ijergs
Open Access
International Journal of Engineering Research and Generic Science (IJERGS)
Available Online at www.ijergs.in
ISSN: 2455 - 1597
Volume -2, Issue-3,May–June-2016, Page No. 04-12

Design and Fabrication of Manual and Solar Powered Water Purification System: A Bicycle Purification Technology

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Abstract
Bicycles hold a dominant role for the transportation as well as hauling purpose used by majority of the people across the globe especially in remote areas. Most of the rural areas and villages are un-electrified and utilizing impure water for drinking, washing and other home-made applications. Much of the power that is provided to people today is done by un-sustainable ways such as from large tanks, lakes and ground water that contain total dissolved solids (TDS) level much greater than the permissible limit. It is essential to figure out innovative technologies in order to provide pure water for the people by some renewable energy resources as population continues to grow and power shortages continue to occur in the upcoming era. So, novelty should be done to transition into a post cheap-petroleum era. In order to attain an appropriate TDS level of drinking water, a manual and solar powered bicycle set-up is designed and fabricated with water purification system that is able to provide less TDS level of water to the people which further improves the health and reduces the chances of health ailments. The purpose of this project is to design, build, and unveil a new technology that will produce power using the mechanical energy generated by a person pedaling a standard bicycle as well as solar energy from the sun through solar panel. Furthermore, the power will be utilized to run water purification system that filters the impure water. A direct current (DC) battery is charged by two power sources and convert DC power to usable alternating current (AC) by inverter. The generated power is utilized to pressurize the impure water and results in the purification of water which is done by different filters and reverse osmosis (RO) membrane. It has been observed that by incorporating the water purification system, the TDS level of impure water is reduced from 500ppm to 25ppm only.
Keywords: Purification system, Solar energy, Pedal Operated Bicycle, Filter membrane, Total Dissolved Solids.

1. Introduction

In today's era, the biggest failure of any organization and government is to provide safe drinking water and energy to the people. Water is essential to sustain life whereas energy cause things to happen around us. No doubt, earth a blue planet has a plenty of water, but that water cannot be utilized for drinking purpose. This saline water from sea, river, lake or ground water has uncertain impurities measured according to the total dissolved solids (TDS) level that are too toxic to the human health. The undissolved particles are always available in the water and to remove these particles, a certain treatment process should be installed. A variety of processes are already utilized in order to acquire clean drinking water. In India, villages do not have any strong infrastructure because of poor economic circumstances. Therefore, a need for cleaning of impure water is significant as remote villages are also lacking of electrical power, tele-communication and sanitation facilities. Some villages use lake water for drinking, cleaning clothes and household applications such as cooking. In order to attain fresh water, a certain mechanism or technology must be installed by communities that reduce the impurities level to the human drinking water comfortable range. Moreover, health factor of people improves on providing pure water. During summer days, a lot of power electricity cuts are imposed on the public sector people. As a result, the purification technologies such as reverse osmosis (RO) run on electric power stops working. So, solar energy is the renewable energy plays a crucial role and can be utilized along with solar chargers. The solar chargers are easy to carry, do not have any complex design, and energy can be utilized easily in remote areas.

India is the second crawling country across the globe. With on growing population, the needs of people and their usage is also growing. In such cases, demand of electricity is very high. Many of the remote villages are still without electricity. People in villages mainly use bicycle as their means of transport for small distances. Energy produced by pedaling can be used for driving small appliances. The charging of batteries can be done easily by connecting battery to the dynamo which is further attached to the pedal of bicycle. In additional, solar panel can also be used to charge the battery. In such a case, both processes of charging can charge battery very soon. Individuals are able to produce around 150 watts of power during bicycle riding. If this power can be utilized for water purification purpose, then a new era can arise in which there will be no shortage of pure water in remote areas.

