International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 12 Ver. IV || Dec 2018 || PP 17-23

Water Security through Solar PV Water Pumping in Uttarakhand, India

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Abstract: *Water is an essential part for all living creatures. But irony is when someone lives in that area which is surrounded by world's one of the biggest water system but has to walk up and down the hills for fetching water.This work helps evaluating interest of solar PV water pumping in the hill town of TIlwara., Uttarakhand which will satisfy the average daily need of 15.50 cubic meter of water to a village which is 500 meter far from Tilwara town and also calculate the life cycle cost for a life span of 20 years. The cost per cubic meter was calculated for different system which came out to be RS. 12.593 for PV solar pumping system without subsidy and Rs. 10.839 for PV solar pumping system with subsidy.*

Keywords - *LCC cost , Solar PV, Solar radiation, ,Subsidy, Total dynamic height, Uttarakhand*

Date of Submission: 13-12-2018 Date of acceptance: 28-12-2018

I. Introduction

If the world doesn't decrease its water intensive electricity production which causes widespread drought then in not more then 30 years world will face severe water crisis. Until countries take mature actions, the demands of drinking water and energy demand will cause incisive water shortages around the world. Over the past hundred years, the world's population has increased three times but there has been a six fold increase in water consumption. If present trends continue there could be a 40% gap between water supply and demand by 2030. The effects of increasing water consumption will be made even worse by climate change.“Three years of research show that by the year 2040 there will not be enough water in the world to quench the thirst of the world population and keep the current energy and power solutions going if we continue doing what we are doing today,”said Bejamin Sovacool, director of the Center for Energy Technology at Aarhus University in reference to the dual reports released Tuesday. The report recommended that nuclear power and coal, which use an excessive amount of water for cooling purposes, should where possible be replaced by wind and solar, which use virtually no water. In northern India, groundwater supplies are being depleted faster than natural processes can replenish them. According to The World Bank, after China India is the largest user of ground water in the world. If something is not done soon, an estimated 114 million Indians will soon face desperate domestic, agricultural and industrial shortages

Another crisis which is increasing today's world is energy crisis. The world is running towards the clean and renewable energy, Solar energy has the big chunk of renewable energy. The Sun is an extremely powerful energy source, and sunlight is by far the largest source of energy received by earth, but its intensity at Earth's surface is actually quite low. This is essentially because of the enormous radial spreading of radiation from the distant Sun. A relatively minor additional loss is due to Earth's atmosphere and clouds, which absorb or scatter as much as 54 % of the incoming sunlight. The sunlight that reaches the ground consists of nearly 50 percent visible light, 45 percent infrared radiation, and smaller amounts of ultraviolet and other forms of electromagnetic radiation.

II. Introduction to problem & Geographical Location

Tilwara 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 Tilwara 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 Tilwara 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.

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

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 2.1

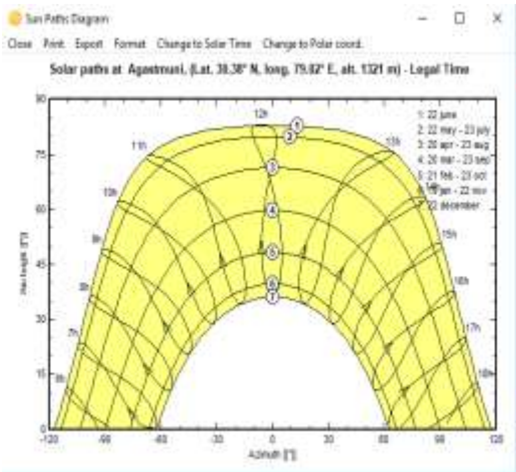

Fig 2.1: Sun path of site location

III. Methodology

3.1 Step 1: Water requirement

A WHO report published in 2011 made a Maslow's hierarchy chart shows that a human being needs 70 Liter of water daily. According to Grass Fed Solution report on domestic animal showed different water requirement for different cattle. In this study we are taking on average of 50 Liter(13.2 gallon) of water daily. In our test village we are considering that village has a population of 150 humans and 100 cattles. Hence Total water requirement for village is (150*70+100*50) = 15500L per day

