ISSN 1454 - 8003
Proceedings of 2016 International Conference on Hydraulics and Pneumatics - HERVEX
November 9-11, Baile Govora, Romania

AUTOMATED OIL TRANSFER SYSTEM FOR AN ELECTROHYDRAULIC EQUIPMENT TESTING STAND

Iulian-Claudiu DUȚU[1], Radu-Iulian RĂDOI[2], Alexandru HRISTEA[2], Mihaela-Florentina DUȚU[1]

[1] University Politehnica of Bucharest, iulian_claudiu.dutu@upb.ro

[2] INOE 2000 - IHP, radoi.ihp@fluidas.ro, hristea.ihp@fluidas.ro

Abstract: *The paper presents an automated oil transfer system implemented on an electrohydraulic equipment testing stand. The stand is made of a working console placed on a parallelepiped oil tank having a volume of 800 liters, a group of oil filters, a block with directional valves for distributing the hydraulic oil to tested equipment, pressure and return pipes from and to the high volume oil tank. The working console is rectangular, having T-shaped canals that allow the operator to mount tested equipment, auxiliary testing and measuring devices. Main scope of the automated transfer system is to direct the hydraulic oil from the main tank to a secondary tank, placed on the testing stand (the working point). This system also comprises an ultrasonic level transducer used to constantly measure the oil level in the secondary tank.*

Keywords*: automated system, testing stand, ultrasonic transducer, simulation*

1. Introduction

The automated oil transfer system is implemented into the structure of an electrohydraulic equipment testing stand [1, 2]. It is being made of an operator working console placed on a parallelepiped oil tank, with a total volume of 800 liters. Other components are a group of oil filters, a block with directional valves for distributing the hydraulic oil to tested equipment, pressure and return pipes from and to the high volume oil tank. The operator working console is rectangular, having T-shaped canals that allow the operator to mount tested equipment, auxiliary testing and measuring devices for mechanic-hydraulic parameters. Main function the oil transfer system is to automatically direct the hydraulic oil from the main tank to the secondary one, mounted on the testing stand, which has a lower volume. Key components of the automated system are an ultrasonic level transducer and an electronic control unit. The transducer is constantly measuring the oil level in the secondary tank, while the electronic control unit detects the minimum and maximum values of oil level thus controlling one electrovalve that starts or stops oil transfer. Here it is used an electronic two-point controller. This paper describes the electrohydraulic diagram of the testing stand and a simulation, made using MATLAB-Simulink, of the automated oil transfer process.

2. System description

In *Fig.1* it is given the electrohydraulic diagram of the testing stand with an automated oil transfer system between one main tank and one secondary tank. This configuration allows the operator to place the pumping unit and main tank, of high volume, in another place distant from the working console in order to reduce noise stress. Oil used in the testing process is afterwards accumulating in the main tank [3]. When not testing any equipment, the remaining hydraulic oil is transferred from the secondary to the main tank using a hydraulic drain pump, *PE* in *Fig.1*. Oil level control in the secondary tank, when testing equipment, uses an automated system. An electronic control unit constantly measures oil level in the secondary tank, by means of an ultrasonic level transducer, turning on the oil intake electrovalve when the oil level in the secondary tank reaches the minimum and turning it off when the oil level reaches the maximum set value. It is important that the hydraulic pump of the testing stand, *PP* in *Fig.1*, must not remain without oil at its intake orifice.

