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Enhanced Design of Automated Solar Still Based on Light-Harvesting Nanoparticles

J Aishwarya[1], S Shiva Ranchani[2]
[1,2]*Department of Electrical and Electronics Engineering, Sri Sairam Engineering College*

Abstract**: *In the current scenario majority of the cities and towns in India are without proper planning for water need versus water availability. The per capita water availability has drastically reduced over the past. Among a range of solutions, water distillation process is optimal to produce potable water without affecting its palatability. In arid remote areas solar distillation offers a promising alternative for saline water resources as it can partially support fresh water need with free energy, simple technology and a clean environment. The aim of this project is to design a solar still for water distillation that can purify water from nearly any source. The system is compact, quick and easy-to-handle and depends only on renewable solar energy for its operation. The low daily productivity of the solar still is the main drawback in the existing system. This project provides an optimized system for monitoring and distillation of saline water using solar still with improved productivity and thermal efficiency thereby significantly reducing the production cost. This process combines the emerging technology of nano-photonics with solar energy which makes it completely off-grid. This stand-alone system is monitored and controlled using a microcontroller. Water is converted into steam, directly and immediately, even before the boiling point. It uses the highly localized & strong photo-thermal response of the nano particles dispersed in the water. In this way the design features of the existing solar still is improved in many ways to make it relatively cheap, portable and automated.Thus an optimized solar still is designed with enhanced productivity providing an eco-friendly solution.***
Keywords: Water distillation, Solar still, Nano-photonics, microcontroller, automated, eco-friendly

I. INTRODUCTION

The demands of clean water throughout the world is rising by each passing day as freshwater resources are fast depleting due to increasing population, prolonged droughts, climate changes, and strict water quality standards. People in developing countries are using unconventional water sources due to limited and depleting fresh water supplies. The existing water treatment methods, distribution systems, and throwaway habits added with huge centralized schemes are no more sustainable. The most prevalent scenario in the world today is the scarcity of clean water resources on one hand and the availability of abundant impure water on the other hand. This gives us a scope for potential conversion of the impure water into potable water. The issues in most of the advanced water purification processes are loss of palatability of water and being energy-intensive. Distillation is one of the processes that can be used for water purification while retaining the natural ingredients of water. Solar distillation is an attractive process to produce portable water using solar energy. Many technological developments are employed on daily basis, both commercial and non commercial, but nanotechnology has proved to be one of the advanced ways for water or waste water treatment. By using different types of nano-particles and nano-fibers it possible to invent environmentally stable and economically feasible treatment practices for effectively treating water, meeting the ever increasing water quality standards.

II. EXISTING MODEL

A. Introduction

Solar distillation systems can be small or large. The existing system has some demerits like low production of output water. So they are primarily designed either to serve the needs of a single family, producing from 2 to 12 litres of drinking water a day on the average, or to give much larger amounts for an entire village or neighborhood. Although there are many innovative products available in the market most of these products are too expensive, inefficient, heavy and cumbersome or too complicated to use. Also it requires constant human intervention in case of refilling the water trough and cleaning the glass cover.

B. Goals

To design and deploy an enhanced system of solar still with improved solar radiation absorption as well as adding a control part to make it automated, thereby leaving it as a self-reliant system. For the absorption enhancement part we are trying to add a small amount of nano particles in the feed water. These nano particles exhibit highly localized and strong photo-thermal response and the use of these broadband light-absorbing nano particles as solar photo thermal heaters will generate high-temperature water vapour and improve the evaporation rate. Reflecting mirrors are also used to concentrate the solar radiation in the centre to improve the efficiency. Added to that, the system is able to pump in water as and when required and collects in the drain under the natural force of gravity, thus eliminating constant human monitoring. Another important consideration is the cost. Here we are using simple and cost-effective components with almost zero maintenance cost which will result in an affordable solution with just the capital cost.

III. DESIGN CONSIDERATIONS

The basin liner of the conventional solar still is painted black to avert condensation of water vapour on the walls of the still. While the side walls are painted white in order to reflect rays to the centre water trough. The next consideration is the water depth since the evaporation heat transfer co-efficient depends significantly on water depth. There is increase in water temperature as the depth decreases because shallow water quickly heats up.

