International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 02, Issue – 05, May – 2017, PP – 113-119

Solar Powered Rope Pump

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Abstract: Rope-pumps are used for lifting water from a well using a hand operated or pedal operated mechanism. A rope pump is a kind of pump where a loose hanging rope is lowered down into a well and drawn up through a long pipe with the bottom immersed in water. On the rope, round disks or knots matching the diameter of the pipe are attached which pull the water to the surface. The primary objective of this work was to develop a system which incorporates a suitable cost effective renewable power source for the operation of a rope-pump for a given well depth, volume of water required and environmental conditions in the proposed installation location. Rope pumps may address the present need of a better irrigation system that utilizes non conventional sources of energy

Keywords: Agriculture, Irrigation, Rope Pump, Solar Panel.,

1. Introduction

Food is essential for life. We depend on agricultural outputs for our food requirements. The importance of agriculture also includes, creating employment opportunities, providing raw materials etc. Agriculture plays a significant role in the overall economic development of a nation. Agriculture in India is more a way of life than a mode of business. Increase in agricultural production and productivity depends on the availability of water to a large extent. A reliable and safe water supply lays the foundation for improvement of living conditions and for development. In rural areas, water is a key factor for subsistence and development of commercial activities including small scale farming and livestock. Hence, the importance of an adequate irrigation is very much needed in India. Lifting of water for drinking or irrigation purposes thus has a great importance.

The main driving factor for selecting the appropriate irrigation technology are regional feasibility, water demand, system efficiencies, initial and long term costs. Considering the above factors, many methods have been developed to pump water. For better irrigation, there is always a need of efficient water pumping system. Normally electricity or fuels will be used as driving source for this water pumping system. But there are various drawbacks associated with the present water pumping systems. Many of the potential users are too far from an electrical grid to economically trap power source. And engine-driven pumping system tends to be expensive as well as unreliable due to the high cost of fuel and inefficient maintenance and repair capabilities. This brings in a need for a better water pumping system and solar water pumping system could be one such solution.

Solar energy might be one of the easiest ways for farmers to produce energy for pumping water. Solar powered water pumping systems can provide irrigation water without the need of any kind of fuel or extensive maintenance. The solar energy harnessing system offers various advantages when compared to conventional systems as it emits no pollutants into the atmosphere, also it is abundant in nature which is available free of cost. As a long term option solar energy systems can be considered as an alternate to conventional systems. Solar photovoltaic systems are powered by an array of solar panels. Solar pumps are designed to operate on DC power produced by solar panels. A solar powered water lifting system is also proven to be cost effective and reliable with respect to all other conventional energy systems. Among all conventional water pumping systems, a solar powered rope pump has been recognized as one of the suitable solutions in rural locations where there are high levels of solar radiations available.

Rope pump is a very simple pump which can usually be made from local materials such as wood, rope and vehicle tyres. Traditionally it has been used vertically on open wells but inclined versions have been used to draw water from ponds or rivers. More recently, designs which allow its use on bore holes have been developed. The basic parts of a rope pump are a pulley wheel above the well, a riser pipe from under the water level to an outlet just under the wheel, and a rope with rubber or plastic washers. The rope comes up through the pipe, over the wheel back down into the well and into the bottom of the pipe, completing the loop. When the wheel is turned, the washers move upwards and lift water into the pipe towards the outflow.This system will be a light weight, and easy to operate as compared to other alternative methods, the rope pump is economical and easy to build. It is made of metal pipes and plastic bushes. It can be built and maintained by people with little technical training. The rope runs up through a tube. The low extremity of the tube reaches the ground water in the well.

The top extremity is above ground. Plastic bushes are attached to the rope at every meter and fits perfectly inside the tube that will go down into the bore well pipe and hold the trapped body systematically.

2. Literature survey

Jennifer Kadlowec [1], pointed out that the rope-pump, also known as the rope-and-washer pump, has been around for at least two thousand years when it was first applied in China. The pump consists of a continuous rope, with pistons attached to it, which passes over a flywheel, down into the well or borehole, and up through a vertical pipe, the bottom of which is submerged in water. In the 70s, rope pumps were rediscovered using PVC pipes and metal pulleys, and introduced in Africa as the rope and washer pump, a low lift pump for irrigation and family wells. It did not take off, probably because of its low lift capacity. This changed in 1986 when a Dutch organization improved the design and disseminated it in Central America.

