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Automation of Filter Press Drive Control for Enhanced Palm Oil Extraction

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ABSTRACT

The study focuses on the automation of the drive system of a filter press in palm oil extraction plants, with the aim of optimizing operational efficiency, reducing manual intervention and improving process accuracy. The proposal replaces the manual drive with a motorized system controlled by a Programmable Logic Controller (PLC). A Siemens motor-reducer, model Z79-LE112MC4P-G040M-PN, was used, which guarantees a torque of 777.75 Nm and an output speed of 40 rpm, sufficient to efficiently tighten and release the filter press. The system control was implemented by a Siemens LOGO 230RC PLC, complemented by an AM2 analog expansion module to interpret strain gauge signals. These signals determine the exact moment to stop the motor-reducer once the programmed tightening force is reached. Programming was done in Ladder language using LOGOCONFORT software. The integration of these components improves system consistency and reliability, standardising processing times and reducing physical effort. The results highlight an increase in productivity and operational safety, aligning with modernisation trends in the palm oil industry. This advance represents a significant step towards greater sustainability and competitiveness of the sector.

1. INTRODUCTION

Palm oil is a vital source of vegetable fats, accounting for approximately 35% of global consumption of oils and fats. Its importance lies in its unrivalled versatility, high productivity per hectare and wide applications in both the food and non-food industries. Its use extends to both edible products and the production of cosmetics and biofuels, palm oil remains the cornerstone of numerous industries around the world [1]. Palm oil has been used for centuries as a food source and in medicinal applications [2-5]. Palm oil is essential as an edible vegetable oil in the daily diet. However, processing technologies and the quality of the produced oil have stagnated in recent decades [6].

Ecuador, as a leading player in this sector, has demonstrated consistent growth in palm oil production, with annual increases ranging between 5% and 10%. This positions the country as a key exporter in South America and underlines its strategic role in meeting growing global demand [7]. The projection for growth in palm oil production to meet per capita demand for vegetable oils and fats by 2050 is an additional 150 million tonnes [8].

Palm oil extraction plants are pivotal in this supply chain, processing fresh fruit bunches (FFB) to produce crude palm oil. This oil is then refined and used in a wide variety of products, ranging from food to biodiesel and industrial chemicals [9]. Given the rising demand for palm oil, these facilities continuously evolve to enhance operational efficiency, environmental sustainability, and the quality of the final product.

Modernization efforts have focused on integrating advanced technologies and automation to optimize production and address challenges such as labor intensity, energy consumption, and environmental impact.

Automating palm oil production begins with improving agricultural practices. Adopting geographic information systems (GIS) and remote sensing technologies enables accurate monitoring of crop conditions, early detection of problem areas, and targeted interventions. These technologies, when combined with precision agriculture and sensor-based smart irrigation systems, help to optimize resource use, improve water efficiency, and reduce the ecological footprint of palm cultivation [10-13]. Furthermore, automated systems have been applied to key processing stages, such as sterilization of raw materials. For example, thermal treatment of FFB using saturated steam is now monitored and optimized using data-driven approaches and advanced mathematical models [14, 15].

In addition to advances in cultivation and initial processing, several plants have improved production organization [16, 17], and Lean Manufacturing principles have been adopted to improve production efficiency [18]. Automation of critical operations, such as the filter press, represents a significant advance in this regard, which has led to improved accuracy, consistency, and overall productivity [19-22].

The palm oil extraction process in industrial plants still faces significant challenges in terms of operational efficiency, accuracy, and cost reduction. Currently, in many plants, filter presses are driven manually by a handwheel or pressing wheel with high human intervention, resulting in inconsistencies in applied pressure, long operating times, and increased physical effort by personnel. This not only limits productivity, but also increases operating costs and reduces system reliability.

Given the sustained growth in global demand for palm oil, it is essential to modernize this critical component by implementing technological solutions. However, there is a gap in the adoption of automated technologies specifically in the filter press drive system, which limits the potential of these plants to achieve greater competitiveness and operational sustainability.

