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Feasibility Study and Design of Solar Water Treatment Plant for Drinking Purpose at Saardo Site, Ethiopia

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Abstract; - *Lack of Clean water which is safe for drinking purpose is the big problem for the most of developing countries especially in rural areas. Safe water and effective sanitation are critical to the health of every child and every community which decreases water born disease. This project is a design of solar water purification system by thermal method with a cooling tower. It has selected a specific area to implement the project, for research and to help the specific area. The whole plant is situated on the 1050 m². The name of the area is Sardo Kebele near Mettu, which is approximately 10km from Mettu city, the people uses the river water named locally as Huluka for drinking, washing and cooking on the daily bases and there is no electric power source around this rural area. The water requirement of the area is 20.4m³ /day. The river will be deviated and will be stored in dam which is constructed from concrete. a submerged solar pump pressurizes the water from the dam and delivers it to the solar heater which uses flat plate collector for absorbing the solar power and pipes which has a material of copper in order to facilitate the absorbance of solar energy. The solar water heater has a capacity of heating the water up to 50⁰c which at this temperature the pathogens in the water will die and will be purified at some level. Then the system uses PET tanker which totally disinfects the water within 1hr. then water is fully disinfected and ready to lead to the cooling tower to decrease the temperature 15⁰c and make it at a suitable and good temperature for drinking. To increase the water pressures at two levels one at the dam and the other to the cooling tower two centrifugal pumps are installed. The cooling tower works with the forced draft which cools the hot water enters in the tanker by using fan a motor is then used to drive this fan. The motor used for the fan gets its power form PV system. This PV module also helps to start and run the pump powers. The designed PV module has area of 0.05m², battery, battery storage and invertors. The water which is ready for use is stored in plastic reservoir to protecting it from corrosion.*

Keywords;- ***[1]Temperature [2]Disinfection, [3]Pressure, [4] Water, [5]Purification***

1. Introduction

Water is basic necessity for human being as food and air, but Clean and healthy water is rare to find. Incredibly, only 1% of the earth's water is suitable for human consumption. While 70% of the earth's surface is covered by water, 97.5% percent of it is salt water. Of the 2.5% freshwater remaining, nearly 68.7% is solid, frozen in ice blocks, icebergs and glaciers.

Solar water purification is a water purification system at house hold level and also community level based on solar radiation treatment and water distillation with additional use of solar heating. It is a combination of two water purification processes, which are solar water disinfection system and solar distillation process. It is only ideal to disinfect small quantities of low turbidity. And for the cases with high turbidity contaminated water will be distilled to drinking water to remove any non-volatile solid impurities such as salt sediment heavy metals and other microorganisms. Water from wells rivulets may be visibly clear that is there turbidity is less than 30Nephelometric Turbidity units, but still it may not be drinkable since the water may still contain in clean, transparent PET bottles and are exposed to the sunlight for a certain amount of time depending on the intensity of the sunlight allowing the solar radiation to deactivate any water borne pathogens in the contaminated water. Solar water disinfection is an effective way to disinfect drinking water as it is recommended by WHO. The solar water purification system uses only solar energy and can be built using easy materials like collector glass and so on, thus the system is environmentally sustainable. To solve the above listed problems there is available source of energy that's simple, to construct solar water purification system. Solar water purification system in general consists of three main components which are solar collector, the solar distillation system and the solar disinfection system, but for this specific purpose solar distillation system is not applied. The project integrated both solar electricity and solar water purification in order to purify the water. Solar panels generate electric power for the pump that pumps the water from the reservoir to the solar heater. Then the solar water purification system can be done by using solar collector to heat the water and disinfection system can be done by using PET material.

2. Objective

General objective
The general objective of this project is to provide solar water treatment plant for the community around rural areas.

Specific objective of this project activity is

To design essential components of solar water treatment plant, by studying the clean water demand for the selected specific site and also solar power availability to run the water treatment plant. studying feasibility of this solar water purification system and depending on clean water demand and solar radiation sizing of solar thermal heater, solar pump and solar water cooling system. Solar disinfectant PET will be selected depending on design analysis. Making awareness for the community on how to utilize water properly and neatly. Awareness towards solar energy utilization.

