THE ENERGY SAVINGS WITH VARIABLE SPEED DRIVE CONTROL IN HYDRAULIC SYSTEMS[1]

Zeynep GÜLER, Sabri SEVİM, Ufuk ALEMDAROĞLU, Tevfik ALPOĞLU, Fikret DALKIRAN

HIPAS Hydraulics and Pneumatics Co.-Design Center, IMES Sanayi Sitesi, Istanbul / Turkey

Abstract: Nowadays, energy efficiency, sustainability and cost savings are of increasing importance in industrial sectors. In this context, electric motors stand out as one of the basic devices widely used in industrial facilities. However, the constant speed operation of electric motors brings with it a constant energy consumption, resulting in high energy consumption and low efficiency, which is one of the main problems faced by the industry. In order to overcome this problem and save energy, variable speed drive systems are increasingly used in the industry. The study presented in this article examines solutions between the motor-pump unit in order to increase energy efficiency in hydraulic systems. In this context, a hydraulic unit was designed using a variable speed control driver. The energy consumed by this hydraulic unit when it operated both at constant speed and under variable speed control was measured and examined in detail. The data obtained as a result of the measurements were evaluated by comparing them with graphics. According to the results obtained, it was observed that 20% energy saving was achieved when variable speed control was used. These results show that variable speed drive systems offer an effective solution in terms of energy efficiency in industrial applications. As a result, it is aimed that the findings revealed in this study will contribute to sectoral efficiency and energy saving. In our future work, we will continue research focused on efficiency and energy saving.

Keywords: Hydraulic System, Energy Efficiency, Variable Frequency Drive, Hydraulic Pump, Electric Motor, VFD

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INTRODUCTION AND THEORETICAL FRAMEWORK

Today, energy efficiency is critical for using energy more efficiently, reducing costs and increasing environmental sustainability. In this world where energy resources are limited, energy efficiency is becoming an indispensable element in the design and maintenance of industrial systems. The development of industry and the increase in production have led to an increase in the cost of electrical energy (Aybeniz et al., 2022). Increasing energy costs and the growing need for environmentally friendly production create challenges for the industrial industry. For this reason, end users require energy-efficient systems and equipment to reduce operating costs and CO2 emissions, especially in systems using drive technology[2-3] (Rao et al., 2022).

Hydraulic systems are power transmission and control systems widely used in industrial applications (Aborobaa et al., 2022). These systems have advantages such as compact structures, long service life, fast response, high power-to-weight ratio and high torque. Therefore, automatic control of hydraulic systems and energy saving methods are considered as one of the highest technological developments (Zhang, 2020). These systems include basic components such as motors, pumps and valves that transmit energy through hydraulic fluids and realize mechanical motion. Motors are the key components that convert mechanical energy into hydraulic motion and therefore play a critical role in terms of energy efficiency. In hydraulic systems, energy is consumed at a consistently high level in applications where motors and pumps are used at constant speed. However, the power required by the system is variable in the case of stand-by or low-capacity operation of the system. Depending on the variable operating conditions of the designed systems, Stand-By times vary. In some systems, Stand-By times can be longer than the operating times. Unnecessary energy consumption reaches its maximum especially in systems where the Stand-By state is very long. According to the US Industrial and Commercial Motor System Market Assessment Report published in June 2022, "main fluid systems such as pumps, fans, and various compressors account for 61% of motor energy use (Rao et al., 2022; Agamloh, 2017). It has been found that 47% of the electric motor systems used operate at loads less than 75% of their full capacity (Rao et al., 2022).

PURPOSE

To improve energy efficiency, the speed and torque of the motors should be adjusted according to the process requirements, depending on the power needed. Current

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[2] https://www.boschrexroth.com/Frequency Converter EFC 3610
[3] https://www.boschrexroth.com/Sytronix – variable-speed pump drives

pumping systems using flow control utilize bypass lines and throttling valves (Alemdaroglu et al., 2023). The flow required by the system is adjusted using the valves. Significant losses occur due to throttling in the valves when the system is running and, in the Stand, -By state, since the pump rotates continuously (Ethrane, 2007). Intelligent designs offer significant opportunities to save energy in pumping systems through retrofit and operational practices. One of these control methods is pump speed control. When the pump speed is reduced, less energy is delivered to the fluid and less energy needs to be throttled or bypassed.