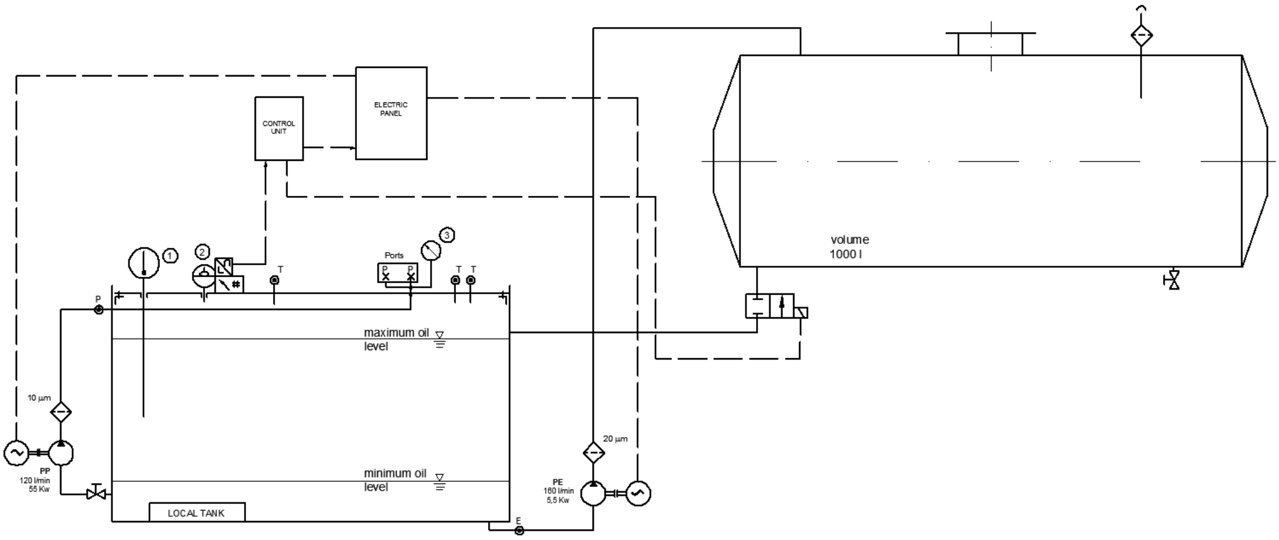
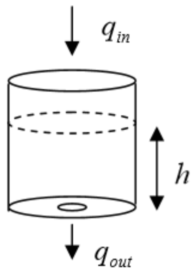


Fig. 1. Diagram of the testing stand for electrohydraulic equipment with automated oil transfer

Operator's working console is placed above the secondary oil tank and it has pressure (*P*) and tank outlets (*T*). In the diagram given in *Fig.1* it can be seen a thermometer (*1*), an ultrasonic level transducer (*2*) and a pressure gauge (*3*). Main hydraulic pump (*PP*) [4] is draining through a 10µm oil filter to a block of outlets used to provide pressure to tested equipment. Using the stand given in *Fig.1* there can be tested proportional valves and directional flow control valves, servovalves and positioning systems (servocylinders).
Next, the authors present the simulation model of a testing stand for electrohydraulic equipment with automated oil transfer.

3. Simulation model for a fill – drain process of a hydraulic oil tank

Simulation of the fill – drain process will begin with writing the mathematical model of the process, for an oil tank considered to be cylindrical, put at atmospheric pressure, filled with hydraulic oil through its upper side with a flow of q_{in} value. The oil tank configuration is given in *Fig.2*.



q_{in} – oil flow in;
q_{out} – oil flow out;
h – oil level;
A – tank cross section.

Fig. 2. Hydraulic oil tank model

We consider that the hydraulic oil flows through an orifice placed in its lower side, having a cross section of *a*. The oil flow through that orifice can be calculated using Bernoulli's law, as follows:

$$q_{out} = a \cdot \sqrt{2gh} \tag{1}$$

where: q_{out} – oil flow out;
a – cross section of draining orifice;
g – gravitational acceleration;
h – current hydraulic oil level.

Using the continuity equation, it can be written:

$$A\frac{dh}{dt} = q_{in} - q_{out} = q_{in} - a \cdot \sqrt{2gh} \qquad (2)$$

where: A – cross section of the tank;

$\frac{dh}{dt}$ – oil level variation in the tank.

