A Study on the Present Scenario of Solar Irrigation in Bangladesh

Al-Amin, Tasmiah Fatema Tanni, Dr.Md. Habibur Rahman, Miah Md. Asaduzzaman, Md. Abdullah Al Matin

Abstract - Bangladesh has a primarily agrarian economy. Irrigation plays a very important role in our agriculture as well as on economy. During dry season, irrigation of the whole country faces an acute crisis due to load shedding of 1400 MW [1]. As Bangladesh has good solar resources, with high availability during the peak irrigation season, therefore, solar pumping of water for irrigation is an innovative and environment-friendly solution for its largely agro-based economy. Infrastructure Development Company Ltd (IDCOL) is providing financial support to solar irrigation. Already 450 irrigation pumps have been installed by IDCOL in different divisions of Bangladesh. In this paper, 450 project's data has been analyzed and the findings are shown by different graphs. Different division's radiation, water-head and required water are mainly focused in the analysis which will be very useful for upcoming irrigation projects. To accomplish the analysis on solar irrigation, several field visits were done at Poradaho, Kushtia, Bangladesh. This is a project of Bright Green Energy Foundation (BGEF) and financed by IDCOL. Numerous important prospects of solar irrigation besides Diesel-based Irrigation in Bangladesh have come out from this comparative study.

Keywords -Solar Irrigation, Field survey, Solar Pump, Diesel Pump, Cost analysis, Extra Energy, Bangladesh.

1 INTRODUCTION

Bangladesh has good solar resources, with high availability during the peak irrigation season. As a result, solar pumping of water for irrigation presents an innovative and environment-friendly solution for its largely agro-based economy. The country has about 1.71 million irrigation pumps, of which 83% run on diesel. The remaining 17 % are electricity-operated. The demand for irrigation is concentrated during February-March. So much so that during the peak irrigation period 2000 MW of power demand is solely required for running the electric pumps [2]. The diesel-run irrigation pumps on the other end consume more than half a million tons of diesel. This comes at a great cost to the exchequer as Bangladesh imports 100% of its diesel requirement which is then distributed to the users at a highly subsidized price.

On the basis of life cycle costs, solar irrigation pumps are much more attractive compared to diesel pumps. In addition to this, PV pumping systems allow low operating cost, unattended operation, low maintenance, easy installation, and long life.

These advantages are especially important in remote rural areas which are yet to be grid connected. The initial high cost is the biggest barrier to adoption. To overcome this, IDCOL has been experimenting with both a 'water as a service' (community) model and 'individually owned small size pumps' model. To accelerate the number of installations, a large part of the capital cost is being provided as a combination of grant and soft loan. IDCOL is providing financial support to solar irrigation projects based on a debt, equity and grant ratio of 30:20:50. As the uptake of solar pumps increases, the aid amount will be gradually reduced.

- *Al-Amin.Lecturer,DepartmentofEEE.City University.Bangladesh E-mail: shuvoalamin784@gmail.com*
- *Tasmiah Fatema Tanni.Lecturer,Department of EEE.University of Information, Technology and Sciences.Bangladesh E-mail: tanni.tasmiah@gmail.com*
- *Dr. Md. Habibur Rahman.Professor,Department of EEE.University of Dhaka.Bangladesh E-mail: mhabib@du.ac.bd*
- *Miah Md. Asaduzzan.Assistant Professor,Department of EEE.Metropolitan University.Bangladesh E-mail: mzaman@metrouni.edu.bd*
- *Md. Abdullah Al Matin.Assistant Manager,Technical, Renewable Energy,IDCOL,Bangladesh E-mail: matin@idcol.org*

2 SOLAR IRRIGATION SCENERIO IN KUSHTIA DISTRICT

In the face of tremendous social, economic and political pressure to solve power crisis in Bangladesh it has become critically important to look for energy solutions beyond the conventional sources like domestic natural gas, coals, hydroelectricity and imported fuels. Irrigation plays a vital role in our social economy. Solar irrigation can be the best solution. In this regards IDCOL helps us a lot by giving proper information about their different survey. Bright Green Energy Foundation (BGEF) is one of the partner organizations of IDCOL. One of the project of BGEF has been visited by ourselves. Our main focus is to study the performance of a practical solar water pumping system. Different features of a working water pump have been studied. Farmers have shared their feelings about their experience using solar pump and diesel pump. Among

several projects of BGEF we selected a large project which is situated at Kushtia. The following figure is the photograph of the project signboard.

