Technical Report

Calculations and Sizing of the DLDAPP System

1. Introduction

The DLDAPP System (Duo Leveraged Double Acting Piston Pump) is a disruptive innovation in hydraulic engineering, designed with a focus on high energy efficiency, mechanical robustness, and operational sustainability. Developed for integration with the ***PMTHPP*** project, this system serves as the core component responsible for pumping large volumes of water at high pressure, with significantly reduced energy consumption.

The technology strategically combines two well-established mechanical principles — leverage and movable pulleys — to enhance piston displacement. This configuration substantially reduces the required operating force without compromising flow rate or hydraulic stability of the system.

Unlike conventional systems described in technical literature, the DLDAPP pumps water into a vertical storage chamber — the water chamber — which extends from the underground level to the upper reservoir. This innovative structure enables optimal utilization of gravitational potential energy and accumulated hydraulic energy, forming a closed-loop circuit with high energy efficiency.

This report details the physical principles, performance calculations, technical operation, and key differentiators that position the DLDAPP as a strategic solution for advanced renewable energy generation projects.

2. System Objectives

The DLDAPP system (Duo Leveraged Double Acting Piston Pump) was developed to provide an efficient and innovative solution for the continuous pumping of large volumes of water under high pressure, meeting the operational demands of the PMTHPP project. The main objectives of the system are outlined below:

- Maximize energy efficiency in the pumping process by significantly reducing power consumption through the combined use of mechanical leverage and movable pulleys.
- Enable water transport to the upper reservoir, overcoming elevation differences exceeding 100 meters with safety, stability, and structural robustness.
- Minimize hydraulic and mechanical losses by employing a design that eliminates the primary inefficiencies commonly found in conventional pumping systems.
- Ensure continuous and self-sustaining operation by integrating into the PMTHPP closed-loop cycle without relying on external energy sources beyond those generated by the system itself.
- Demonstrate the technological feasibility of a disruptive approach not described in traditional literature, expanding the possibilities for the large-scale application of renewable hydraulic energy with minimal environmental impact.

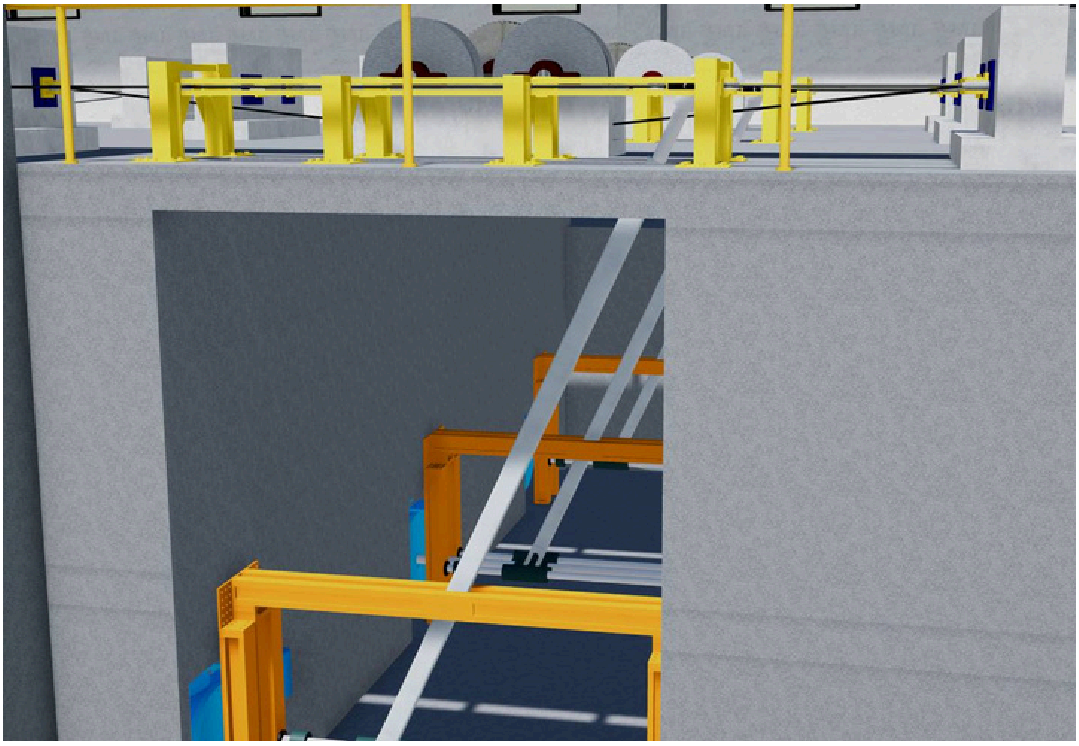
3. Fundamentals and Operation

The DLDAPP system (Duo Leveraged Double Acting Piston Pump) is based on classical mechanical and hydraulic principles, applied in an innovative manner to overcome the limitations of conventional pumping technologies.