Lambert [2], stated that the rope-pump was simultaneously introduced to Africa and Latin America during the 1980s as a result of various water development projects. Notable projects took place in Zimbabwe, where it was developed primarily for micro-scale irrigation and Peru and Bolivia, where the pump was identified as meeting the Village Level Operation and Maintenance (VLOM) criteria. The VLOM criteria are that the pump is able to be easily maintained by a village, manufactured in country, robust and reliable under field conditions, and cost effective. The Peruvian version of the rope pump was easy to operate, maintain and manufacture locally, and provided a particularly high discharge rate, but was able to operate only at low heads up to 6m. A major evolution in rope pump technology took place in Nicaragua in 1990 when a small workshop created a rubber washer made by injecting moulds. This innovation allowed a dramatic increase in the operating head of the pump of up to 40 meters for the standard design.

Harvey and Drouin [3], had mentioned that, Subsequent adaptation of the design, including the use of smaller diameter pipes and a double crank led to an increased reach depth of 60 to 80 meters. This evolution transformed the pump from one used primarily to meet low-lift irrigation needs into a hand pump suitable for raising even relatively deep groundwater for domestic use. Despite the development of washers that need to be made by equipped workshops, the technology remained cheap, around US$150 for a complete pump. As a result, the pump spread quickly in Nicaragua which adopted it as a standardized pump in 1996. Consequently, more than 30,000 rope-pumps are currently in use in Nicaragua and provide water to approximately 25% of the total population. The rope-pump is a public domain design and consequently there are no restrictions regarding who is able to manufacture it or where it can be manufactured. A major attempt to introduce the rope pump to Ghana was made in 1999. The World Bank funded exchange visits between Ghana's Community Water and Sanitation Authority. The Rope pump was introduced in 2004 in Ethiopia by the Japan International Cooperation Agency (JICA). The model first introduced was a frame model as used in Tanzania and Zambia, which in turn was based on the models from Nicaragua.

Gorter et al. [4], pointed out that the rope pumps are a low-cost technology, suitable for both shallow and deep wells. Because of their high pump capacity they can potentially serve productive uses such as car washing, animal watering and irrigation of small plots, although their capacity should not be overestimated. The installation of a simple rope-pump on family wells improves the water quality and availability at a favourable cost/benefit ratio. Rope-pumps are now widely promoted as a low cost, easily maintained means to improve water availability in developing countries. The rope-pump is to be used to lift 1 to 10m^3 of water per day from a well of 10m deep. This is a volume that is more than can be reasonably lifted by hand and a suitable amount for a typical small rural institution such as a school or hospital in Malawi. The environmental data used in the simulations were taken from a number of online sources.

By considering the inefficiencies of above rope pump systems such as the use of human power or animals in the early era, there is a need to overcome the human efforts by implementing a system that utilizes solar energy to run the system.

3. Objectives and methodology

The objectives and methodology of the rope pump is listed below.

3.1 Objectives

- To design and fabricate a water lifting system to lift the water from the well that utilizes solar energy to make it functional.
- To determine the feasibility of using photovoltaic (PV) modules to power water pump for small scale irrigation systems.

- To study and understand the basics of solar-PV based pumps and to understand the issues involved in these applications.

3.2 Principle of rope pump

A rope pump is a closed loop of a rope with attached pistons, equally spaced, is pulled through a pipe which is immersed in water at its lower end. The pistons entering the rising main pipe are transporting the water upwards until it reaches the top parts with the spout through which it can escape out. A guide near the bottom of the well makes sure that the rope with the pistons is entering the rising main smoothly and pistons are prevented from being hooked at the edge of the lower end of the riser pipe. A conventional rope pump can be either of hand operated or pedal operated type. Hand operated rope pumps are mostly used for drawing water from dug wells with depths between 0 to 20 m.

