ISSN: 1231-4005
e-ISSN: 2354-0133
ICID: 1133891
DOI: 10.5604/12314005.1133891

THE WIRELESS HYDROSTATIC TRANSMISSION CONTROL BY THE USE OF MOBILE TECHNOLOGY

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Abstract

The paper presents the concept of a new approach for remote control and monitoring of parameters of mobile or stationary machines in real time on the example of the hydrostatic transmission drive test stand. The proposed system control and monitoring is the mobile system which is closely related with the three applications written in a different programming languages, such as: java (Android) – mobile application runs on the tablet, C language – server application joins xPC Target with tablet, PHP – admin panel to manage mobile control platform. Controlling of the hydrostatic drive stand is implemented using an application installed on the tablet. This application is connected with computer's real-time (xPC Target) module, generated in Matlab. The computer with xPC Target is equipped with a measuring-control card, to which the control signals are transmitted. This hardware-software component plays the connecting role between machine and operator of the mobile platform installed on the tablet. The application allows observe important parameters such as pressure, volumetric flow rate, temperature, velocity, torque in real-time, as well as, it enable, by use of special graphic slider on the tablet's screen, to set control parameters such as: speed of electric motor, the opening and switching positions of the directional valve, as well as, setting the load by pressure relief valve. Based on this system research related to the verification of system operation were performed for different setting of the hydrostatic transmission drive speed controller, and selected results are presented in the paper.

Keywords: *fluid power control system, hydrostatic transmission system, wireless control system*

1. Introduction

Currently in extensive measurement and control systems using advanced control algorithms, computational efficiency based on industrial PCs, PLCs or microcontroller begins to be limited. In particular, the problem appears in the transferring information to the operator in real-time, to inform the user about the current state of the machine or the current state of the device, or – in the opposite direction – transferring control data from the operator panel to the controller. Another challenge posed control and measuring systems is to create a user (product engineer) the possibility of remote direct access to the system from anywhere and at any time with the ability to change operation parameter settings. The solution to this problem could be the use of applications called mobile platforms (Fig. 1) installed on tablet or smartphone, that has capabilities to connect to the supervisory device (e.g., controller, industrial PC) by the use of internet, with the ability to monitor and control the device or machine. Such opportunities can be obtained by the use industrial computer operating in a real time environment based on the "xPC Target Stand Alone" generated by the Matlab-Simulink software and a platform for PHP and SQL Server. Industrial Computer with real-time system "xPC Target Stand Alone" is used as a hardware platform with implemented analog to digital cards used for data acquisition and control elements on the real object. Additionally, the computer applications that was created to realize the control of the procedures of this computer, performed in an automatic way. System allows for rapid implementation of different control functions with easy tuning of control parameters, and creates customized control functions for applications running in real time, regardless of the control

program. Due to the prevalence of the devices based on Android technology (OS tablets and smartphones), these devices combined with innovative and convenient-to-use applications become the reason for interest in machine and equipment manufacturers to simplify and make flexible communication between man and machine.