3.1 Operating Principles

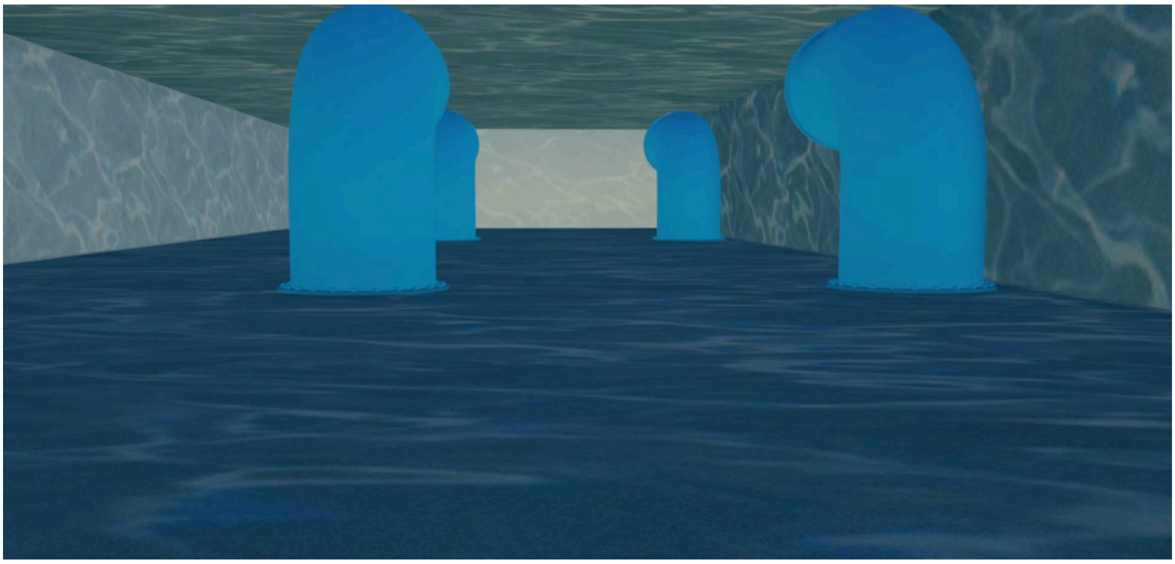
The DLDAPP consists of a set of double-acting piston pumps operated through mechanical levers and movable pulleys. This configuration enables the alternating motion of the pistons to pump water during both strokes, optimizing the work cycle and effectively doubling the volumetric efficiency compared to single-acting pumps.

The system applies mechanical leverage with a transmission ratio of approximately $i = 2.76$, significantly reducing the force required to drive the pistons. Additionally, movable pulleys are incorporated to distribute the applied load, further decreasing the mechanical effort needed for operation.



3.2 Vertical Storage Chamber (Water Chamber)

Unlike conventional systems described in the technical literature, the DLDAPP pumps water into a vertical storage chamber — the water chamber — which extends from the underground level to the upper reservoir, with an approximate height of 125 meters. This chamber functions as a pressurized conduit, efficiently accumulating gravitational potential energy.



3.3 Integrated Hydraulic Cycle

The water pumped into the water chamber is subsequently released to feed the turbines of the PMTHPP system. The accumulated potential energy is converted into kinetic energy, and then into mechanical energy by the Francis and Pelton turbines, completing a continuous, high-efficiency closed-loop cycle.

This process enables the energy used for pumping to be recycled within the system itself, maximizing operational sustainability and overall efficiency.

4. Calculations and Sizing

The sizing of the DLDAPP system was developed based on specific operational parameters, taking into account the required flow rate, pumping height, and the system's energy efficiency.