The objective of this research is to automate the filter press drive control system in palm oil extraction plants, by implementing a motor-reducer controlled by a programmable logic controller (PLC), in order to improve the precision, reliability and operational efficiency of the extraction process, reducing manual intervention and optimizing costs and operating times.

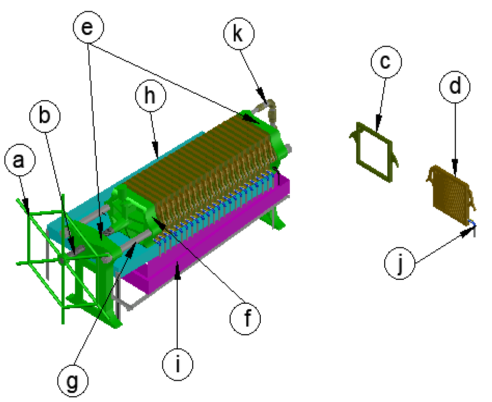
This study focuses on promoting these advances by proposing automation solutions for the filter press drive system, contributing to the continuous evolution of palm oil extraction technologies.

2. MATERIALS AND METHODS

Filter presses are equipment designed to separate palm oil from the pulp, by forcing it to pass through plates with special fabric that traps the pulp residues, releasing the oil. Below is a description of its component parts and principle of operation.

2.1 The filter press: Essential parts and working principle

The oil and palm paste are driven by a pump to the filter press through the metal pipe (k), see Figure 1.



a) pressing wheel; b) adjusting screw; c) pasta collection plates; d) oil filter plates; e) supports; f) mobile clamping base; g) guide columns; h) metal tray; i) oil collection channel; j) oil outlet pipes; k) paste-oil mixture access

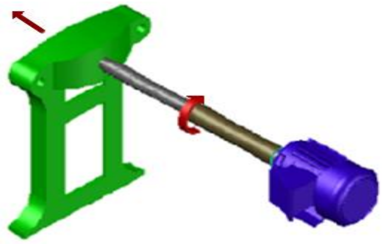
Figure 1. Scheme of a filter press

The bases (e) serve as support for the entire structure. The pressing wheel (a) rotates the adjustment screw (b), which drives the mobile clamping base (f) with longitudinal movement on the guide columns (g), to compress the hollow plates (c) for collecting paste and oil filter plates (d). The filtered oil falls onto the oil collection channel (i). The metal tray (h) collects unfiltered oil and impurities that fall when plates (c) and (d) are removed for cleaning. This content is taken back to the unfiltered oil tank to begin a new filtering cycle.

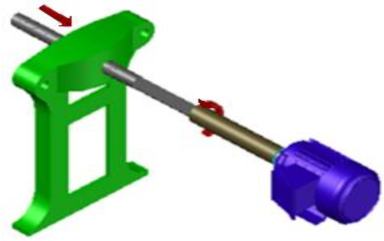
2.2 Electrical and control proposal for the filter press

The improvement includes replacing the manual press drive by means of a handwheel (press wheel) with a motor-reducer driven system as shown in Figure 2. The motor-reducer will be anchored to a support and the adjustment screw will be coupled to the motor-reducer by means of flanges. When the motor-reducer is turned clockwise (Figure 2a), a combined movement of rotation of the screw in that direction and the linear displacement of the mobile clamping base towards the plates for collecting paste and filtering oil will occur, to tighten the press.

When the anti-clockwise rotation of the motor-reducer is activated, the adjustment screw will now turn counter-clockwise, producing the linear movement of the mobile clamping base separating itself from said plates, to loosen the press (Figure 2b).



a) Clockwise rotation during tightening of the filter press



b) Counterclockwise rotation during loosening of the filter press

Figure 2. Movements of the adjustment screw coupled to the motor-reducer

2.2.1 Calculation of the necessary power of the motor-reducer

The selection of the motor-reducer is made based on the power value required to ensure the number of revolutions of the output shaft of the reducer to which the adjustment screw b) of Figure 1 is attached, and the torque or torque allowed by the adequate push of the mobile clamping base f) against the pasta collection plates c) and oil filtering plates d), to achieve palm oil extraction.