3. Problem Statement

Ethiopia is one of the countries which do not have clean water especially in the rural and country areas. There is also no proper use of water. Even in the areas where there is enough knowledge about water people do not utilize water properly in fact by this reason it causes water born diseases like diarrhea and it also exposes many children to harmful diseases. In order to kill these harmful pathogens in the water the people can boil the water by using fuel and fire woods but they do not have the potential to afford the fuel and most of the people are morally weak to boil and also according to their other works they do to sustain their life it will be very tire some to do this on the daily bases therefore using the contaminated water is an easy way out for them to use the water directly from the lake or river. The solar power that is free and available in the rural area is very helpful to fight these problems. The people around the area in which this project is implemented will utilize the solar power by the aid of this project. The people of the Sardo kebele uses the river water and use this river for cleaning washing and drinking at the same time, which is very dangerous for health

4. Research hypothesis and description of Materials /components

4.1 *Description of the water treatment plant:*-The source of our water is from a river and in order to store the water a reservoir is used this reservoir stores the water by the form of dam besides the river, then the next step will be to pump the water from the dam to the heater for this purpose a photovoltaic pump is installed, then solar water heater will receive the water, this solar water heater works by solar collector (flat plate type) that is used to absorb solar radiation and change it this radiation to heat and boil the water up to maximum of 60^0 c for one hour, then next step will be exposing this hot water to direct solar radiation by using pet transparent material which is used to disinfect the water's directly by the ultraviolet radiation of the sun for only one hour. after this procedure the water is clean enough to be drunk but hot to make it cooler and suitable to use the water will have pumped to a reservoir with a cooling system. The reservoir is aided with two fans rotating to cool the pressurized water. Then the water will be clean and at optimum temperature for drinking.

4.2 Main Components /Materials:

4.2.1 *Solar energy collector;* - They are composed of columns of painted black aluminum can, a frame to house the columns. Solar water heater is suitable for hot climates and can be much simpler and cheaper and can be considered an appropriate technology

4.2.2 *Solar disinfection unit;* - Solar disinfection unit is constructed with simple and efficient way of water treatment process which is appropriate for use in developing countries. It uses polyethylene terephthalate (PET) plastic bottle. To improve the effectiveness of the solar disinfection, reflective surface such as mirror or fine finished metallic surface can be used to concentrate radiation onto the contaminated water

4.2.3 *Cooling towers ;*- The most efficient means to remove large amounts of heat from air and equipment or also from liquids. in our project we will use fan cooling tower to cool the water which comes from solar heater.

4.2.4 Solar pump ;- It is type of pump running on electric power generated by photovoltaic. In the case of our project we choose AC pump because of its high compatibility (inverter works with different kinds of AC motor and pump also its suitable for large scale application.

4.2.5 PV (photovoltaic);- Photovoltaics' (PV) system is a method of generating electric power by converting solar radiation into direct electricity using semiconductors that exhibit the photovoltaic effect. This photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material, such as monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium and sulfide. PV power generation system is used for two main purposes in our project the first is generating power for the pump and the second one is generating power for the cooling system.

5. Methodology and Design of Each Components

5.1 Data Collection; -The first step to do this design analysis is to select site which has lack of clean and safe water therefore by setting a number of questions I forwarded it to different places which are concerned for this case, like water resource and energy agency which gave us important information about the areas which get the clean water and areas which uses river waters for their daily purpose. Hence, the selected Sardo site is one of nearest rural areas which does not have electric power and number of community who lives around this site is 340 households with minimum of 4-6 family at each house. People around here uses Huluka river which is raw water/unclean for drinking, cleaning and washing also different purposes.

5.2 Electronic sources; - In this research the electronic sources were used by visiting websites. Here internet was a good instrument to get information we needed. Through electronics sources we accessed different Journal and online books which played a greater role to improve the idea we had related to our study.

5.3 Design Parameters to be Considered and sizing of the components

Design Parameters to be considered are :-

- Type and size of the system
- Amount of radiation energy available at the side
- Proper insulation
- Tilt angle and orientation

5.4 Sizing of each components

A. Sizing of flat plate water heater

As explained on the pervious discussions the collector selected for this project is flat plate collector.