2.1 Overview of the Project:

Location	Tegoria, Kushtia
Water head	10-20m
Solar Panel Capacity	19.2KWp
Water discharge rate	15-18 lac lit/day
Crop	Different
Tracking	No
Area coverage	125 bigha
Borewel pipe dia	12m
Pump	13K
Duration	6am - 6pm
Farmer	30-40

Table-1: Project Overview

3 WATER-SUPPLY SYSTEM FOR IRRIGATION IN KUSHTIA DISTRICT

As Kushtia is quite a low lying land, water is found in just 60 ft. below the ground. Still the pumps have boring up to 240 ft. The boring has been this deep because of the uncertainty of water level which may go down below a lot more than 60 ft. The 240 ft. boring is divided into 120 ft. of filter and 120 ft. of blank pipe. It is not that the filtered pipe runs along 120ft and after that it is 120 ft. blank pipe rather it is a hefty mixture of the both. When water is raised by the pump, it flows through a 12 inch diameter pipe. Then the water travels through 8 inch diameter pipe which leads to a header tank through an 8-inch diameter pipe which goes underground and the water travels to the rising valve. This valve determines how much water gets out of the system. Between Header tank and rising valves there are gas pipes which takes out the gas bubbles remaining in water [8,9].

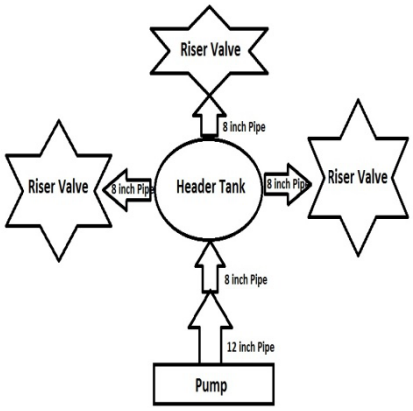

Fig. 1. Water suppling system for irrigation of that visited area along with pipe diameters.

3.1 Discussion with Farmers

A. Several visits were done in the project area for data collection and better understanding of the real picture. Cultivating Boro, a breed of peddy, is expensive while much cannot be earned by selling them. Farmers prefer cultivating tobacco, wheat, Lentils. But in real scenario cultivating tobacco for a long term is unhealthy for the soil.

Noticeable findings from the site visit:

- The Owners still consider solar pump as a deficient and lossy system
- Use of extra energy
- Battery charging station
- Rice husking
- Mini grid
- Utilization of land under panel
- Problems with solar irrigation

3.2 Comparison between Diesel pump and Solar pump

PV based irrigation can be economically competitive (even less expensive) when compared to diesel based irrigation system [3]. While talking with farmers various information has been collected about diesel pump and solar pump. They have shared their experience about growing crops using those. Here the difference has been shown between them:

Issues	Diesel pump		Solar pump
Land area	1 bigha		1 bigha
Irrigation	1 time		1 time
Cost 1bigha and 1 irrigation	Engine rent	Diesel price	3 months, total 50 times irrigation cost= 3500 tk
	200 tk	70 tk/lit *2	
	Total=340 tk		Only 70 tk
Cost per season per bigha(Boro)	25 irrigations (200*25)+(50*70) **= 8500tk**		50 irrigations**Only 3500tk**
Labor	1		None
Quality of crop	Good		Better
Availability of water	Not available		Available

Table-2: Comparison between Diesel and Solar pump based on the cost of irrigation

It is quite clear from the table that the cost per season per

bigha for 25 irrigation using a solar pump is much less than that of a Diesel pump. Besides, using Solar pump does not require any extra labor for operating the pump since it is automated and it does not require to be refueled like Diesel pump. So no labor cost is added in case of a solar pump. After considering this fact the overall total cost for irrigation using solar pump becomes much more less than that of a diesel pump which is shown in the table.