The calculation of the engine power is determined by the following expression:

$$P_1 = \frac{T * n_2}{9550 * \eta} * f_s \quad (1)$$

where,

P_1 = Reducer input power (kW)

T = Torque at the output of the reducer (Nm)

n_2 = Reducer output speed (rpm)

η = Motor-reducer efficiency

f_S = Machine service factor

The required torque is calculated from the following expression:

$$T = F \times r \quad (2)$$

where,

F = force on the flywheel (N)

r = steering wheel radius (m)

The value of n_2 will be determined based on the functional requirements of the press. Using the calculated input power of the reducer, the type of reducer will be selected according to Eq. (1), specifying the corresponding reduction ratio *i*.

Next, the motor that meets the power and rotational speed requirements at the reducer's output will be chosen from the catalog, based on the reduction ratio *i*. Finally, the output rotational speed n_2 of the reducer will be determined using Eq. (3).

$$i = \frac{n_1}{n_2} \quad (3)$$

where,

i = Reduction ratio

n_2 = Reducer output speed (rpm)

n_1 = Reducer input speed (rpm)

2.2.2 Filter press control proposal

The operation of the filter press will be carried out in three stages.

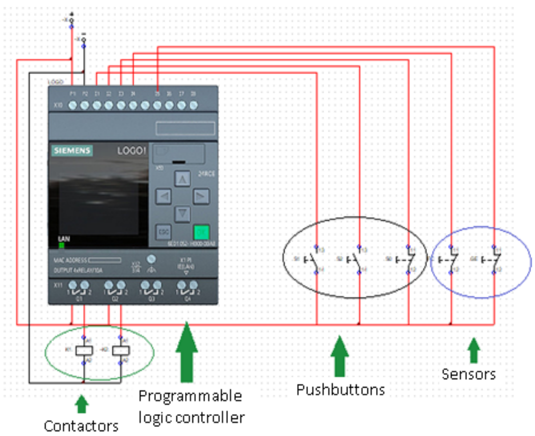


Figure 3. Basic control scheme for the filter press of the oil extraction plant

1) Release of the press: The button to start the release stroke is manually activated; this stage ends when the stroke sensor with a single lever located at the end of the travel carriage guide is activated.

2) Cleaning of the press: The oil collection tray is moved, checking that it reaches the limit of the travel, leaving the space free for cleaning the paste and filter collection plates, it will be checked that the waste collection tray filter is in position; Next, each of the plates is moved for its respective cleaning. Once cleaning is completed, the oil tray will be placed in its working position.

3) Tightening the press: The button to start the tightening stroke of the press is manually activated. This stage culminates with the signal delivered by the strain gauges to the programmable logic controller (PLC), which compares the value of the signal delivered with the tightening force value previously set in its programming.

The basic scheme for the control system for adjustment and release of the filter press is presented in Figure 3.

The operation control of the press will be carried out by programming logic, using a Programmable Logic Controller (PLC) that will send activation signals when the filter press is tightened or released.

3. RESULTS AND DISCUSSION

The operation control of the press will be carried out by programming logic, using a PLC that will send activation signals when the filter press is tightened or released.

3.1 Motor-reducer selection

The tightening of the filter press is done manually. Using a dynamometer, it was determined that the average value of the force to be applied to the regulating screw at the end of its stroke is 735 N. To achieve the required pressure on the pulp collection and oil filtering plates (Figure 1), it is necessary to apply the torque value on the regulating screw determined by Eq. (2) when considering the 1 m radius of the pressing wheel.

$$T = F \times r$$
$$T = 735\ N \times 1\ m = 735\ Nm$$
$$T = 735\ Nm$$

According to the operating characteristics of the filter press and for proper operation of the motor-reducer-press system, a value of the number of revolutions at the output of the reducer (n_2) of 40 rpm has been set. Operating conditions close to a full load demand of the motor-reducer will require an efficiency value (η) of at least 95%.