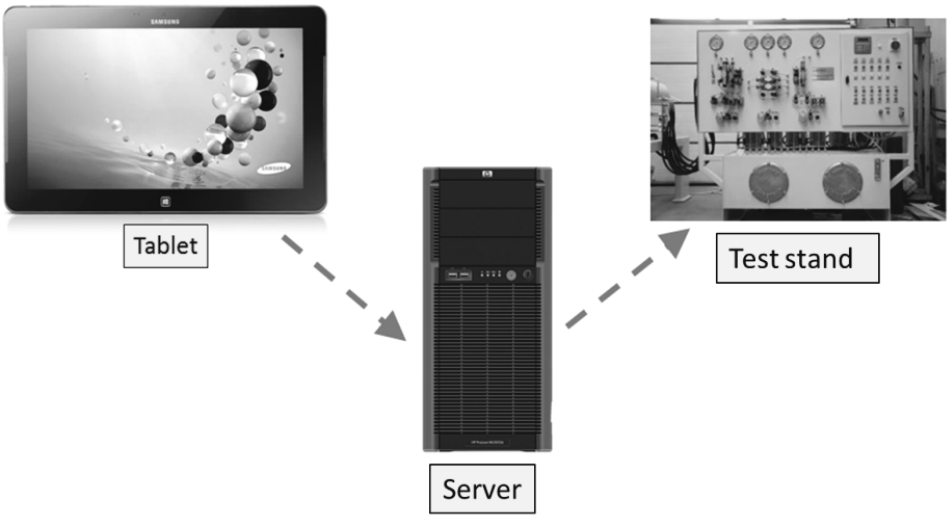

Fig. 1. Scheme of mobile platform

2. The structure of the mobile platform

The tests have been applied to the mobile platform (Fig. 2) consists of the following elements: tablet with mobile application, exchange server, test stand with industrial computer with real-time system "XPC Target Stand Alone", support camera control test stand. The tablet running the Android operating system, allows to use the system to create own mobile application. The exchange server allows communication between a mobile application installed on the tablet and the test stand located in the laboratory. Additionally, the exchange server allows for the secure and efficient data transmission between the two sides of the system, tablet and test stand. The test stand located in the laboratory can communicate with the command and file exchanges server and contains elements of control and measurement system, which allow assessing selected parameters based on data transmitted to the tablet. The overall structure of the system, of remote monitoring and controlling of the test stand, was based on the device with "xPC Target Stand Alone," because this device has the possibility to implement complex intelligent control systems with the possibility of rapid prototyping.

The developed application designed for Android provides opportunities for the user to perform certain procedures under the control by the use of remote access. This requires the application to take full control over device / machine, especially the control signals of actuators such as driving motors, control valves, etc. (Fig. 3). Remote operation of the test stand is based on a technology, which use industrial computer with a multi-purpose card measuring and control, operating in real-time mode with the appropriate software.

Software package, deployed to develop a system of remote management machine is Matlab / Simulink. It allows building individual executive control applications system components, such as, valves, relays or motor controllers, as well as a preliminary analysis and data acquisition. The structure of the control platform Matlab, a computer executive is called the xPC Target and a master computer is called host. The elaborated algorithm of control and measurement in Matlab / Simulink on the host computer is compiled and sent to the computer with xPC Target Stand Alone, which automatically and independently, followed by acquisition and performance of applications with remote device: call tablet or smartphone, performing preview of operating parameters and change

control parameters. An additional element of improving safety and comfort, allowing the observation of the test stand are installed cameras, which views are displayed in the preview window on the tablet / smartphone. Control system using computer xPC Target is a high-quality environment for fast prototyping, building and run measurement in real-time for devices compatible with the architecture of the PC. While xPC Target has the capacity for rapid prototyping and simulation, using hardware-in-the-loop, to control systems and signal processing, and is used for projects in different sectors.

