Development of a Renewable Energy Powered Water Treatment Plant

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Abstract: Renewable energy resources like tidal, geothermal, solar, wind, etc., play a vital role in our energy needs with the decline of fossil fuels. The efficient use of solar energy will be of primary importance to replace the conventional energy source in future. The present study details the utilization of solar energy for desalination of water for domestic purpose. It involves the designing of ground water desalination plant for small scale domestic purpose. Ground water is heated by solar radiation directly into the receiver and the generated steam is collected & condensed. Overall cost of this plant is kept low & also it is not harmful for the environment. This Solar based distillation system is optimum to remove minerals & hardness found in ground water and make it suitable for drinking. For a normal Indian family of 5 persons requiring 25 Liters of pure water per day under normal conditions the design conditions was calculated. With heat load of 3584 W, Area of Aperture was found to be 8.54m^2 and the area of one module was calculated as 1.31m2. Total number of modules calculated was 8. The diameter of absorber was calculated as 0.0264Meters while the focal length of dish was calculated as 0.36 Meters. Economically it was found that with per day distilled water production of 5000 litres, the total savings are of Rs 12500 and a payback period of 6 Years was also calculated.

Keywords: Solar Energy, Desalination, Dish Collector, Flash Chamber, Absorber

Introduction: Energy is human beings and nature's primary and most universal kind of work. For the input to their bodies or computers, many people use the word power and speak of raw fuels and electricity. The key source of power can be solar energy. And also it could give the greatest potential is a small amount of it is usedIt is a resource that would become the main energy provider if the other energy sources were exhausted. Where sun hits atmosphere the solar power at that point is 1017 watts, where as the power reaching the earth surface is 1016 watts. The average demand for power in all society uses is 1013 watts. This solar energy can be used for many purposes such as heating, desalination, distillation and raising stem which further can be used to run prime movers.

Utilization of solar energy in India is of great importance since it lies in a temperature climate region of the world where sunlight is available in abundance for the major part of country throughout the year. In the village, long-distance travel is very common for people to collect drinking water. The abundant solar energy available at the site can be used to convert the available groundwater, which is salt, to desalinated water.

Fresh water is a necessity for the livelihood and the key to success. Culinary water sources become quickly unsatisfactory, both for domestic and agricultural applications and constantly developing industries, to meet the needs of an increasing population. In arid and semi-arid regions and some coastal zones, the problem with water is acute. The definition of salty or brackish water is any water with fewer dysfunctions than that of sea water.

Desalination means conversion of saline water into suitable form so that human can consume it.. But this separation needs energy. Solar energy is thermal energy in radiation form, so it can be used for water distillation.

Salty or brackish water distillation solves the diverse and innumerable water problems to some extent. Most existing plants use fossil fuels as an energy source. While few techniques such as multifaceted evaporation, flash evaporation of several stages and thin film distillation have been applied, the process is energizing and expensive. Hence, application of solar powered or solar augmented distils, can replace need for a large proportion of oil or other desalination plants.

W.R.Mccluney et al explain the basic principles of solar distillation of water and its economics over bottled drinking water purchased in the store. Also researcher discussed about details of purity of water by solar distillation method. After experimentation researcher found that purity of water is increased by slow distillation rather by rapid. Also Solar distillation of tap water or brackish ground water can be a pleasant and energy efficient option. [1]

The design of solar energy systems both thermal and photo voltaic types is illustrated by another author Bagget. He also discussed about the Solar Resource and the ability of various types of solar collectors to capture it effectively. Along with this design tools are developed which integrate performance of isolated solar collectors considering Economic and Environmental effects. [2]

Solar dish concentrators provide high temperature and efficiency. And solar thermal energy at a price comparable to residential satellite dish antennas. The assessment of this relationship results in an economic analysis and return on investments by using the refined production references for solar energy collectors. Researcher estimated cost of thermal output per kilowatt and found that annual efficiency could be better or worst depending on the site, dish opening temperatures and maintenance. Also solar steam is possible. [3]

For different climate conditions, plant capabilities, cost of solar collector and costs of a conventional energy supply, special cost of the product is evaluated. Researcher tried to explain the working of a direct solar distillation system and solar multi-effect distillation plant and multistage flash distillation plant. The economical benefit of solar direct steam generation from brine is pointed out as having better thermo dynamic efficiency. [4]

2 Solar energy based for domestic purpose water desalination: Solar desalination plants have proven to be efficient, quick, scalable, sustainable and affordable for the production of potable water from almost any locally required water. The ground water is pumped into the overhead tank and can then travel under a controlled flow rate through the absorber coil. The solar collector relies on the absorber spool with the power of the wind.