Number of people served 1360 people in which one person uses 15L/day.
Therefore, the water demand will be =1360*15L/day =20400L/day

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=20400L/day

The required heat demand is calculated as

$Q_{required} = \dot{m}_{cold} * Cp\ (T_{hot} - T_{cold})$, where Cp=4.182

$\dot{m}_{Cold} = (20400*1/1000*1000)/21600$

$\dot{m}_{Cold} = \underline{0.944\ Kg/s}$

$Q_{required} = 0.944 * 4.182\ (60℃ - 20℃)$

$= 157.9$ KW

Total amount of energy required will be calculated as (taking solar radiation day time from 9:00am- 4:00pm which is for 7 hours)

$Q_{total} = 157.9 * 7 * 3600$

$= 3,979,089$ KJ

From data's of the tables we can calculate the tilt angle β will be

β = latitude $\pm$ (5 - 15) = 11.56 $\pm$ 5

$= \underline{16.56} \approx \underline{17°}$

But the optimum solar radiation occurs when β equals 19.2 . for accurate installation and calculation we take beta to be 20 .

Month	Air temperature	Relative humidity	Solaradiation – horizontal	Pressure	Wind speed	Earth Temperature	Heating degree -days	Cooling degree -days
	°C	%	kWh/m²/dy	kPa	m/s	°C	°C-d	°C-d
Jan	19.5	39.2%	6.20	80.4	3.1	23.3	3	287
Feb	20.9	36.6%	6.53	80.3	3.1	25.6	1	298
March	21.6	43.1%	6.52	80.3	3.0	26.4	0	350
April	20.8	54.0%	6.69	80.3	2.9	24.8	1	320
May	19.9	63.5%	6.32	80.4	3.1	23.1	1	310
June	17.6	79.7%	5.71	80.4	3.7	19.7	13	237
July	16.3	82.2%	5.16	80.4	3.5	17.7	42	205
August	16.4	82.0%	5.18	80.5	2.9	17.7	38	209
September	17.3	73.1%	5.81	80.4	2.4	18.5	14	230
October	18.0	52.2%	5.86	80.4	2.3	19.5	10	255
November	18.4	43.1%	6.01	80.4	2.8	20.5	5	257
December	18.7	40.7%	5.95	80.4	3.0	21.5	4	269
Annual	18.8	57.5%	6.00	80.4	3.0	21.5	132	3227
Measured(m)					10.0	0.0		

Table.1 Mettu city annual data (source NASA)

$T_e = \frac{1}{\beta} + \frac{\beta-1}{\beta*\eta} F_R$, where F_R is water removal factor and has a value of 0.882 and η= 0.87

$$T_e = \frac{1}{20} + \frac{20-1}{20*0.87} * 0.882$$

= 1.0131 k

We will then calculate the heat transfer coefficient h h= 5.3 + 3.8(v), v is m/s and has a value of 5 m/s

h=24.3 w/m²°C

Then finding the value of f f = (1.0 -0.04h+ 5.0*10⁻⁴h²)(1.0 + 0.058n), where n is number of glass cover plates which is 2 = (1.0 -0.04*24.3+ 5.0*10⁻⁴*24.3²)(1.0+ 0.058*2)

= 0.3604

The overall thermal loss coefficient $_{top}$

$\bar{U}_{top}$= [n/(344/ T_e)[(T_e-T_a/(n+5)]$^{0.31}$+ 1/h]$^{-1}$ + δ (T_e+T_a)(T_e^2+T_a^2)/[E+0.0425n(1-E)]$^{-1}$+[(2n +f1)/En]-n

Where T_e - mean absorber plate temperature in k which is 1.0131 k T_a - average ambient temperature in k and has a value of 298 k f -0.3604 from the above calculation h- Convective heat transfer coefficient, 24.3W/ (m².°C) , δ -Steffan Boltzman constant 5.667*10⁻⁸ W.m².k⁴ , E - emittance of absorber plate, in this case for black chrome absorber plate take 0.17

E_n -emittance of the glass plate with a value of 0.9

By substituting these values we get $\bar{U}_{top}$= 2.224 W/(m.²°C)

The back loss coefficient is determined by assuming h on the collector of the back and front are the same.