By applying a defined integral to the *(2)* equation, it is obtained:

$$h(t) = h_0 + \int_0^t \frac{1}{A} \cdot [q_{in}(t) - q_{out}(t)]dt = h_0 + \int_0^t \frac{1}{A} \cdot \left[q_{in}(t) - a \cdot \sqrt{2gh(t)}\right]dt \qquad (3)$$

where: h_0 – initial oil level in the tank.

Using equation (*3*) it can be structured the simulation model in *MATLAB-Simulink*.

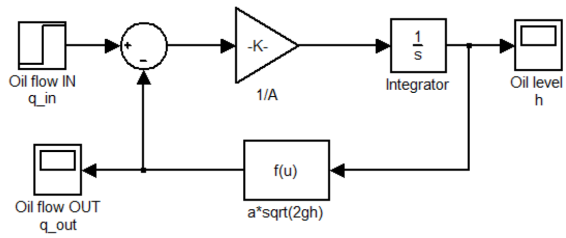


Fig. 3. Simulation model of the oil tank

Automated system control is made using an electronic unit based on a two-point controller, given in *Fig.4*. The setpoint value is given in *meters* meaning oil level in the secondary tank, *SP = 0.15 m*.

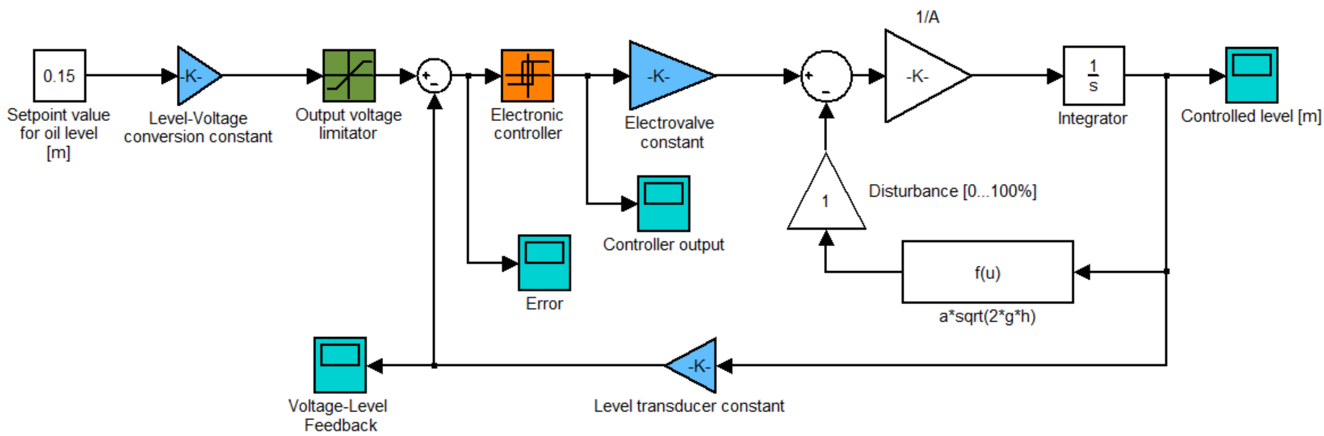


Fig. 4. Simulation model of the automated fill-drain process, using a two-point controller

When simulating the model given in *Fig.4*, there were studied the following cases:

a. constant setpoint value for oil level, *SP = 0,15 m* and *v = 0 %* disturbance influence;