SCOPE

The speed is controlled with the help of variable frequency drives (VFD) (Chun-Lien Su et al., 2014), (Hamim et al., 2024). Variable Frequency Drives are systems used to control the rotational speed of an AC electric motor by controlling the electrical power supplied to the motor with the help of frequency (Enemuoh et al., 2013).

In this study, variable speed control method is used to minimize the energy consumption of the systems especially in standby state. Variable speed control aims to minimize energy consumption by dynamically adjusting the speed of the electric motor.

METHOD

Stand-By times are known to be very long in some hydraulic systems designed according to the process to be realized. An example of these systems is the pull test bench. In these benches, although the pulling process is completed in a few minutes, the preparation processes can be several times longer than the test process. Figure 1 shows a schematic representation of the hydraulic system of a tensile test bench.

The variable displacement hydraulic pump used in this system transmits pressurized oil to the drawing bench with the drive it receives from the electric motor. The hydraulic system tries to keep the pressure constant at the set value according to the flow rate requirement. When the pump reaches the set pressure value, it continues to rotate by minimizing its angle (displacement). Since the use of pressurized oil in the system varies during the test, the system must be ready under pressure even in the Stand-By position.

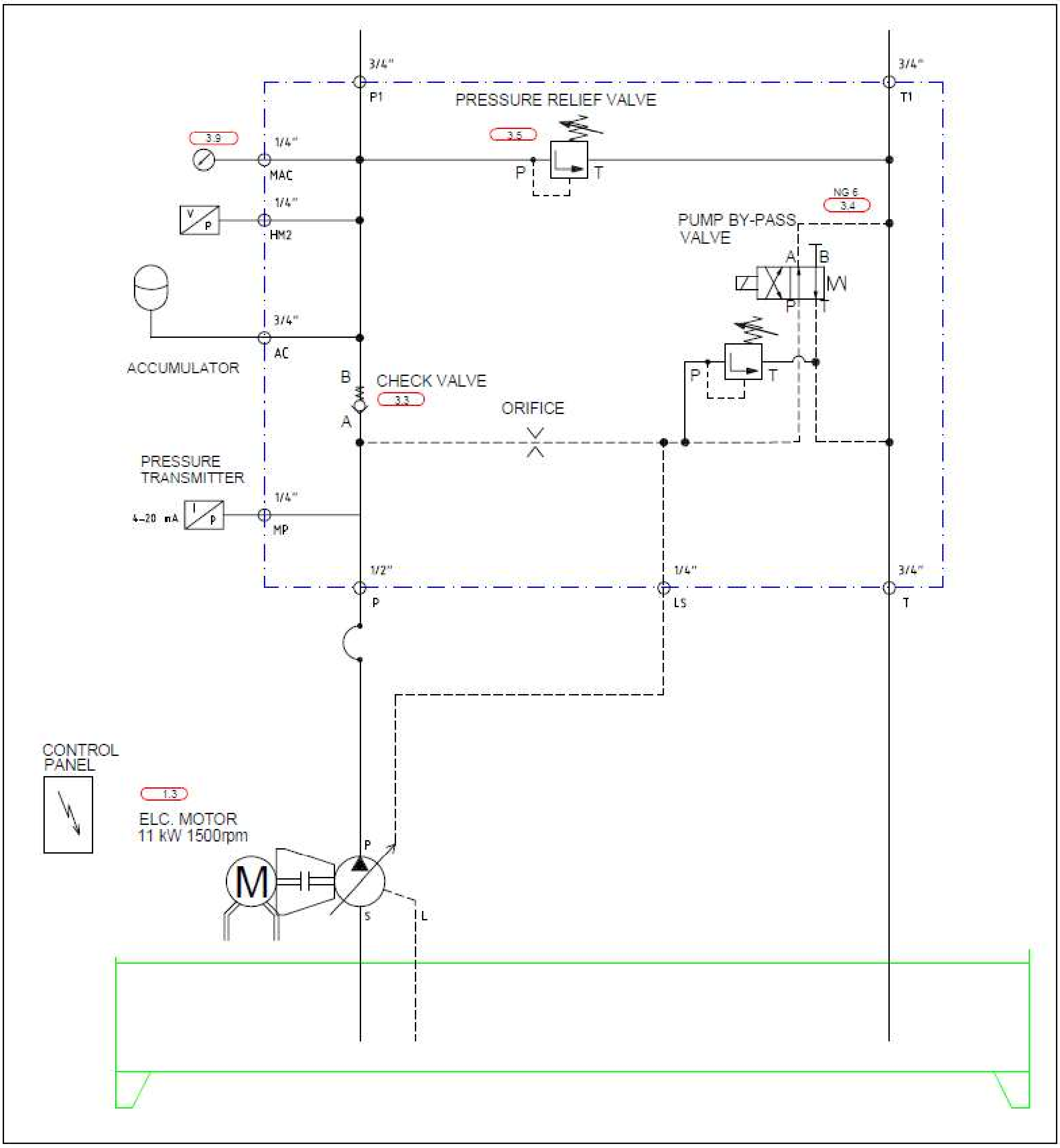

Figure 1. Schematic Hydraulic System for Pull Test

In this case, the electric motor driving the pump runs continuously. The 11 kW electric motor driving the pump is controlled by a frequency converter. Rexroth's EFC5610 series frequency converter with DRn function[4] was used in the system for pump speed control. This drive (DRn) has a 4-20 mA analog input for pressure feedback. A control panel and PLC were used to ensure the operating conditions of the system.

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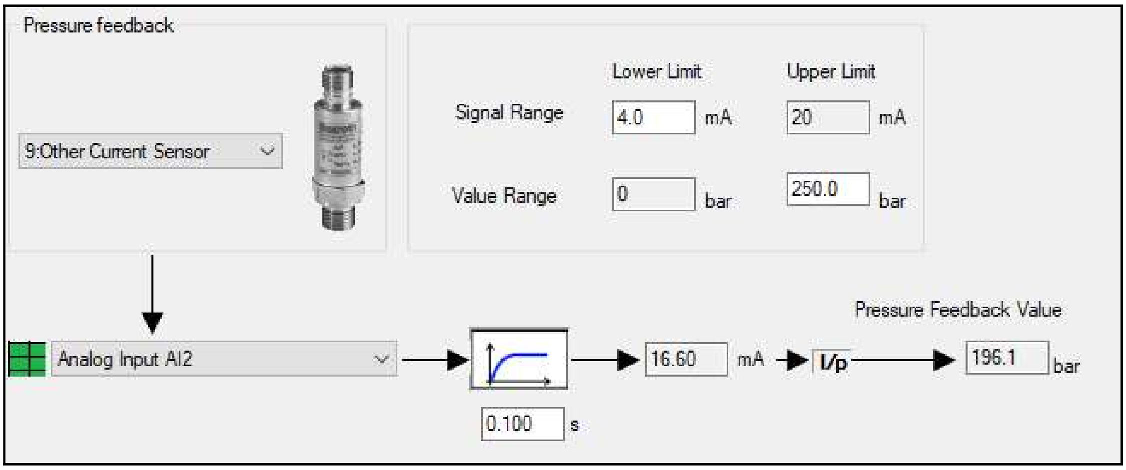
[4] https://www.boschrexroth.com/Frequency Converter EFC 3610

The installation and settings of the frequency converter are made with Rexroth's "Indraworks DS" program [5]. DRn function is activated from the setup parameters with the related program. In addition, a button was added to the panel cover to activate or deactivate the DRn function and the digital output of the frequency converter was adjusted with the relevant parameters and the electrical connection was made.