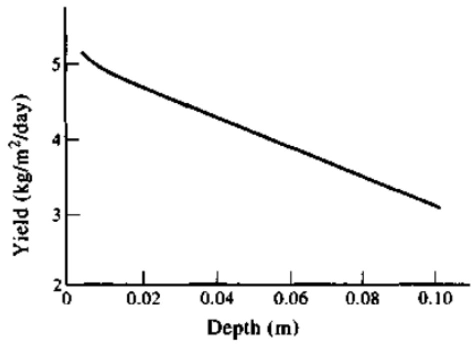
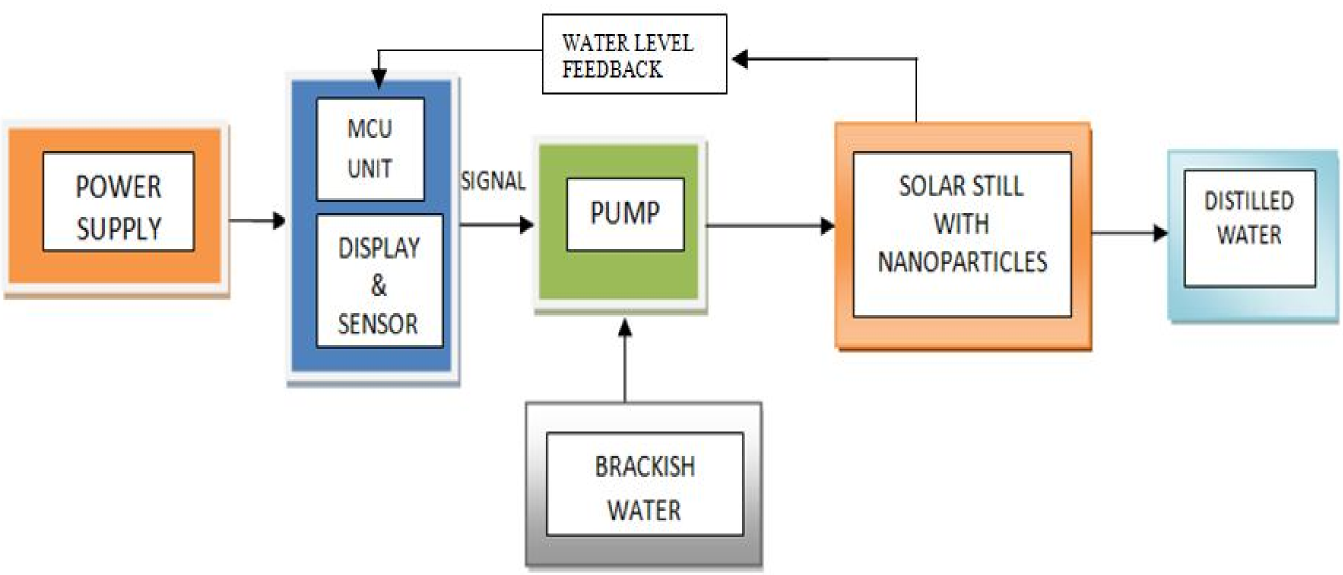


Fig. 1 Variation of yield with water depth

The system is designed with glass cover having low absorption glazing whereas the surface of the basin liner containing the feed water has good radiation absorption property. The temperature difference between the feed water and the condensing surface must be high to enhance condensation rate. It is important to minimize heat losses by insulating the distiller and walls of the still with thermocol and using a plane mirror reflector for maximum utilization by focusing the scattering radiation to the trough.

A. *System Overview*



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The overall design is to add the control part to the mechanical construction of the solar still. With the use of a microcontroller and pump the whole process is automated. All the above mentioned enhancements in the design parameters of the still improves the efficiency. Added with that, the use of nano-particles has marked a significant increase in the output yield. The micro-controller unit is powered from the mains and with further work it can be replaced by a 10W, 9V solar panels, thereby making it completely stand-alone application. The MCU senses the water level and controls the water flow through pump. The centre trough in the solar still contains the nano particles dispersed in the feed water pumped in. The same trough is fitted with the float switch to continuously monitor the water level and pump in water as and when required. The ambient temperature, temperature of the feed water and glass cover are continuously measured by the temperature sensors places at the required positions and the data is converted by ADC to display the equivalent temperature in the LCD. The final distillate is collected in the outlet through a slope due to the force of gravity. Observations are made for the temperature and yield throughout the day and the readings are tabulated.