Siemens motor-reducers are widely used in different industrial applications and specifically in the Food Industry due to their great versatility, efficiency and safe work. The service factor (*fs*) of the motor-reducer was determined in the study [23] for the operating conditions indicated below. Resulting in a value of *fs*=1.14.

Operating conditions:

- Shock level: almost shock-free
- Operating frequency: less than 100 operations per hour
- Daily service time: 16 hours (two work shifts)

The power requirement of the gear motor to ensure proper operation of the press is determined by Eq. (1).

$$P_1 = \frac{T \times n_2}{9550 \times \eta} \times f_s = \frac{735\ \text{Nm} \times 40\ \text{rpm}}{9550 \times 0.95} \times 1.14$$
$$= 3.69\ \text{kW}$$

The Z79-LE112MC4P-G040M-PN motor-reducer was determined in the study [23] which meets the drive design requirements in terms of power and torque value. Its main characteristics are summarized in Table 1.

Table 1. Characteristics of the selected gearmotor

Ra	*P* [kW]	n_1 [rpm]	T_1 [Nm]	IE-CL	*i*	n_2 [rpm]	T_2 [Nm]	*fs*
1:5 (Y)	4,00	300-1500	25,46	IE3	30.54	9,823 - 49,116	777,7	1,14

Source: Siemens SiaPortal

The meaning of the parameters in Table 1 is indicated below:

Ra: Adjustment range

P: Power of the motor-reducer [kW]

n_1: Range of the number of revolutions at the input of the motor-reducer [rpm]

T_1: Torque supplied by the motor-reducer [Nm]

IE-CL: Energy efficiency class of the electric motor

IE3: Corresponds to the High Efficiency category within the IE-CL efficiency class.

I: Transmission ratio

n_2: Range of the number of revolutions at the output of the motor-reducer [rpm]

T_2: Torque at the output of the motor-reducer [Nm]

F_S: Service factor

Using Eq. (3) the number of revolutions (n_1) that the motor must deliver was determined. The value of the transmission ratio of the motor-reducer (i) is equal to 30.54 (Table 1). Solving this gives:

$$n_1 = i \times n_2$$
$$n_1 = 30.54 \times 40\, rpm$$
$$n_1 = 1221.6\, rpm$$

Likewise, the values of (n_1) and (n_2) are within the range of the number of revolutions delivered by the selected motor-reducer system (Table 1).

3.2 Selection of electrical components

Breaker selection:

The breaker was selected according to NTC2050 and NEC standards, which consider short-circuit protection equivalent to 125% of the nominal current.

For a three-phase motor of 4 kW power and 16.1 A nominal current, a 20 - 25 A adjustable breaker from the Siemens brand, type 3VT1702-2DC36-0AA0, is chosen.

Contactor selection:

These command or switching devices are selected based on the power of the motor, they work at the intensity of the AC3 category corresponding to motors with squirrel cage rotor, 16A contactors were selected.

Deformity Sensor Selection (Strain Gauges):

This type of sensor measures the deformation of an object subjected to great stress. For this project, it is recommended to use strain gauges because they withstand higher nominal forces for long periods of time 4 strain gauges are needed to form a Wheatstone-type bridge. This type of bridge generates a signal at its output, assigning a stop order to the motor-reducer, ending the tightening process.

3.3 PLC selection and programming

Table 2 shows the characteristics of the selected PLC LOGO 230RC, a Siemens AM2 analog expansion module will be used, since this PLC only has digital inputs, and it is necessary to measure and interpret the signal from the strain gauges that will send the stop signal to the motor-reducer. The brand's products are used in the sector and the chosen model is suitable for the 220 Volt supply voltage used by the company. Table 3 shows the characteristics of the selected analog expansion module LOGO! AM2.

The programming was carried out through the LOGOCONFORT software using the Ladder programming language, which is characterized by managing control schemes in block structures, see Figure 4.

