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FLEXIBLE TEST STANDS BASED ON LabVIEW

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ABSTRACT: *Research departments and laboratories, as well as industry itself need to become more flexible. They need to adopt new trends and technologies as quickly as possible. It is obvious however, that any hardware should be changed minimally in order to reduce costs and the complexities of any changes necessary. Therefore, any update has to be made mainly by software changes. This article introduces a concept of a transmission test-stand modified into a hydraulic test-stand, using the same equipment and changed software based on LabVIEW. LabVIEW uses G programming language with block diagrams which is, compared to a text-based program, easier to understand and update.*
KEYWORDS: LabVIEW, test-stand, transmission, hydraulics, graphic programming

INTRODUCTION

Test-stands are used by engineers, scientists, and researchers on a daily basis, therefore their users want to get the most out of them. The test-stands need to be flexible in order to keep up with light-speed of the modern research. The flexibility of the test-stand has to be considered during its designing process. Every laboratory or research department should consider improving the flexibilities of their test-stands because their purposes may change in the future. Such a change could be caused either by new trends and technologies in their field of research, or new requirements for the test-stand, such as the measurements of additional signals.

*This article presents and describes a flexible transmission test-stand based on the LabVIEW system (**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench). The flexibility of this test-stand is be demonstrated regarding the addition of sensors, which require certain wiring and minor software updates. The software update is simple, since LabVIEW uses block diagrams for programming which are easily surveyable and upgradable. Later, the transmission test-stand will be converted to a hydraulic test-stand, using the same data acquisition devices, and slightly modified software.*

BRIEF HISTORY OF TEST-STANDS

The origins of test-stands go back to the industrial revolution of the 19^{th} century, when the measurements of basic physical quantities were needed for the evaluation and researching of products. Data was measured using mechanical sensors, and gathered mainly from gauges manually, and then written in tables. [1] With the evolution of sensors with current or voltage output, data acquisition was then performed using oscillographs. [2] Later on oscillographs were replaced by printers, and then nowadays data acquisition is performed using computers, and data is stored on hard-disks. More detailed history of test-stands is shown in table 1.

Table 1 – Comparison of test-stands

Test-Stand	Test-Stand Control	Data Acquisition	Flexibility
mechanical sensors mechanical control	manual signal generation buttons and knobs	manual – pen and paper	none
electro-mechanical sensors special (ad-hoc) electronic circuits	manual signal generation buttons and knobs	oscillograph	very limited
electrical sensors, relays, simple microcontrollers	semi-automatic manual start/stop automatic signal generation	printer via RS232	limited
electrical sensors, computer based or stand-alone modular data acquisition devices	automatic virtual operator panel	computer (hard-disk)	advanced

LabVIEW

LabVIEW is a graphical programming environment for developing measurement, test, and control systems manufactured by the National Instruments Corporation. It is easier and faster for engineers and scientists to program in LabVIEW than in traditional programming languages, because LabVIEW uses *block diagrams for programming. This specific programming language is known as the G programming language. Programming actions are constructed with connections between graphical symbols, and their execution order is defined by data flow. [3] A block diagram of a simple program for multiplication made in LabVIEW is show in Figure 1.*

Programs written using LabVIEW are called 'virtual instruments' (VIs). This is because the instruments front panel is virtual – it exists only on a computer screen. Interaction with the virtual front panel is achieved using standard human machine interfaces (such as muse, keyboard, or touch screen). Such a feature reduces the costs and development time of the physical front panel (displays, buttons, knobs, wiring ...). Moreover, it makes the front panel easier to design and update. Figure 2 shows the front panel of a simple program for multiplication.