IV. HARDWARE SPECIFICATIONS

A. Control Unit

In this project we are employing a basic range of hardware components to make it cost-effective and affordable. The brain of the control unit is the microcontroller which senses the water level and sends appropriate signals to the pump. Thus the system is made automated.

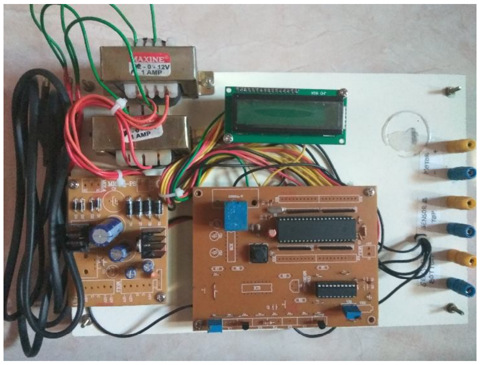

Fig. 2 PCB board with Microcontroller Unit

1) *Microcontroller:* We are using the basic level 8051 microcontroller board with AT89S52 series which is sufficient for our system requirements. The controller unit has voltage regulation section and Input & Output ports through which the sensors, LCD display, ADC and pump are interfaced and data are stored.
2) *Sensors:* The circuit uses LM35 analog temperature sensor, ADC0808 and float switches. LM35 is an analog temperature sensor IC which can measure a temperature range of -55 to 150°C. Its output voltage varies 10mV per °C change in temperature. The float switch is used as water level indicator which works on the principle that water conducts electricity. A wire connected to V_{CC} and two other wires are dipped in feed water trough at different levels namely empty and full. Their output signals are sent to pins in one of the ports via a transistor (BC547). The port is connected to data pins of LCD and another data port is respectively connected to RS, RW, and EN pins of LCD. Initially when the tank is empty, LCD will display the message "WATER LEVEL LOW" and "PUMP ON". Then the controller sends a signal to the pump to turn on the motor and starts pumping water in. As the tank starts filling up and reaches full the wire gets some positive voltage, due to conducting nature of water. This voltage is then fed to their corresponding pin on controller and in turn the pump is switched off. Then the LCD displays the message "WATER LEVEL HIGH" and "PUMP OFF".
3) *Pump:* A low power submersible pump is used sufficient for a small scale application. Here a 3W, 9V pump is used with a flow rate of 1.5L/min. It is placed in the tank supplying the feed water to the still.

B. Enhancement through Broadband Light Absorbing Nano-Particles

Using of iron nanoparticles in the conventional technologies of water treatment can represent a significant qualitative step in drinking water purification. The conventional solar still sometimes doesn't effectively remove the inorganic minerals. However the iron nanoparticles are extremely reactive, thus offer a possibility to solve persistent problems with a high content of inorganic minerals like uranium and arsenic in a variety of water resources. In addition, they can be used for a reduction of heavy metals,

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nitrates and phosphates in the drinking water.

The removal of these inorganic contaminants by standard technologies is energy intensive and expensive. But with the usage of Fe(0) nanoparticles they can be effectively removed. This kind of proposal is in its early stage for the present, yet in the near future, we can expect a surge in their application in the area of purification processes. They have better decontamination effect, formation of non-toxic product of oxidation of nanoparticles (mostly Fe3O4), which is either deposited in the local surface and almost negligibly increases the natural occurrence of iron oxides or settles in filtration devices of cleaning units. The nano-iron exhibits a large surface area along with an extraordinary reactivity in contact with contaminants. Hence, it simultaneously acts as a solid sorbent, which may bind colloidal and solid impurities present in the water. Thus nanotechnology can sufficiently address many of the water quality issues by using different types of nanoparticles.