3.3 Methodology

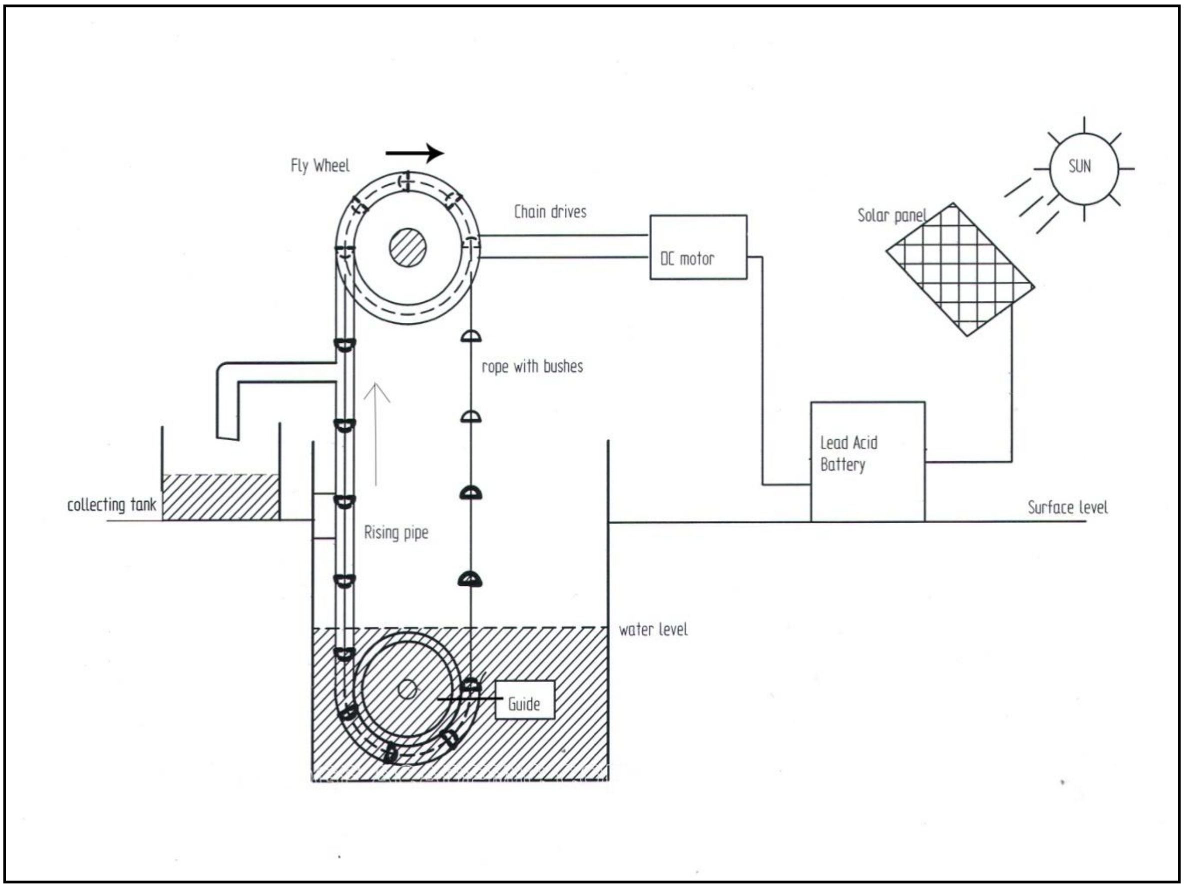

Fig. 2 block diagram of solar powered rope pump

Fig. 2 shows the diagrammatic representation of lifting of water from well by rope pump mechanism. The system consists of a solar panel, lead acid battery, DC motor, Rope and Bush arrangement, Worm and worm wheel (Spur gear), guide and water tank.

Solar panel absorbs the solar energy and converts it into electricity. The power thus developed is stored in the battery. The motor becomes functional once charge is drawn from battery. Energy is then transferred to a flywheel with the help of worm and worm wheel mechanism, meanwhile flywheel releases stored energy to the rope pump by applying a torque. The rope pump consisting of a loop of rope thus passes up inside a rising pipe.

The rope is driven by a pulley wheel (flywheel) at ground level which pulls the rope down into the water and then pulls up through the rising pipe with the help of a suitable guide. Along the rope at equal space, rubber bushes or discs are mounted between which water will be lifted and can be stored in a collecting tank.

However, this type of pump can also be installed on boreholes providing an attachment for leading the rope into the borehole and a smaller guide that fits into the borehole casing is available. The simplicity of this low cost pump makes it possible that the users can understand how it works and are therefore able to maintain and repair it.