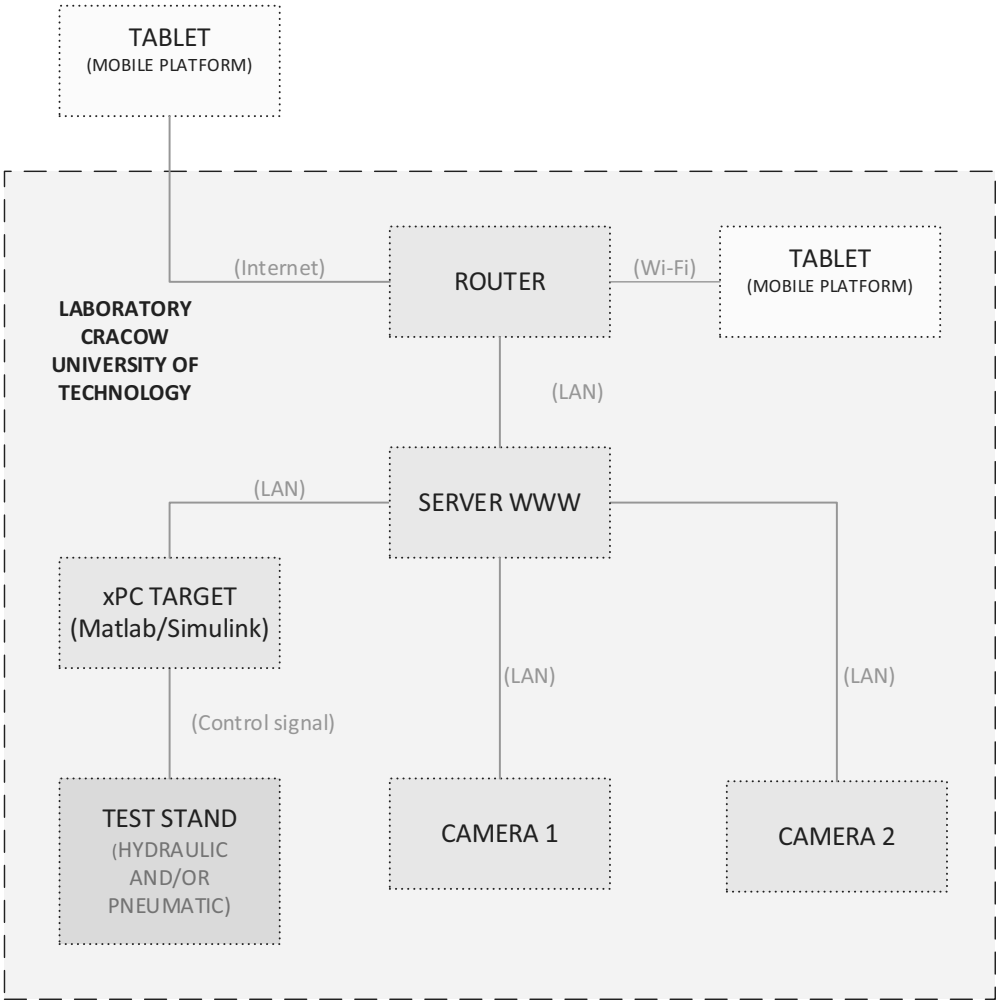

Fig. 2. Structure of mobile platform

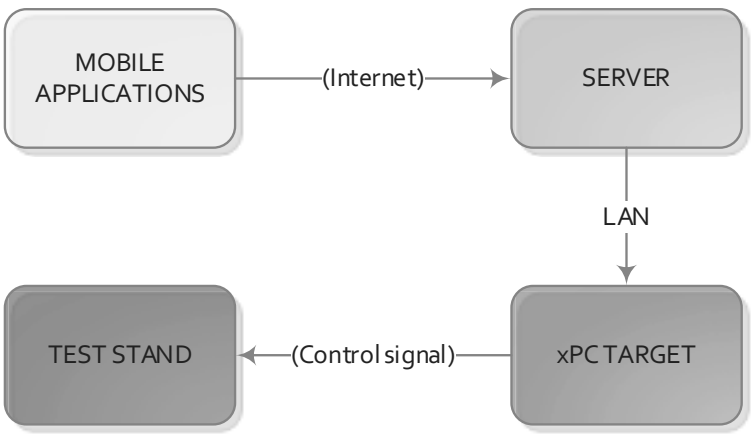

Fig. 3. The structure of the flow of information using the mobile platform

The main advantages of this type of system are:
- run applications generated by Simulink and Stateflow models using real-time kernel on any PC,
- support any PC as a target real-time system,
- possibility of working with a sampling frequency of 100 KHz, depending on the performance level of the processor and the size of the model,
- service more than 250 standards I/O cards with an extensive library of device drivers, input-output with source code drivers,
- possibility of signal recording and configure the parameters of a local or remote PC,
- registration and acquisition of real-time data to RAM or system files on the target PC,
- display measurement data and signals charts on the local, target or both PCs,
- provide communication between computers via RS-232 or TCP / IP (LAN or Internet)
- opportunity to develop own graphical user interface for access to the signals and parameters,
- providing a graphical user and object-oriented interface in MATLAB command line, and providing access to the target application running on one or more PCs.