4 MEASURED DATA OF TEGHORIA VILLAGE, KUSHTIA DISTRICT, BANGLADESH

Detailed data collection for this comparative study has been done in Teghoria village of Kushtia district, Bangladesh. The measured parameters are given below:

Time	Air Temp °c	Radiation (W/m^2)	PV O/P I_L (A)	PV O/P V_L (V)	Inverter O/P I_L (A)	Inverter O/P V_L (V)	Water discharge Rate (Lit/min)	Frequency (Hz)
11:00	38	860	23.70	569	25.56	232	3100	45
11:20	38	928	23.88	569	26.11	234.2	3100	48.5
11:40	37	939	24.00	570	25.52	234.8	3000	48.5
12:00	38	926	23.72	579	25.12	233.9	2400	48.4
12:20	38	882	23.68	572	25.23	212.9	3000	48.1
12:40	39	962	23.43	569	25.54	235.2	3100	48.5
13:00	37.5	864	22.8	561	24.7	224.4	3000	41.5
13:20	37	910	23.27	563	24.85	229.2	2700	47.9
13:40	38	865	23.14	561	24.74	268.6	3100	48.1
14:00	38	737	23.74	566	25.45	232.2	3100	48.2
14:20	38	864	23.20	569	25.54	232.14	3100	47.6
14:40	37	820	23.14	565	25.43	244.68	3000	47.6
15:00	37	825	23.15	564	25.40	230.84	3000	47.4
15:20	36	752	22.60	560	25.32	229.18	3000	46.8
15:40	36	778	23.04	558	25.30	229.50	3000	46.8
16:00	35	740	22.82	557	25.31	228.44	3000	46.4

Table-3: Day long different measured solar data from the visited area.

4.1 Graphical Representation of Measured Data:

Various data of several days were collected but a particular day was focused for result optimization. Air temperature, radiation, PV output, inverter output, water discharge rate and efficiency of the system (motor + pump) were measured at 20 minutes interval [11, 12]. The following graphs show the present condition of irrigation in Teghoria village. Figure-2 shows the air temperature (in degree) of that area from on a typical day of July. The highest temperature 39 degree is found at 12.40pm and the lowest temperature 35degree is measured at 4.00pm. From the Figure-3, it is seen that the output of the PV increases with the increase of radiation. The average radiation was found 856 W/m2 of that particular day. The rating of the PV was19.2 kWp and it served 13.68 KW when the radiation was 939 W/m2. For the lowest radiation 740 W/m2 the PV showed 12.71 KW as output.