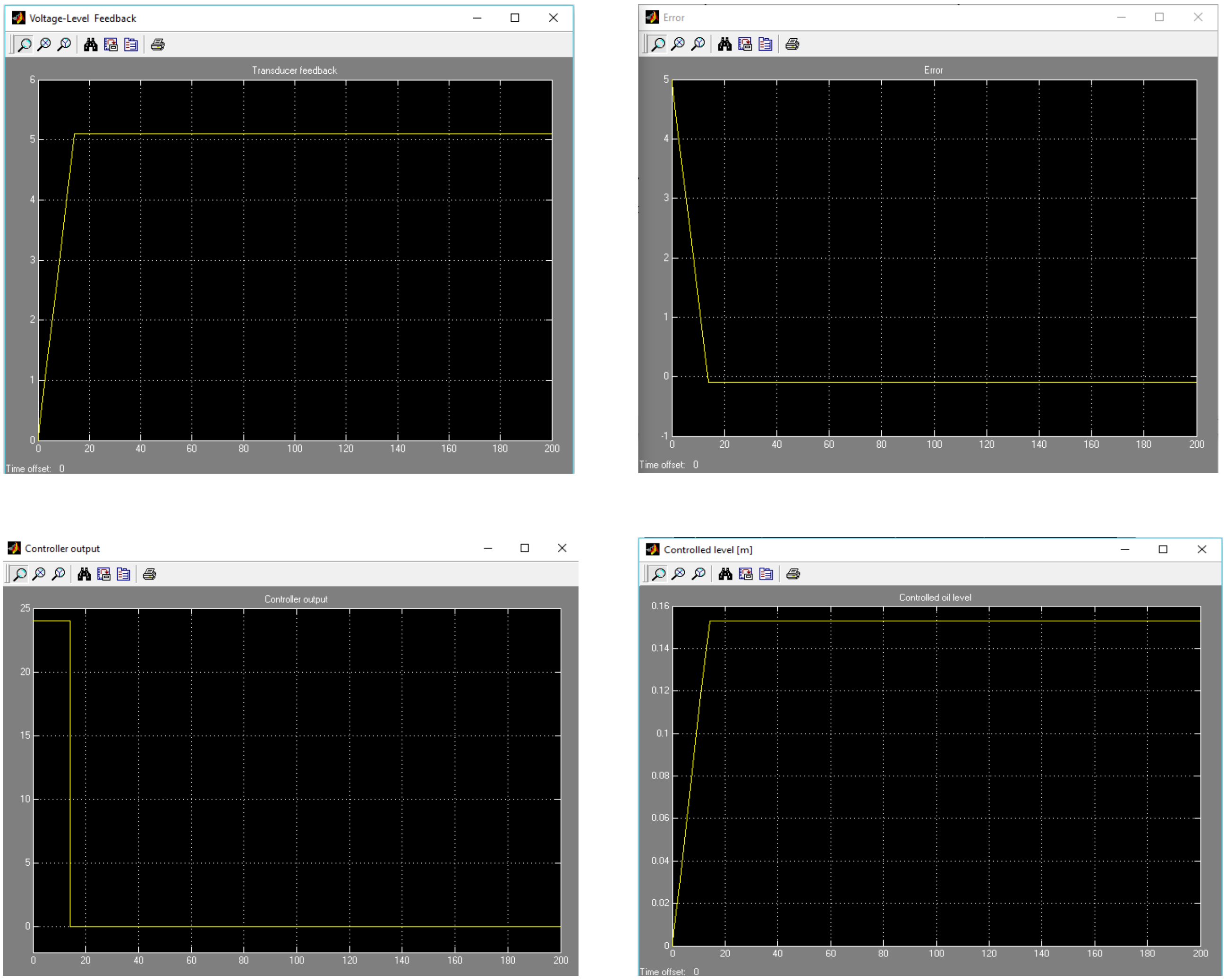


Fig. 5. Simulation results for *SP = 0,15 m* and *v = 0 %* disturbance

From simulation results above, given in *Fig.5*, it can be seen that in the absence of disturbances the oil level reaches and holds the setpoint value in short time, almost 12 *s*. Command sent to the electrovalve has a value of 24*Vcc*, when open, during the filling period of the tank, afterwards becomes 0*Vcc*, when closed – therefore the filling process will end.

b. constant setpoint value for oil level, *SP = 0,15 m* and *v = 50 %* disturbance influence;