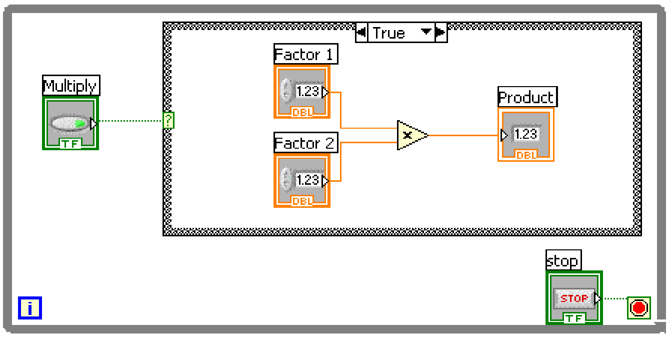

Figure 1 – Block diagram of a simple multiplication program

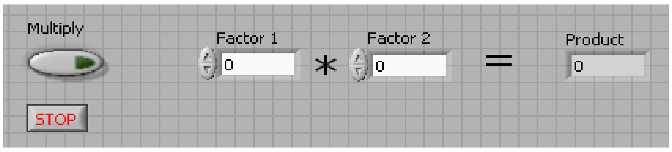

Figure 2 – Front panel of a simple multiplication program

Another big advantage of using LabVIEW is that it has a lot of built in functions, such as spectral analysis, signal manipulation functions, filters, curve fitting, advanced maths operations (derivative, integral, ...). More functions can be added by purchasing special add-ons (fuzzy logic, system simulation (similar to Simulink), Matlab .m code execution..). LabVIEW programs can be deployed easily to all modern computer platforms (Windows, MAC, Linux) and to FPGAs, microcontrollers, and other embedded systems. [4]

*In combination with special drivers for data acquisition devices NI-DAQmx API (**A**pplication **P**rogramming **I**nterface), LabVIEW can be used to communicate with data acquisition cards. This means that LabVIEW can acquire and generate one or more signals. The most common type of measured signal is voltage, which can be converted easily to other units of measurement using built-in scales. All the properties regarding acquisition or generation, including channels, timing, and triggering information, can be collected in a NI-DAQmx task. [5]*

TRANSMISSION TEST-STAND - HARDWARE OVERVIEW

The transmission test-stand can measure all the important parameters of various transmissions and stress tests and prototype tests can also be done. The test-stand is equipped with two liquid-cooled synchronous servomotors with a built-in resolver, and is manufactured by Baumüller. Both motors can be used either as a motor or a brake with energy regeneration capabilities, and are controlled by two separate inverters manufactured by this same company. A strain-gauge based torque sensor is mounted on the output shaft of each motor. By using regular measurements, one motor is operating as a motor and the other as a brake with regeneration. A functional diagram of the test-stand, is show in Figure 3.

*A PC-based platform for measurements and automation is used for status monitoring and control of the test-stand. A National Instruments PXI (**P**CI e**X**tensions for **I**nstrumentation) uses a data acquisition card to control the SCXI modular data acquisition system. The state of the test-stand is monitored via a digital-input module and the safety functions are controlled using a digital-output module. Control of the inverters is implemented through an analogue-output module, and simultaneous data acquisition through an analogue-input module with built-in filter and amplifier.*

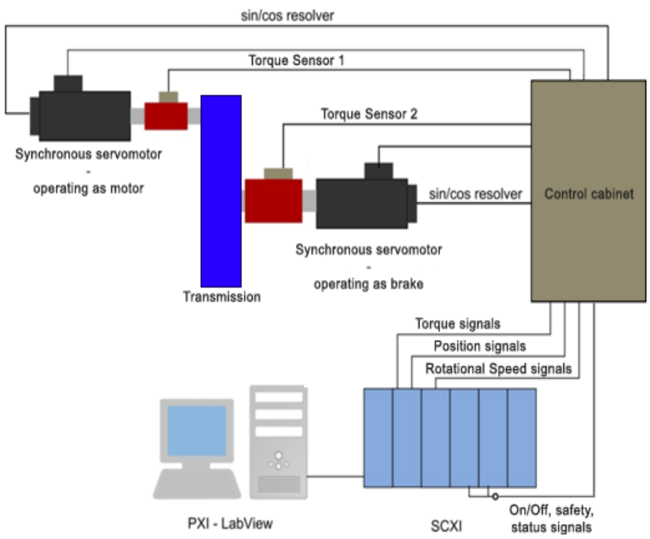

Figure 3 – Transmission test-stand – functional diagram

SOFTWARE OVERVIEW

The software for controlling the transmission test-stand is based on the LabVIEW environment and consists of two VIs. The first one monitors the status of the transmission test-stand and the second is responsible for simultaneous signal generation and acquisition. The program automatically checks the validity of the desired control signal (mostly rotational speed of the motor) before each test, which should not cause the speeds or accelerations to be too high anywhere in the transmission. Figure 4 shows the front panel of the test-stand control program.