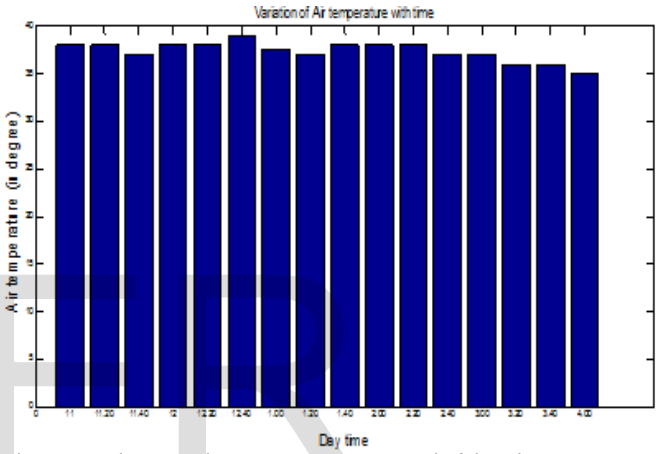

Fig. 2. Day time vs. Air temperature measured of that day

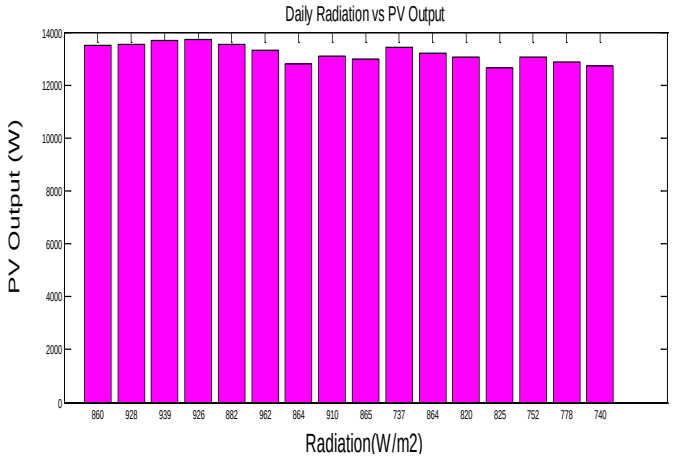

Fig. 3. Radiation vs. PV output

A Flow meter was used to measure the water discharge rate (lit/min) [13,14]. Figure-4 shows the variation of water discharge rate with the variation of solar radiation. As the average radiation was 856 W/m2 and the other radiations did not vary too much so that the water discharge rate was approximately same over the measured period. The value of the average water discharge rate was 2982 lit/min.

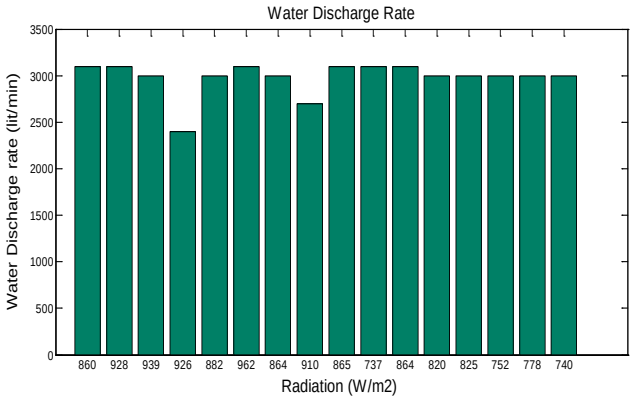

Fig. 4. Radiation vs Water discharge rate

4.2 Graphical Analysis of IDCOL Data

Solar based irrigation systems are innovative and environment friendly solution for the agro-based economy of Bangladesh. The program is intended to provide irrigation facility to off-grid areas and thereby reduce dependency on fossil fuel. IDCOL has approved 459 solar irrigation pumps of which 324 are already in operation [5]. The remaining pumps are expected to come into operation shortly. IDCOL has a target to finance 1,550 solar irrigation pumps by 2017. The World Bank, KfW, GPOBA (Global Partnership on Output-Based Aid), JICA (Japan International co-operation agency), USAID (United States Agency for International Development), ADB (Asian Development Bank) and Bangladesh Climate Change Resilience Fund (BCCRF) are supporting this initiative [6]. There are 37 PO's (partner organization) of IDCOL are working for different solar irrigation projects in Bangladesh. Bright Green Energy Foundation (BGEF) is one of the active PO of IDCOL. The present scenario data for different divisions has been collected and given in the following graphs.

Figure-5 shows the average pump head for different divisions in Bangladesh. The highest pump head is required at Rajshahi division and the value is 16.7m. On the other hand, Chittagong division needs only 12.8m pump head for solar irrigation. It is the lowest pump head among different divisions. Around 450 solar irrigation pumps are installed by IDCOL and 37 pumps are installed in Rajshahi division. Rangpur is one of the leading divisions for solar pumping with 13.44m pump head and almost 200 pumps are already installed in this division. Therefore, it is very important for every upcoming irrigation project in different divisions to consider the above pump head before installation as the pump capacity increases with the pump head.

