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A brief study of the prospect of hybrid solar irrigation system in Bangladesh

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ABSTRACT
Solar energy is an efficient alternative source of energy in Bangladesh for its geographical location. After its long term success the solar energy use in irrigation phenomenon to replace conventional energy. This paper presents the prospect of a hybrid solar irrigation system with both technical and financial point of view. In an existing solar irrigation system PV panel is applied to produce DC current and by the inverter it converts into AC current and finally operates 3 phase submersible AC pump. By applying the hybrid system, it is possible to increase the operating hour and cultivate more agricultural land without any extra installation cost. In this system the solar energy and grid electricity use alternately to operate same pump. After the financial analysis of solar and proposed hybrid solar irrigation system the payback period is decreased 5 to 7 years. Therefore the hybrid system release the excessive load on the grid connected irrigation system.

Keywords: Solar, Hybrid, Irrigation, Bangladesh, Grid electricity.

1. Introduction

Bangladesh is an agro based country in the South Asia. Most of the people of it's depends upon the agricultural work for their living. It holds lots of agricultural land and the amount of total cultivable land is 8.52 million hectares. About 37.266 % million metric ton crops and other vegetables are cultivated in various seasons in this land [1]. Though Bangladesh is a realm of the river, but it has huge water crisis for irrigation, especially in summer and winter season. Moreover the amount of lands beside the river and canal are not so much so as to cultivate this land by these water sources. Particularly in the semi-arid region (Barind tract) there is a sufficient lack of water for irrigating the lands. As a solution in Bangladesh most of the farmer uses underground sources of water for irrigating purposes. This is done by picking up the bore water through the pump. Here there are almost about 2 lakh such type of pump used for picking up water. These pumps are running by grid electricity and diesel oil. From the statistic it has seen that about 25% electricity of the entire output is employed for operating these pumps, which stands for that irrigation pumps consume 1300 MW electricity in a day. In the irrigation sector of Bangladesh nowadays there are approximately 84% irrigation are depend on diesel oil. Meanwhile about 1.34 million diesel operating pumps emit 0.9 million tons of exhaust per year [2]. So for the green milieu it is high time to decline the use of conventional fossil fuel and create the alternative sources of energy. Though Bangladesh is an agricultural country and huge amount of energy are consumed in this sector. So agriculture sector is a good concern to replace by renewable sources of energy.

It is also illicit phenomenon that applies just the conventional energy without creating any renewable sources. In the wisdom of renewable energy Bangladesh is abandoning to use solar energy rather than wind, hydro and tidal energy. Bangladesh situated between 20° 34´-26° 38´ north latitude and 88° 01´-92° 41´ east longitude [3]. So geographically the solar radiation effect in this region is satisfactory to utilize solar energy. The solar radiation is vary from 4 to 6.5 kWh/m^2 in various districts of Bangladesh [4]. This solar energy makes a strong renewable sources in Bangladesh. The Bangladesh government vision is to replace the 10% conventional energy by renewable energy within the year 2020 and the solar energy considers as great renewable sources of energy . For this purpose solar power pump is introduced in recent year by various government and private organization over the country. Infrastructure Development Company Ltd. (IDCOL) has a plan to set up approximately 18,750 solar power pump over the country between 2016 yr.

Only the primary obstruction of solar power pump of its higher installation cost and long term payback period. Generally in the existing solar irrigation system DC current is converted into AC current and directly run the AC pump without using any battery. Moreover at low sunshine and during night time it is not possible to run the system. So in this situation to sustain the project it needs to supply water all the day and night. Solar energy is far behind to use at night and also for higher maintenance cost of the battery system is totally shut down during the night. For this situation it is difficult to earn profit from the project. The idea of the hybrid system increases the working hour while solar energy has failed to run the pump. So if hybrid system is replaced by the solar irrigation system, then it is possible to earn profit from the project and cultivate more land in the region.