3. Test stand

To test the control system based on mobile platform test stand has been designed and built (Fig. 4) based on the hydrostatic transmission used as travel drive a working machine. The test stand allows controlling the parameters of the hydrostatic transmission at different rotational speed of the wheels and different load when moving in different directions of travel (Forward, Reverse). The resistance to motion of the vehicle wheels are simulated by rollers connected to the shaft of the hydraulic pump, with torque controlled by the use of proportional pressure relief valves. Wheel is driven by a hydraulic motor supported on two rollers. It is similar to a well-known system of car test bench or rollers to test the effectiveness of the brakes used on vehicle diagnostic stations. This system provides stable cooperation with rollers and wheels at the same time reduce the possibility of slippage. The load on the rollers is achieved by throttling system installed in the line of high-pressure hydraulic system. The size of the load is directly proportional to the set level pressure at the pressure relief valve. Simulating the load on the hydraulic pump is connected to one of the wheel shafts of the guide rollers by the means of jaw clutch. This concept allows simulate different characteristics of external load of the hydrostatic transmission, such as:
- increasing load linearly,
- decreasing load linearly,
- step load changing,
- loading by the use of torque spectrum characteristics recorded or taken from the real machine operation.

By the use of the mobile mode of the test stand operation, it is possible to determine static and dynamic characteristics of the installed proportional valves, the total hydrostatic transmission efficiency and allows testing different control algorithms of the drive system speed control.

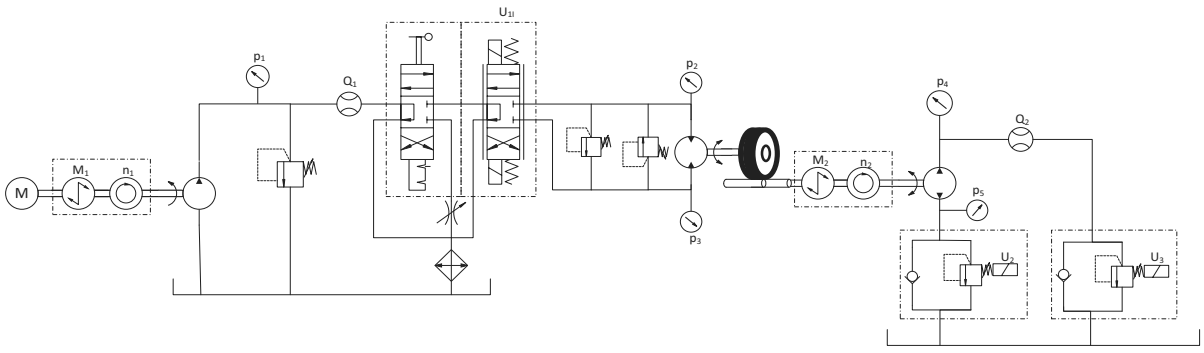

Fig. 4. Schema of the mobile system test stand

The proposed research test stand due to the control of the mobile platform without human supervision requires the use of a few elements to protect unwanted turn on/off of test stand as well as improper control by not authorized users. It was necessary to apply the appropriate security systems that prevent such a situation and enable safely perform certain tasks on the test stand without fear of destruction and causing a dangerous situation by the user. That why such the test stand should be also equipped with appropriate measurement instrumentation that will send signals to the computer responsible for controlling.
This system should achieve the following functions:
– monitor the operating parameters of the test stand before starting,
– monitor the operating parameters of the test stand during operation.