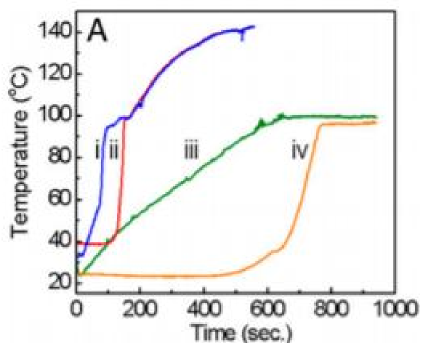

Fig 3. Temperature Vs Time graph from solar simulator for iron particles-dispersed feed water (i)liq (ii)vapour and for normal water (iii) liq and (iv) vapour

C. Solar Still Arrangement

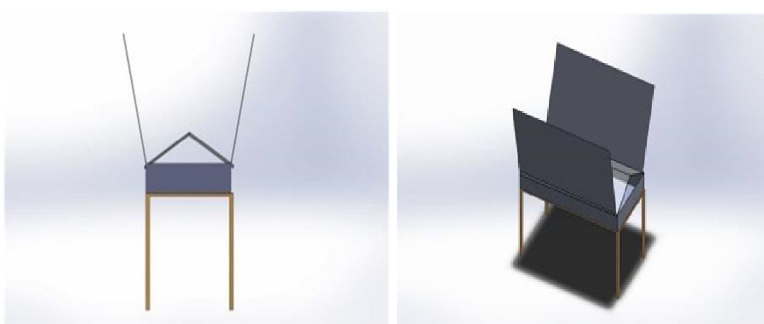

Fig. 4 Solar still (a) Front view and (b) Isometric view

Fabrication of the whole unit is pretty straight forward and involves metal cutting, welding, glass cutting, sealing, painting and drilling. All these processes can be done at any local workshop using simple machines – lathe, drill, welding, milling etc. Reflectors are fixed on two sides of glass cover in order to increase efficiency. The whole system is sealed using sealant to prevent the air from leaking in from the atmosphere.

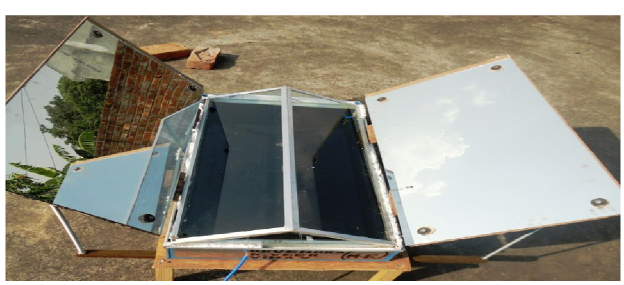

Fig. 5 Double slope solar still - working model construction

Table.I Experimental Output Values

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TIME (hour)	Output water from Conventional still (ml)	Output water from Enhanced still (ml)
9:00	350	400
11:00	550	650
13:00	800	900
15:00	700	850
17:00	400	500

Total quantity of Potable water achieved = 3.3 litres.
The increase in efficiency is seen to be nearly 18% under the given conditions with the use of dispersed nanoparticles in water.

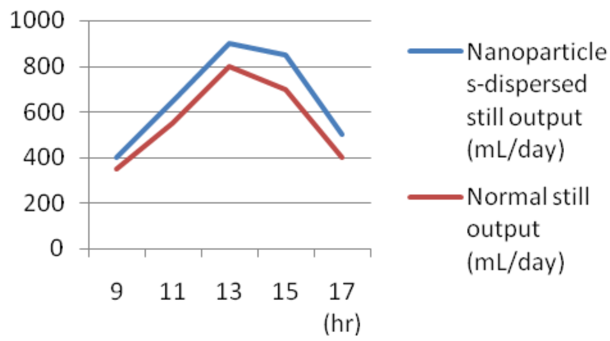

Fig 6. Output from Conventional still Vs Enhanced still

V. CONCLUSIONS

Only very preliminary results were obtained for estimating the amount of water that evaporated from the centre trough. Based on the observations, it was estimated that this system can generate between 3L and 3.3L of evaporated water out of 6L water added to the trough, which would theoretically be condensed and collected at the outlet of the system. If we estimate the water demand for a household or small community, accordingly the size of the solar distillation system can be scaled to have the desired amount of distillate output based on the purification rate. The optimal time period of the day was found to be 11.00 a.m. to 3.00 p.m. due to the maximum temperature gradient, between feed water and the cover glass plate. The distilled water on analysis showed drinkable standards in palatability, turbidity, conductivity and pH values. From the observations, it is found that there is significant increase in the quantity of the distillate yield and the result is majorly attributed to the addition of nano-particles, next to the design enhancements.