$\bar{U}_{back} = \frac{1}{\frac{Di}{ki}+\frac{1}{h}}$ where D_i is thickness of insulation 5mm K_i is thermal conductivity 0.7

$\bar{U}_{back}$ =1/ (5/ 0.7)+1/24.3

= 0.139 W/m²°C

The overall loss coefficient is

Ū= Ūtop+ Ūback

= 2.224 + 0.139

= 2.363 W/m²°C

The effective absorbance of cover absorber assembly is

$(\tau\alpha)_{eff} = \alpha\,\tau_n/1-(1-\alpha)\,\rho_n$

The reflectance at the interface between two materials for incident angle of θ_1=20 is

$$\rho = \frac{1\ \sin^2(\theta_1-\theta_2)}{2\sin^2(\theta^1+\theta_2)}\,[1+\cos^2(\theta_1+\theta_2)/\cos^2(\theta_1-\theta_2)]$$

n= sin 1/sin 2

sin 2= sin 1/n

2= sin⁻¹ (sin 1/n)

= sin⁻¹ (sin 20/2)

= 9.84

By substituting the value of on the reflectance we get

$$\rho = \frac{1*\sin^2(20-9.84)}{2*\sin^2(20+9.84)}\,[1+\cos^2(20+9.84)/\cos^2(20-9.84)]$$

$\rho = 0.1136\varphi$

$\rho_1 = \rho\,[1+(1-\rho)^2\tau^2/1-\rho)^2\tau^2]$

$\tau_1 = \tau\,(\frac{1-\rho}{1+\rho})\,(\frac{1-\rho^2}{1-\rho^2\tau^2})$ where, τ=0.9

$\rho_{11} = \rho_1 + \rho_1\tau_1^2/1-\rho_1$

$\tau_n = \tau_1^2/1-\rho_1$ $\tau\alpha eff = \alpha\tau n/1-(1-\alpha)$ n

Then substituting the given values we get the following values for different variables described above

$\rho_1 = 0.1136[1+(1-0.1136)^2\,0.9^2/1-0.1136)^2 0.9^2]$

$\rho_1 = 0.203$ $\tau_1 = 0.9[\frac{1-0.1136}{1+0.1136}]\,[\frac{1-0.1136^2}{1-0.1136^2(0.9)^2}]$

τ_1= 0.708

$\rho_{1_1} = 0.203 + 0.203(0.9)^2/1 - 0.203$

$\rho_{11} = 0.409$

$\tau_n = 0.708^2/1-0.203^2$ τ_n =0.5232

$\tau\alpha_{eff} = 0.9(0.5232)/1-(1-0.9)\,(0.409)$

$\tau\alpha_{eff}$=0.491

Daily solar radiation is maximum 6.69 on April and minimum is 5.16 on July and solar insulation is between solar times of 9:am to 4:pm average sunset hour angle is 89.5 . Then sunset time (average sunset time) is 11.95.

td =2*Wss/15 t_d =2*89.5/15

t_d=11.99≈12hrs

The instantaneous hourly average insulation at time from 9:00am to 4:00 pm is $q_s = I_b\text{Cos}\,/\text{Sin} + H_d\cos^2/2$ + Hpr (sin /2), Where I_b total beam terrestrial insulation 6.69

H_d= (H-H_b) =H- $I_b$sin $_s$ The following data is gathered from NASA metrology and solar energy αs the solar altitude 37.37 H insulation on horizontal surface 7.67KWh/m²/day θ is angle between the solar beam and normal to the tilted surface

For horizontal surface $\beta = 0$ $\cos\theta = sin\alpha s$

For tilted surface cos = sin(Ø −) sin + cos (Ø −) cos cosw Where the sun angle, w is the hour angle which is 7hr

