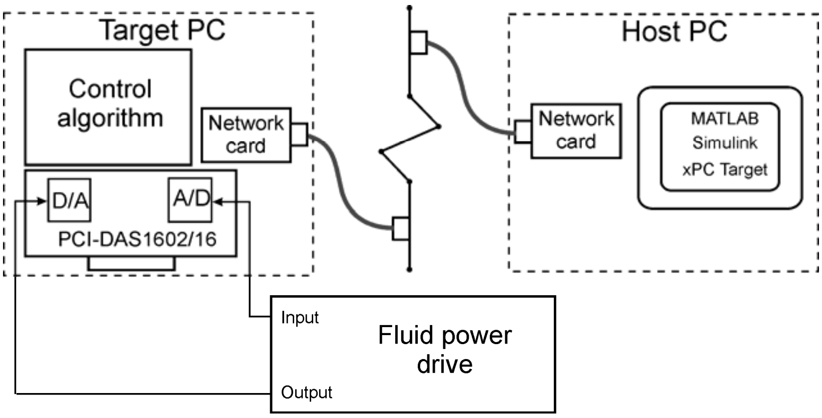

Fig. 1. Schematic diagram of distributed measurements and control systems for fluid power drives.

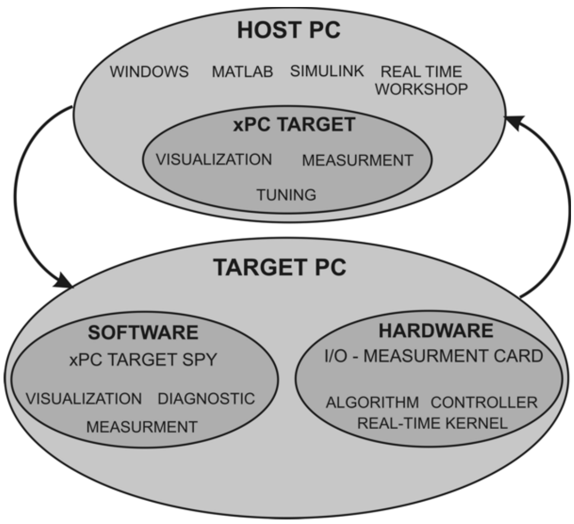

Fig. 2. Diagram of Host PC and Target PC connections according to [1].

2. Distributed Control System for Rapid Prototyping of Fuzzy Logic Controller

On the basis of the proposed distributed measurement and control system a test stand for fast prototyping of fuzzy logic controller of electro-pneumatic servo-drives was set up. The distributed control system with FLC (*Fuzzy Logic Controller*) of PD type controlling pneumatic servo-drive is schematically presented in Fig. 3 [2]. Fuzzy PD controller constructed in Fuzzy Logic Tollbox of Matlab-Simulink package was suggested for the purpose of controlling pneumatic servo-drive. The pneumatic servo-drive together with fuzzy PD controller constitute a system of MISO type with two inputs: position error $e(t) = y_o - y(t)$ and change of position error $\Delta e(t)$ and one output: proportional valve coil voltage $u(t)$. Output and input signals underwent fuzzification process with regular distribution of 7 fuzzy sets of triangular and trapezoid membership functions. The database rules of fuzzy controller are 49 Mac Vicar-Whelen rules described in the table entered to Fuzzy Logic Toolbox. In the inference process the firing degree was determined by means of MIN operator, implication operator and all the inputs of particular rules were aggregated by MAX operator. In the defuzzyfication process the center-of-gravity-method (COG) was applied. The dialogue window ”Rule Viewer” of Fuzzy Logic Toolbox is a kind of diagnostic device which enables to trace which fuzzy rules were activated on particular states of input. It also enables observation of fuzzy system output value. The fuzzy logic controller of PD type was tuned by means of Simulink Response Optimization Toolbox of Matlab-Simulink package.