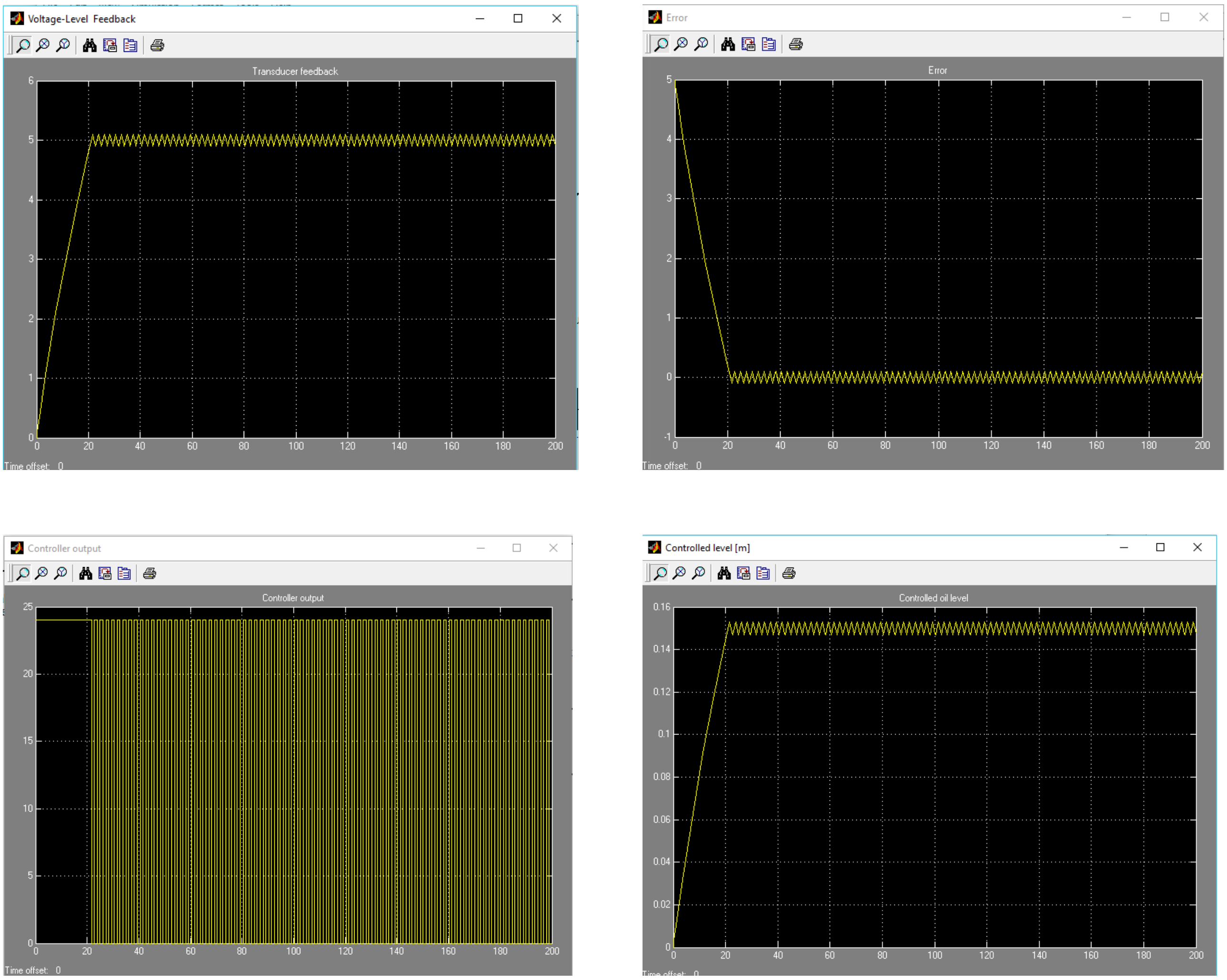


Fig. 6. Simulation results for *SP = 0.15 m* and *v = 50 %* disturbance

From simulation results above, given in *Fig.6*, it can be seen that when the disturbance reaches a 50% value from its maximum, the oil level in the secondary tank needs more time to reach the setpoint value than the case before. This is caused by the presence of the disturbance – practically the oil tank is filled but there is a small amount of oil that drains through its lower orifice, causing the oil level to drop. The electronic control unit must compensate the disturbance influence in order to maintain a constant oil level in the second tank, the command sent to the actuator – electrovalve – will be “open - close” according to oil level variation. As it can be seen from *Fig. 6*, the electronic controller has an “ON-OFF” output (0*Vcc* – 24*Vcc* – 0*Vcc*) in order to maintain a constant oil level in the second tank. It can be observed that the oil level is permanently oscillating near the setpoint value, causing an early mechanical wear of the electrovalve.

c. constant setpoint value for oil level, *SP = 0.15 m* and *v = 100 %* disturbance influence.