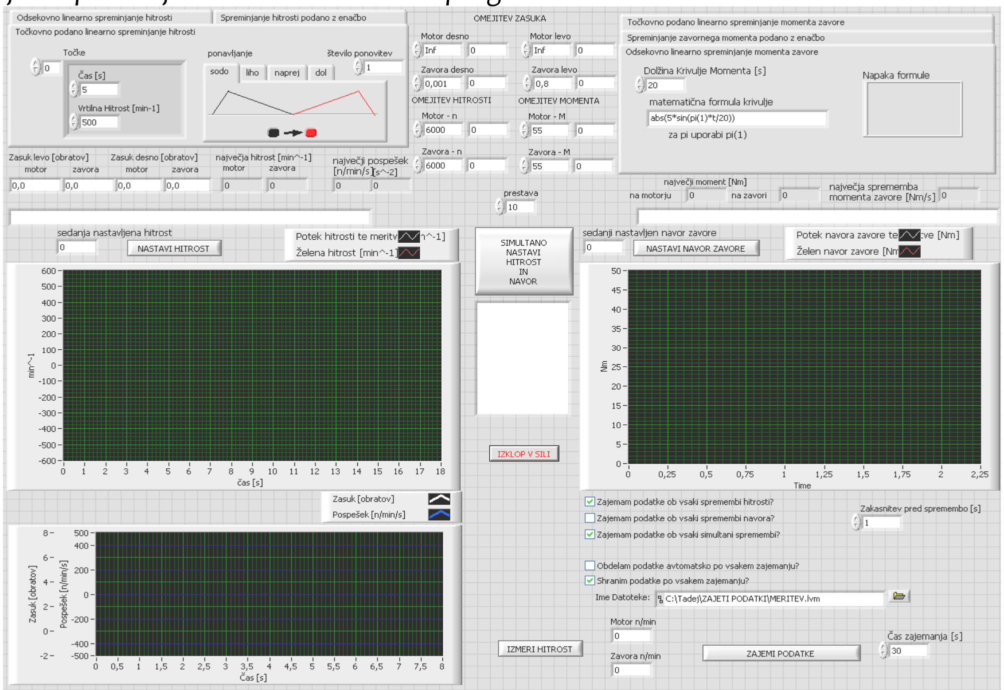

Figure 4 – Front panel of the virtual instrument for the transmission test-stand

The current set-up is capable of automatic simultaneous signal generation and acquisition, with sample rates up to 100 kHz. Since such high sampling rates generate a large amount of data, the sampling rate is chosen depending on the requirements of the test. The most commonly used sampling rate is 1 kHz or 1 kS/s which is, according to Shannon's theorem, enough to reconstruct all signals with frequencies lower than 500 Hz. [5] The acquired raw data is stored on a hard disk after the completion of each test, in order to reduce processing time during test. All the stored data is analysed later using a separate program, depending on the needs of the analysis. The data can be only filtered and resampled. A frequency analysis or curve fitting can also be performed for more complex tests.

ADDING NEW MEASUREMENT CHANNELS

Currently, a prototype of a cable-drive is being tested on this test-stand, which utilizes a Kevlar rope and two drums with different diameters for torque transmission from the input to the output shaft. A CAD model of the cable-drive on the test-stand, is shown on Figure 5. The behaviour of the cable-drive depends on the tension in the rope, therefore dynamometers are mounted in the rope tensioners, in order to measure and monitor the tension in the rope during the operation. Two new measuring channels had to be added to the data acquisition program, since regular transmission tests don't require force measurement.

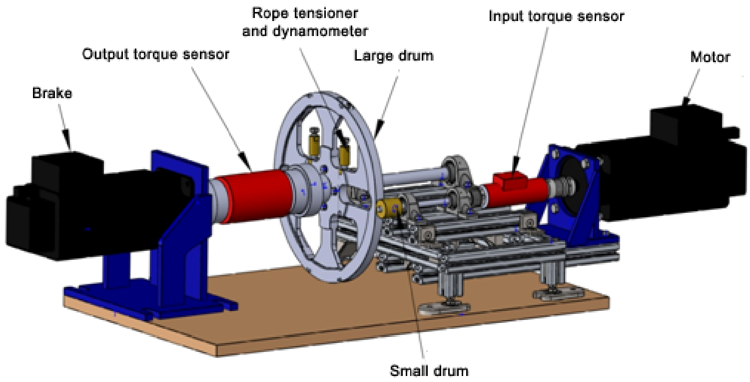

Figure 5 – Model of a transmission test-stand with the cable-drive

Adding two channels is simple, because all our data acquisition programs are based on built-in tasks. We just had to modify the task by adding two new channels to it. No other modification is needed, of either the block diagram or the front panel. A sample task configuration is shown in Figure 6.