Now a day's hybrid irrigation system is used in various countries all over the world. It is usually used to overcome the limitations of continuous supply of energy and to supply energy in remote places. Hybrid power system is a combination of different sources of producing electricity that confirms the uninterrupted supply of electricity [5]. Generally wind solar hybrid energy system is used most of the country for irrigation sector. This hybrid system is an admirable sources of renewable energy which release the

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gravity of conventional energy and retain the environment green. But this solar wind hybrid system is very much expensive to setup. It is not possible for developing countries like Bangladesh to install such type solar wind hybrid energy system. It is why not only for its exorbitant installation cost, but also not possesses a moderate wind speeds for its geographical location. But equally it has inherent of abandoning sunshine and then the solar irrigation pump has installed in recent years, it is possible to combine the photovoltaic system with grid electricity to run the pump as a means of the hybrid solar energy system. Through this hybrid solar irrigation system there is no any additional installation cost. This paper presents the prospect of a hybrid solar irrigation system in Bangladesh. For this, both technical and financial analysis of the solar irrigation system and grid connected pumping system is considered and finally combined the analysis for further results. Methodology and study area are described in the second and third section while the technical analysis is summarized in the fourth section. The fifth section is compiled with financial analysis. Finally at the last section is deliberated with the conclusion and prospect of the hybrid solar irrigation system.

2. Methodology

The methodology was occupied to find out the prospect of hybrid solar irrigation system in Bangladesh is concise here. At first the area was selected at where the solar irrigation system and grid connected irrigation system has already installed. Then by making a visit in these designated areas required technical information were gathered. The economic essential information was noted by making questionnaire to the agrarian and the employers. Afterward finding all the necessary evidence the final analysis was done showing the actual scene of the hybrid solar irrigation system. For technical analysis overall efficiency, discharge of water, operating hour and liter per watt peak were considered. And for financial analysis consider the simple payback period, NPV and IRR. Finally, compare the financial improvement of the hybrid solar irrigation system after solar irrigation system.

Photo.1 Solar irrigation system in Naogaon

3. Study area

The study area was selected based on the districts where the solar and grid electricity irrigation is running at least several years. By these, three districts were selected namely Rajshahi, Naogaon and Jessor. In Rajshahi there are about three solar irrigation projects and in Naogaon there is one solar irrigation project. In Mirjapur and Mandoel under Godagari and in Poba under the Rajshahi Solar irrigation project is built up by KOICA. Here 5hp AC submersible pump is running directly by 5.16 kW photovoltaic panels. In Shapahar, Naogaon Solar irrigation project is built up by Grameen Shakti namely Grameen Shakti Solar Pump Pilot Project shown in the Photo 1. Here 10hp submersible pump is operated by 11.2 kW photovoltaic panels. In Jessor ten solar irrigation project is newly set up by IDCOL. Here 10 HP submersible pump is also run by 11.84 kW photovoltaic panels. For the analysis consider the 10 HP solar pump system for its accessibility and large discharge capacity of water. Besides grid electricity connected pump is available in several districts of Bangladesh. For analyzing the grid connected pumping system Rajshahi and Naogaon district are randomly selected. The grid connected pumping system is shown in Photo 2.

Photo.2 Grid connected pumping system

4. Technical analysis

Hybrid solar irrigation system is an improvement of the existing solar irrigation system. In this system both the solar energy and grid connected electricity used simultaneously as alternative sources. For the analysis solar irrigation and grid connected pumping system is considered. Finally proposed the improved hybrid system which reduces the conventional energy from grid connected pumping system and also reduce the net cost of the solar irrigation system.

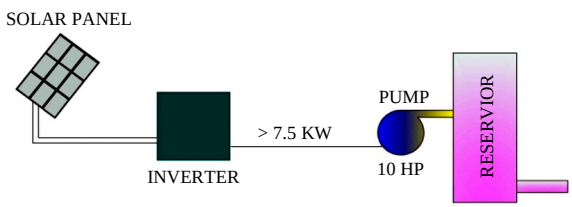

Fig.1 Solar irrigation project

4.1 Solar irrigation system

From the visited areas, it has seen that the existing solar irrigation system consists of mainly photovoltaic panels, inverter and AC pump. Photovoltaic panels generate DC current using solar radiation. This DC current is then

converted to AC current through the inverter [6]. Finally a submersible AC pump is running by using this AC current. The diagram of the solar irrigation system shown in Fig.1. As there is no use of any battery here for minimizing the maintenance cost so there is no chance for preservation of extra power. The entire panel power kept much higher than the pump power to run the pump uninterruptedly. In the considered system a 10hp submersible AC pump is running when the power produce from the panel is above 7.5 kW. The corresponding technical parameter of solar irrigation project is presented in the Table 1.