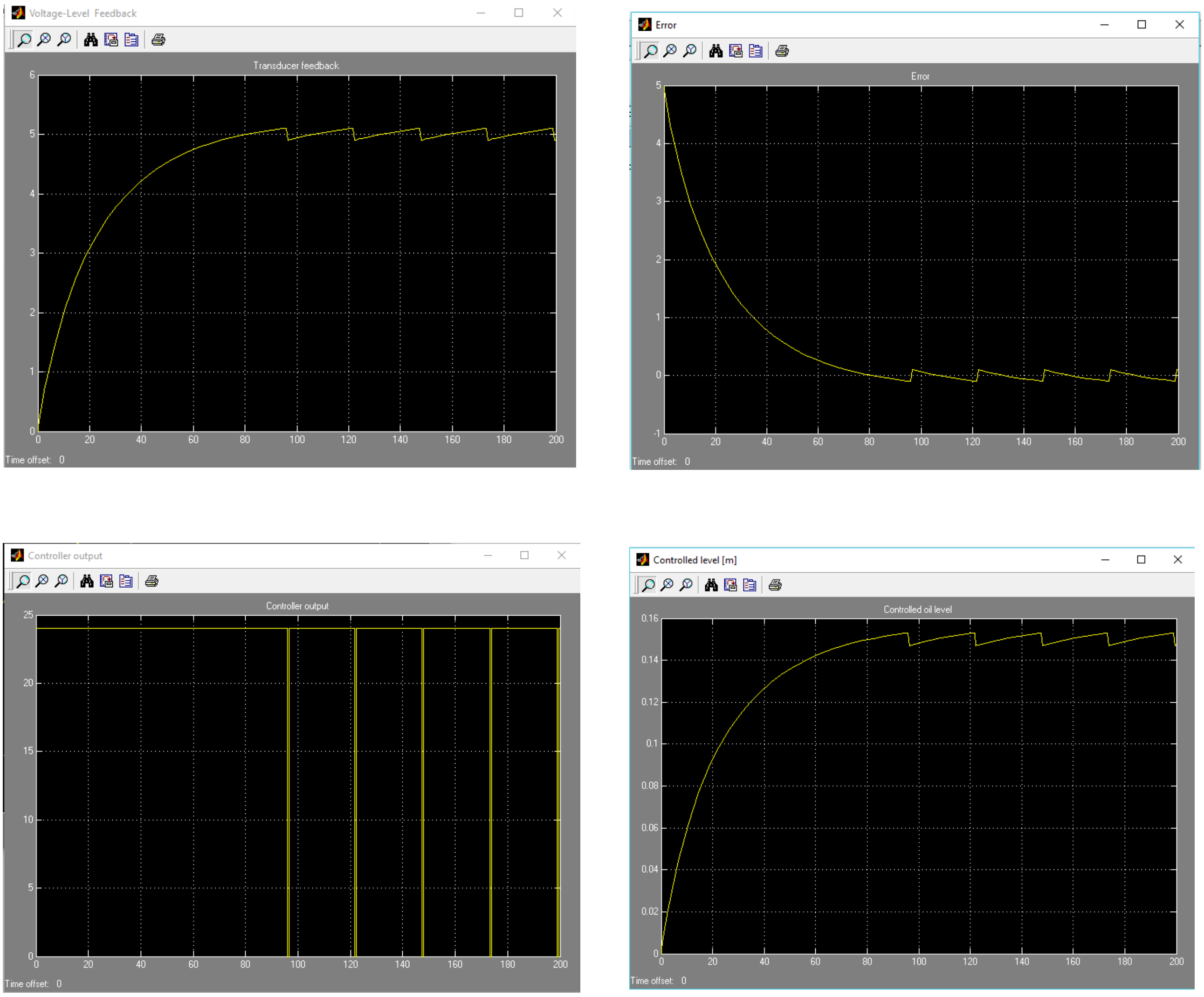


Fig. 7. Simulation results for *SP = 0,15 m* and *v = 100 %* disturbance

From simulation results above, given in *Fig.7*, it can be seen that when the disturbance reaches its maximum value, the oil level in the secondary tank reaches very slow the setpoint value because meanwhile the tank is filled with oil there is a large amount of oil draining through the lower orifice. The draining flow value is considerably higher than the case before. In this case, the setpoint value is reached around 80 *s*. If the electrovalve would not be opened from time to time, than the tank will drain totally. In order to maintain a constant oil level in the tank, the electronic controller must sent “open-close” commands to the electrovalve much more quickly than the case before due to the higher disturbance value. The “open” time of the electrovalve is significantly higher than the case before, having very short “close” times. The mechanical wear of the actuator – electrovalve – will be significantly higher. Filling time of the oil tank is higher in this case, the oil level oscillating near the setpoint value.

4. Conclusions

The automated oil transfer system used in an electrohydraulic equipment testing stand is proving its usefulness because it reduces to almost zero the intervention of the human operator when supervising the oil level and opening – closing the electrovalve manually.