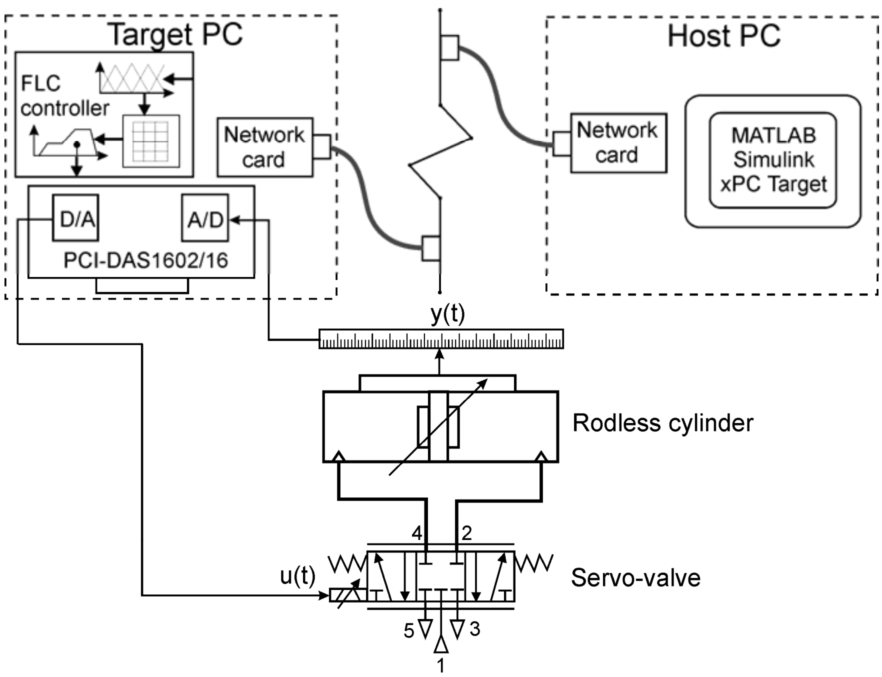

Fig. 3. Schematic diagram of electro-pneumatic servo-drive control system.

3. Distributed Control System for Rapid Prototyping of Adaptive Controller

On the basis of the distributed measurement and control system a test stand for rapid prototyping of adaptive controller of electro-hydraulic servo-drive was set up [3]. To test electro-hydraulic servo-system control algorithms the experimental test stand presented in Fig. 4 was constructed. The experimental test stand consists of two separately controlled control objects composed of hydraulic cylinders controlled by servo-valves (proportional 4/3 valves). The load in the analysed electro-hydraulic servo-drive resulted from slide and resistance movement caused by load cylinder. Piston displacement *y(t)* of hydraulic servo-cylinder was conducted by means of optical transducer. To measure pressure values in cylinder chambers p_1 *(t)* i p_2 *(t)* and pressure in supply line p_o and *F* force exerted by load cylinder tensometric transducers were used. The distributed control system enables rapid prototyping of adaptive controllers resistant to random interferences resulting from sudden changes of masses and load forces electro-hydraulic servo-drive. In hydrostatic servo-drives the attempts are made to work out such control algorithms which would be insensitive to outer disturbances caused by load mass and external forces and would ensure high precision of positioning and good dynamic properties.

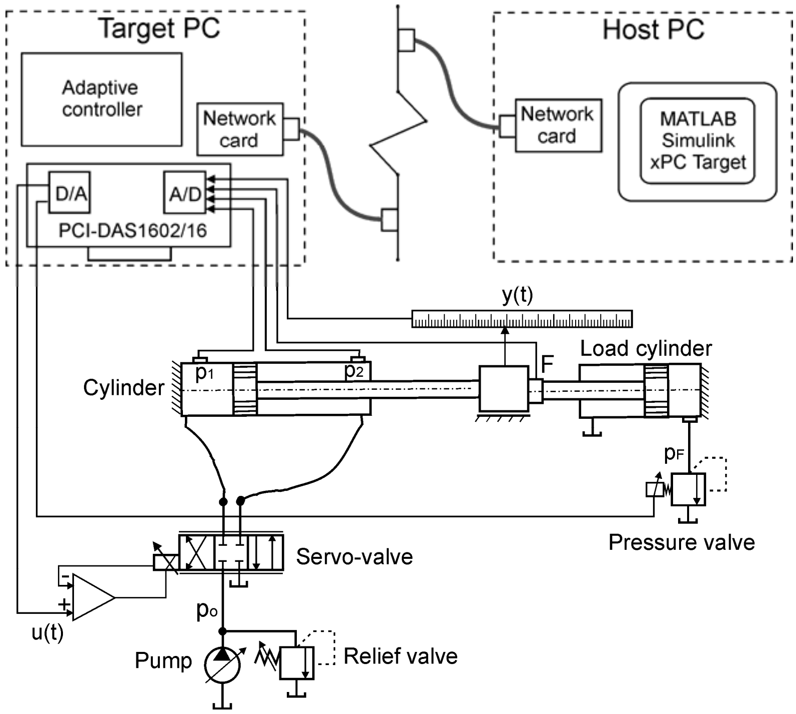

Fig. 4. Schematic diagram of electro-hydraulic servo-drive control system.

4. Conclusions

The article presents the concept of a distributed system for acquiring measurement data and a control system for the rapid prototyping of artificial intelligence controllers of fluid power drives. The proposed measurement and control system consists of two computers: Host PC and Target PC. The Target PC makes up the direct control layer and is connected to the controlled systems (hydraulic and pneumatic servo-drive), while the Host PC makes up the supervisory control layer and serves as an operator of the direct control layer.

References

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