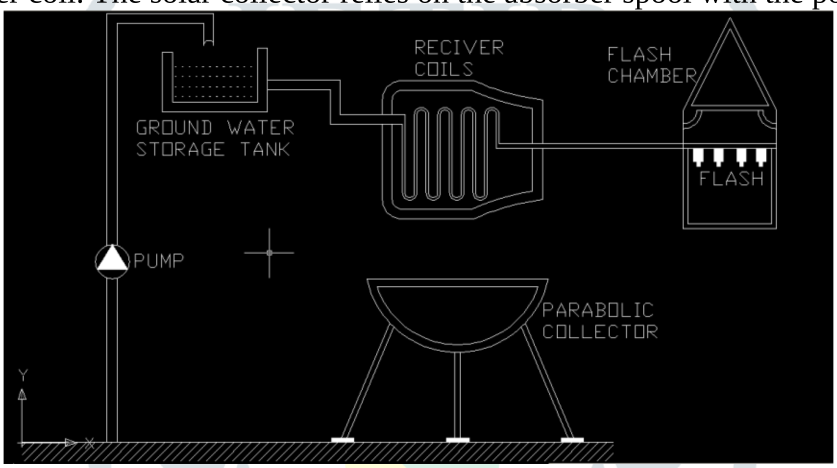

Figure 1: Domestic Purpose Water treatment Plant

The focused incident rays thus heats the absorber pipe and water gets heated up due to this. This will change heated water into steam. The steam is then made to pass through the pipe which is then collected into the flash chamber. The flash chamber made of mild steel with a pyramidal shape top made up of glass. The steam thus moves up and gets condensed. Water is then collected from the top of the flash chamber which can be used for drinking.

3 Design Calculations:

Design of solar desalination plant using parabolic dish collector for a normal Indian family under normal environmental conditions is done and dimensions are calculated:

Family size = 5 members

Drinking water needed, (M) = 25 litres/day

Operating hours/day = 6 hours

Average beam radiation, HbRb = 700 W/ m²

Peak sunshine = 5 hours

Pressure = atmospheric

Enthalpy of dry steam at atmospheric pressure hg = 2706.3 KJ/kg

Enthalpy of water at 30 degree centigrade, hf = 125.79 KJ/kg

Collector efficiency (?ib) = 50%

Concentration ratio (Cr) = 20

1, Heat load, Q = M * (h_g - h_f) = [25 / (5*3600)] * [2706.3 – 125.79] = 3.584kw = 3584 W

Area of aperture, Aa = [Q / (?ib * HbRb)] = [3584 / (0.6*700)] = 8.54 m²

$Aa = 4/3\pi r^2$

Radius of aperture = 0.6 meter

Area of one module = πr^2 = Π (0.6)² = 1.31 m^2
Modules required = (Aa/A) = (8.54/ 1.31) = 8
2, Area of absorber/ receiver Ar = Aa/ Cr = 1.131/ 20 = 0.0566 m^2
0.0566 =$\Pi d^2/4$
0.0566 = 3.927 d^2
d = 0.0264 meters
3, Focal length of parabolic dish (f) = DXD/16d = 1.2X1.2/6X26= 0.36 meter
5 Economic Analysis: The estimated cost of a parabolic dish collector used in homes for desalination process using solar energy is Rs 9430 (Approx.)
Equipment model for 8 modules = Rs 9430 x 8 modules = Rs 75440
Distilled water produced in a year = 25 litres/day x 200 days = 5000 litres/year
Savings in cost per annum = 5000 litres x Rs 2.5 / litre = Rs 12500
Simple payback period = total cost/ savings = Rs 75440/ 12500 = 6 years (approx.)

4 Construction:

4.1 Parabolic Dish: Number of panels and required area of absorber is calculated and radius was found to be 600 mm and cross-sectional area of 1.47m^2. the depth of the dish was taken as 26 cm. Focus for the dish is calculated and found to be 36 cm from the depth. The frame of the parabolic dish was then made as per the required dimensions and the sheet metal was cut into 8 segments. These segments were then settled and welded onto the frame. A required tracking system was then incorporated with the dish to give the east west movement..

4.2 Absorber: Absorber dimensions were calculated taking the ratio of the aperture area to the concentration ratio. The required value was found and the base diameter of the coil was then set with the calculated value. Keeping inlet and outlet straight, the coil was formed in the middle. With the help of a conical die cooper tube was bent.

4.3 Flash Chamber: Flash chamber is a tank used for collection of desalinated water. The construction of the tank is simple having a pyramidal top used for condensing of the steam generated and also used to give the pure desalinated water.

The parabolic dish collector thus made for the solar desalination of domestic purpose water is shown in fig 2 below:

Fig 2: Parabolic Dish Collector

4.4 Components used: Various components used for the construction of parabolic dish collector are shown in table 1 below:

Table 1: Components used for the construction

Component	Material	Dimensions
Parabolic Dish	G.I. Sheet	120 cm X 120 cm
Reflector Sheet	Polished Aluminium	15 Mtrs.
Ground Water Tank	--	20 Ltrs.
Cone	Glass	

Supporting Stand	Mild Steel	Height – 40 cm Length – 80 cm
Infra Red Thermometer	--	Upto 530 ^{0}
Pipes	Plastic	Length – 6 m Diameter – 8 mm
Absorber Tube	Copper	Length – 8 m Diameter – 8 mm

5 Theory of Design: The various factors that influence the design are as follows:

1. Performance factor
2. Structural factor
3. Environmental factor
4. Reliability factor
5. Cost factor

5.1 Performance Factor: The design of the equipment mainly depends on its performance requirement. It should be able to deliver the required performance

5.2 Structural Factor: The structure of the equipment should be such that it should be able to withstand the stress created. The material for the outer cover of the collector is chosen as G.I.Sheet because of its low cost, sturdiness and heat reflecting capacity. The receiver tank should be made of sufficient thickness, so that the failure does not occur due to the pressure created inside. Hence mild steel is used.