Table 2. LOGO PLC variant and its characteristics

Designation	Feeding	Inputs	Outputs
LOGO! 230RC#	115…240V CA/CC	8 digitals	4 relays 230Vx10A

Source: catalog logo – manual edition 06/2003

Table 3. Expansion module for LOGO PLC

Designation	Feeding	Inputs	Outputs
LOGO! AM 2	12/24 V CC	2 analogics 0-10 V o 0-20mA	none

Source: catalog logo – manual edition 06/2003

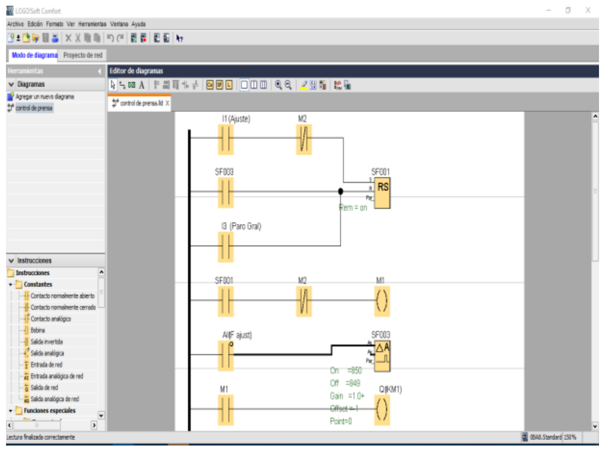


Figure 4. Programming in LOGO!SOFT Confort

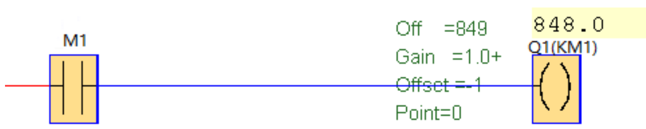


Figure 5. Mark M1 to order the tightening of the press

Figure 6. Mark M2 to order the release of the press

The filter press drive control program consists of 2 brands M1 and M2 respectively, one for each PLC output, as shown in Figures 5 and 6.

The diagram for tightening the filter press is shown in

Figure 7, which initially displays a normally open contact corresponding to input I1, which comes from the button used to start adjusting the press. This is followed by a closed contact of M2, serving as a protection measure to prevent the simultaneous activation of both outputs, which are connected to the set input of a set-reset relay.

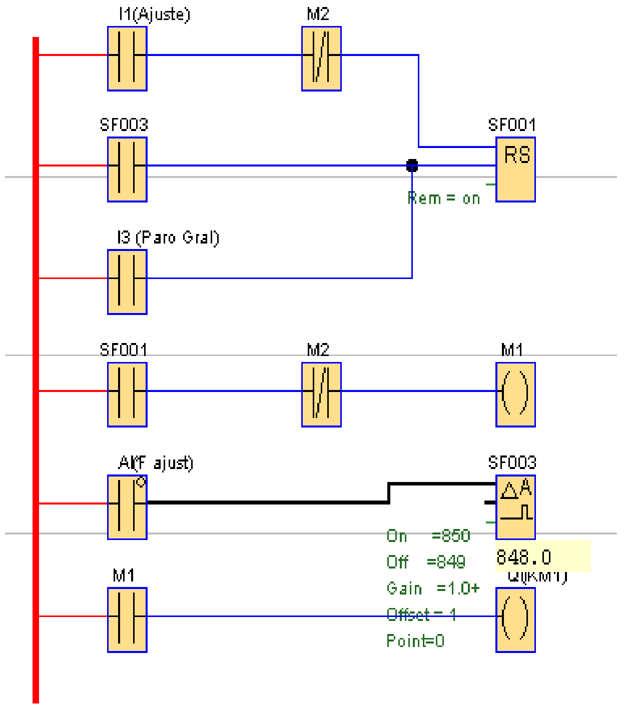


Figure 7. Diagram for tightening the filter press

The reset terminal, or process endpoint, is linked to the I3 contact (general stop button) and the analog comparator contact. The analog comparator monitors the value provided by the strain gauges and will be activated once the previously programmed value is reached.

At the third level, the open contact of the first relay is shown, followed by a closed M2 contact as protection against simultaneous activation of both outputs. When the relay is activated, M1 is triggered, which in turn activates output Q1, sending the command to the motor to begin tightening the press. M1 will deactivate when the reset terminal is activated, either by the general stop button or when the programmed value is reached. The release of the press is as shown in Figure 8.