4.1 Pressure at the Base of the Vertical Storage Chamber

$H = 109,5m$

$\rho = 1000kg/m^3$

$g = 9,81m/s^2$

$$P = \rho \times g \times H$$

$$P = 1000 \times 9,81 \times 109,5$$

$$P = 1.074.195Pa$$

$$P = 10,74bar$$

4.2 Displacement Area and Volume per Piston

$r = 0,5m$

$d = 1m$

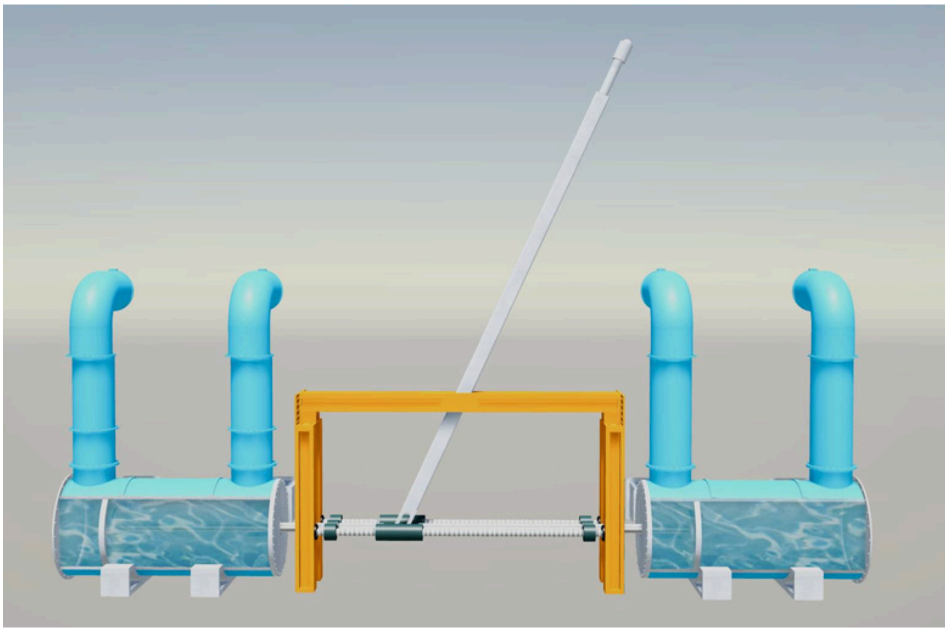
$A = 0,7854m^2$

$V = 1m^3$

$V = A \times L$

$L = \frac{1}{0,7854}$

$L = 1,273m$



4.3 Force Required per Piston

$P = 1.074.195 Pa$

$A = 0,7854 m^2$

$$F = P \times A$$

$$F = 1.074.195 \times 0.7854$$

$$F = 843.672 N$$

$$F = 86,01 kgf$$

4.4 Force Reduction via Leverage and Movable Pulley

Since the DLDAPP system operates with two pistons simultaneously, the total force generated is:

$F = 843.672 N$

Total Force = $F_t = 2 \times F$

$F_t = 1.687.345 N$

$i = 2,76$

$$F_r = \frac{F_t}{i}$$

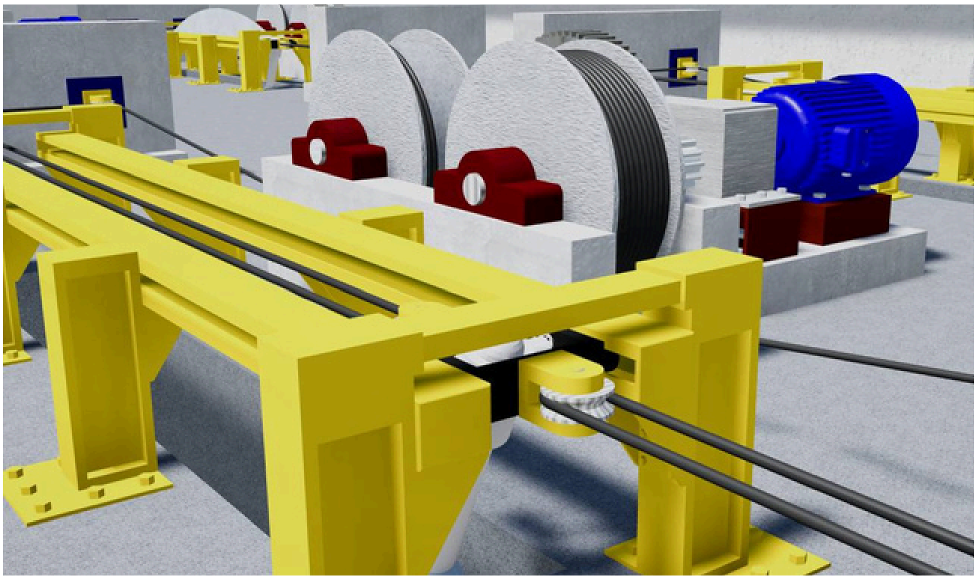
$$F_r = \frac{1.687.345}{2.76}$$

$$F_r = 611.357 N$$

$$F_f = \frac{611.357}{2}$$

$$F_f = 305.678 N$$

$$F_f = 31,17 kgf$$



5. Power Requirement Calculation for the Pumping System

To drive the hydraulic pistons in the DLDAPP system (Duo Leveraged Double Acting Piston Pump), an articulated lever mechanism was implemented, designed to amplify the applied force with high mechanical efficiency. The upper arm of the lever performs a linear stroke of 3.76 meters per complete pumping cycle.

Considering that the system operates with movable pulleys to multiply force and redistribute the load, the steel cable connected to the drum must have an effective length of 7.52 meters, which corresponds to twice the linear stroke of the lever arm. This dimensioning is essential to ensure the full activation of the piston in both directions of motion.

5.1. Drum Sizing

To enable the 3.76-meter linear displacement of the upper lever arm, a drum is used for winding the steel cable.

$r = 0,4m$

$D = 0,8m$

$C = 2,513m$

The number of drum revolutions required to wind the 7.52 meters of cable per cycle is calculated using the following formula:

N = number of revolutions
L=7.52m

$N = \frac{7,52}{2,513} = 2,99$ Revolutionsor or $f = 3Hz$

5.2. Motion Transmission and Gearing

To ensure the drum rotates three times per second, a mechanical transmission system was configured starting from a 4-pole, three-phase induction motor with a nominal rotational speed of 1800 rpm. The transmission system connects this motor to an intermediate sector-type gear (half gear) with a diameter of 0.9 meters, rotating at 30 rpm.

From this gear, motion is transmitted to a smaller gear coupled to the drum, which operates at 180 rpm as required to ensure the 3 rotations per second.

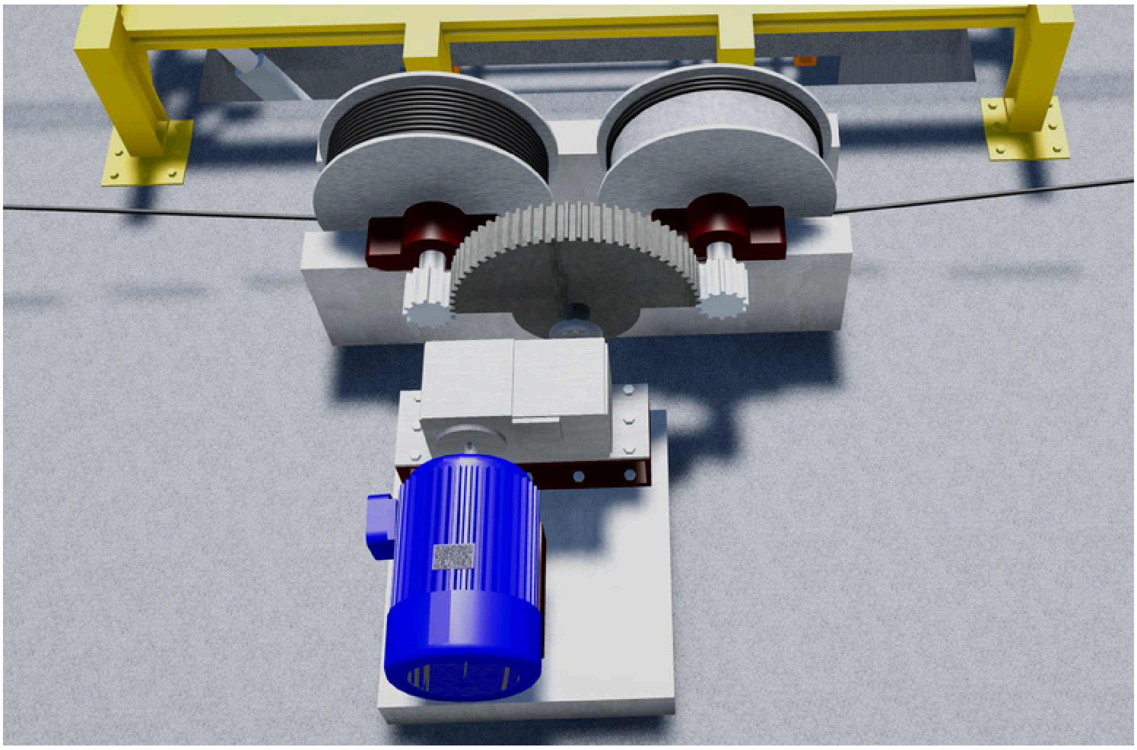
Sector-type Gear

$$N_{mot} = 30rpm$$
$$D_{mot} = 0,9m$$

Driven Gear

$$N_{mov} = 180rpm$$

$$\frac{N_{mot}}{N_{mov}} = \frac{D_{mov}}{D_{mot}} \qquad \frac{30}{180} = \frac{D_{mov}}{0.9} \qquad D_{mov} = 0,15m$$