5.3 Environmental Factor: The equipment should be not polluting and should not pose any hazard to the surroundings. It should be capable of performing effectively under the required environmental conditions.

5.4 Reliability Factor: The equipment should have a long life and should be reliable. The maintenance costs have to be less.

5.5 Cost Factor: The design and selection of the materials should be such that the cost of the equipment comes within the economic limits of the people in the country.

6 Performance Analysis: An investigation using different instrumentation had been carried out to access the performance of the collector. Infra-red thermometer was used to measure the temperature of water at inlet, outlet and the absorber temperature. The readings were tabulated and shown in table 2 below:

Table 2: Readings

Local Time	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**
Ambient temperature (^{0}C)	33	34	35	35	36	35	34
Solar Insolation (W/m^2)	723.78	827.18	960.12	901.12	856.72	653.21	451.23
Beam radiation (W/m^2)	550	650	700	680	650	450	300
Inlet Water Temperature (^{0}C)	33	33	33	33	33	33	33
Outlet Water Temperature (^{0}C)	40	58	73	82	78	71	63
Reciever Surface Temperature (^{0}C)	73	92	106	123	114	96	88

7, Conclusion: Present study details the utilization of solar energy for desalination of water for domestic purpose. It involves the designing of ground water desalination plant for small scale domestic purpose. For a normal Indian family of 5 persons requiring 25 Liters of pure water per day under normal conditions the design conditions was calculated. With heat load of 3584 W, Area of Apreture was found to be 8.54m^2 and the area of one module was calculated as 1.31m2. Total number of modules calculated was 8. The diameter of absorber was calculated as 0.0264Meters while the focal length of dish was calculated as 0.36 Meters. Economically it was found that with per day distilled water production of 5000 litres, the total savings are of Rs 12500 and a payback period of 6 Years was also calculated.

Readings taken at various times of a day are shown in the form of a graph as fig 3 below:

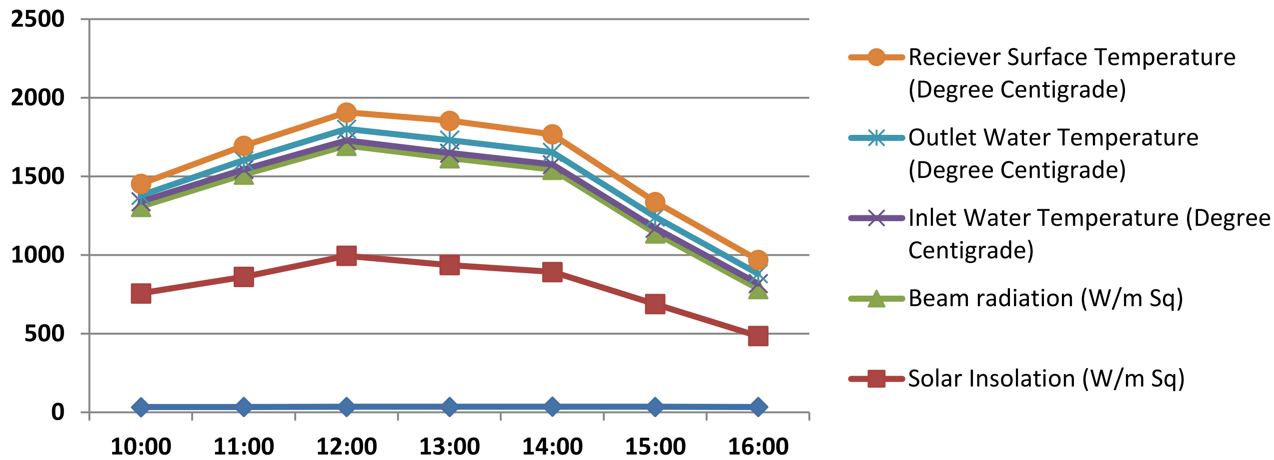

Fig 3: Graph representing various reading

The above graph shows the variation of receiver, inlet water and ambient temperature at different time period in a day. The temperature of the water leaving the collector was found to increase as the intensity of solar radiation was more at high solar insolation rates. The ambient and inlet water temperature was observed to increase slightly with increase in solar insolation.

1. Desalination appears to be one of the best options to palliate the problem of water scarcity.
2. As high solar irradiance levels characterized arid areas, the energy demand for the desalination process can be supplied by a solar thermal system
3. Direct steam generation from parabolic dish exhibit potential for improving solar desalination.
4. The replacing of oil based technology by DSG presents many advantages from point of view of thermodynamics, environmental hazards, land use, use of material, etc.
5. Heat exchangers are not necessary to generate stem.
6. The area occupied by the solar system is a worrying factor and it can be optimized by improving the collection efficiency.
7. The optical efficiency is improved by keeping the reflector clean and polished.

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