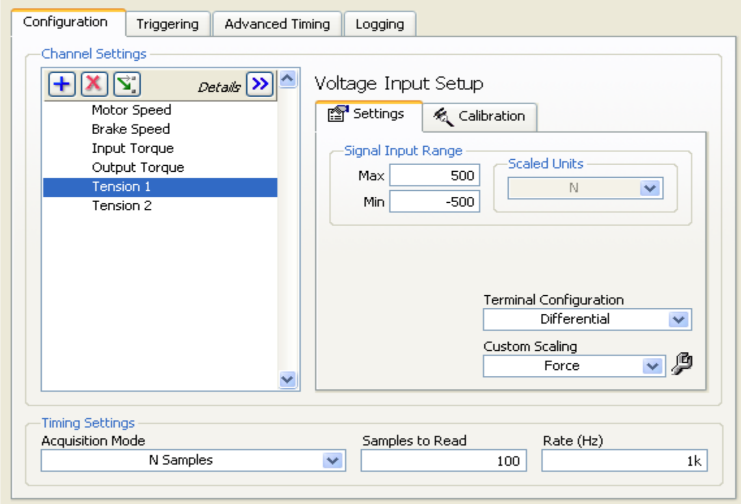

Figure 6 – Adding new channels to the task

MEASUREMENT RESULTS

After we had added two new measurement channels, we performed some test measurements on the test-stand. In the first test, we applied a combined cycle rotational speed signal to the motor and constant torque signal to the brake. The combined cycle of rotational speed signal consists of a ramp, step and constant values which are periodically repeating. Figure 7 is showing both applied signals and both responses which could have been measured before the addition of the two new measurement channels and the Figure 8 is showing measurement results of both of the newly added measurement channels.

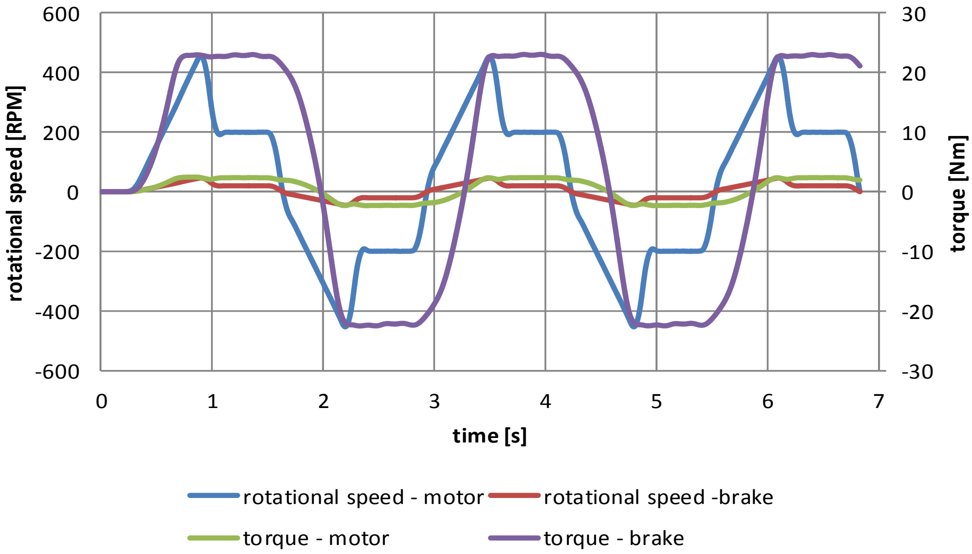

Figure 7 – Rotational speeds and torques of the motor and the brake during the combined cycle test

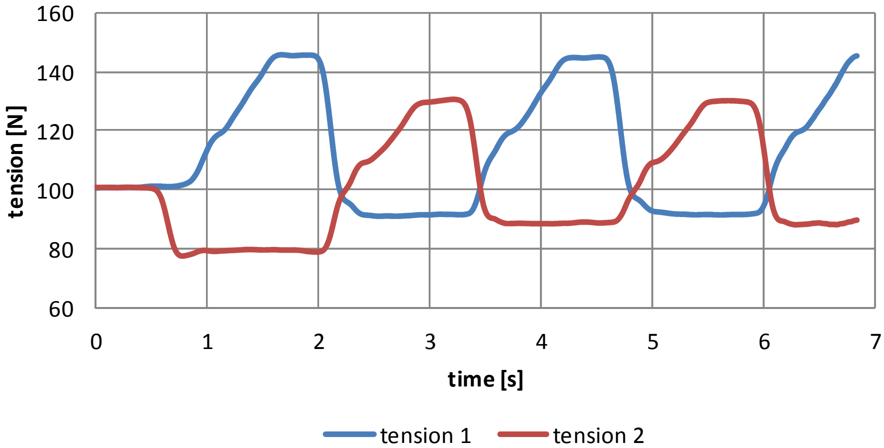

Figure 8 – Rotational speeds and torques of the motor and the brake during the combined cycle test