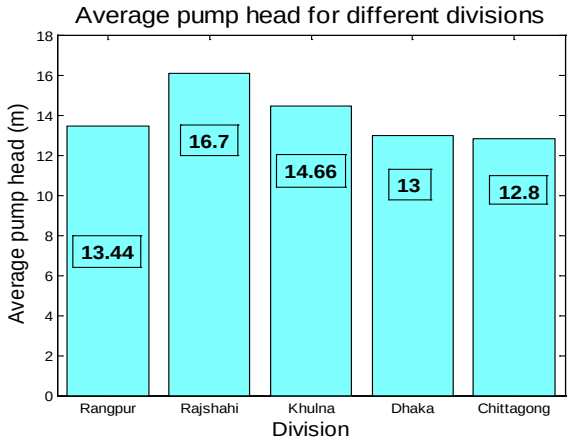

Fig. 5. Average pump head for different divisions

Figure-6 shows how the PV capacity varies with different pump heads in different divisions of Bangladesh. Total 450 solar pumps are installed in five divisions of Bangladesh. It is seen from the graph that average PV capacity increases with the average pump head in every division of Bangladesh except Rajshahi. The maximum average pump capacity 13kw is needed for a solar irrigation project with average 14.2m pump head in Khulna division. Only average 3.75kw pump is required for a minimum average pump head of 12.8m. So it can be concluded that place or division with higher pump head will require the higher PV capacity. Khulna division has the maximum averagePV capacity and it is at the top of chart among 205 solar irrigation projects.

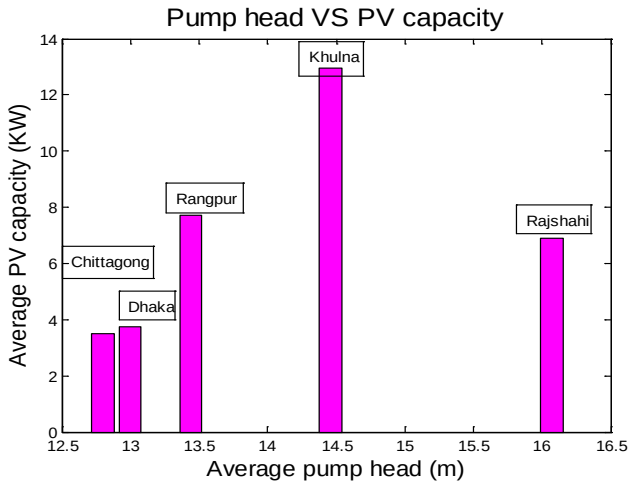

Fig. 6. Pump head vs. PV capacity

Figure-7 shows that among different divisions the maximum average pump capacity is 13 KW in Khulna division and it takes almost 19 kWp PV for running this higher rating pump. In case of Dhaka division, average pump capacity is 3.75 KW and it requires only 7.5 kWp PV panel to the project. But Chittagong division shows a

different figure from the rest. Here 12.5 kWp PV capacity is required for supporting only 3.5 KW pump. Insufficient solar radiation is the reason behind this kind of problem. Therefore, this types of issue should be kept in mind before installing a solar pump in such divisions. Though the PV capacity increases with the increase of pump capacity, sometimes it may show different scenario depending on the solar radiation for different divisions.

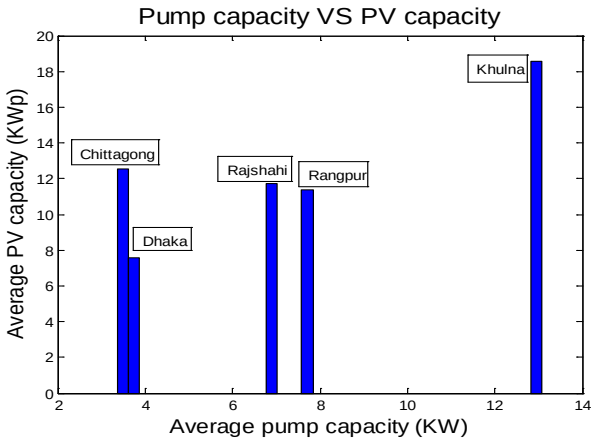

Fig. 7. Pump capacity vs. PV capacity

Already 450 solar irrigation projects have been installed by IDCOL in different divisions of Bangladesh. As the average sunshine hour and water head is not same for all areas in Bangladesh, therefore the average water flow per day is not equal for all divisions. Figure-8 shows that the highest average water flow (m3/day) has been found at Khulna division. In addition, 46% of the total installed pumps are at Khulna. So the higher rate of water flow can be a blessing reason behind this number. Chittagong has the lowest average water flow per day and only two irrigation projects has been installed so far. Rangpur is at 2nd position in the figure with average water flow of 688.12 m3per day. As a result, 44% of total installed pumps are found at Rangpur.