VI. ACKNOWLEDGMENT

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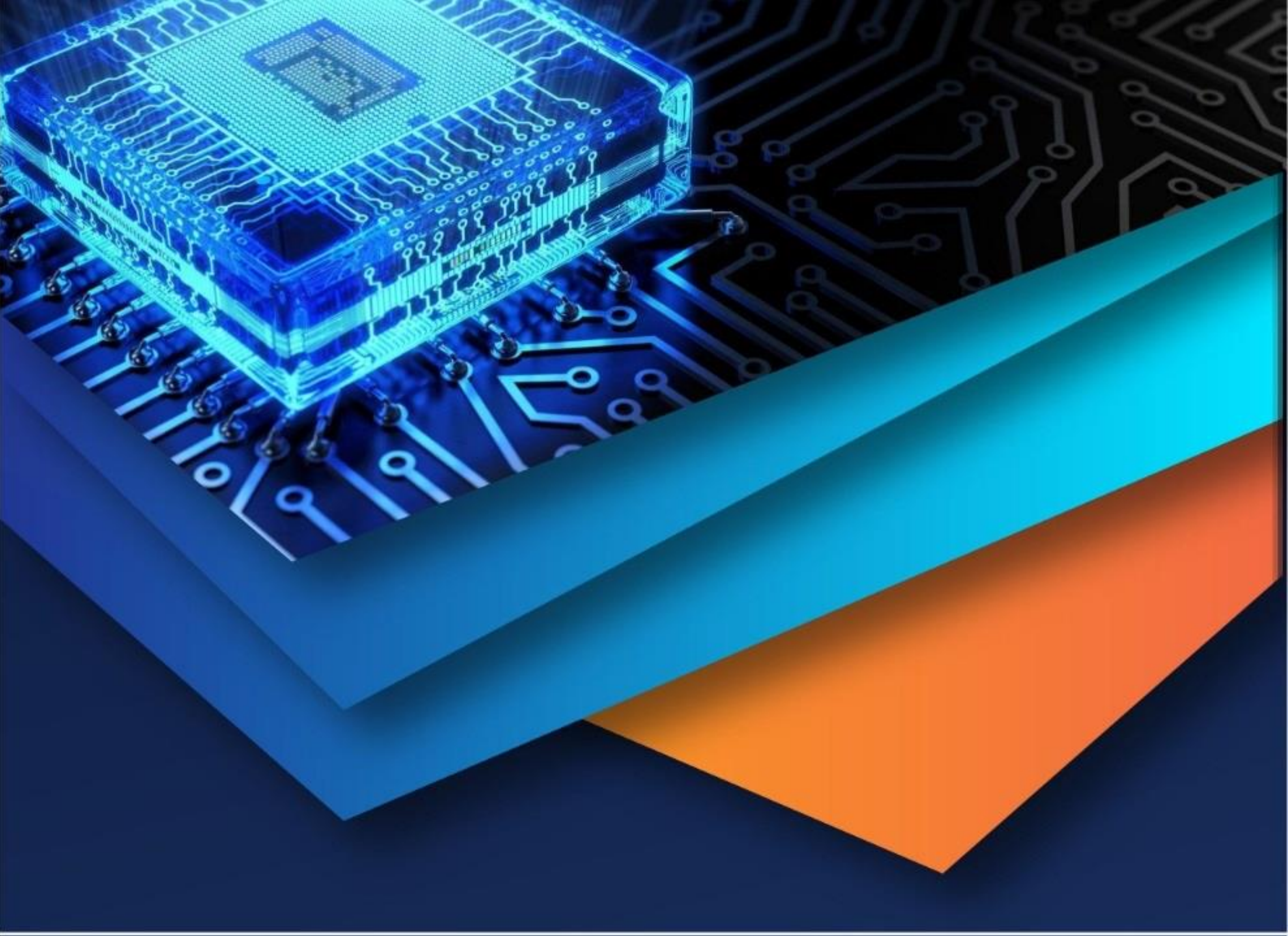

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