3.2 Water Source and water needed for storage

Geographical location shows that our water source is a running Himalayan river called Mandakni, This river has continuous water flow 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. If there will be tank in every 500m distance, 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 15500*4 =**62000 Liter (62 cubic meter)**

3.3 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 3.1**

Fig 3.1: PV panel location

3.4 **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 Tilwara is 5.325 hour (Table 5.2)

Hence $\frac{15500}{5.325} = 2910.8 \text{ liter per hour}(2.91 \text{ cubic meter per hour})$

3.5: Total Dynamic head

TDH= Vertical lift + Friction head + other losses

If we calculate both location's altitude (Chopta has 5166ft and Tilwara 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 3.2 graph shows that 2.91 m^3 per hour (48.51 L per min) with 40 mm diameter has a friction loss of 1.4 m/100m.For 500 meter of length friction loss would be 7 meter. If we choose steel pipe then it will become 1.3*7=9.1 meter (For steel pipe multiply the no of 1.3) and approximately 3 meter loss in various elbows and valves.

Fig 3.2 Friction loss graph

Therefore the TDH = 10.58 meter + 9.1 meter +3.3 meter+ 5 meter (tank height) = 28 meter

3.6: Pump power requirement

The formula for power requirement is

$$P_h = \frac{q.p.g.h}{3600} \quad (1)$$

Where P_h = hydraulic power (W)

q= flow capacity (m^3/h)=2.91 m^3 per hour

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

g= 9.81m/s^2

h= TDH= 28 meter

Hence $2.91 * 1000 * 9.81 * 28 = 799318.8 \text{Nm/hour}$
1W=3600N-m/h
so required power is **222.033** W
A pump converts mechanical energy to hydraulic energy with 45 % of average efficiency.
DC Motor converts the electrical energy to mechanical energy with 55% of average efficiency
Electrical power required= (hydraulic power) / ($\eta_{pump} \times \eta_{motor}$) (2)
= 897.103W
Pump run for 5 hour energy requirement = 897.103 ×5 W-hr /day = 4485.52 W-hr/day

3.7: Photovoltaic panel sizing
Here considered average loss
PV power loss: 5%
Heat loss: 10%
Dirt loss: 10%
Wiring loss: 5%
Inverter loss: 8%%
Battery loss: 30%
Total loss = 60%
Energy requirement = 4485.52W-hr/day
after including 60% for losses,
Hence Total requirement of energy =4485.52*1.60 = 7176.82 W-hr/day Peak sun hour =5.325 hours/day
Recommended wattage for PV panel = (7176.82) / (5.325) =1347.76 W (1348 W)

3.8: 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.
Thus: Installed solar panel power= Required power * 1.25 (3)
= 1347.76* 1.25 = 1684.7 W
A minimum 2hp submersible PV water pumping set is needed to produce 1685W power

IV. LCC Analysis of Solar PV water pumping

4.1 Capital Cost:
In India, generally a 2hp solar pumping set would cost Rs. 2, 10,000 (+GST 5%). Which will be sum of Rs. 2,20,500 (including installation charges + transportation charges) **(fig 4.1)**

Fig 4.1: A typical 2hp solar pump specification in India
Source:https://solarenergypanels.in/price-list/solar-water-pumps-price-1-2-3-5-10-hp(Kenbrook solution)

But according to a report published in ECONOMIC TIMES Energy World report dated Feb 03, 2018 stated that under the scheme of New and Renewable Ministry OF GOI total 90% subsidy will be given to purchase solar pump set. Farmers will effectively bear only 10% of capital cost said Power Minister R. K. Singh

(Fig 4.2) which was unveiled in Budget 2018-19. 90% subsidy will complete by combined of NABARD, GOI and state government.