Table 1 Solar irrigation project specification

Parameter	Unit	Value
Maximum power	kW	11.2
Panel number	no.	64
Per panel capacity	W	175
PV array area	m^2	81.7
Pump head	ft	100

The overall efficiency of this system is calculated by the ratio of the power supply to the pump (kWh/day) to the average solar radiation (kWh/day) that incident on the photovoltaic panel.

$$\eta = \frac{P_1 \times t}{A \times I} \quad (1)$$

By using Eq.(1) the overall efficiency was found about 16.52% for 11.20kW power supply to the pump. It may change from system to system for different PV array area, solar radiation and per panel capacity. The average solar radiation of the visited area is assumed 5 kWh/m^2. Another technical parameter Liter per Wp was determined by the ratio of the water supply per year to the maximum Wp given by the equation.

$$L_p = \frac{Q \times t \times 365 \times 1000}{P_2 \times 60} \quad (2)$$

The Liter per Wp for this system was calculated by the Eq.(2) and it was found 9680 for a year when the discharge was 550 L/min and the average operating time was 8 to 10 hours per day. The Liter per Wp also varies from system to system depending upon the pump capacity and panel ability. In Table 2 the calculated value is shown.

Table 2 Solar irrigation project evaluation

Parameter	Unit	Value
Operating time	h/day	8-10
Flow rate	liter/min	550
Average water supply	liter/day	2,50,000
Litter watt peak	liter/Wp/y	9,680
Average solar radiation	kWh/m^2	5
Overall efficiency	%	16.52

In this analysis, it determines that the main problem of the solar irrigation project is less operating time due to dependence on sunshine. Also the solar irrigation project is switch off during the cloudy and gloomy environment. Hence decrease the supply of water and also lost the public draw.

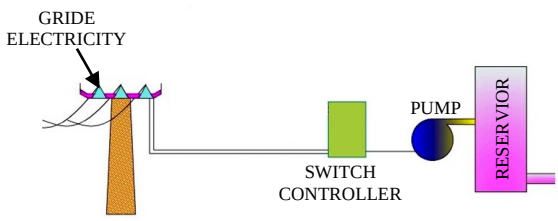

Fig.2 Grid connected irrigation system

4.2 Grid connected irrigation system

Grid connected irrigation system is a popular medium of irrigation. In this system grid electricity is used to run the AC pump directly. There are 2HP to 12HP pump are used according to various demand. The project design and equipment is very simple. The project consists of a submersible AC pump and switch controller. In the Fig.2 the grid connected irrigation project is shown. When the electricity is available that time the pump supply water. The respective information of the grid connected irrigation is given in Table 3.

Table 3 Grid connected irrigation project information

Parameter	Unit	Value
Pump capacity	HP	10
Head of pump	ft	60
Discharge	liter/min	900
Operating time	hour	20
Consume electricity	kWh/day	150

By the study it was found that the discharge of the pump varies from 600 to 700 liter/min and the pump is in operation about 16 to 20 hours according to demand. In this case a huge amount of electricity is consumed for irrigation. There are above 1300 MW electricity are used for cultivating land under grid connected pumping project. Thus it is desirable to put back the grid connected irrigation system with alternative sources totally or partly

4.3 Hybrid solar irrigation system

The hybrid solar irrigation is an improvement system rather than solar irrigation system. Though the solar irrigation system is a good practice of renewable energy, but the main problems are the longest payback period and less operating time comparable to grid connected irrigation system. On the other hand the grid connected irrigation system used up a large amount of conventional energy and pollute the surroundings by using fossil fuel. The hybrid solar irrigation system minimizes the two major problems of the previous system. The proposed hybrid solar irrigation system are shown in the Fig 3. In hybrid solar irrigation system the task consists of two units, solar is one unit which is renewable sources of energy and other is a grid connected unit which is conventional sources of

energy. The two units are united by the controller switch. In solar unit the DC current is converted into AC current by the inverter. On the other hand, in the grid connected unit the grid electricity directly supply AC current. And by the both unit finally run the AC pump to lift water and supply for irrigation. When the solar panel failed to produce 7.5 kW power the 10hp pump cannot be started with the solar unit that time the grid connected connection is available to run the same AC pump [7].