2. Literature Review

An expatiate literature survey is done on the purification technology that works on the power of renewable energy resources and manual human effort. Some of the highlights of recent studies are as follows:

Suhalka et al. [1] conducted an experiment on generation of electric power using bicycle pedal. The main objective of the system was to harness human power to useful work. In this, the mechanical energy was changed to electrical energy in the form of alternating current by the use of alternator, which used a rotating magnetic field with a stationary armature. Upon started rotating, it induced voltage at the terminals of the alternator and started powering a load to the devices which was connected directly to the alternator. A MATLAB simulation model of pedal powered generation and various graphs were also elaborated.

Ganorkar et al. [2] performed an investigation on the fabrication of pedal functioned water pump. The main aim of the experiment was to utilize power from the human muscles. For the experiment, a standard bicycle gearing system with a flexible coupling was used in order to create inexpensive human powered flywheel power unit. When the peddler started pedaling, power was stored in the flywheel and axle was connected to the transmission gear system that turned the input gear to a transmission with multiple gear. The power generated by this process was used to lift the water and pushed the water from the pipe into the farm for cultivation. From this mechanism, it was predicted that an average rider travelled at speed of 12mph could produce 0.1hp and for the speed of 18mph, it could produce 0.25hp.

Islam et al. [3] designed a pedal operated mechanism used for lifting the water in irrigation applications. A pedal pump was fabricated and operated at less input power which could be operated by young man for a longer time without being tired. From the analytic statistic, it was found that the effectiveness of pump was 46.53% on considering the head of 1.65 m.

Sneha et al. [4] generated the power from bicycle pedaling effort. Dynamo attached to the cycle pedal made mechanism for converting mechanical energy from pedal to electrical energy. An inverter was utilized in order to convert DC power to AC power. The key components were alternator, inverter, bicycle, pedal and LM317 charger circuit.

Peramanan et al. [5] filtered the water by human effort through Reverse Osmosis (RO) filtration system. The salt water was used and filtered by purifier mechanism run by pedal pump. The first filter as sediment filter and second filter as salt filter were used in purifier system. This Reverse Osmosis (RO) system was worked on the input energy attained from the human effort. As the peddler started pedaling, the pump operated. The pump pressurized the salt water and sent to the first filter. Afterwards, the filtered water crossed the second filter (salt filter) automatically due to gravitational force. The purifier removed the dust and unwanted particles from water and collected pure water in another sump.

Samuel et al. [6] designed a centrifugal pump run by human effort. The forward and backward movement of tube was utilized to generate the pressure and system consisted of a peristaltic pump, carbon filter and flexible tube. As the operator started pedaling, it rotated the rotor and compressed the hose. The vacuum was created through which water was drawn into the pump and discharged to the system. On visualizing the design parameters, it was showed that one rotational cycle discharged approximately 1.1 litres of water.

Garg et al. [7] analyzed the pedal operated pump that was constructed by raw material and household stuff. A pump was fabricated and it was concluded that capacity to discharge the water was around 2-3 gallons per minute from wells. Furthermore, pump was also able to lift the water from the boreholes up to 23 feet depth. This water was provided for irrigation applications. Some amount of water was also utilized for drinking purpose in remote and rural areas.

Girish et al. [8] conducted an experiment on water pumping centrifugal pump and battery charging system. The aim was to make a theoretical model of battery incorporated water pumping system and charged through human effort. The system consisted of bicycle whose rear wheel was attached to the dynamo located near the v-belt. When the operator began pedaling a bicycle, a centrifugal pump was triggered and water was pumped from ground to the tank. Moreover, this action operated the attached dynamo and converted the mechanical to electrical energy which was stored in the battery.

Phuse et al. [9] performed an experiment on water filtration mechanism for rural areas with the help of photovoltaic renewable energy. The set-up was consisted of a solar panel, reverse osmosis (RO) along with ultraviolet (UV) lamp sterilizer system. Solar panel was used to charge the battery and a booster pump needed the energy to run the system. As the pump sucked the water, it started flowing through the pipe to the carbon filter that led to the removal of chlorine sediments and volatile organic compounds. The pump pressurized the water to 12.5 bar and pressurized water passed through the RO membrane where water soluble were eliminated.