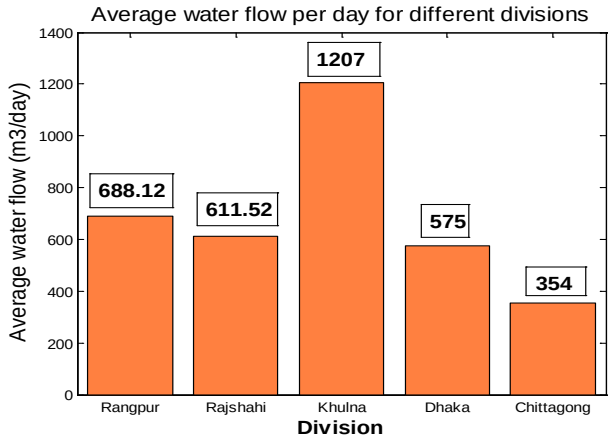

Fig. 8. Average water flow per day in different divisions

Since Bangladesh is an agricultural country and it receives sufficient solar energy that's why solar irrigation is becoming popular day by day. Infrastructure Development Company Limited (IDCOL) has installed almost 450 solar irrigation projects in different divisions of Bangladesh. Solar irradiation, water head, water flow per day and irrigation water demand are some of important issues for feasible solar irrigation. Considering these issues all divisions are not same preferable for solar irrigation. Figure-9 shows that 46% of the total pumps are installed at Khulna and the number is 205 pumps out of 450 pumps. With the number 198 out of 450 Rangpur is at 2nd position and it covers almost 44% of the total installed pumps. The contribution of Rajshahi is 8% of the total pumps and the number is 37. From figure 3.5 it is clearly observed that Dhaka and Chittagong division are listed below with less than 1% contribution in solar irrigation.

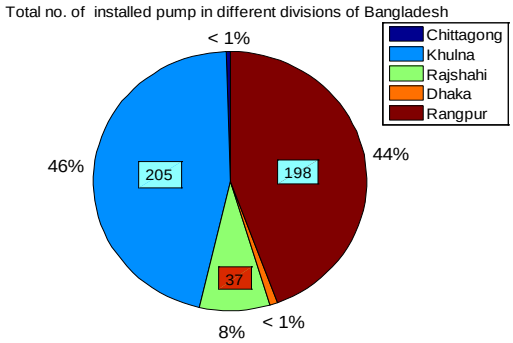

Fig. 9. Total no. of installed pump in different divisions of Bangladesh

Figure-10 shows the monthly average sunshine hour for different divisions of Bangladesh over the year. From the figure it is found that the maximum monthly average sunshine hour is 6.2 at Rangpur. The highest average sunshine hour is found at the season of March, April and May. In June, July month monthly average sunshine hour becomes very low due to the heavy rainfall. Almost in every month the average sunshine hour is same for Rangpur and Khulna division. May be that is why most of the irrigation pumps have been installed in those divisions. July, August and September are the months of low radiations. The average sunshine hour for these months is near about 4.2 hours. The sunshine hour for Dhaka division in consistently poor over the year compared to other divisions.

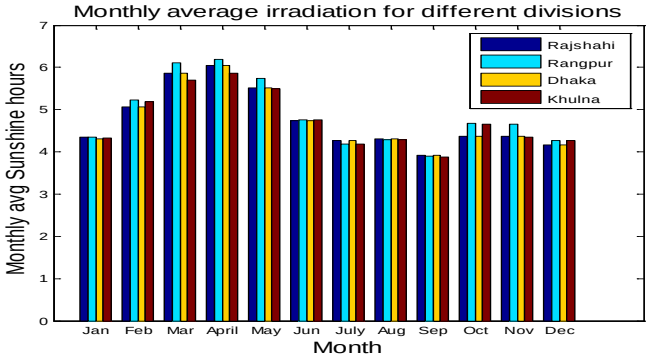

Fig. 10. Monthly average radiation for different divisions over the year

Figure-11 shows the average water required (m3/hectare/month) for different divisions of Bangladesh.

From the figure it is found that Rangpur requires least average water requirement for irrigation per month per hectare land. On an average 2768 m3 water is needed per hectare per month for irrigation purpose. 198 pumps are installed out of total 450 pumps by IDCOL at Rangpur. Less amount of required water helps Rangpur to achieve this. Rajshahi division needs 3742 m3/hectare/month which is the maximum amount of average required water among all divisions and as a result only 37 solar pumps are installed at Rajshahi. Therefore, amount of required water per month is a important factor for solar irrigation.