To the SF002 set-reset relay, at the input of its set terminal, an I2 contact, or release button is connected, and the protection mark M1. Contacts I3 and I4 are located in the reset terminal to complete the adjustment process, I3 corresponds to the general stop button and I4 to the limit switch sensor.

When M2 is activated, Q2 is immediately activated giving the order to release the filter press. The release of the filter press will end when I3 is pressed or automatically when the limit switch sensor is activated.

The closed contacts of the marks M1 and M2 prevent the simultaneous activation of the outputs Q1 and Q2 to avoid a short circuit when reversing the rotation whether the press is being tightened or released.

A fully automatic tightening or loosening operation has not been taken into account for this program. If you wish to have an automatic cycle, a timer must be implemented in the program, so that based on the previously calculated time it starts, in addition to entering a control for the oil pump and solenoid valves to open and close the oil passage and the air passage, establishing an average operating time.

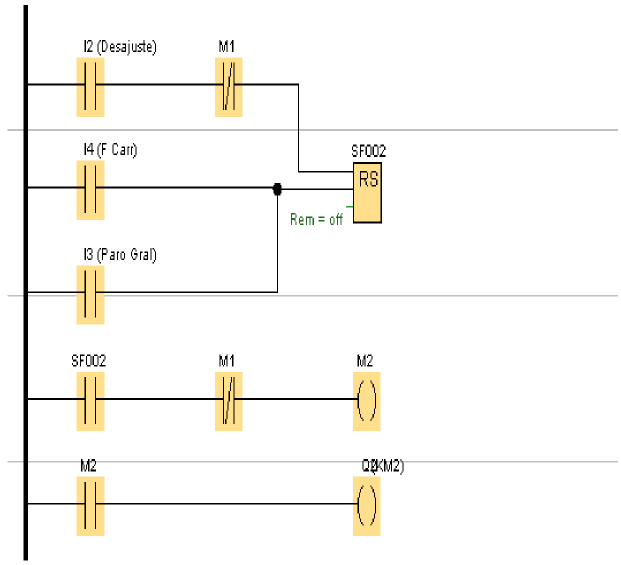


Figure 8. Diagram for the release of the filter press

4. CONCLUSIONS

The manual drive system of the filter press was successfully replaced by a Siemens gearmotor, model Z79-LE112MC4P-G040M-PN, offering a reduction ratio of i=30.54. The output torque of 777.7 Nm and a speed of 40 rpm from the reducer are sufficient to perform the critical function of tightening the adjustment screw efficiently. This configuration ensures reliable and consistent mechanical performance, enhancing the filter press's operational capacity.

For system control, the Siemens LOGO 230RC PLC was chosen, paired with an AM2 analog expansion module to interface with the strain gauges. These strain gauges, configured in a Wheatstone bridge circuit, deliver precise measurement signals to accurately determine when the tightening process reaches the desired clamping force. The control logic was implemented using LOGO! Soft Comfort software and the Ladder programming language, which provided an intuitive and modular approach to programming. This methodology not only ensured seamless integration but also allowed for easy scalability, positioning the control system for future enhancements and expansion.

The selection of electrical components was carefully aligned with the system's power and safety requirements. A Siemens adjustable circuit breaker, model 3VT1702-2DC36-0AA0, rated at 20-25 A, was chosen to comply with NTC2050 and NEC electrical standards. Additionally, 16 A-rated contactors were used to manage the motor's electrical connections, ensuring durability and safety under operational conditions. These components collectively safeguard the system against electrical overloads and faults while maintaining smooth operation.

The implemented solution significantly advances the automation of the filter press operation in palm oil extraction. By integrating a PLC-controlled motor-reducer system, the clamping and unclamping processes are now more efficient, precise, and safer. This automation not only enhances the quality and consistency of the operation but also standardizes processing times, enabling better production planning and scheduling. The overall improvements contribute to increased productivity, reduced manual labor, and enhanced operational safety, marking a pivotal step in modernizing palm oil extraction technologies.

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