Sreejith et al. [10] studied an experimental investigation of pedal operated centrifugal pump. The centrifugal pump was run on different impeller speeds using human effort and results were taken out according to the considerable amount of discharge and head. Experimental results showed that discharge of about $0.0025m^3$/sec could be obtained at around 140

rpm using human effort. The power of pump was easily utilized for pure water supply such as drinking purpose as well as household or garden applications.

Megalingam et al. [11] conducted an experiment on power generation by pedaling the bicycle. The objective was to charge small powered lighting devices by using alternator. By operating pedaling, the attached alternator generated electricity from mechanical energy and stored in the battery which was used during night times. From the study, it was concluded that the alternator could generate 100 to 300 Watt of power during its full operational conditions.

Sermaraj [12] developed a reciprocating pump that was driven by pedaling the cycle using human effort. The system included reciprocating pump and pedaling device. When an operator started pedaling by foot instead of arm then mechanism lifted the water from a depth of 7m. From the analysis, it concluded that an operator while pedaling could produce more power than by hands. Also, it was inferred that pedaling about 10 minutes, a person could generate a power at the rate of 0.25 horse power (hp).

Jawahar et al. [13] conducted an experiment on pedal operated centrifugal pump for low head applications. The objective of the system was to design pedal operated pump for small irrigation purpose like gardening. The system consisted of pump and a pedaling device. The pump worked on the principle of compression and sudden release of a tube by creating negative pressure in the tube. During pedaling, it extracted the water from the ground and pressurized the sucked water and then discharged the water.

Kamalchandran et al. [14] conducted an experiment on voltage fluctuation system and used a direct current capacitor current limitation technology. The project proposed a direct current capacitor module for a grid-side converter (GSC) and the main focus was to remove the negative affect of grid voltage on the capacitors. A resonant controller was recommended in the system.

Bhutia et al. [15] conducted an experiment to design the three phase DC-AC voltage source inverter. The aim was to convert the DC voltage to AC voltage. The equipment could be used in different applications such as using high power through the low voltage DC source by step up transformer.

Hossain [16] conducted an experiment on solar panel based mobile charge and small Led lamp. The research involved designing a mobile phone charging system and a LED lamp triggered by solar panel. The task was to charge multiple mobile phone batteries simultaneously from DC-DC. A solar panel was used with the voltage regulator, which extracted heat from the sunlight and gave constant voltage to the mobile regulator. Generally, mobile regulator needed 5-10 volt which was sufficient for the chargers to charge the mobiles.

Islam [17] made an investigation on the thin film solar charge controller. The aim of this work was to study design and implementation a thin film solar charge controller for commercialization the thin film solar system. Solar panels were used to convert sunlight energy into electric energy by an electro-chemical process called photovoltaic process. Battery lifetime reduced due to overcharging and deep discharging. A charge controller played an important role to prevent the battery from overcharging. It was indicated that the voltage level from 14 to 14.5 volts were enough to fully charge the battery and discharged level moved down to 11.5±0.2 volts.

Drake et al. [18] conducted an experiment on human powered reverse osmosis for producing potable water. A device was designed to test the practicality through a numerical analysis. A Reverse Osmosis (RO) filtration system was operated by human effort obtained from the bicycle pedaling power. It was an incredibly economical and effective meant for providing potable water for developing countries.

Roy et al. [19] performed a bicycle experiment on battery charging system. The system used a bicycle, alternator and DC-DC converter. As the action of the bicycle began, the flywheel attached to the alternator generated the power and that power was stored in the battery. To increase the lifetime and performance of the battery, a DC-DC converter was placed between the alternator and the battery. This converter acted as a regulator and ensured the charging capacity of battery.

Lee [20] had designed the water pump that could be utilized for drew water in order to irrigate farmlands and other household applications. The design was fabricated by considering the cost statistics and time deadlines.