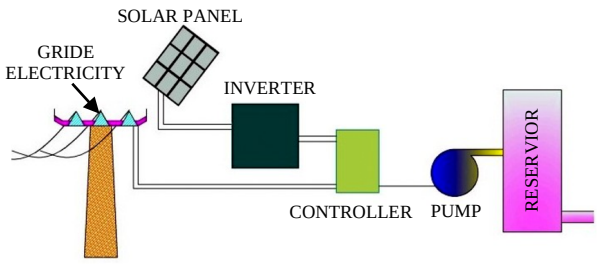

Fig.3 Hybrid solar irrigation system

In this system there no technical variation only the two units work separately according to the condition. The average sunshine in the Bangladesh is about 8 to 10 hours and this respective time solar energy is applied for irrigation [8]. But at the evening to next morning this energy cannot use without any battery storage. For saving the maintenance and replacement cost battery is eliminated in large production unit. So the system was shut down about 14 to 16 hours per day. To increase the operating time and production in hybrid system, it has the opportunity to run the pump at night while the solar energy is absent. Therefore at night hour 10 pm to 6 am it is perfect to feed the pump. This increase the 8 hour operating time and remaining time of the day it should keep idle for better life of the pump. The daily operating and idle time of the solar irrigation and hybrid solar irrigation system are presented in Fig 4. Its indicated that daily idle time is decreased in the hybrid solar irrigation system and increase the operating time. The hybrid system increases the operating time in existing solar irrigation system so this project will more viable and profitable. [9]

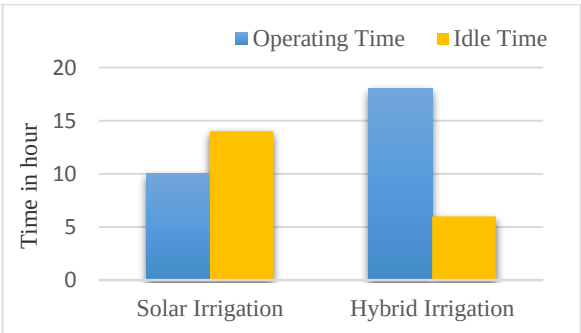

Fig 4 Daily Operating and Idle time of the systems

5. Financial Analysis

Generally a project is acceptable when the project is financially viable. Besides the technical improvement it is another concern about the investment and its quick return. In solar irrigation project the installation cost is much higher and it is tough to recover the total investment earlier in its project life time. By the field visit, it has seen that the installation cost is variable from 30 lakh to 50 lakh BDT for setup 10HP submersible AC pump. Now a day these types of projects are established by the government and non-government association. Infrastructure Development Company Limited (IDCOL) with the World Bank, KFW, KOICA, JICA, ADB and Bangladesh Climate Change Resilience Fund are financially supported to set up the project in rural areas of Bangladesh. In Grameen Shakti solar irrigation project the 70% of its total investment was donated from IDCOL and KFW and 30% of the total cost was invested by Grameen Shakti. Though the solar irrigation system is an alternative sources for irrigation but for its high investment cost it is not suitable for the full investment without any grant. Thus the hybrid solar irrigation system may be a good prospect to recover the investment within a shortest possible of time. [10]

In terms of financial analysis, both the solar irrigation project and grid connected pumping project was considered and finally estimate the analysis of grid connected hybrid solar irrigation system. For financial analysis Net present value (NPV), Internal rate of return (IRR) and simple payback period were calculated both for solar irrigation and hybrid solar irrigation system. The survey had indicated that the expected project life of the system is 20 years. The total expense calculated from the installation cost, maintenance cost, repair cost, replacement cost and operator salary. On the other hand the total income of the project comes from the charge of the water supply to the cultivable land. There are approximately 80 to 100 bigha lands are cultivated by the 10HP irrigation pump in a season. In case of solar irrigation system water supply charge for different crops are shown in the Table 4.

Table 4 Average charge to supply water per season

Type of cultivation	Charge BDT/Bigha
Paddy	1750
Wheat	560
Potato	560
Onion	210
Garlic	210

On the other hand in the grid connected pumping system water supply charge for paddy per season is about 3000 to 3500 BDT. And for per hour water supply the charge from the farmer is about 100 to 120 BDT in a different district. There is no running charge for solar irrigation, but when the irrigation is conducted by the grid electricity about 1000 BDT is charged for running costs. In a grid connected pumping system per unit electrical charge for irrigation are shown in Table 5 [10]. In finance observation the project is viable when higher NPV and the higher IRR rate and also desirable shorter payback period. NPV is calculated by bringing all the expenses and income from the investment year to the expected lifetime with various

lending and deposit interest. The various lending and deposit cost were collected from the Bangladesh Bank [11].

