

Comet-ME Solar Magnetic Plunger Pump (SMPP)

September 2019

Introduction

Comet-ME's Solar Magnetic Plunger Pump (SMPP) is a first-of-its-kind, double-action, submersible borehole piston pump designed for shallow aquifer pumping (with a pumping head in the range of 10-45 m) that can deliver 20-30 cubic meters a day, enough to irrigate up to 1 hectare per day or for daily domestic usage for a small community.



The SMPP offers a game-changing water-pumping solution for off-grid smallholder farmers in the Global South. Developed by Comet-ME over the past five years, the SMPP is in advanced stages of alpha-site testing, showing impressive performance levels.

The SMPP's innovative design takes the ancient and proven piston pump technology and transforms it into a high-flow, robust, simple, and reliable solar pump that outdoes existing solar pumps on the market in efficiency, serviceability, operation in a high-sediment environment, and of lowest cost of ownership. The unique mechanical design (US patent application 2019-023495 A1) of the SMPP allows for dual action pumping that fits into 4" borehole diameter

This document provides an overview of existing pumping technologies and outlines the SMPP's technological innovativeness and competitive edge in the field.

Plunger pumps – an overview

Plunger pumps are positive displacement pumps known to be very robust and immune to solid and sand particles in the pumped fluid. They are used in different applications such as water, oil, and sewage pumping, or high-pressure water pumps for industrial applications.





The basic design of the plunger pump includes a piston that moves inside a cylinder to create a progressive change in the volume, an inlet non-return valve, and an outlet non-return valve. When the piston retracts, fluid enters the cylinder through the inlet valve. When the piston moves forward into the cylinder volume, the pressure increases inside the cylinder and the fluid is forced through the outlet valve. A plunger pump differs from a piston pump in the fact that the seals are stationary and are not part of the piston assembly. In both cases the pump's piston is driven by a mechanical arrangement.



Plunger and piston pumps

Crank-shaft motor driving plunger pumps

The most common mechanical arrangement for driving the plunger is a crank shaft that translates a spinning motor motion into a linear motion. The crank shaft is connected to a rod that drives the piston.



Crank shaft driving a plunger pump





This type of design is common in the old windmills that pump water and in the oil pump-jacks that are used for pumping oil. Such pumps are still operating in many parts of the world and are considered very reliable.





However, this type of mechanism has several disadvantages:

- The mechanical gear translating the circular motion to a linear motion has limited efficiency. Adds extra cost to the system and has limited life time cycle
- All of the gear designs that are used in these pumps must translate the circular motion of the motor or the wind vanes into a linear motion with a speed profile of a sine. This means that the piston cannot maintain a fixed speed along the stroke, resulting in lower flow rate.
- Flow rate is generally low as the rod design makes it impractical to apply a double action pumping mechanism in a small diameter borehole.





Linear tubular motor driving piston or plunger pumps

Using a linear tubular motor instead of a crank-shaft gear is a way of overcoming these disadvantages and maximizing the fundamental advantages of the plunger pump technology. Indeed there have been many attempts in the past to include a linear tubular motor as a driving mechanism for a plunger or a piston pump.

US patent 6015270, dated Jan 18, 2000, is a typical example of such an attempt:



This design includes a static part with coils and a mover with magnets and pole pieces. In most cases the mover is hollow and includes a non-return valve inside, which is the classical piston-pump design. Such a design requires a large mover diameter to allow for high flow capacity and cannot be applied in narrow boreholes, which are the most commonly used for shallow-aquifer pumping across Africa and the Global South.





Dual action piston pump

Turning the simple piston pump design into a double action pump that delivers water in both stroke directions allows us to double the flow rate.



Dual Action pump design with two inlet and two outlet ports.

In this design, there is an inlet port at the top and at the bottom ends of the stroke. Water is discharged from both the top and bottom outlet valves of the pump. The flow paths from each side of the piston then merge and continue towards the top of the pump where it exits into the riser pipe.

The major problem with existing dual-action plunger pump designs is that they are not sufficiently compact to allow the pump to fit into a 4" borehole without sacrificing flow rate. This is one of the main technological challenges we have addressed in the development of the SMPP.

The Solar Magnetic Plunger Pump (SMPP)

The SMPP is a high-end submersible solar magnetic plunger pump developed for off-grid rural communities and smallholder farmers for irrigation and domestic purposes. To meet the needs in the field, the SMPP was designed with the following specifications:

- High-flow, robust, simple and reliable
- Can deliver 20 to 30 cubic meters per day from 15 to 45 m pump head, enough water for small plot irrigation or the daily domestic needs of a small community (pump head can be extended easily to reach 70 m head)





www.comet-me.org

- Modular assembly with few subassemblies. No special tools or accurate alignment are necessary for assembly and disassembly, allowing for easy field servicing of the pump.
- Compatible with different solar array combinations, from 300-900Wp depending on the pump head and water capacity requirements. No batteries required.
- Pump can operate with high level of sand and sediments in the water with high reliability for very long period of time.
- Integrated Maximum Power Point Tracker (MPPT) that optimally harvests available solar power
- High efficiency throughout the full range of pump head
- Ability to operate at low solar power (at lower pump flow rate) to reach higher daily flow capacity.
- Less than one half the cost of comparable products
- Length: 120 cm. Weight: ~12Kg.
- Can fit into a 4" borehole, the most common borehole size for shallow aquifer pumping

Core technology: 3-phase tubular linear BLDC motor

At the heart of the SMPP is a 3-phase tubular linear BLDC motor, directly driving a plunger in a dual action mode. This core technology, designed and built in-house by Comet-ME over the past five years, can be used to power a family of pumps with higher flow rates or higher heads, as well as applications in other fields, expanding product portfolio at limited investment.