3. Experimental Set-up

A. Components and Installation

An experimental set-up of multistage purification system was installed on the bicycle and consumed the input energy from the solar panel and human effort that charged the battery. A number of components were incorporated that were classified into mechanical, electrical and other components.

B. Mechanical components

i. **Alternator**: It is the device by which mechanical energy is converted into electrical energy as shown in Figure 1. It is D.C. generator for generating D.C. voltage at output. The voltage can easily be produced by rotating the coil under certain magnetic field and the level of voltage depends upon the strength of magnetic field. The alternator specifications are shown in Table 1.

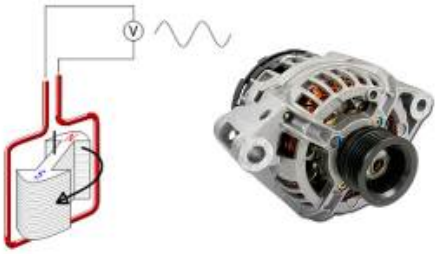

Figure 1: Alternator

Table 1: Specifications of Alternator

Performance Output	5000 rpm
5SI	50Amp- 12V
7SI	70Amp- 12V
Rotation	Clockwise
Polarity	Negative Ground
Stator Diameter	
5SI	105mm
7SI	115mm
Length	
5SI	158.2mm/6.23 in
7SI	6.89mm/6.89 in
Weight	
5SI	3.3 kg
7SI	4.0kg

ii. **Solar panel:** The power can also be attained by using solar panels that takes the sunlight and converts into voltage which can be further used for charging the battery as shown in Figure 2. Different types of cells are used in solar panels but wafer-based crystalline silicon cells or cadmium telluride or silicon dominant the cell categories. These cells can generate near about 75 W, 21.6 V and 4.8 ampere of current.

Figure 2: Solar panel

iii. **Bicycle**: It is used to rotate the rear wheel of the bicycle, which act as flywheel with different gear ratio.

iv. **Diaphragm pump**: A Teflon or rubber type diaphragm is used for pressurize the water and acts as a positive displacement water pump. It is also known as a membrane pump as shown in Figure 3. The membrane pump works on the 24 V, 0.65 A and generates 100 psi pressure for the suitable working of the filter mechanism.

Figure 3: Membrane pump

C. Electrical components

i. **Inverter (300W)**: The function of electronic inverter is to convert D.C. to A.C. 12 volt D.C. supply converts into 230 volt A.C. with the help of electronic inverter unit. The function of inverter is switching the 12 volt D.C. and act as a step-up transformer.

ii. **Battery (12V)**: It is the source of D.C. voltage as shown in Figure 4.

Figure 4: Battery

D. Other components

i. **Sediments filter**: The filter is designed to filter impurities and sediments and shown in Figure 5. A natural media like cover restricts the passage of dirt and sand particles. The water enters the chamber and particulates get trapped inside this chamber. At the outlet, water is free from these sediments.

Figure 5: Filter

i. **Carbon filter**: It removes sediments but also remove chlorine, volatile organic compound, any unwanted colour, taste, and odour of water. Bonding sites are designed in order to catch more and more sediments by activated carbon. This results in the much purer water. It is shown in Figure 6.

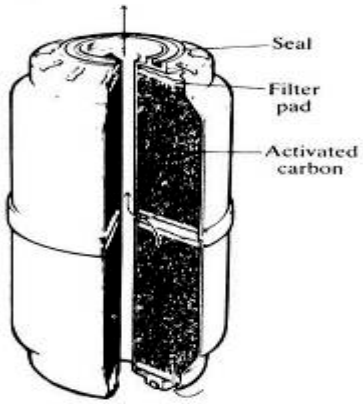

Figure 6: Carbon filter

ii. **Reverse osmoses membrane**: - It is the heart of the system as shown in Figure 7 and it removes all particles down to 0.0001 micron in size. A semi-permeable cover type membrane is used to trap dirtier water sediments and known as reverse osmosis system.