Table 5 Charged of electricity for irrigation

Distributor	BDT/Unit
DPDC / DESCO	2.51
BREB	3.39-3.96

In the Table 6 for the different discount rate the NPV is shown for both the solar irrigation project and hybrid solar irrigation project. From field visit feedback these financial analysis assuming both the project expected life time is 20 years. There were no replacement on solar panel and pump. But the inverter was replaced after 10 years. Also assuming in the hybrid solar irrigation system added the extra installation cost only for electricity supply line and switch controller. For hybrid solar irrigation system the net income is increased by increasing water supply more than 8 hours and expense is include the electricity charged for per unit use.

Table 6 NPV of the project

Discount Rate	Solar irrigation	Hybrid solar irrigation
2.5	128644.8527	2899070.514
7.17	-	588926.3382
8.4	-	173995.1968
8.61	-	108972.1892
10.29	-	-358623.4856

IRR is another financial parameter calculated from the graph including the NPV for the different discount rate for both the solar irrigation and hybrid solar irrigation project. The NPV vs. discount rate in Fig.1 denoted the discount rate where the NPV is zero that point is considered as the project IRR.

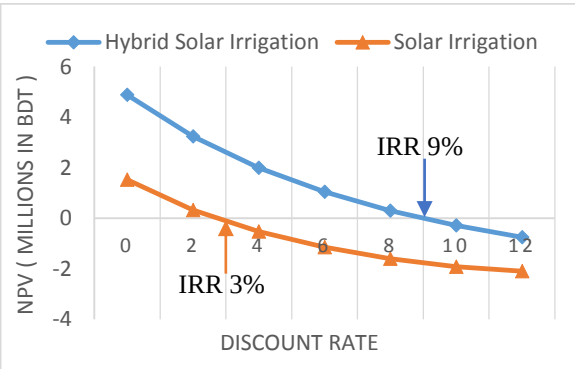

Fig.5 NPV vs. Discount Rate

Besides the NPV and IRR the simple payback period is the vital term of the project financial analysis and it should be minimum as possible. The IRR and simple payback period are presented in Table 7. In solar irrigation by the survey report, assumption and analysis the simple payback period is about 14.57 years and while improving the hybrid solar irrigation system the simple payback period is reduced at 9.11 years only. Therefore in the hybrid solar irrigation the simple payback period is decreased 5 to 7 years from the existing solar irrigation project.

Table 7 IRR and simple payback period

Parameter	Solar irrigation	Hybrid solar irrigation
IRR (%)	3	9
Simple Payback period (y)	14.57	9.11

By the financial analysis, it is found that the hybrid solar irrigation system is more feasible than the solar irrigation project.

6. Conclusion

As a developing country, Bangladesh has a massive dependency on agriculture. Therefore water is mandatory to cultivate the land basically in the agro seasons. The grid connected irrigation project depends only grid electricity which accelerate energy crisis more than a hybrid system. The ultimate conversation is concise in the following points:

a. Solar irrigation is considered as a new epoch for alternating the conventional energy sources in irrigation sector which reduces the excess load on the electricity.
b. The average efficiency is found to be 16.52% and the water supply per day is 2,50,000 liter in case of solar irrigation.
c. Solar irrigation project is not financially feasible due to high initial cost and less operating time. Such as 30 to 50 lakh BDT are required for installing a 10 hp solar pumping project.
d. In terms of solar irrigation the simple payback period is found 14.57 years and operating time is about 8 to 10 hours per day.
e. Besides in a hybrid solar irrigation system the simple payback period is found 9.11 years which reduce up to 5 years to return the investment and operating time increases about 8 to 12 hours per day.
f. After introducing hybrid solar irrigation the NPV and IRR are also increased and simple payback period is decreased than solar irrigation system.
g. Moreover this hybrid system reduces the CO_2, NO_X and SO_2 emission and declines the oil importation that requires (about 1,44,000 billion liters of oil every year) to operate more than two lakh diesel pumps.

A hybrid solar irrigation system may create the intensity to the private organizations for investment. Also the government should install some project to make this hybrid system more dynamic.

NOMENCLATURE

P_1 : Pump power, kW
P_2 : Panel power, kW
A : Surface area of panel, m^2
I : Solar radiation, kWh/m^2
t : Operating time, hr/day
Q : Flow rate, liter/min

η : Overall efficiency, %
W_p : Watt peak, W
L_p : Liter per watt peak, liter/Wp/y

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