The sun angle can be calculated as =23.45 sin360 (284+n/365), where n day of the year= 120 = 14.48

cosΘ=sin (11.56-20) sin14.48+cos (11.56-20) cos (14.48) cos(-7) cosΘ=0.9135

H_d=7.47KWh/m²/day-6.69 (sin 11.56) H_d= 6.129 q_s = 6.69(0.9135)+6.129cos²20/2 + 7.47(0.1) (sin 20/2) q_s=12.073KWh/m²/day q_s=12.073KWh/m²/day solar time = 12.073*3600 = 43.462 MJ/m² solar time = 43.462/ (7*3600) qs= 1.724 KW/m²

The size of the collector is:-

$Q= [(\tau\alpha)eff *qs-U(Tfin-Ta)] Ac$

$157.9KW= [(0.49)*A_c *q_s-U*A_c (T_{fin}-T_a)]$

From the standard of solar collector size, we selected a collector for 1m side and 4m length then the size of one module is $4m^2$, so number of modules required is from equation

$157.9KW= [(0.49)*A_s *n (0.49*q_s)-2.363 (50-25)]$

$n=157.9KW/ 4m2(0.49*1.724)-2.363 (25)$

$N= 157900W/3142 =50.2 \approx 51$

Therefore we need 51 collectors with each size of $4m^2$ then they are arranged horizontally, the total area will be $204m^2$.

B. Sizing of Solar pump

Calculating total dynamic head (TDH): TDH is the effective pressure which the pump must operate against. It is expressed in meters or feet and it's the sum of 3 factors: these are; total vertical lift, friction loss, tank pressure.

Total dynamic head = total vertical lift + friction loss + tank pressure

Calculating total vertical lift = Total vertical lift= Standing water level + drawdown + elevation

Total vertical lift= well depth + elevation

Well depth= Standing water level + drawdown

Total vertical lift= standing water level +drawdown+ elevation

Assume elevation equals 0.5m (0.2m for tank of the solar collector and 0.3m for the basement) Well depth=standing water level+ drawdown = 2m , Therefore, the total vertical lift= 2m+0.5 = 2.5m *Calculation of friction loss:* The friction loss, measured in equivalent meters or feet, is the pressure required to overcome friction in the pipes from the pump to the point of use. The friction is based on: rate of flow, the length, diameter, and type of pipe, and also the number and type of pipe fittings used. The greater flow has greater the friction losses. Tables are used to calculate friction loss.

From table below for flow rate of $3m^3$/ hr or 50L/min the nominal pipe size is selected 35.1mm in diameter and for this PVC pipe size the constant friction loss will be =0.0084
Friction loss =0.0084* total vertical lift

= 0.0084*2.5m = 0.021m

Flow in liters per minute	Nominal pipe size Loss in meters of head per one meter of pipe					
	15.8mm 1/2"	20.9mm 3/4"	26.6mm 1"	35.1mm 1 1/4"	40.9mm 1 1/2"	52.5mm 2"
5	0.0058	0.0053				
10	0.021	0.011				
15	0.044					
20	0.076	0.019	0.0057			
25	0.11	0.029	0.0086			
30	0.16	0.041	0.012			
35	0.21	0.054	0.016			
40		0.069	0.021	0.0055		
45		0.086	0.026	0.0069		
50		0.1	0.031	0.0084		
60		0.14	0.043	0.012		
70		0.19	0.058	0.016	0.0073	
80			0.074	0.020	0.0093	
90			0.092	0.025	0.012	
100			0.11	0.030	0.014	
125			0.17	0.046	0.021	
150				0.064	0.030	
175				0.085	0.040	
200				0.11	0.051	
225				0.14	0.064	
250				0.17	0.077	

Table 2 (metric) *friction loss for sch 40 pcv pipe in equivalent meters*

Tank pressure: Tank pressure, expressed in equivalent meters or feet of head, is the operating pressure of the storage tank. However, systems with battery power can be used to pump to pressurized tanks, For non- pressurized systems, tank pressure equals zero, in our project case also the water is allowed to flow free into open tank therefore tank pressure is zero. (Tank pressure=0) By using the above equation we calculate the following;

Total dynamic head= total vertical lift+ total friction loss+ tank pressure = 2.5+0.125+0

= 2.625m

Hydraulic pump power

The ideal hydraulic pump power to derive pump depends on the mass flow rate, liquid density and differential height.