Pressure feedback

9:Other Current Sensor

	Lower Limit		Upper Limit	
Signal Range	4.0	mA	20	mA
Value Range	0	bar	250.0	bar

Analog Input AI2

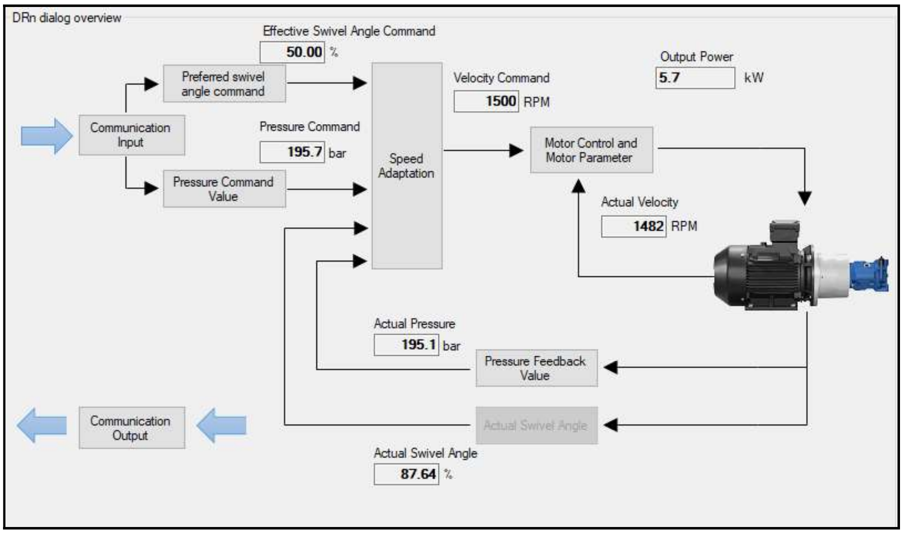
0.100 s

16.60 mA

Pressure Feedback Value 196.1 bar

Figure 2. Pressure Transducer Scaling Interface

Figure 2 shows the adjustment of the system by scaling the software interface according to the output lower limit and upper limit values received from the pressure transducer.



DRn dialog overview

Effective Swivel Angle Command 50.00 %

Output Power 5.7 kW

Velocity Command 1500 RPM

Pressure Command 195.7 bar

Actual Velocity 1482 RPM

Actual Pressure 195.1 bar

Actual Swivel Angle 87.64 %

Figure 3. Variable Speed Control Block Diagram Interface

Figure 3 shows a block diagram of how the DRn function of the software interface changes the speed of the electric motor according to the power demand. The frequency converter evaluates the system requirement by comparing the value taken from the pressure transducer and the current drawn by the motor to detect the system

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[5] https://www.boschrexroth.com/IndraWorks 14VRS

requirement. According to this evaluation, the speed is 1500 Rpm, the pressure is 195.7 Bar and the effective angular ratio is defined as 50%. If the system reaches the set pressure and the motor current drops, the frequency converter reduces the motor speed to the effective angular ratio value set in Figure 3 for more efficient operation of the system.

As it is known, there are two factors affecting the synchronous speed. These are the frequency of the source from which the motor is fed and the number of poles of the motor stator windings. Stator speed (ns) according to frequency (f) and number of stator poles (P) is given in Equation 1.

$$ns = 120.\frac{f}{p} \quad (1)$$

The speed of the motor can be easily adjusted by changing the frequency applied to the motor. Changing the number of poles, the other variable in Equation 1, is another way to adjust the motor speed, but this would be a physical change.

RESULTS

In the designed pull bench, the frequency converter senses the power requirement and pressure of the system instantaneously and tries to keep it at the most efficient point. When the variable displacement pump reaches the working pressure, the pump angle is minimized and the current drawn by the electric motor is minimized. By comparing the feedback from the pressure transducer and the power information, the Frequency Converter automatically detects that the system has switched to the Stand-By position. Thus, it reduces the motor speed at the set effective angular ratio value. Accordingly, the results obtained are given below.

