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RESEARCH ARTICLE OPEN ACCESS

Solar Pumps: A Solution to Improving Water Security in Mountainous Region of Uttarakhand, India

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ABSTRACT
Water is an essential part for all living creatures. There is no water in other planets so there is no life. But irony is when someone lives in that area which is surrounded by worlds one of the biggest water system but has to walk up and down in hills for fetching water. In this study, a water pumping system is introduced for combating this situation. Deployment of solar PV based water pumping is used because it is pollutant free and the price of clean energy sources are decreasing day be day. Solar system is best alternative to age old conventional systems which were costly and they emits greenhouse gases. This paper consists of a proposed design and calculation of a efficient solar based water pumping system for drinking and daily use. The region opted for this study and analysis is 30.283^0N Latitude and 79.016^0E Longitude in Mid Himalayan range of Uttarakhand ,India. The designing of PV based water pumping system is done in such a way that it can capable of supplying water in a village which has a population of 100 people. All these analysis are done while keeping in view the probable growth of population and reliable performance of our system for that supply. These measures will open the door a lot and will circulate economy of that region to a degree.
Keywords – domestic application, Himalayan region- Uttarakhand, rural development, solar water pumping, water crisis

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I. INTRODUCTION

Water is a big part of every living creature's life. Mother Nature provided fresh water to everyone in solid, liquid and gas all form. But due to human blatant activities we are losing our fresh water resources. This problem is so severe that the Himalayan range villages where water should be available throughout the year are facing difficulties. Recently we saw an article on 'The Hindu' dated 28May 2018 that 'the Shimla in the throes of a water crisis'. This problem is not only limited to Shimla region but spread across the whole Shivalik and Mid Himalayan range. Major cause of this problem are deforestation, jungle fire caught in midst of summer, many water resources are contaminated (main cause in Shimla), government policies etc. For human, upcoming years are going to be succumbing years to nature.

Another big part of our life is electricity. We are using more fossil fuels rather than renewable energy sources which scourge of pollution. But some years down the line, more intense research on renewable energy will make fossil fuel passé. Solar is main source of natural energy. Earth gets 175petawatts of incoming solar radiation in upper most atmospheres. And world's population lives in a area where

insulation level is 3.5-7.0 K-Wh/m^2 (Fig. 1) which is sufficient condition for working a solar panel.

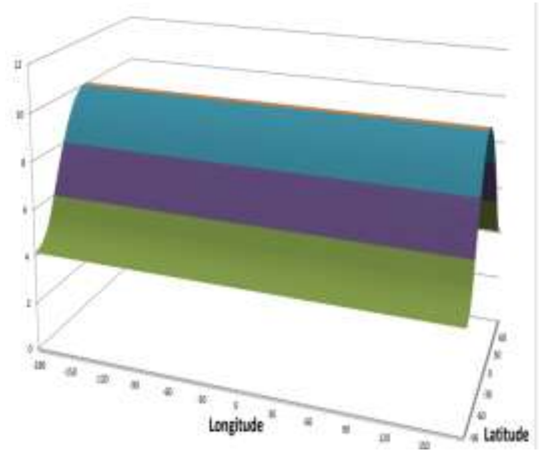

Fig:1 Source: NASA Surface Meteorology and Solar Energy (SSE) Data

Some advantages of solar water pumping is follows:
- Renewable energy source
- Very low maintenance cost

- No fuel cost
- No pollution
- Easy to install
- No inflation burden
- Reliable warranty of 20+ years

This study will focus on a particular geographical location in Uttarakhand which is described in next heading. A typical and simple solar water pumping system is shown in fig 2.