$P_h = {Q * \rho * g * h}/{(3.6 * 10^6)}$

Where P_h= power (KW) , Q = flow capacity (m^3/h) ρ = density of fluid (kg/m^3) g = gravity (9.81m/s^2), h= differential head (m)

From the data the water needed per day is 20,400 L/day with required time of 7 hr/day. 20,400/7= 2915 L/hr

Volume of the tanker for the first cycle for one hour equals 2915 L/hr= 3m^3

We have 7 hr/day to boil the water, so 3*7= 21 m^3 or 21000 L/day

To determine the flow capacity

$Q = {v}/{t} = {21\ m^3}/{7\ hr}$

Q = 3m^3/hr

Therefore, the pump power calculated as

$P_h = \frac{3*1000*9.81*2.7}{(3.6*10^6)}$

= 0.022 KW

We can estimate the pump efficiency from the equation

$\eta = 1-[{1.6}/{GPM * 0.27}]$ to change into gallon per minute it will be 3m^3/hr= 13.2 G/min

Efficiency of solar pump can be estimated by using the formula

$\eta = 1-[{1.6}/{13.2 * 0.27}]$

= 1- 0.448

Then efficiency becomes η= 0.55= 55%

To determine p_s (shaft power)

$\eta = {Ph}/{ps}$, where p_h is hydraulic pump power

From the above formula we get the following arrangement

$P_s = {Ph}/ 0.55$

$= {0.022\ KW}/{0.55}$

= 0.04 KW

Sizing of *Solar Pump-2* This pump is situated between the PET tanker and the cooling tower. The need for this pump is when the water is out of the PET tanker it comes out very clean but with a low pressure to reach to the cooling tower in order to increase the pressure and to facilitate the process in the cooling tower this pump is designed as follows.

Total vertical lift 2m, Calculation of friction loss, tank pressure=0 , Friction loss=0.0084*TVL

=0.0084*2m

Friction loss=0.0168m

Total dynamic head= TVL+TFL+TP

= 2m + 0.0168m

Total dynamic head= 2.0168m Hydraulic pump power will be $P_h = q*\rho*g*h/3.6*10^6$

Flow capacity Q=V/t, Q=21m^3/7hr Q=3m^3/7hr

Pump power (P_h) = 0.022KW For this pump also we can estimate the pump efficiency from the equation

$\eta = 1-[{1.6}/{13.2 * 0.27}]$ = 1- 0.448

Then efficiency becomes η= 0.55= 55%

To determine p_s (shaft power) $\eta = {Ph}/{ps}$, where p_h is hydraulic pump power Then from the above formula we get the shaft power

$P_s = {Ph}/ {0.022\ KW}/{0.55}$ = 0.04 KW Since power consumption of this pump is the same as the first pump the same motor is which has the following specification is selected

From the standard table there is no value of 0.04 KW. *Therefore, to have a greater efficiency that is 66% the selected motor have the following specification*	
P	0.185KW
η	66%
Full load rpm	1650 rpm

Torque	0.110 kg-m
Power factor	70
Amp	1
Starting torque	280
Maximum torque	250
Amp	6
Inertia	0.003 kg.m³

Table 3. Specification of selected motor for running pump

C. **PV Sizing for Solar Pumps and Fan;**

For this Standalone photovoltaic system is used

PV Sizing for Solar Pumps;- *Load determination* Ac watt.hr/day= Ac device (Watt)*hour of daily use = 80 W*7 hr = 560 Whr/day Dc watt.hr/day=AC/Whr/day/invertor loss = 560Whr/day/0.85

System-load=658.82Whr/day=

Dc.amp.hr/day= system load/system nominal voltage=658.2/12volt

= 54.9 Amp.hr/day Total amp.hr/day with batteries= total.amp.hr/day*1.2[losses and safety factor] = 54.9*1.2 = 65.88Amp.hr/day

Total PV array current =total daily.amp.hr/design isolation

= 65.88/7 = 9.41 Amps

Selection of PV module type

BP solar=solarex msx-30 After the selecting the type of the PV module we found from table from table for Msx-30, Current rating= 30 W