We can clearly see the changes in tension of both sides of the rope. Firstly tension 1 is the tight side and tension 2 is the slack side, after the change in the direction of rotation, their roles change. If we look closer to the alignment of the change in tension and the change in direction, we can see that they are correctly aligned.

After the combined cycle test we also performed a slip test. The slip test consists of a constant rotational speed signal applied to the motor and a ramp shaped torque signal applied to the brake.

When the output torque is too big the rope at the small drum slips and the output shaft no longer turns. After the measurement is done we can also perform some calculations and calculate the input and output power of the drive. Power can be calculated out of rotational speed and torque.

$$P = \omega \cdot M = \frac{2 \cdot \pi}{60} \cdot N \cdot M \qquad (1)$$

Power P is a product of the angular frequency of the shaft ω and the torque M applied to that shaft. Angular frequency can be substituted with the rotational speed N by adding the appropriate conversion factor as shown in equation 1. The results of the slip test are shown in Figure 9 and 10. It is obvious that the transmission doesn't transfer any power when the output shaft is in the standstill, which happens approximately 1,75 s after the beginning of the test at the output torque a bit greater than 36 Nm.

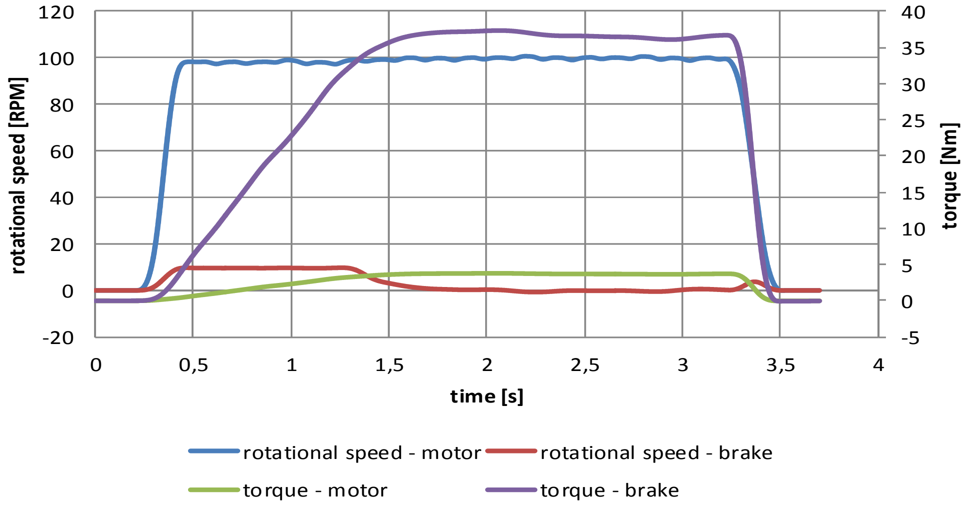

Figure 9 – Rotational speeds and torques of the motor and the brake during the slip test