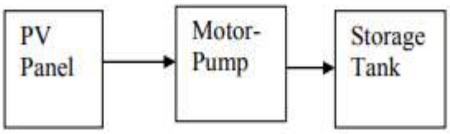

Fig 2: Simple solar water pumping

II. GEOGRAPHICAL LOCATION

Agastmuni a small town ($30.283^{0'}$N 79.016^{0}E, elevation 4334ft) in Garhwal hills of Ruderprayag district is situated in the bank of river Mandakni which is a main tributary of Alaknanda river which itself a main water source body of Ganga river. Mandakni river originates from Chorabari glacier near Kedarnath. Being a part of Himalayan river system, it never dries up despite of seasonal condition. And also it has Class 3 rapids, some class 4 rapids and some very strong class 5 rapids which indicate strong water turbulent. An another small town Nagnath Chopta (Elevation 5166ft) which is aprrox 12Km far from Agastmuni is situated in a water prone area. It has a very steep slope towards Alaknanda river side and gentle slope on Mandakni river.(fig 2) It also faces acute water crisis especially in summer months and problem is so serious that people of this region are relay on government's water tanker.. This study will measure the cost of water supply per 500m basis.

Solar radiation data of Agastmuni for whole year is shown below (Table 1) which clearly indicate that solar radiation of that area is feasible for solar energy all year long.

Fig 3: Location of test site

Table 1: Daily Solar radiation horizontal kWh/m^2/day data of Longitude 30.28^0 N and Latitude 79.01^0E

Month	Radiation(kWh/m^2/day)	Month	Radiation(kWh/m^2/day)
Jan	3.75	July	5.36
Feb	4.50	Aug	4.83
Mar	5.64	Sep	5.25
Apr	6.76	Oct	5.42
May	7.42	Nov	4.49
June	6.73	Dec	3.69

Source: NASA Atmospheric Science Data Center

From the table 1, the annual average value of radiation for the location (Agastmuni) is 5.325 kWh/m^2/day. This data is very helpful to design the solar power system because it provides peak sun hour.

According to PVsyst simulation software the sun path in Agastmuni is shown in fig 4

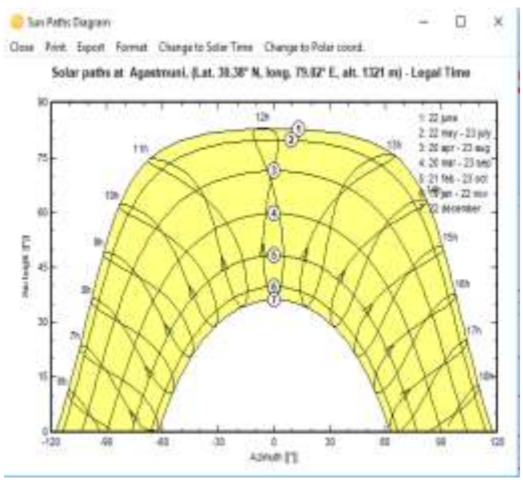

Fig 4: Sun path of site location

III. METHODOLOGY

It can divided into following steps:

2.1 Step 1: Water Requirement

A World Health Organization (WHO) report shows that on average a human being needs 70Liter of water daily. A Maslow's hierarchy shows below.

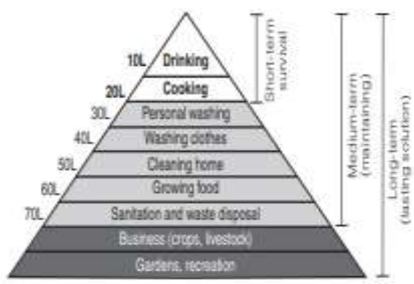

Fig 5: Average water need for human

According to Grass Fed solution report data of water requirement for different cattle is shown in Table 2.
In our study we take a test village which has a population of 100 humans and 100 cattle. Fig 2 shows that an average water for human is 70L per day (including drinking, washing, household work) and Table 2 gives an idea about water requirement for a cattle is 13.2 gallon (50L/day).

Cattle Age / Weight Group	Daily Cattle Water Requirements gpd ([illegible]) gallons per day ([illegible])
Dry Cows & Heifers	6-15 gpd ([illegible])
Lactating Cows	11-18 gpd ([illegible])
Bulls	7-19 gpd ([illegible])
Growing Cattle (400 lbs)	3.5-10 gpd ([illegible])
Growing Cattle (600 lbs)	5-14.5 gpd ([illegible])
Growing Cattle (800 lbs)	6-17.5 gpd ([illegible])
Finishing Cattle (1000 lbs)	8.5-20.5 gpd ([illegible])
Finishing Cattle (1200 lbs)	9.5-23 gpd ([illegible])
Dairy Cattle	10-25 gpd ([illegible])

Table 2: Average water need for cattle

So Water requirement for 100 human being are 70*100 = 7000 L per day
Water Requirement for cattle are 50*100 = 5000L per day
Hence total water requirement for village is 7000 + 5000 = **12000L per day**

3.2 Step 2: Water Source

Water source can be two types- one is running water sources like rivers and second is static water sources like pond.