4. System components of a rope pump

A solar powered water lifting system basically consists of ten main components:

- Solar panel
- Battery
- DC motor
- Frame
- Pulley
- Rope
- Piston
- Rising pipe
- Discharge pipe
- Guide

4.1 Solar panel

Solar panel can be used for absorbing the sun rays as a source of energy for generating electricity. Solar or photovoltaic (PV) cell are made of semi conducting materials that can convert sun light directly into electricity. The process of making electricity begins when the silicon atoms absorb some light. The light's energy knocks some electrons out of the atoms. The electrons flow between the two layers. The flow of electrons makes an electric current. The current can leave the cell through the metal contacts and be used. When light hits a solar cell, much of its energy is wasted. Some light bounces off or passes through the cell. Some is turned into heat. Only light with the right wave lengths or colors, is absorbed and then turned into electricity. Specifications of solar panel used in the rope pump model are as follows, Maximum Power (Pmax) =10W, Maximum Voltage (Vmp) =18.10 V**.**

4.2 Battery

Battery is used for storing the energy produced from the solar power. The battery used is of a lead acid type and has a capacity of 12 volt 7.5 watt ampere. Lead acid cell is widely used for commercial purposes. A lead acid cell contains two plates immersed in a dilute sulphuric acid (H_2SO_4) of specific gravity about 1.28. The positive plate (anode) is of lead-peroxide (PbO_2) and the negative plate (cathode) is lead (Pb). When the cell supplies current to a load (discharging), the chemical action that takes place forms lead sulphate ($PbSO_4$) on both the plates with water being formed in the electrolyte. To charge the cell, direct current is passed through the cell in a reversed direction. This reverses the chemical process and again forms a lead peroxide (PbO_2) positive plate and a pure lead (Pb) negative plate. At the same time H_2SO_4 is formed, restoring the electrolyte to the original condition. These are the chemical changes that occur during discharging and recharging of a lead acid cell.

4.3 DC motor

A direct current (DC) motor is an electric machine that converts electrical energy into a mechanical energy. In normal motoring mode, most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force within the motor. In certain applications, such as in the transportation industry with traction motors, electric motors can operate in both motoring and generating or braking modes to also produce electrical energy from mechanical energy. In applications DC Series motors are used in fans, blowers and pumps, machine tools, household appliances, power tools, and disk drives. DC motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as from the power grid, inverters or generators. Small motors may be found in electric watches. General-purpose motors with highly standardized dimensions and characteristics provide convenient mechanical power for industrial use. DC motor used for the design is of 350W power.

The power transmission from motor to the flywheel takes place with the help of worm and worm wheel drive mechanism mounted within the motor.

A worm gear (or worm drive) is a specific gear composition in which a screw (worm) meshes with a gear/wheel similar to a spur gear. The set-up allows the user to determine rotational speed and also allows for higher torque to be transmitted. This mechanism can be found in devices both at home and in heavy machinery.

Unlike with ordinary gear trains, the direction of transmission is not reversible when using large reduction ratios, due to the greater friction involved between the worm and worm-wheel, when usually a single start (one spiral) worm is used. This can be an advantage when it is desired to eliminate any possibility of the output driving the input. If a multi start worm (multiple spirals) is used then the ratio reduces accordingly and the braking effect of a worm and worm-gear may need to be discounted, as the gear may be able to drive the worm. Advantages of a worm wheel includes self locking, good mesh effectiveness and can be used for reducing speed and increasing torque.

4.4 Frame

The frame or a pump structure supports the pump above the well. It is usually made of metal (welded steel rods or pipes). But it needs to be protected against corrosion such as by painting, if the water is corrosive. It can also be made from wooden planks, which requires more frequent maintenance and replacements.

4.5 Pulley

A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a taut cable, supporting shell is referred to as a "block". The drive element of a pulley system can be a rope, cable, belt, or chain that runs over the pulley inside the groove or grooves. Pulleys are assembled to form a block and tackle in order to provide mechanical advantage to apply large forces. Pulleys are also assembled as part of belt and chain drives in order to transmit power from one rotating shaft to another.

4.6 Rope

Ropes can be used for dragging and lifting, but are too flexible to provide compressive strength. As a result, they cannot be used for pushing or similar compressive applications. Rope is thicker and stronger than similarly constructed cord, line, string, and twine. Fiber rope is made from fiber, whereas wire rope is made from wire. The characteristics of a rope are strong, durable, water resistant and will not stretch during its use. It is also not too smooth to avoid sliding on the wheel.