Depending on the individual parameters, the system should respond appropriately to the turn on or turn off particular functions of test stand informing the operator about the dangers and the actions they should perform to avoid it. The most important parameters that should be monitored before starting test stand are the fluid level in the hydraulic tank, the temperature of the fluid in the tank and the position of the distributor valve. These signals determine whether there is a possibility of starting test stand when all signals are in position ready (ready state, state is not ready), then it may be safe to start test stand. At the start of the test stand, the safety system is switched to the monitoring mode of the stand operating parameters such as temperature of the fluid in the system, pump and motor pressure, loading torque, rotational speed, pressure in the hydraulic loading system, electrical load on the electric motor, volumetric flow rate in the hydraulic circuit. Part of the monitored parameter is used only for registration and execution of commands asked by users, some of the parameters are used to protect stand against failure or damage. The parameter determines the operation of the safety system in the event of an investigation to the maximum load range, is the pressure in the high-pressure hydraulic line of the hydrostatic transmission. The control system in the event of being close to the pressure limits, inform the user to reduce load and blocks the possibility of further increasing the load. In the event of a to high temperature of working fluid, safety system switching on the cooling system if the temperature rises even though the test stand is switched off.

For the different test, performing the hydraulic system of test stand (Fig. 5) is equipped with transducers, which allow measuring the following parameters:
– torque on the shaft of the hydraulic pump – M_1,
– rotational speed of the pump shaft – n_1,
– pressure at the outlet of the hydraulic pump – p_1,
– volumetric flow rate at the pump outlet – Q_1,
– pressure at the inlet and outlet of the hydraulic motor – p_2, p_3,
– rotational speed of the wheel – n_s,
– pressure in the hydraulic loading system – p_4, p_5,
– loading torque of the drive wheel – M_2,
– volumetric flow rate at the outlet of the loading pump – Q_2.

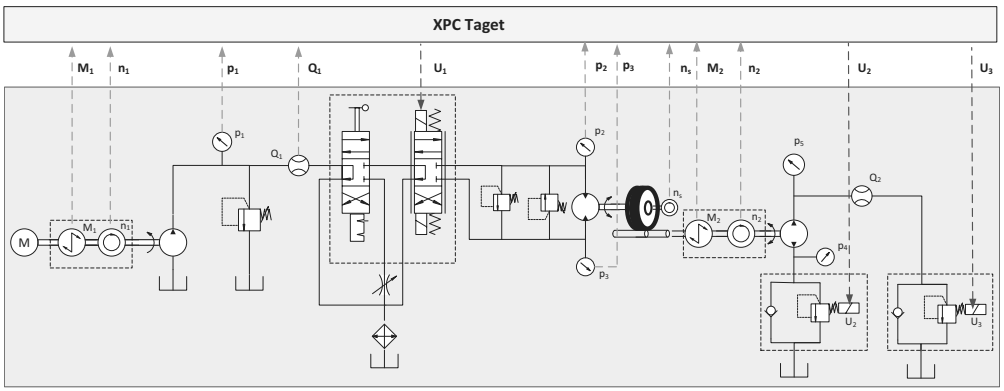

Fig. 5. Schema of the measurement system of the stationary part of the mobile control system

The developed mobile platform application allows the user perform the following tasks:

- study of static and dynamic characteristics of proportional distribution valve. The user can use the sliders or enter the value by use of the virtual keyboard, to change the control voltage of proportional solenoids distribution valve, change the type of control signal (linear, step, sinusoidal, etc.), change the value of the load (Fig. 6 and Fig. 7),
- study of the efficiency of the hydraulic motor and study of the efficiency of the hydrostatic transmission. The user, to perform this task, change parameter settings, i.e.: speed of the pump shaft, speed of the hydraulic motor shaft, hydraulic motor loading torque. So, that the resulting data set allows the execution of user characteristics overall efficiency of the hydrostatic transmission as a function of engine (electric motor) torque, and speed, as: $\eta_c = f(M_s, n_s)$,
- study of different control systems of the shaft rotational speed of the hydraulic motor. The user has the ability to check or/and test the speed control system in an open or closed control system, using, among others, PID or fuzzy logic controllers.