In this study, a hill river is taken for water source which flows throughout the year. A small tank can be made in riverbank to treat the water so that silk and stone will sit on the floor and water will be mud and sand free.

3.3 Step 3: Water Resources

If there will be a tank in every 500 meter distance. Then capacity of tank should contain at least minimum 3-4 days water. If there will be more requirement for water supply in near future due to population growth, storage tank should be capable for fulfillment of need. And also in adverse weather condition or no sunny day for a long time, tank capacity should be capable of supplying at least for3-4 days.
So water storage capacity for a tank is 12000*4 =**48000 Liter (48 cubic meter)**

3.4 Step 4: PV panel location

PV panel location can be made in a open field and a small tank to purify the water can be made in river bank. Both field and river bank location is shown in fig 6

Fig 6: Solar panel location in Agastmuni town

3.5 Step 5: Flow rate for the pump

Flow rate for pump is calculated by dividing total water requirement per day by peak sun hour. The average peak sun hour in Ayugustmuni is 5.325 hour (Table 1)
Hence

$$\frac{12000\ L\ per\ day}{5.325} = 2253.52L\ per\ hour(2.25\ m^3\ per\ hour)$$

3.6: **Step 6:** Total Dynamic head

Total Dynamic head is described as sum of vertical lift, friction loss and other loss

TDH= Vertical lift + Friction head + other losses (1)

If we calculate both location's altitude (Chopta has 5166ft and Agastmuni has 4334ft) from sea level and calculate difference is 832ft or 254 meter. Distance between both two town is approx 12km.So average vertical head for every per 500meter is 10.58 m per 500 m.

Friction loss is the loss of pressure due to friction of water which flows through pipe. It is totally depending upon pipe size (inside diameter), flow rate, Length of the pipe and pipe roughness. By observing the Fig 7 graph shows that 2.25 m^3 per hour (37.56 L per min) with 40 mm diameter has a friction loss of 0.9m/100m.For 500 meter of length friction loss would be 4.5 meter. If we choose steel pipe then it will become 1.3*4.5=5.85 meter (For steel pipe multiply the no of 1.3) [14] and approximately 3 meter loss in various elbows and valves.

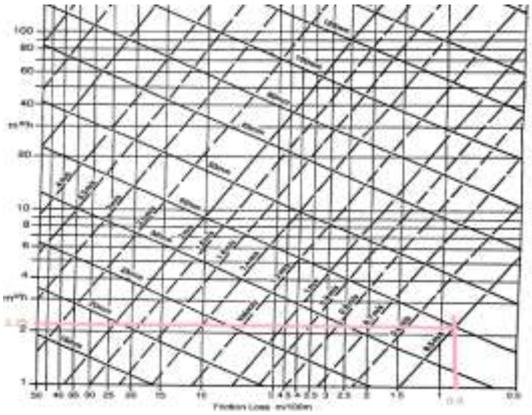

Fig 7 Different friction head for 3 mm diameter metric size pumping Source : http://www.mcnallyinstitute.com/Charts/metric_friction_loses.html

Therefore the TDH = 10.58 meter + 5.85 meter +3 meter+5 meter (tank height) = 25 meter

3.7 Step 7: Pump power requirement

The formula for power requirement is

$$P_h = \frac{q.p.g.h}{3,600}$$

(2)

Where P_h = hydraulic power (W) [16]

q= flow capacity (m^3/h)=2.25 m^3 per hour

p=density of fluid (kg/m^3)=1000kg/m^3(water)

g= 9.81m/s^2

h= TDH= 25 meter

Hence $2.25 * 1000 * 9.81 * 25 = 551812.5 Nm/hr$

1W=3600N-m/h

So Required power is 153.28 W

A pump converts the mechanical energy to hydraulic energy with an average efficiency of 45 %.