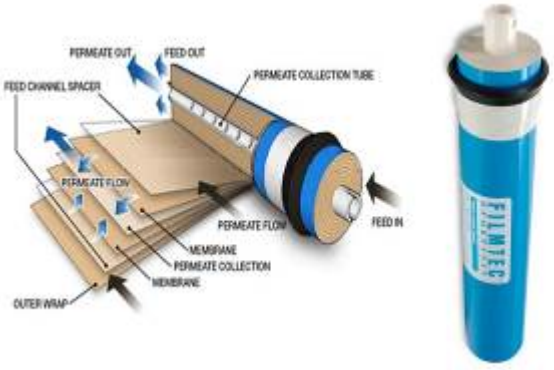

Figure 7: Reverse Osmosis System

4. Methodology

Human effort by pedaling rotates the rear wheel which acts as a flywheel. The alternator is attached to the flywheel with the help of belt. When rider drives the cycle, alternator converts the mechanical energy into electric power and gets stored in the battery. On the other hand, solar panel is also used to charge the battery. So that, this is the faster way to charge the battery by both sources. From both the processes of charging, DC supply is attained from the battery and converted into AC supply for home appliances such as fans, mobile chargers etc. For conversion of DC to AC, an inverter is used and AC supply provides power to diaphragm pump, so that it can easily pressurize the impure water from the tank and passes through the sediment/ carbon filters and delivers the water to reverse osmosis (RO) membrane. The pure water from the RO membrane is collected in another container for drinking. The complete installation of water purification system is shown in Figure 8.

Figure 8: Multistage water purification system

5. Results and Discussion

The most significant results obtained from the experimental set-up are as follows:

A. Water Purification System Calculations

The results show that before filtration, the TDS level of impure water is 500 ppm and after filtration process through reverse osmosis, it is reduced to 25ppm. This is done with the help of carbon, sediment filters and RO membrane. The ceramic material pores are used to eliminate the cryptosporidium and other impurities from the impure water. In order to kill the bacteria, certain type of chlorine and ozone bacterial method is used and then water is to pass through the carbon filter that acts as a trapping layer of fine impurities. At the last stage, water passes from a semipermeable synthetic membrane that changes the impure salt water to pure fresh water. Under the normal conditions, the efficiency of reverse osmosis system is near about 90% to 98%.

B. Solar Panel Calculations

It is observed that solar panel can charge the 12V battery in 6-7 hrs. According to the analysis, the solar panels can charge the battery at the rate of 14.1V and 3.3 Ampere of current is produced by it.

C. Alternator Calculations

It is observed that a normal person produces up to 200 Watt by driving the cycle pedal for an hour. Experimental results show that by pedaling bicycle, it can charge the battery at the rate of 16.0V and 5 to 7 amperes of fluctuation current.

D. Calories loss

Results revealed that a man can reduce 15 calories in 2 minutes by cycling and measured by a mobile application and validated with pedometer device.

6. Conclusion

A time will come when there is energy crisis and water-related diseases will occur around the globe and researchers have to search for new renewable sources of energy. One alternate technology to provide safe drinking water is elaborated in the paper. Some of the most significant results obtained from the experimental analysis are as follows:

- An incorporation of the water purification system results in the reduction of TDS level of impure water from 500 ppm to 25 ppm only.
- Solar panel that absorbs the energy from sun rays charges the battery within 5 hours and human effort from bicycle charges the battery within 8 hours.
- A healthy man can loss 15 calories in 2 minutes by cycling and it is also a good physical exercise.
- Cleaning of membrane is easily done by switching position of flexible tubing direction and pedaling, so that clean water flows in reverse direction and it will flush out the particulates stuck on membrane surface.
- It can be used to filter stagnant water in disaster affected area and can transport stagnant water in mountainous region.
- Manufacturing cost is lesser than modern technology and it is compact and portable.

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