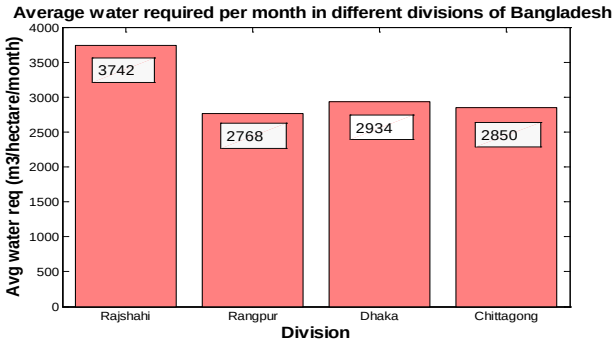

Fig. 11. Average water required per month for different divisions

Potato, Boro and Aman are the main crops of Bangladesh which require huge amount of water for irrigation. These three major crops are totally dependent on irrigation. Figure-12 shows the amount of average water required for these three main crops. It is seen that in every division Boro requires the highest amount of water for irrigation compare to other crops. It needs almost 5500 m3 water per month per hectare for irrigation. That means Boro costs much for irrigation compare to other crops. Therefore, farmers are not willing to cultivate Boro in their land. Farmers switch to other crops for low cost which require less amount of water. Potato requires only 1600 m3 water per hectare per month which costs less than other crops.

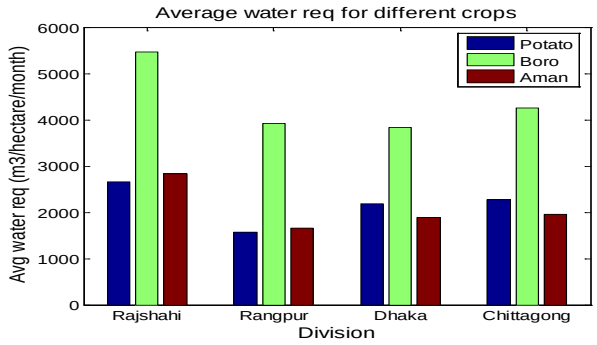

Fig. 12. Average water required for different crops

In Figure-13, the pie chart shows the month amount of water consumption by different crops. In rural area total amount of irrigation water is consumed by main three crops – Potato, Boro and Aman. It shows that 51% of irrigation water is consumed by Boro rice. Potato and Aman consumes almost same amount of water for irrigation per month per hectare. Boro consumes 4367.5 m3water per month per hectare for irrigation. Since a huge amount of water is consumed by Boro that's why farmers has to pay a lot for Boro irrigation. This cost is an alarming issue for solar irrigation. This is because it may discourage farmers to cultivate Boro rice.

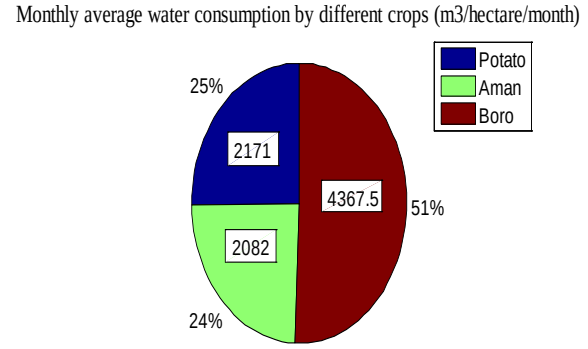

Fig. 13. Water consumption by different crops

5 RESULTS

Two sets of results were calculated. The first set is from the practical field visits and second set is from the data provided by IDCOL. Both findings are given below:

5.1 Result from the Measured Data

Efficiency of the existing system can be calculated using various formulas. Here one of the formula is used to find the efficiency of the system (pump+motor) [4,8,9,10,11,12].