- It is seen that high energy efficiency can be easily achieved by using a frequency converter with VFD in hydraulic systems.
- It is observed that the consumption of the electric motor, which consumes 3kW power in the Stand-By scenario, decreases to 2.4kW with the help of VFD.
- Savings were achieved by reducing the energy consumption of the drawing bench by 20%.

It has been shown in this study that in hydraulic system technology, only the required energy consumption can be provided instead of continuous operation of the motors at maximum speed.

CONCLUSION

The speed control of the draw bench at standstill was performed for two different scenarios. In the first scenario, measurements were performed for 900 rpm and in the second scenario for 400 rpm. These measurements were performed by connecting to the frequency converter for the designed hydraulic system with the program interface.

Figure 4 shows the output power and instantaneous speed values measured from the electric motor for 900 Rpm and Figure 5 for 400 Rpm.

Figure 4. Energy Consumption at 900 RPM

When the recorded graph in Figure 4 is examined, the power used by the system operating in the Stand-By position at 1500 rpm was measured as 3kW. By activating the DRN function in the system, the speed of the motor was reduced to 900 rpm and the output power used was measured as 2.55kW.

When the recorded graph in Figure 5 is analyzed, it is observed that the instantaneous speed of the motor was reduced to 400 rpm by activating the DRN function again and the output power was observed to be 2.4kW on average.

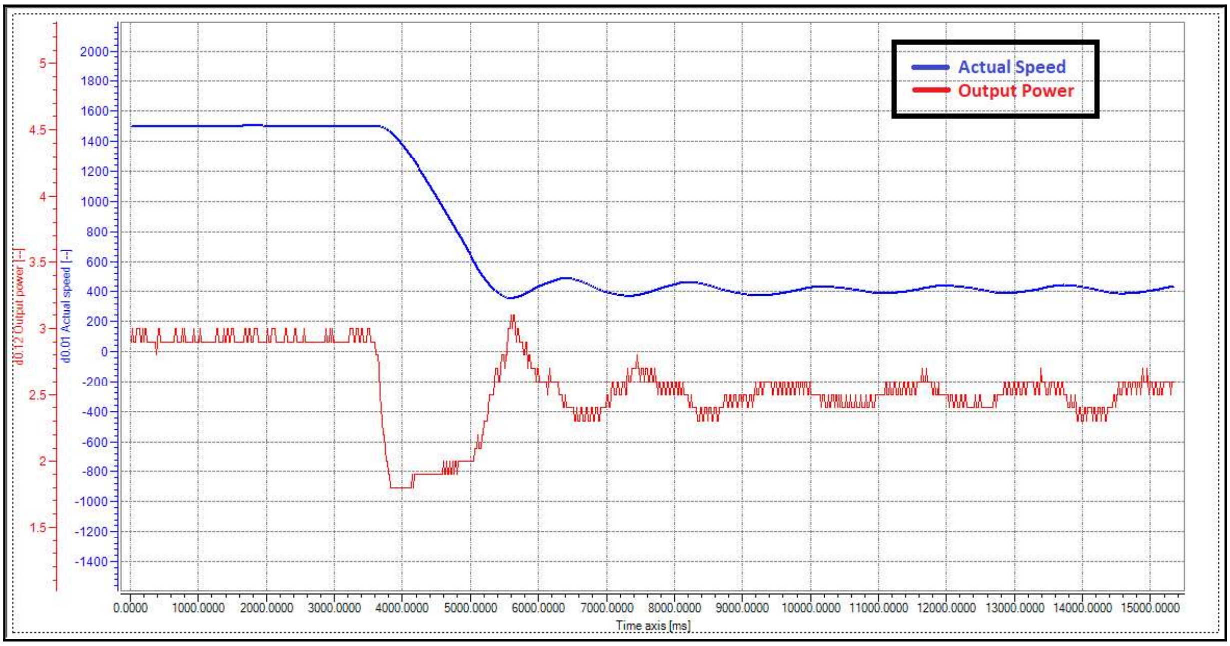

Figure 5. Energy Consumption at 400 RPM

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INTERNET RESOURCES

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