One noticeable advantage of using the described automated system is that the main oil tank and pumping station can be placed in a soundproofed room, therefore reducing the noise stress on the human operator.

Main pumping station can be equipped with an automated oil cooling unit, as an extension to the transfer system presented, useful when testing time is larger or performing endurance tests on hydraulic equipment.

References

[1] C. Cristescu, P. Drumea, "Laboratory for testing lubrication systems and equipments", In: Proceedings of The 2-th International Proficiency Testing Conference-Ptconf, (15)16 – 16 September 2009, Sibiu, Romania, pp. 172 – 175, ISSN 2066-737X;

[2] C. Cristescu, P. Drumea, M. Neacsu, P. Krevey, C-ta Cristescu, G. Vranceanu, "Stand pentru testarea componentelor si echipamentelor de ungere", În: vol. 18 „Stiinta si Inginerie", Lucrarile celei de-a X-a Conferinta Nationata Multidisciplinare cu participare internationala – „Profesorul Dorin Pavel – fondatorul hidroenergeticii românesti, Sebes 2010, pp. 577 - 582 , Editura AGIR, Bucuresti 2010, ISSN 2067 – 7138;

[3] C. Cristescu, C. Dumitrescu, I. Ilie, L. Dumitrescu, "Hydrostatic transmissions used to drive electric generators in wind power plants", In: Hidraulica no.1/2015, pp. 60 – 72, ISSN 1453-7303;

[4] C. Cristescu, P. Krevey, C-ta Cristescu, G. Vranceanu, "Theoretical and experimental research for determining the volumetric efficiency of the pumps", In: Hidraulica, no. 1/2009, pp. 13 – 21, ISSN 1453-7303.