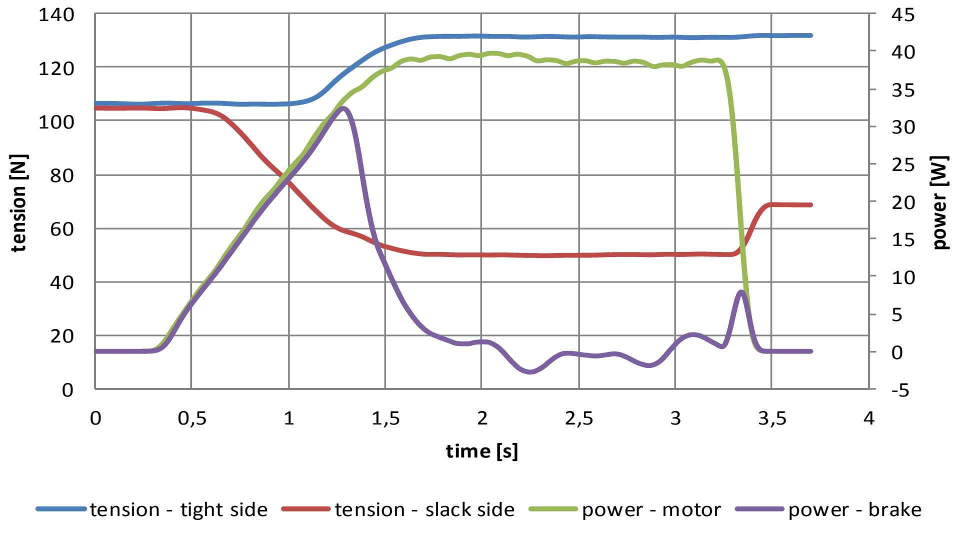

Figure 10 – Powers and tensions during the slip test

CONCEPT OF THE CONVERSION TO A HYDRAULIC TEST-STAND

In order to test the efficiency and monitor the responses of hydraulic systems we will redesign the transmission test- stand into a hydraulic test-stand. The cable-drive transmission will be replaced with a hydraulic transmission – a hydraulic motor, and an axial piston variable displacement pump. This hydraulic pump will be mechanically coupled with the synchronous servo motor and a hydraulic motor will be coupled with the brake. There will also be a torque sensor mounted on both shafts in order to measure input and output torque. Hydraulic components will be connected with flexible tubing through a small fluid tank. The hydraulic tubing will be designed in such a way that it contains as little fluid as possible, which will enable easy and fast change of the operating fluid.

A flow and pressure sensor will be added to monitor the pressure and flow produced by the pump, which will also enable separate efficiency calculations for both the hydraulic pump and the *motor. The swashplate of the hydraulic pump will be actuated with an electronically operated proportional valve. Figure 11 shows a functional diagram of the hydraulic test-stand.*

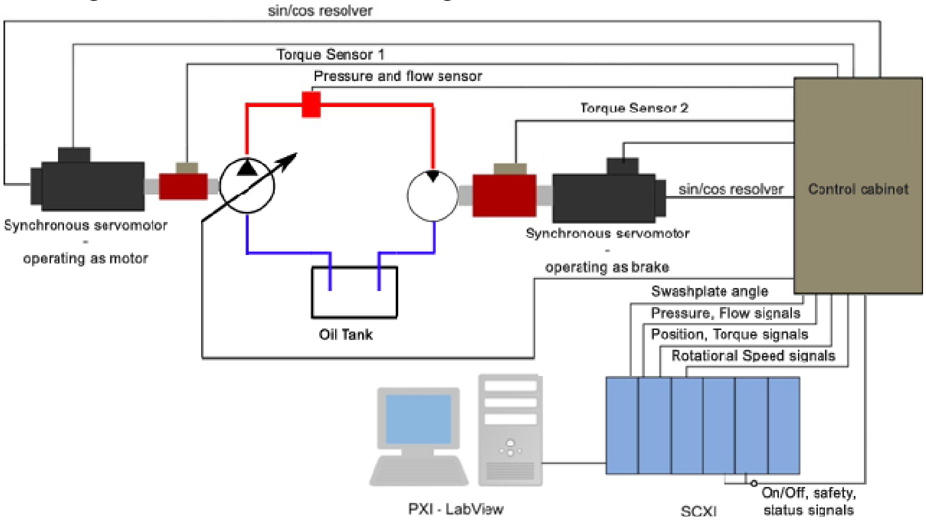

Figure 11 – Functional diagram of the hydraulic test-stand

In the above case the whole control program for the hydraulic test-stand has been prepared in advance. A new channel for controlling the swashplate angle has been added too the signal generation task, and pressure and flow signal channels have been added to the signal acquisition task. An additional tab for swashplate control had to be added; therefore some changes have been made in the program's block diagram and front panel.

CONCLUSIONS

This paper presented the development of universal, on LabVIEW-based, data acquisition program to be used for different test-stands. Firstly a transmission test-stand was described and modified using a simple modification to fit the requirements for testing the cable-drive. Since current needs dictate that we will need a hydraulic test-stand soon, a concept for it was described. With a few simple modifications, which can be completed in a few hours, the control program can be changed from transmission to hydraulic. This test-stand represents the trend of modern test-stands, with good scalability and flexibility realizing "one machine – multiple usages", thus saving investment costs because this system can be used for various tests.

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