DC Motor converts electrical energy to mechanical energy with an average efficiency of 55%.[16]

Electrical power required= (hydraulic power) / (η_{pump} × η_{motor}) (3)

= 619.31 W

Pump run for 5 hour energy requirement = 619.31 ×5 W-hr /day = 3096.6 W-hr/day

3.8 Step 8: Photovoltaic panel sizing

PV-power tolerance: -10%/+10% [17]

Heat loss: 10% [18]

Dirt loss: 2-15% [19]

Wiring loss: 2-10%

Inverter/charger loss: 2-15%

Batteries: 30%

Here considered average loss

PV power loss: 5%

Heat loss: 10%

Dirt loss: 10%

Wiring loss: 5%

Inverter loss and battery loss not included to make our system as simple as possible according to rural development

Total loss = 30%

Energy requirement = 3096.6W-hr/day

After including 30% for losses,

Total requirement of energy =3096.6*1.30 = 4025.58 W-hr/day

Peak sun hour =5.325 hours/day

Recommended wattage for PV panel = (4025.58) / (5.325) =755.98 W (756 W)

3.9 Step 9: Sizing of solar power supply system

The power supply system was a system adopted with a standalone system with no battery backup and no any other storage device. It is because to make a simple and a cost effective robust system. Many manufactures recommend taking 25% margin for any potential reduction due to high heat, dust, weather condition. [20] [21]

Thus: Installed solar panel power= Required power * 1.25 (4)

= 756* 1.25 = 945 W

A solar panel is generally having 12V, 24V voltage which is connected in series to make highr voltage and power. A economic evaluation of solar water pumping as Indian standard are shown inn table 3

Table 3 PV panel specification as per MNRE guideline for 945W solar panel [23]

.S.No.	Specification	Value
1	Input	DC
2	Min Input Power	1200 W(For 1 hp pump)
3	Max input DC voltage	410 Vdc
4	MPPT voltage	150-360 Vdc
5	MPPT efficiency	99%
6	Applicable motor	1 hp

A typical 36 cell ARKA series mono crystalline 60 module specifications given below in table 4

Table 4: Data of a ARKA series PV module [24]

S.No.	Specification WS-75/ 24V	Value
1	Nominal max power	74 W
2	Open circuit voltage	43.80 V
3	Short circuit current	2.25 A
4	Max system voltage	1000 V
5	Voltage at max power	35.35V
6	Current at max power	2.10A

IV. CONCLUSION & FUTURE WORK

Following results have been made of from PV solar water pumping feasibility analysis of Ayugustmuni region of Uttarakhand state. India:

- Final result of our analysis is shown in Table 5

Table 5: PV water pumping system specification

S. No.	Specification	Detail
1	Type	DC
2	Pump type	Submersible
3	Head	25 meter
4	Water flow	2.25 cubic meter per hour
5	Pipe diameter	Steel 40mm
6	Daily water requirement	12000 L per day
7	Water storage capacity	48000 Leter
8	Power requirement	945 W
9	Capital cost of PV(Including GST)	1,47,000 Rs for 1hp motor[25]

- Maintenance cost per year is given as = depiction cost * Capital cost [22] (5)
  = 0.1*147000= 14700Rs.

To further minimize the laborer cost we can use workforce from MANREGA which is India's largest ongoing scheme for guarantee of work scheme under ministry of rural development. It will also boost employment for both skilled and unskilled workers of surrounding areas.

- Although its initial cost is comparably high but in a long run like 20+yrs, it is a cheap source of water pumping. Also Indian government has invested heavily in solar energy so subsidy will reduces solar water pumping cost even further.
- Due to green energy device, it will set an example for other Himalayan regions because Himalayan glaciers are melting fast as never before.
- Further study can be done to integrate with national grid to sell surplus power.
- A proposal can be send to water supply department of Uttarakhand state to practically implement for this project

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