4.7 Pistons

Pistons can be made of rubber, for instance out of the side part of an old car tire. Also leather or wood has been tried with less success. Pistons made of high-density polyethylene are efficient and easy to make standard sizes. These ropes don't slip and don't stretch too much. The alternative is a rope made of nylon, but these ropes tend to slip and stretch. The rope diameter should be 6mm. Pistons can be fixed to the rope by knots or melting a piece of rope on both sides of the piston. The distance between two pistons is 1m. More pistons on the rope will create slipping between the pistons and the wheel. Piston diameter varies with the size of the rising main. To secure the piston a knot can be placed before and after each piston.

4.8 Rising pipe

Rising pipe used here is a vertical pipe that rises from the ground to supply water to the discharge pipe. Since pressure in the rising main is low, the tubes used here is of low pressure type. At the top, (the discharge and outlet) the tube diameter should be more than the diameter of the rising main tube. The discharge tube should be fixed to the pump structure or another fixed point. The diameter of the rising pipe controls the amount of water that can be lifted, with larger diameters meaning more water that is heavier to lift. Therefore for very small wells smaller diameter pipes need to be used to prevent the lifting from being too strenuous.

4.9 Discharge pipe

Discharge pipe is the pipe through which fluid is passed out to the outlet tank. With respect to the rising pipe, the discharge pipe is slightly inclined in order to increase the flow of fluid. The water is lifted by the rope and pistons which fit with a clearance of 1mm in the rising main. The rising main ends in a The inclination is made with an angle less than 90° in order to ensure a maximum rate of discharge.

4.10 Guide

The guide is another key piece of the pump. Its function is to guide the rope and particularly the pistons into the raising main and keep them from rubbing against its entrance. It is essential with the guide to find the right combination of materials that will not wear out underneath the water rope with glaze or glass.

5. Assembled model

The fabricated model is designed with a solar panel, DC motor, Pulley, Rope-bush arrangement along with a frame to which all the above components are attached. Initially a frame is made by using cast iron. The length of the frame is selected as 0.41m and the width of the frame is selected as 0.46m. A height of 0.95m is maintained for the frame. A rising pipe made from mild steel of length 0.44m is welded with the frame. Fig. 3 shows the front view of the assembled model and Fig. 4 shows the working model of the proposed system.

Fig. 3 front view of the assembled model

Fig. 4 working model of rope pump

A pulley is mounted just above the rising main which is connected to a DC motor with a suitable worm gear arrangement. A 350W power motor is used for this operation. The worm gear arrangement transmits the power from motor to the pulley. A rope with equally spaced bushes makes a closed loop and is allowed to rotate over a top and bottom pulleys. The bottom pulley act as a guide that helps the smooth entry of rope into the rising main inlet. The spacing between two bushes is set to be 0.17m with the help of suitable knots.

Solar panel of attached on top of the frame consists of a number of silicon cells. The capacity of solar panel used here is 12V 10W. When light falls on this panel it generates electricity that charges a 12V 4.7 AHC battery. The energy thus stored is used for powering the DC motor that initiates the working of the model.

6. Advantages, Disadvantages and Applications

The advantages, disadvantages, applications and future scope of this proposed model are:

6.1 Advantages

The advantages are as follows:

- Cost effective
- Reliable
- Free fuel
- Low maintenance
- Local generation of power
- Easy transportation
- Energy Conservation
- Water conservation
- Environmental friendly
- Smooth and continuous flow of water

6.2 Disadvantages

The disadvantages are given below:

- The rope becomes worn because it is exposed to the sun or because it is used heavily
- The installation of the rope pump was poorly done and its performance is suboptimal
- The pulley wheel malfunctions
- Users need to exercise care when using the pump as it is susceptible to contamination

6.3 Applications

The different applications are mentioned below:

- Drinking water supply
- Village water supply
- Livestock watering
- Irrigation
- Process industry

7. Conclusion

The operating principle of a rope pump enables a cost effective, efficient and less energy consuming water pumping system that uses renewable sources of energy like solar energy for achieving the irrigational requirements. Since the weight of the water column is equally distributed over the pistons, the static pressures in the pump pipe are very small and the radial loads are minimal. The main characteristics of a rope pump is that the output of the pump is determined by the rope speed , the cross-sectional area of the pump pipe and the critical pump speed at which it starts pumping. The rope pump is also little sensitive to silt and corrosion. Unlike its main competitor the piston pump, the rope pump produces a smooth, continuous flow without any dynamic loading of the rope and the pump pipe. Based on these above characteristics, one can conclude that the rope pump is a high-quality pumping device, also in comparison with the piston pump and the centrifugal pump.

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