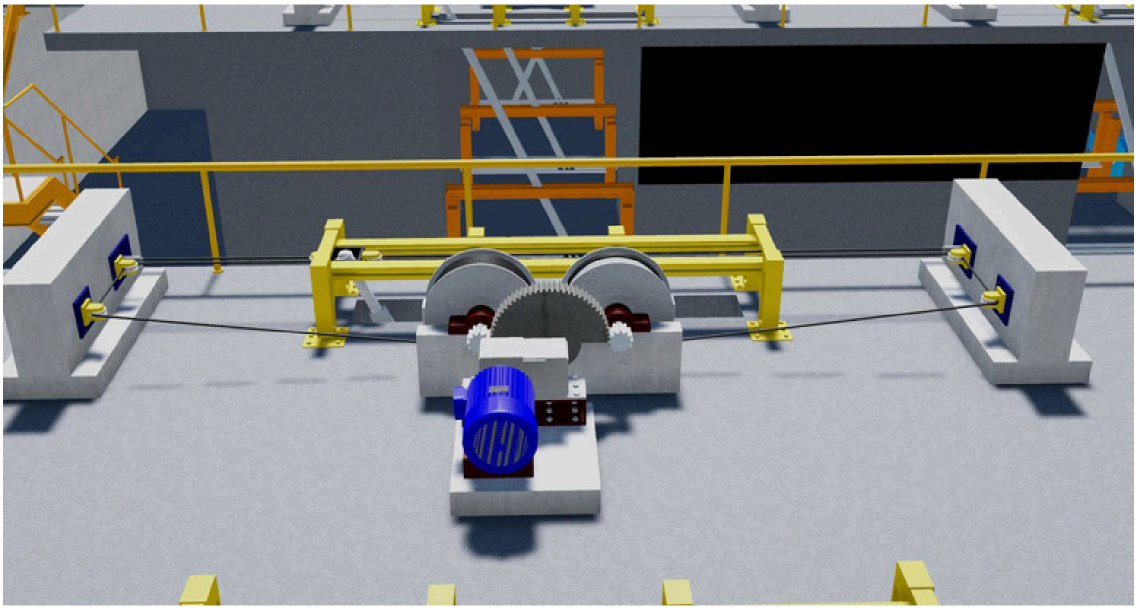


5.3. Torque Calculation on the Drum

$$F_f = 305.678N$$
$$r = 0,4m$$
$$f = 3Hz$$
$$\pi = 3,14$$

$$T = F \times r$$
$$T = 305.678 \times 0,4$$
$$T = 122.271Nm$$

$$\omega = 2\pi \times f$$
$$\omega = 2 \times 3,14 \times 3$$
$$\omega = 18,84rad/s$$



5.4. Power Requirement per Pump Unit

The power required for the operation of each individual DLDAPP unit is calculated based on the force applied to the piston, the piston stroke length, and the number of cycles per second (frequency of operation). Mechanical efficiency, frictional losses, and the system's load distribution are also taken into account in this calculation.