Fig: 4.2: A report on Economic Times

Source: https://energy.economictimes.indiatimes.com/news/power/farmers-to-pay-only-10-cost-of-solar-pumps-under-budget-scheme-minister/62765093

Hence total capital cost after subsidy will be = 220500*0.1 = Rs. 22050

4.2 Maintenance Cost:

Maintenance cost for solar PV pump in every year is = Deprecation Rate * Capital Cost = 0.001 * 220500 = Rs. 220.5 (4)

Land rent cost = 5000 *12 = Rs 60000

Total Maintenance cost per year is Rs.60220.5

4.3 **Fuel Cost**: No fuel is needed.

4.4 **Replacement Cost**: We are taking our analysis for a life span of 20 years and PV solar pump has life cycle of 20 years. So no need of replacement.

4.5 **Salvage Cost**: We are not going to change solar pump in between of 20 years. So no need to included salvage cost for PV solar pump

Total cumulative cost (Without Subsidy) of PV solar pump for 20 years is given in table 4.1

Table 4.1: Total Cost (Without Subsidy)

Year	Capital Cost (in Rs)	Maintenance Cost (in Rs.)	Fuel Cost (in Rs.)	Replacement Cost (in Rs.)	Total Cost (in Rs.)
0	220500.00	0	0	0	220500.00
1	0	60220.50	0	0	280720.50
2	0	60220.50	0	0	340941.00
3	0	60220.50	0	0	401161.50
4	0	60220.50	0	0	461382.00
5	0	60220.50	0	0	521602.50
6	0	60220.50	0	0	581823.00
7	0	60220.50	0	0	642043.50
8	0	60220.50	0	0	702264.00
9	0	60220.50	0	0	762484.50
10	0	60220.50	0	0	822705.00
11	0	60220.50	0	0	882925.50
12	0	60220.50	0	0	943146.00
13	0	60220.50	0	0	1003366.50
14	0	60220.50	0	0	1063587.00
15	0	60220.50	0	0	1123807.50
16	0	60220.50	0	0	1184028.00
17	0	60220.50	0	0	1244248.50
18	0	60220.50	0	0	1304469.00
19	0	60220.50	0	0	1364689.50
20	0	60220.50	0	0	1424910.00
Total	220500.00	1204410.00	0	0	1424910.00

LCC cost per cubic meter water requirement is 1424910/113150 = **Rs. 12.593 per cubic meter**

Total cumulative cost (With Subsidy) of PV solar pump for 20 years is given in table 4.2

Table 4.2: Total Cost (With Subsidy)

Year	Capital Cost (in Rs)	Maintenance Cost (in Rs.)	Fuel Cost (in Rs.)	Replacement Cost (in Rs.)	Total Cost (in Rs.)
0	22050.00	0	0	0	22050.00
1	0	60220.50	0	0	82270.50
2	0	60220.50	0	0	142491.00
3	0	60220.50	0	0	202711.50
4	0	60220.50	0	0	262932.00
5	0	60220.50	0	0	323152.50

6	**0**	**60220.50**	**0**	**0**	**383373.00**
7	**0**	**60220.50**	**0**	**0**	**443593.50**
8	**0**	**60220.50**	**0**	**0**	**503814.00**
9	**0**	**60220.50**	**0**	**0**	**564034.50**
10	**0**	**60220.50**	**0**	**0**	**624255.00**
11	**0**	**60220.50**	**0**	**0**	**684475.50**
12	**0**	**60220.50**	**0**	**0**	**744696.00**
13	**0**	**60220.50**	**0**	**0**	**804916.50**
14	**0**	**60220.50**	**0**	**0**	**865137.00**
15	**0**	**60220.50**	**0**	**0**	**925357.50**
16	**0**	**60220.50**	**0**	**0**	**985578.00**
17	**0**	**60220.50**	**0**	**0**	**1045798.50**
18	**0**	**60220.50**	**0**	**0**	**1106019.00**
19	**0**	**60220.50**	**0**	**0**	**1166239.50**
20	**0**	**60220.50**	**0**	**0**	**1226460.00**
Total	**22050.00**	**1204410.00**	**0**	**0**	**1226460.00**

LCC cost per cubic meter water requirement is 1226460/113150 = **Rs. 10.839 per cubic meter**

V. Conclusion

Major points to be concluded in this thesis are given below:

- Output of solar PV pumping system is much dependent on accurate site geographical location and good system designed. This paper focused on a specified location which geographical coordinate are defined and solar data of this site are taken from reliable sources. Study focused on a village which population is assumed to be 150 humans and 100 cattle. Water requirement of this village is 15500 liter per day with a vertical head of 10.58 meter. Water source is a river which is a part of Himalayan river system. So no need to worry about water deficiency problem or slow downstream flow rate problem.
- Total life cycle cost comparison between PV solar pumping system (with and without subsidy) is shown in Fig.5.1. Total cost at initial year i.e. o year of installation and at the end of 20 years is compared for both the pumping system. Shown in Fig 5.2.
- Capital costs are taken from India's commercial market as per MNRE guideline.

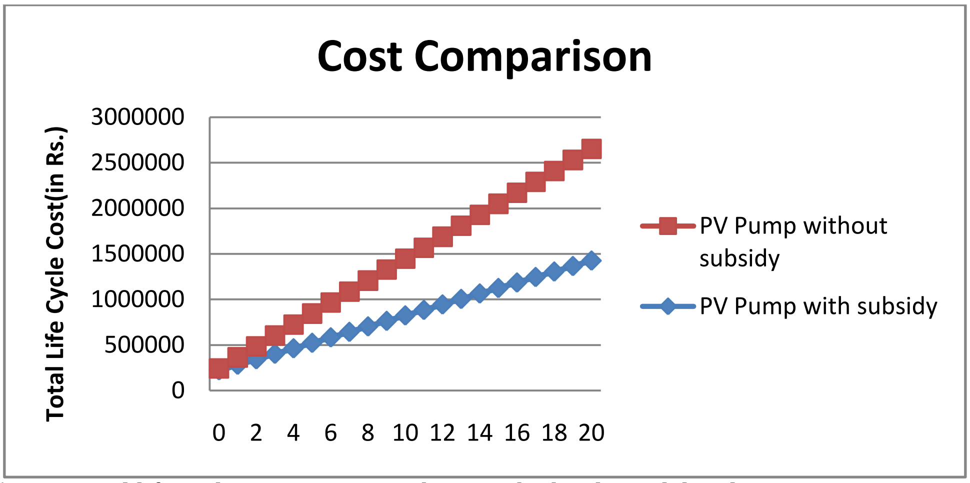

Fig 5.1: Total life cycle cost comparison between both solar and diesel water pumping system

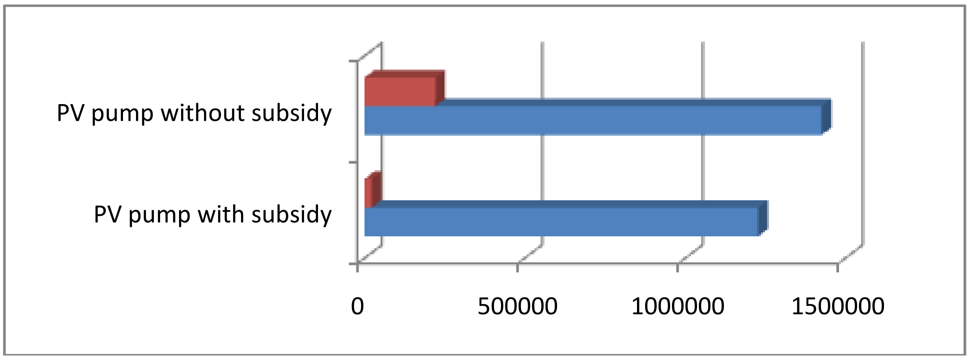

Fig 5.2: Cost comparison in 0 year and 20 year of both solar and diesel pumping set

LCC cost per cubic meter for 20 years is calculated as Rs.12.593 for Solar PV water pumping system (without subsidy), Rs.10.839 for Solar PV water pumping system (with subsidy).
By observing the analysis and result of this thesis, It is clearly visible that for a longer life span of 20 years, whether solar pumping system considered with subsidy or without subsidy remain cheap and affordable system for supplying water in mountainous region of Uttarakhand.

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