Current maximum voltage or peak power= 1.75A, Peak voltage = 17.1v Dimension=600mm*500mm*50m Weight= 3kg, Number of cell=18

Module determination;- Number of module= total PV array current/module operating current*module derate current For DC PV module- derate factor is from 0.8 to 1.05 $= \frac{9.41 Amp}{1.75*0.8}$

Number of module=6.74≈ 7 module

To check whether the power which comes from the sun is efficient to produce the required power or not Power $_{\text{from the sun}}$= solar radiation* area of module taking the smallest solar radiation that's on July=5.16 and

Area of the PV module= number of cell per module* cross sectional area of cell = 7*[6*5] cm² = 210 cm² or 0.021 m² By assuming the peak hour we have good solar radiation as 7 hr Power from the sun= solar radiation*area of the module = 5.16*0.021m²*$^{24}/_{7}$ = 0.37 KW Our power demand is 0.08 KW therefore we have efficient power from the sun.

I. **PV Sizing for Fan**

Ac watt.hr/day= Ac device (Watt)*hour of daily use = 372.7 W*7 hr = 2608.9 Whr/day

Dc watt.hr/day=$\frac{AC\ Whr/day}{invertor\ losses} = \frac{2608.9Whr/day}{0.85}$

System load= 3069.2

Whr/day Dc.amp.hr/day= $\frac{system\ laod}{system\ load\ voltage} = \frac{3069.2}{12volt}$ =255.7Amp.hr/day

Total amp.hr/day with batteries = total.amp.hr/day*1.2[losses and safety factor] =255.7*1.2 = 306.9Amp.hr/day

$$Total\ PV\ array\ curren = total\ daily.amp.hr/_{design\ of\ insulation}$$

$$= {}^{306.9}/_{7} = 43.84Amps$$

Selection of PV module type BP solar=solarex msx-30 After the selecting the type of the PV module we found from table from table for Msx-30. Current rating= 30 W

Current maximum voltage or peak power= 1.75A , Peak voltage= 17.1v Dimension=600mm*500mm*50m, Weight= 3kg , Number of cell=18

Module determination Number of module= $\frac{total\ PV\ array\ curren}{module\ operating\ current*module\ derated\ current}$

For DC PV module- derate factor is from 0.8 to 1.05 $=\frac{43.84Amp}{1.75*0.8}$

Number of module=31.14≈ 32 module

Area of the PV module for the fan = number of cell per module* cross sectional area of cell = 32*[6*5] cm^2 = 960 cm^2 or 0.094 m^2

The total area of the PV becomes; Area of the PV module for the fan + Area of the PV module for the pump1+ Area of the PV module for the pump2

Total area = 960 cm^2 + 210 cm^2 + 210 cm^2

= 1380cm^2 or 0.138m^2

II. **Battery Storage;- Selected type**-GC15DT 230Ah 6V Flooded Lead Acid Deep Cycle Battery , Nominal voltage= 6v, Rated capacity=230amp-hr ,Minimum battery capacity , Assume efficiency of battery is 0.9. Total daily Amp hours/day with batteries* desired reserve time/battery efficiency = (27.45* 3)/0.9 = 91.5 Amp-hrs

Number of batteries needed is only one.

Inverter selection;- Inverter is required to converter direct current to alternating current. If the power rating of inverter is less than the total power of electrical load our system will be overloaded so the inverter rating should be 25%-30% greater than the power of appliances

D. Sizing of cooling tower

There are two types of cooling towers mechanical draft and natural draft cooling towers, from those types of cooling towers we selected mechanical draft cooling tower that is induced draft cooling tower. a high efficiency fans is used to suck the air from the bottom of the cooling tower and it discharges air to atmosphere at high velocities. By using cooling towers, the water can be cooled up to its wet bulb temperature.