Inverter output = (motor+ pump)'s Input = VI cosΘ = 25.56*232*0.8 = 4743.936 W

(Motor+ Pump)'s output = 3100 lit/min = 3100*8*60 = 1488000 lit/day

1488000 lit/day = (1488000*18.25)/367 =72223.40 Wh/day , Water head = 18.25 m

72223.40 Wh/day = 72223.40*0.0416666667 = 3009.30 W

System Efficiency = $\frac{System\ output}{System\ input} = \frac{3009.30}{4743.93} = 63.43\ \%$

5.2 Result from the Data provided by IDCOL

Before planning to set new solar water pumping system some important concerns should keep in mind. As there are seven divisions in Bangladesh so the radiation, water head and water demand for crops are not same for geographical reason. Therefore some important concerns were found from the data analysis which will help to set up a feasible solar pump for different divisions in Bangladesh.

- Almost 200 solar pumps are installed at Rangpur division out of 450 pumps and the average pump head is 13.44m for Rangpur.
- PV size in KW increases with the increase of pump head.
- Division with higher pump head will require the higher pump capacity.
- Highest average water flow (m3/day) has been found at Khulna division is 1207m3/day and 46% of the total installed pumps are at Khulna.
- Rangpur is at 2nd position in the figure with average water flow of 688.12 m3per day and 44% of total installed pumps are found at Rangpur.
- 205 solar pumps are installed at Khulna division.
- The maximum monthly average sunshine hour is 6.2 at Rangpur division.
- The sunshine hour for Dhaka division in consistently poor over the year compare to other divisions.
- Rangpur requires least average water for irrigation per month per hectare land among seven divisions.
- It is seen that in every division Boro requires the highest amount of water for irrigation compare to other crops. It needs almost 5500 m3 water per month per hectare for irrigation.

6 CONCLUSION

Since agriculture is the single largest producing sector of the economy which comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total labor force [7], irrigation plays a vital role in this sector. In addition, considering load shedding and off-grid areas of Bangladesh IDCOL is providing financial support to solar irrigation projects in different areas of Bangladesh. In this paper, almost 450 irrigation projects data have been analyzed for different divisions. Some important concerns are shown by graphical representation from the analysis which can be very helpful for upcoming irrigation projects of Bangladesh. Comparison between diesel pump and solar pump are found from the practical field visits of a project at Kustia under IDCOL. During the conversation with local farmers it is also observed that they do not need water daily for irrigation. So that this extra energy from Solar irrigation can be used in mini-grid, rice-husking and battery charging for easy-bikes.

7 REFERENCES

[1] Khaled Shafiullah, Load shedding of Electricity in Bangladesh, April 16, 2009.

[2] Ahmed, R. (2010). "Power crisis In Bangladesh", http://hubpages.com/hub/Power-crisis-In-Bangladesh

[3] M Rezwan khan; Prospect of Solar PV Based Irrigation in Rural Bangladesh: A Comparative Study with Diesel Based Irrigation System ;

[4]www.seai.ie/Your_Business/Resources/Pump_Energy_Efficiency_Calculation_Tool.xls

[5] Official web site of IDCOL; http://idcol.org/home/solar_ir

[6] Cleantechnica. -Bangladesh-solar-irrigation- pumps

[7] Central Intelligence Agency, The world fact book, Retrieved 24 February 2016.

[8] Robert V. Enochian, (1982), Solar- and Wind-powered Irrigation Systems, U.S. Government Printing Office

[9] Robert Vaughn Enochian, (1982,Digitalized-2009), Solar- and Wind-powered Irrigation Systems U.S. Department of Agriculture, Economic Research Service

[10] Godfrey Boyle, (2012), Renewable EnergyPower for a Sustainable Future, Oxford University Press

[11] Jeremy Shere, (2013), Renewable: The World-Changing Power of Alternative Energy, St. Martin's Press

[12] Robert Ehrlich, (2013), Renewable Energy: A First Course, CRC Press

[13] Waqar A. Jehangir, Hugh Turral and I. Masih, 'Water productivity of rice crop in irrigated areas',4th International crop Science Congress, 2004, Brisbane, Australia

[14] V. Geethalakshmi, A. Lakshmanan, T. Ramesh, 'Assessment of water requirement for different systems of rice cultivation',Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, A report on field experiment conducted in 2008.