$$T = 122.271 Nm$$

$$\omega = 18,84 rad/s$$

$$\eta = 0,9$$

$$P = T \times \omega$$

$$P = 122.271 \times 18,84$$

$$P = 2.303.593 W$$

$$P_{f=} \frac{P}{\eta}$$

$$P_f = \frac{2.303.593}{0,9}$$

$$P_f = 2.559.584 W$$

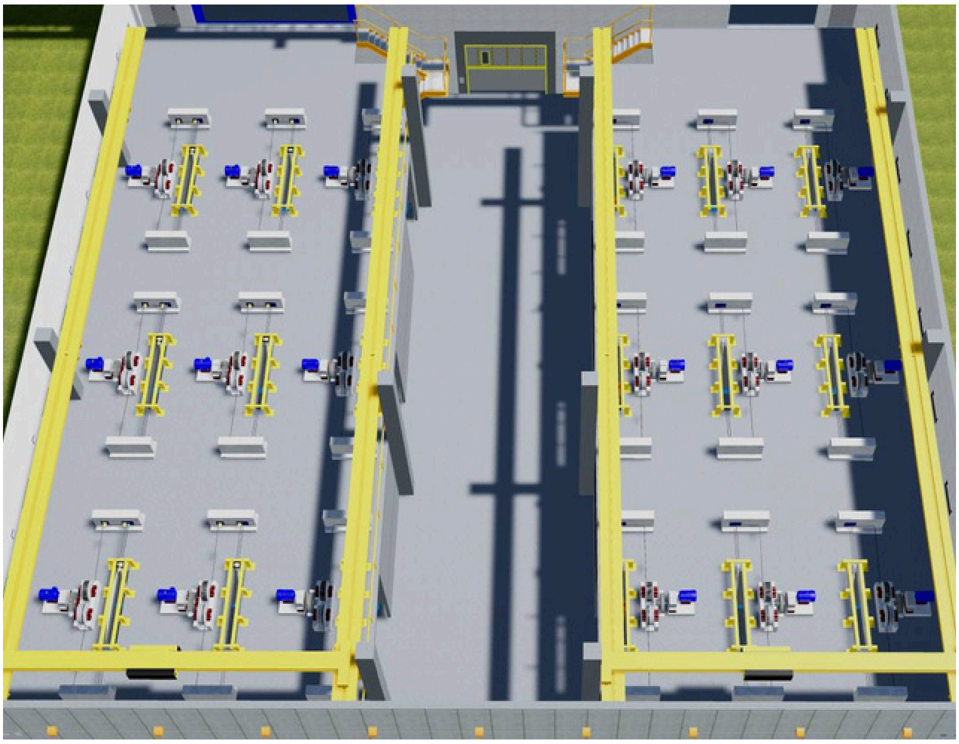
Since the system consists of 18 pumping units operating simultaneously, the total power required is:

$$P_t = 18 \times P_f$$

$$P_t = 18 \times 2.559.548$$

$$P_t = 46.071.868 W$$

$$P_t = 46,1 MW$$



6. Energy Balance of the PMTHPP System

The PMTHPP system, operating with the integrated set of Francis and Pelton turbines and the closed-loop DLDAPP pumping circuit, was designed to ensure energy self-sufficiency, with a significant surplus of net power output.

The total power generated by the system is the sum of both turbines:

$$P_{Pelton} = 68,8MW$$
$$P_{Francis} = 21,8MW$$

$$P_T = 68,8 + 21,8$$
$$P_T = 90,6MW$$

The total power consumed by the 18 DLDAPP system pump units operating continuously is:

$$P_C = 41,6MW$$

Net Available Power:

$$P_N = P_T - P_C$$
$$P_N = 90,6 - 41,6$$
$$P_N = 44,5MW$$

The system operates with a 44.5 MW surplus, demonstrating its energetic efficiency and operational viability in a closed-loop configuration.

The power generated by the turbines not only fully compensates the consumption by the hydraulic pumps, but also delivers a substantial net output available for commercialization or external use — ensuring the system remains self-sustaining without reliance on external energy sources.

Conclusion – DLDAPP System and Hydraulic Pumps

This report has provided a detailed explanation of the operation, technical principles, and sizing calculations of the DLDAPP (Duo Leveraged Double Acting Piston Pump) system, which serves as the core component of the hydraulic circuit in the PMTHPP.

Unlike conventional pumping approaches, the DLDAPP utilizes mechanically driven double-acting pistons in combination with a system of levers and movable pulleys. This architecture significantly reduces the force required to operate the pistons, without compromising flow rate or operational stability, resulting in a system that is both mechanically and energetically efficient.

The calculations were based on real physical parameters — including hydrostatic pressure, piston area, volumetric displacement, torque, and power requirements at the drum — demonstrating that even under conditions involving deep operation and high flow, the system remains stable and energy efficient. The analysis also confirmed that, thanks to the applied mechanical leverage mechanisms, the effort required per pump is substantially reduced, allowing operation through appropriately rated electric motors.

The DLDAPP system proves that it is possible to develop a robust and high-efficiency pumping solution without relying on conventional rotodynamic technologies. The concept is particularly suited to closed-loop projects like the PMTHPP, where hydraulic energy control and pressure recovery are critical to the overall feasibility and sustainability of the system.