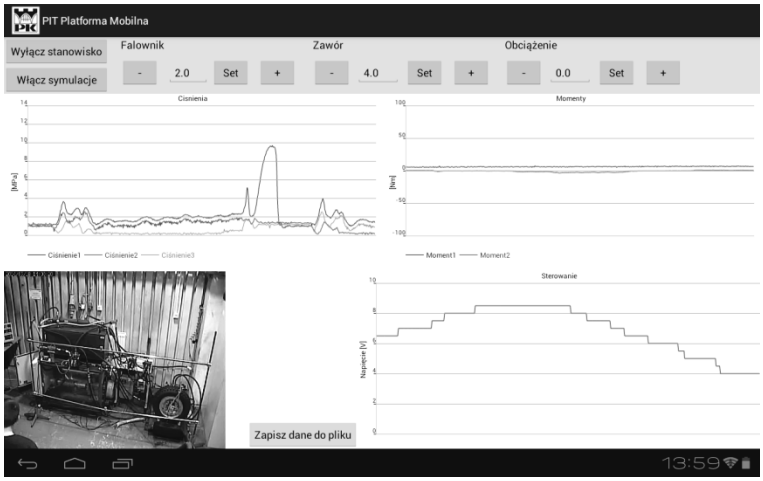

Fig. 6. View of the mobile application control panel for the study of the static characteristics of proportional distribution valve

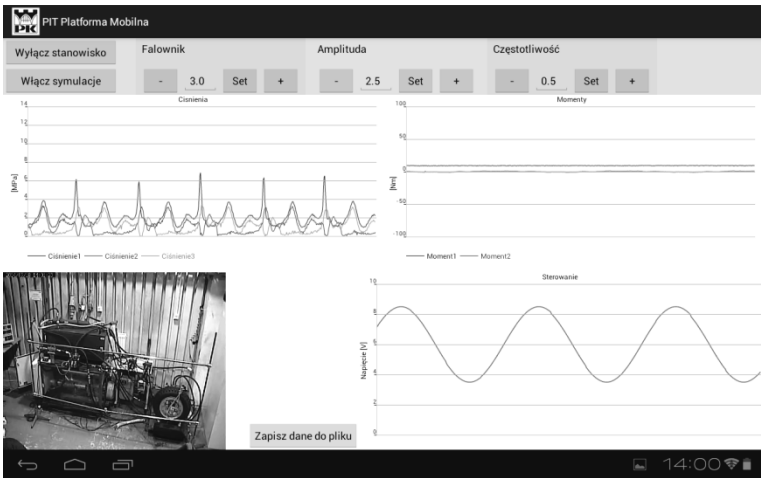

Fig. 7. View of control panel mobile application for the study of the dynamic characteristics of proportional distributor valve

4. Summary

The concept of the diagnostic and measurement system based on the mobile platform with remote access via mobile devices, which are not only laptops but also tablets, iPads and smartphones, appears to be capable of a good way to improve the process control of machines or

other equipment's. The proposed mobile platform enable be realized typed task remotely, using the Internet, in not only the run, but also the possibility to plan and control the process. Then it can import the saved operating parameters that are necessary to prepare the object characteristics and develop report from the task made by the user. Regardless mobile platform provides access to the history of the operating parameters. Through the mobile platform, it is possible to create customized applications integrated with the tablet or smartphone support machine operators through the use of new diagnostic concept of control and measurement.

The use of hydraulic system takes place in most industries and specialized equipment such as: heavy industry, means of production, transport industry, construction – including road construction, mining, firefighting vehicles and mobile machines, robots, manipulators and tools, ships and aircraft, agriculture, forestry, food industry, pharmaceutical industry, hospital equipment, rehabilitation and recreation. These requires the development of specialized programs, applications engineers, who in their practice, deal with devices that use hydraulic drive and control, where the knowledge of their construction, principle of operation, performance characteristics, as well as, diagnose malfunctions are essential for the maintenance of different types of processes. Presented mobile platform creates new opportunities for the design of high-performance, intelligent control systems and control with remote access from anywhere using mobile communication devices such as a tablet or smartphone, which can be utilized in commercial or/and research and modern education (extended to remote operation of the real test stand) applications.

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