The tubular linear BLDC motor driving the plunger makes the SMPP very efficient and reliable, with only one moving part (the plunger itself) directly pushing the water up to the surface. No mechanical gears or crank shafts are required. Moreover, the relatively slow speed of the plunger reduces the wear that is common for high revolution speed centrifugal or helical pumps, making the pump very reliable even in the presence of sediments or sand in the water.

The SMPP's 3-phase tubular linear BLDC motor is cooled by the stream of water inside the pump and is designed for more than 1 KW of input power. The magnets and the pole pieces are encapsulated inside a thin sealed stainless steel wall tube to allow for minimal magnetic air gap between the plunger and the iron core of the motor. The fact that the pump operates in a plunger mode and there is no need to have a flow of water inside the piston, allows for very simple design and better magnetic properties of the mover. The motor can produce > 400N of thrust force at less than 600W input power and it can be scaled up. Furthermore the motor is designed to have minimal cogging magnetic forces, which increases efficiency during acceleration of the piston.





Dual-action mechanical design

The innovative mechanical design of the SMPP allows for double-action pump flow inside narrow spaces. (All existing double-action positive displacement pumps, allow for high flow rate capacity but are too big to be submersed in a borehole.) Our design fits into 4" borehole (which is the most common borehole size for shallow aquifer pumping) and can be scaled up and down. The design is protected by our submitted patent application, both for the US patent office and worldwide through the PCT.

Following is a schematic of the water flow inside the pump:



When the plunger moves to the right, water fills the pumping chamber through the left inlet check valve as seen by the red arrow. At the same time, pressure is built in the pumping chamber to the right, and water flows out through the outlet check valve on the right-hand side of the pump. The water flows inside the pump cover to the outlet port on the left-hand side of the pump. When the plunger moves to the left, water fills the right side of the pump and is pumped out of the left side of the pump. The flow of water cools the motor.





The SMPP design model

Plunger motion control

The pump motion controller is designed to provide an adequate speed profile of the plunger to maximize the flow rate under all solar conditions. Because a plunger pump can produce a flow in a single stroke (contrary to centrifugal pumps that must reach high revolution speed before they may push water up), the control mechanism allows the SMPP to pump water at a usable rate under low solar radiation conditions. The SMPP can deliver water from 45 m deep with as little as 50W of continuous solar power.

The pump motion controller calculates the water flow by monitoring the progressive volume that the plunger creates during the stroke motion and provides accurate flow rate readings that may be used for different payment methods such as Pay As You Go (PAYG). It also includes:

- Smart dry-well and over-heating protection
- Automatic float switch that stops pump operation when the water tank is full
- Pump starts operating automatically as the sun rises and stops at sunset.





www.comet-me.org

Online monitoring system

The pump will include a dedicated monitoring system that transmits all pump parameters live to the net via mobile communication. Monitoring the pump's performance is especially important in remote rural locations, where remote tracking of the pump's health facilitates scheduling of service routines. The monitoring system will support PAYG infrastructure, provide relevant data from the pump such as flow rate, solar power, soil moisture, temperature, and pump events (dry well, motor overheating, full water tank etc.).

The monitoring system will give the SMPP several advantages:

- Support proactive maintenance and service of the pump
- Allow for financing services for end-users
- Data collected from the various sensors will be valuable for various stakeholders along the value chain (financers, agri-businesses, policymakers)

Pump performance

We have several working models of the SMPP that have been tested on a test rig at our facility for more than two years, in a very high-sediment environment (underground rain harvesting cistern with very high concentrations of sand and mud).

The data in the graphs below was acquired through the SMPP's integrated monitoring system in various solar array configurations and shows the pump's outstanding performance:







By its very design (like all plunger type pumps) the SMPP's efficiency curve is much shallower with respect to the head in comparison with helical or centrifugal pumps, thus providing better flow throughout its performance envelope. The next graph shows the current pump efficiency in comparison to Grundfos SQF 5A-7E centrifugal pump (when the SMPP hits the markets it will have better efficiencies than shown here) at various operation points. At all the tested power inputs, the peak efficiency is around 50%.



Moreover the SMPP can start pumping under very low solar conditions as shown in the following daily monitoring chart, taken during a cloudy day in the winter of 2019:



info@comet-me.org





In the graph below we see how above 170W the flow rate depends almost linearly on the input power, due to constant high efficiency of the pump at large operating range:



Contact

Noam Dotan, Comet-ME Technical Manager <u>noam@comet-me.org</u> Elad Orian, Comet-ME General Manager <u>elad@comet-me.org</u>