The parameters used to determine the cooling tower performance are;

I. *Range*; this is the difference between the cooling tower water inlet and outlet temperature. A high CT Range means that the cooling tower has been able to reduce the water temperature effectively, and is thus performing well. The formula is:

CT Range (°C) = [CW inlet temp (°C) – CW outlet temp (°C)]

Cooling water inlet=55^{0}c

Cooling water outlet=15^{0}c

CT Range (°C) = [CW inlet temp (°C) – CW outlet temp (°C)]

= 55 ^{0}c - 15 ^{0}c

CT Range °C = 30^0 c

II. ***Approach;*** is the difference between the cooling tower outlet cold-water temperature and ambient wet bulb temperature. The lower the approach the better the cooling tower performance and although, both range and approach should be monitored, because the `Approach' is a better indicator of cooling tower performance, the formula is:

CT Approach (°C) = [CW outlet temp (°C) – Wet bulb temp (°C)]

Wet bulb temperature=25 ^{0}c

Cooling water outlet=15^0 c

CT Approach (°C) = 25 ^{0}c – 15 ^{0}c

CT Approach (°C) = 5^{0}c

III. ***Effectiveness;*** is the ratio between the range and the ideal range (in percentage), for example difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach), the higher the ratio is, the higher the cooling tower effectiveness.

CT Effectiveness (%) = $\frac{range}{range+approach} * 100$

CT Effectiveness (%) = $\left(\frac{30}{30+5}\right)100$ = 85.7%

IV. ***Cooling capacity***; is the heat rejected in kcal/hr or TR, given as

Cooling capacity = mass flow rate of water* specific heat *temperature difference

Specific heat of water =4.184j/g^{0}c

Mass flow rate of water =3m^3/hr

Cooling capacity =3m^3/hr * 1.00cal/g^{0}c * (55-15)

Cooling capacity = 120 cal/g^{0}c or 0.12Kcal/g^{0}c

V. ***Evaporation loss***; is the water quantity evaporated for cooling duty, Theoretically the evaporation quantity works out to 1.8m^3 for every 1,000,000 kCal heat rejected. The following formula can be used Evaporation loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T1-T2) $T_1 - T_2$ = temperature difference between inlet and outlet water Evaporation loss (m^3/hr) = 0.00085 x 1.8 x 3m^3/hr x (55-15)

Evaporation loss (m^3/hr) = 0.102 m^3/hr

VI. **Cooling tower efficiency;** mostly cooling tower efficiency will range from 60% -75%

$$\mu = \left(\frac{(Ti-Twb)}{(Ti-To)}\right)*100, \quad \mu = \frac{(55-20)}{(55-15)} *100$$

$\mu = 75\%$, Therefore, the cooling tower has maximum cooling efficiency.

6. RESULT AND DISCUSSION

The water from river is diverted and inters to the dam and the cover of the dam has a filter in order to protect the dam from the dust particle. And after it settles down its pumped to Flat-plate collectors for solar water heating purpose the angle will vary according to geographical location, but for Sardo kebel the calculated tilt angle of the collector is 17^0 and for better installation and to get maximum solar radiation we chose the tilt angle 20^0. For this water purification purpose 51 modules of collector in which each have area of 4m^2 can be installed by parallel series arrangement. the PV size is 0.05m^2 it should be properly ground in order to reduce the threat of shock hazards and induced surges. Solar pump types include diaphragm, helical rotor (HR), rotary vane and piston pumps. In this project we have 2 pumps the first one is submersible pump which has total vertical head of 2.5m and it's installed after the dam and it pumps water from the dam to the solar heater. And the second one is installed between PET and cooling towers which are used to pump the water from PET to the cooling tower with the total vertical head of 2m.

Results obtained from the sizing of water Plant proposed

Component	***Description of component***	***Result***
Dam	Area of this dam is7m*3m=	21m^2
	Volume with depth of 1m	21m^3
Flat plate collector	No of module	51
	Total area of the collector	204m^2
PV photovoltaic	Are of the panel	0.05m^2
Two solar powered Pumps	Submerging water pump dam from river to dam.(vertical head)	2.5m
	Pumps from PET to Cooling Tower	2m
PET	PET Volume polyethylene tryphalate volume, depth	3m^3
Cooling tower	Length from ground height	0.5m
	Volume of tower 1.5m*2m*1m	3m^3

7. REFERENCES

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BIOGRAPHIES

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